Application of Disaggregate Modeling in Aviation Systems Planning in Nigeria: A Case Study

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This paper deals with the application of disaggregate modeling in airport choice by domestic air travelers in Nigeria. The major factors influencing passengers' choice of airports in a developing country such as Nigeria are discussed. Knowledge of these factors will greatly assist in the planning of aviation systems on a more reliable basis. A travel survey was conducted in August 1987 in Nigerian airports to collect disaggregate data on air travelers for use in model calibration using the multinomial logit model (MNL). The results of the analysis suggest that the travel time of access is the major determinant of airport choice in Nigeria and that variables such as flight frequency and air fare, which were found to be significant in previous studies in the United Kingdom and the United States, were not significant in the Nigerian context.

Nigeria, a developing country on the west coast of Africa, has 16 major airports; many more are either planned or under construction. The Nigerian government's goals is to establish airports in all state capitals and important commercial centers and to foster air travel, social mobility, national integration, and commercial and industrial development. However, a challenge has been inadvertently put to airport planners and managers. They must provide facilities that serve the social and economic needs of Nigerians and yet are economically justifiable by matching investments with returns. Another reason for building a large number of domestic airports is the general belief that each airport will serve a particular territory or "catchment area." Airports are centers for modal change between air and ground transportation, therefore there is bound to be competition between airports. The concept of catchment areas is invalidated because people do choose between airports (*1–3*). Figure 1 shows the 16 major airports in Nigeria. Figure 2 shows the trip generation zones for the two competing airports considered in this research.

The aims and objectives of this work are to:

- Determine the traffic distribution among airports in Nigeria, with special focus on two selected airports that are possible competitors.
- Give insight into the major determining factors of airport choice by Nigerian domestic air travelers and to compare the findings with earlier research, particularly in the United States and the United Kingdom.
- Use the model as a predictive tool to determine the effect of building a new Nigerian airport in Onitsha, to serve that city and its environs.

An important consideration in deciding the scope of this project was that no prior research existed on airport choice in Nigeria. Therefore, such research would likely add significant knowledge about air transportation in Nigeria. Other developing countries with a similar structure of commercial aviation would also benefit from the research. Ultimately, aviation systems planning in Nigeria will be enhanced, because, planning will be done on a more reliable basis through clearer understanding of how demand is shared among the components of a multiple airport system.

DATA REQUIREMENTS AND PREPARATION

Demand is treated in a micro context, specifying the consumption, choice patterns, and behavior of the individual consumer (the air traveler). The model is disaggregate and requires data at the personal level for calibration. Such data are not routinely available in Nigeria and had to be obtained through a survey of air travelers at the two regional airports in Enugu and Benin.

These airports were selected because:

- They are situated near each other;
- They attract air travelers from nearby regions;
- They offer the promise of competition, should competition exist;
- They have relatively high aeronautical activity in terms of aircraft and passenger movements; and
- They each have two commercial air carriers providing service to Lagos.

To calibrate successfully the airport choice model, it is important that the destination city have only one major airport; otherwise, the choice of departure airport may be influenced by the options of the destination airport. This requirement was satisfied because Lagos has one airport that serves all domestic traffic.

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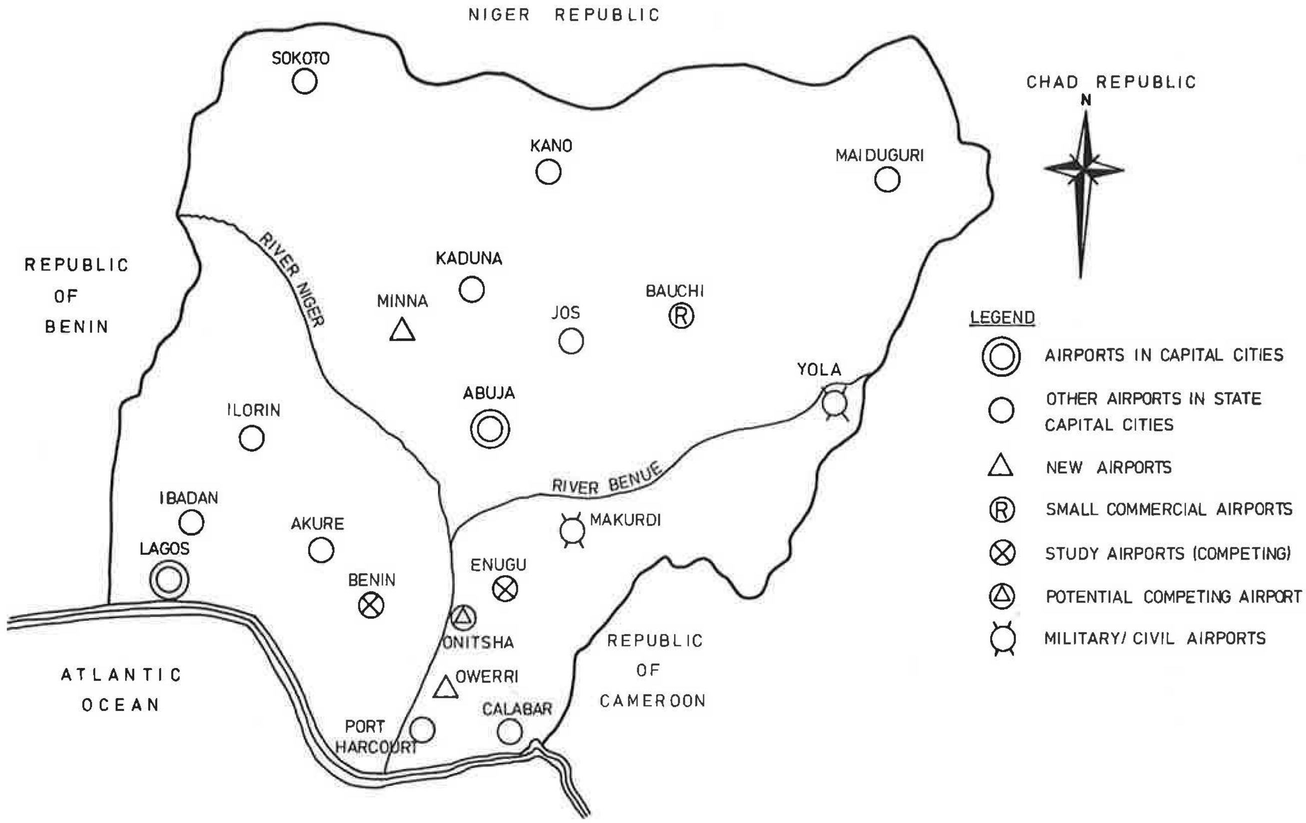

FIGURE 1 Main Nigerian airports.

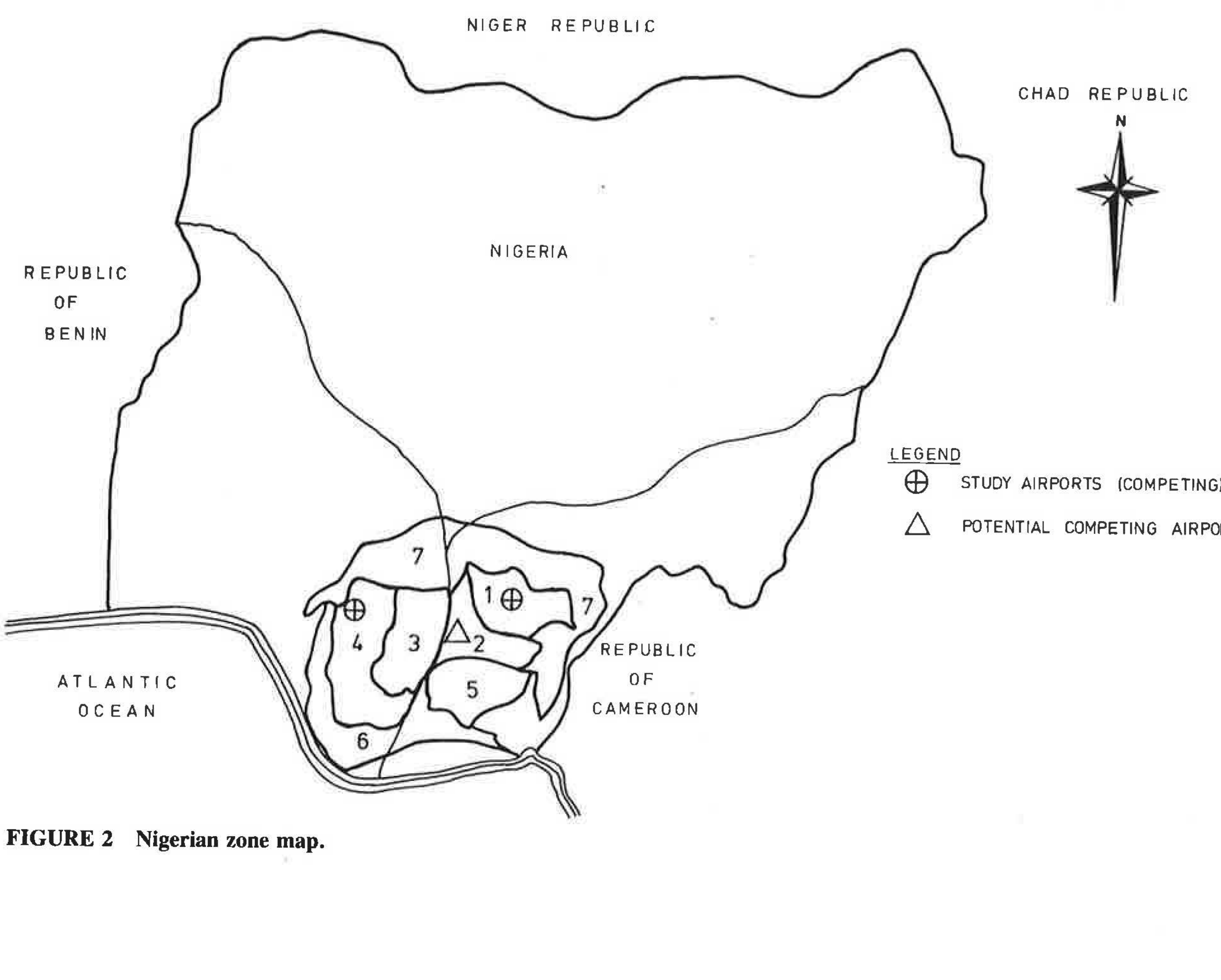

FIGURE 2 Nigerian zone map.

Questionnaires were designed as stipulated by Oppenheim (4). The questions were largely in line with the United Kingdom's Civil Aviation Authority format (5) but were greatly modified to suit the purposes of this study. Low levels of literacy and the lack of complexity of air travel—there are no connecting flights and each flight is a complete journey in its own right—were taken into account. The survey was conducted during a 2-week period in August–September 1987 and completed inflight by travelers en route to Lagos—all flights from the departure airports terminated in Lagos.

The format of the questionnaire shown in Figure 3. For each traveler, the following data were collected or computed from both survey and nonsurvey sources:

- place of residence in Nigeria,
- surface origin of the traveler,
- sex,
- age,
- occupation and education,
- day of the week,
- trip purpose,
- selected airport or nonselected airport,
- access travel time from surface origin,
- number of flights from the competing airports to the destination (Lagos) for that particular day of the week,
- air fare from the competing airports to the destination,
- airline used for the journey, and
- reasons for choosing the airport.

Not all the data collected were found to be relevant to the study. Irrelevant data included income, occupation, age, sex, and education. These data were not cited by the air travelers surveyed as the reasons for their airport choice. They were included in the questionnaire because leisure and recreational travel is largely undertaken by educated men and women in the top economic group. (6). Tardiff concluded that a socioeconomic indicator such as occupation was superior to income in explaining travel behavior (7).

Data relevant to the study were the air passenger trip records (local origin, destination, airport used, flight number, trip purpose, and day of the travel), passenger access travel time, air fares, and flight frequencies to the destination airport. These were necessary data both in terms of the choice made and the choice rejected.

Values of the access travel times used in the research are

- Reported access travel time, which is the time reported by the passenger in the questionnaire, and
- Computed access travel time, which is the time computed from passenger's origin to the airport not chosen for the flight.

More than 85 percent of the survey respondents used family cars or taxis to travel to the airport. The time needed to travel to the airport usually depended on drivers' characteristics, road quality, and vehicle performance.

Because road quality from the observed zones to both airports was similar, identical estimated network access speeds were used. Another reason for calculating travel times for each passenger is that both Harvey (2) and Benchemam (8) suggested this procedure in the U.S. and U.K. studies. However, they did not use the procedure in their study because values of individual travel times to the airports not chosen were not accurately available to them.

Air fare and flight frequency were obtained from those airlines operating at the airport (Nigeria Airways and Okada Airways). Economy air fares were used in the research and the frequency variable included was the total of the round-trip weekly frequency between the individual airports and Lagos. The data were organized and edited into the form acceptable to the model. A total of 1,002 observations were used for the study.

Each observation described the airport choice made, characteristics of the chosen alternative, and characteristics of the unchosen alternative. Table 1 indicates how data were arranged. It was determined that three factors were cited more frequently than any others as reasons for airport selection: access time, flight frequency, and air fare. For each record (observed passenger), the airport chosen was indicated, then the values of these variables for the airport chosen, followed by the values for the airport not chosen.

AIRPORT CHOICE MODEL

Discrete choice models can be developed based upon the hypothesis of random utility maximization. The form of the model used in this research was the multinomial logit model (MNL). The MNL was selected because the airports were perceived to have different, mutually exclusive attributes. The MNL also has numerous advantages (9), including easy mathematical manipulation; easy parameter estimation; and easier application than the other forms of choice models, notably the multinomial probit model (MPL).

The mathematical expression of the MNL is written as follows:

$$P_{gk} = \frac{e^{V_{gk}}}{\sum_{r=1}^{G} e^{V_{rk}}}$$

where

P_{gk} = probability that alternative g will be chosen by individual k,

$V_{rk} = a_0 + a_1 \cdot X_1 + a_2 \cdot X_2 + \ . \ . \ . \ a_n \cdot X_n$,

= utility function assumed to be a linear combination of the explanatory variables (X),

a_1 = parameters of the equation to be determined by calibration ($i = 1, 2, \ldots n$), and

G = number of alternatives available.

The equation implies that the ratio of the probabilities of choosing alternative i over alternative g, that is, P_{ik}/P_{gk}, is independent of the presence or absence of any other alternative in the system, thus satisfying the equation

$$\ln\left(\frac{P_{ik}}{P_{gk}}\right) = V_{ik} - V_{gk}$$

This property is called the independence of irrelevant alternatives (IIA). IIA is a strength of the MNL because it allows new alternatives to be introduced into the model without re-estimating the model once a numerical functional form of V is established. The IIA property was useful in this research when a new airport was introduced into the system to deter-

QUESTIONNAIRE

DATE:........................ DAY: .... SERIAL NUMBER: ....

INTRODUCTION: I am carrying out a survey for Loughborough University of Technology, England, for research work sponsored by the Federal Ministry of Transport and Aviation, Lagos, to assist in Aviation Systems planning in Nigeria.

Your cooperation in providing answers to the Questionnaire will be highly appreciated and please note that your name is not required and the information will be used only for research and planning purposes.

Can you tell me please:

Q.1. Where do you live in Nigeria? Town/City ____________________

Local Govt. Area ______________

State ________________________

Q.2. What is the name of your departure airport (the airport from which you have just taken off or about to take off)? ________________________________

Q.3. Which Airline are you flying with? ______________________________

What is your flight number? ______________________________

Q.4. Where did you begin your journey to the departure airport?

Town/City ____________________

Local Govt. Area ______________

State ________________________

Q.5. What means of transport did you use to arrive at this departure airport? (Check most appropriate means.)

Private Car	Airways/Airline Bus
Taxi	Company Vehicle
Commercial Vehicle or Bus	Another Aircraft
Airport Authority Bus	Other (please describe below)

____

FIGURE 3 Inflight questionnaire.

Q.6. Why did you choose the particular means of transport, e.g. taxi, bus, car to the airport? (Mark one answer below.)

The only means available	Cheapest means	Fastest means	Free ride or family car	Company vehicle	Other (please specify) ___________

Q.7.a. How long did it take you to reach the airport from your home or the place where you started the journey today? _________ (hours and minutes)

7.b. How much did it cost you to get to the airport today? (by taxi, bus, car petrol) ___________

Q.8. How far away from the departure airport did you start this journey today? _______ km (approx)

Q.9. Why did you choose this particular airport for your journey? (mark one answer below)

Nearest to place I stayed last night	Most convenient and has many flights	In my state, or affiliated to airline	Cheaper air fares	Recommended by company or agent	Convenient and cheap parking

Other (specify) ___________________________

Q.10. Which airport are you travelling to from here? ______________________

Q.11. Are you travelling to that airport just to change flight? (yes/no) __________

If "yes", which airline are you continuing your flight with? ____________

Q.12. What is your final destination airport? __________________________

(airport you are really travelling to)

Q.13. What is your final destination city/town? ____________________

State ____________________

Q.14. By what means will you travel to your final destination city/town from that airport? (car, bus, taxi, train, etc.) ____________________

Q.15. What is the chief purpose of your journey?

(please check one box only)

Official - Government duties/armed forces/civil servant

Business/trading/private consultant

School/leisure/holidays/personal reasons/visiting

Q.16. What is your profession/occupation? ______________________

Q.17. Where is your usual place of work or business? ____________________

FIGURE 3 ***(continued).***

Q.18. What is your age group? (please mark group only)

Under 21   20-29   30-39   40-49   50-59   60-69   Over 70

____

Q.19. What is your sex?   Male   Female

Q.20. What annual salary/business income range do you belong in Naira?

(check one box only)

0 -	4,999 p.a.
5,000 -	9,999 p.a.
10,000 -	14,999 p.a.
15,000 -	19,999 p.a.
20,000 and over	p.a.

Q.21. How often do you travel from the departure airport?

Occasionally   Regularly

Please give approx. number of times per week,

per month, etc. ______________________________

Q.22. What suggestion would you give to the following, concerning the improvement of Aviation services?

a. Airport Authority ______________________________

____

b. The Airways or Airline ______________________________

____

c. The Government/Ministry of Transport & Aviation

____

____

What is the air fare on your ticket? (1st Class or Normal) __________

Q.23. If all the items listed below are available, which one best serves your interest? (check only ONE answer please)

a. More flights + night flights

b. More airlines for competition

c. Direct flights to your destination

d. Punctuality of departures, and seat numbers on boarding passes

e. Cheaper air fares

f. Better road, less congestion and cheaper cost to the airport

Q.24. a. Are you a Nigerian   Non-Nigerian   (check box)

b. Where is your permanent residence? Country __________

Q.25. Finally, how many people saw you off at the airport? 1   2   3+

FIGURE 3 ***(continued).***

TABLE 1 ARRANGEMENT OF DATA FOR MODEL CALIBRATION

Obs No	Alternative Chosen	TT_1	FF_1	AF_1	TT_2	FF_2	AF_2
0001	2	141	66	69	90	86	48
0002	2	131	'	'	15	'	'
'	'	'	'	'	'	'	'
'	'	'	'	'	'	'	'
'	'	'	'	'	'	'	'
1002	1	15	'	'	138	'	'

The number of alternatives = 2 (codes 1 and 2)

TT_1 = Travel Time to airport 1 by an observation
TT_2 = Travel Time to airport 2 by same observation (calculated)
FF_1 = Flight Frequency from airport 1
FF_2 = Flight Frequency from airport 2
AF_1 = Air Fare from airport 1 to destination
AF_2 = Air Fare from airport 2 to destination.

NB: If the observation chose airport 2, then TT_2 is the travel time to airport 2 which was reported, while TT_1 is then calculated for that observation for the unchosen airport (which is airport 1).

TABLE 2 RESULTS OF INITIAL MODEL CALIBRATION

Initial likelihood function value	-692.4606
Final likelihood value	-146.1230
"Rho-squared" (ρ^2) wrt zero	0.7986
"Rho-squared" (ρ^2) wrt constants	0.7847

	Travel Time	*Frequency*	*Fare*
Estimated Coefficient	-.4789E-01	.7547E-01	.8013E-01
Standard Error	.373E-02	2.36	2.25
"t" Ratio	-12.8	0.03	0.03

mine its effects on these two airports within the existing airport system. The model was calibrated using the ALOGIT Maximum Likelihood Method of Estimation (MLE) because the choice model is nonlinear and requires a more complex estimation procedure than simple linearized demand models such as regression techniques and least-squares estimation methods.

A number of variables, namely travel time (*TT*), flight frequency (*FF*), and air fare (*AF*), were used for the initial calibration of the model to determine whether they were significant in airport choice in the airports studied. These variables were used because they were cited most frequently by the air travelers surveyed as the reasons for choosing an airport. They were also found to be pertinent in the previous studies in developed countries (*2,3*). Other variables were rejected by inspection because they were so infrequently cited.

Results of the initial calibration given in Table 2 showed that of the three variables tested, only the travel time variable had a "t" ratio significantly different from zero, with a value of −12.8. The flight frequency and air fare variables were not significant and were therefore dropped from the model.

Final Structure of Model

The model was recalibrated using the only significant variable—access travel time. The utility function could now be written as

$$U = \beta \cdot TT$$

where TT is access travel time to the airport, and β is the coefficient to be estimated.

The final model calibration output is given in Table 3. The output of the model shows that the rho-squared values of 0.8 and the standard error for travel time (β_1) = 0.0038 both indicate a high degree of fit.

Results of Calibration

Comparison of Observed and Forecast Data

The theoretical probabilities of choice are calculated for a number of observations as follows:

$$P(X_1/E) = \frac{1}{1 + \beta^* \exp\,[\beta_1\,(X_2 - X_1)]}$$

where

β_1 = −0.048 (from model calibration),
β^* = exp (−β_0) = exp (−0.1729) from calibration = 0.84122,
X_1 = access travel time to Airport 1 (Enugu airport),
X_2 = access travel time to Airport 2 (Benin airport), and
$P(X_1/E)$ = probability of choosing Enugu airport given knowledge of its access travel time.

Values of the theoretical probabilities obtained are plotted against the differences in travel times for the observations (see Figure 4). The shape of the resulting logistic curve is in close agreement with those found in standard texts. As demonstrated by the curve, the slope is greatest at the midpoint where the probability (P) = ½ which means that changes in independent variables will have their greatest impact on the probability of choosing an alternative at the midpoint of the distribution. Additionally, the gentle slopes near the ends of the curve imply that large changes in X are necessary to bring about a small change in probability (*10*).

Goodness-of-Fit

The same goodness of fit is shown in Table 4, which is a tabular comparison (in percentages) of the observed and forecast shares of the two airport choice. Similarly a χ^2 test indicated a very high level of significance to the fit.

EFFECT OF INTRODUCING A THIRD AIRPORT

The model was used to forecast the effect of introducing a third airport into the system (the Onitsha airport, now under construction). The forecast shares are shown in Table 5, where the redistributions from a two- to a three-airport system are shown. Table 6 indicates the predicted losses at Benin and Enugu engendered by the introduction of the Onitsha airport to the system.

Overall, the introduction of the third airport reduced the share of Lagos-bound traffic from the region for Enugu from 58.8 percent to 41.2 percent and for Benin from 42.8 percent to 33.0 percent. Using the available 1985 annual traffic volumes 295,992 for Enugu and 364,996 for Benin—figures provided by the Nigerian Airports Authority—the traffic for Enugu would drop to 207,396 and traffic for Benin would drop to 255,838. Onitsha would pick up these losses, which amount to a total of 197,754 passengers, and would also be expected to generate its own traffic. These results indicate model capability for forecasting the choice made in the event of the construction and operation of the third airport.

DISCUSSION OF RESULTS

Results of the model suggest several implications regarding the role of the variables in airport choice in Nigeria.

First of all, flight frequency and air fare are not important variables at the levels investigated. This conclusion implies that reasonable changes in both frequency and air fare will have very little effect on airport choice.

Second, travel time is the major determinant in choosing an airport in Nigeria. This implies that shares of air travel could be increased by improving the general ground accessibility of the airport; however, this is likely to be a useful policy tool in only a few instances. Travel time factor also implies that the introduction of additional airports into a region will cause a predictable redistribution of airport passenger traffic. This implication has important locational considerations when additional facilities are being considered.

Third, at the outset of this study, it was felt that tribal origin could have an effect on airport choice—that passengers might travel from airports and make a choice of airport within their own tribal districts or region. This was not found to be a significant factor in airport choice.

Additionally, the results imply that the level of service and the level of investment in each airport can be based in part on the accessibility to population in each airport region, because airports will be expected to serve the demand of nearby areas. Harvey (*2*) found travel time and flight frequency to be important determinants of airport choice in the San Francisco Bay Area airports (air fare was not introduced in the model and its effect was not determined), whereas Benchemam found that travel time, flight frequency, and air fare were important determinants of airport choice in the UK airports studied (*8*).

Air fare and flight frequency were insignificant to the study for two reasons. First, the study involved domestic travel of less than 1 hr duration, and there are no significant variations in both fare and frequency for the two airports. The number

TABLE 3 FINAL MODEL CALIBRATION OUTPUT

Initial likelihood function value		- 694.5402
Final likelihood value		- 146.1283
Likelihood		- 146.1283
Rho-squared (ρ^2) wrt zero		0.7986
Rho-squared (ρ^2) wrt constraints		0.7847
	K-Enugu (β_0)	K-Travel Time (β_1)
Estimates (coefficients)	0.1729	- 0.04845
Standard Error	0.151	0.00381
"t" Ratio	1.1	- 12.7
No. of iterations	7	

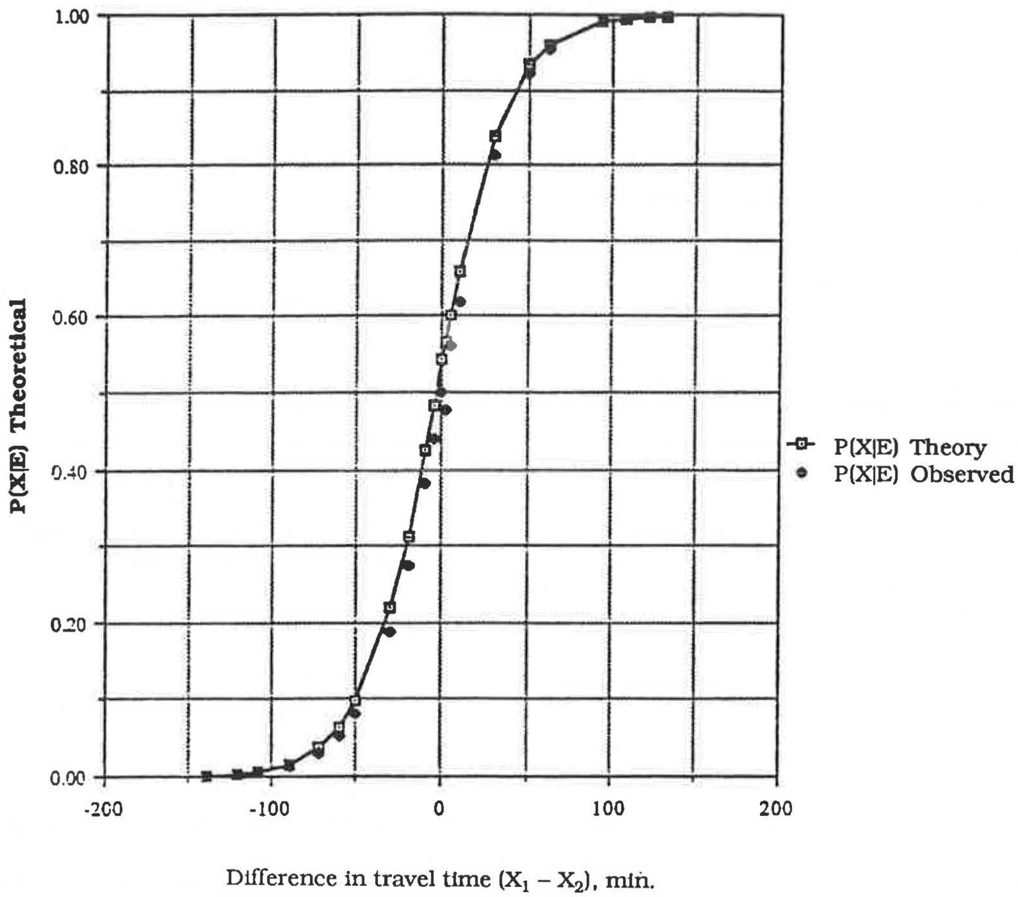

FIGURE 4 Probability versus difference in travel time.

TABLE 4 ZONE COMPARISON OF OBSERVED AND FORECAST SHARES FOR TWO AIRPORTS FOR THE 1,002 OBSERVATIONS

ZONES	*OBSERVED SHARE OF TRIPS*	*FORECAST SHARE OF TRIPS*	*OBSERVED %*	*FORECAST %*
1E	282	281	0.28	0.28
1B	3	4	0.00	0.00
2E	99	105	0.10	0.10
2B	40	34	0.04	0.03
3E	2	1	0.00	0.00
3B	36	37	0.04	0.04
4E	4	5	0.00	0.00
4B	190	189	0.19	0.19
5E	28	25	0.03	0.02
5B	2	5	0.00	0.00
6E	0	0	0.00	0.00
6B	2	2	0.00	0.00
7E	174	180	0.17	0.18
7B	140	134	0.14	0.13
TOTAL TRIPS	1002	1002		

TABLE 5 FORECAST SHARES FOR THREE-AIRPORT-CHOICE SITUATION

	FORECAST (based on sample of 1002 passengers)			*FORECAST SHARE (%)*		
ZONE	ENUGU (A 1)	BENIN (A 2)	ONITSHA (A 3)	A 1	A 2	A 3
1	256	2	27	89.8	0.7	9.5
2	25	8	106	18.0	5.8	76.2
3	1	16	21	2.6	42.1	55.3
4	4	181	9	2.1	93.3	4.6
5	7	1	22	23.4	3.3	73.3
6	0	2	0	0	100	0
7	136	121	57	43.3	38.5	18.2

TABLE 6 ZONAL LOSS FROM TWO- TO THREE-AIRPORT SYSTEM (%)

Zone	Enugu	Benin
1	9.1	0.4
2	53.2	23.0
3	2.7	52.6
4	0	4.5
5	69.9	3.4
6	0	0
7	12.1	6.1

of daily direct flights from Enugu to Lagos is five, and from Benin to Lagos is seven. Air fares are noncompetitive and are effectively controlled by the government. It should be noted that access to the airports is mainly by private car and taxi, because there is no rapid transit, rail service, or bus service as observed in previous studies in the developed countries (United Kingdom and United States). Passengers appear not to have found the small differences in air fare and frequency sufficient attraction to choose an airport that is farther away from their trip origin because of increased access time and access cost. Total travel time and cost (air and ground) would also increase.

Second, air fare and flight frequency are, to a large extent, outside the control of the airlines and airports; these factors are influenced and controlled by the Nigerian government. The government's intent is to balance regional with national needs, which are not necessarily economic. In effect, there is no strict competition between the airports and airlines. The advertising and promotional fares used as market strategies in the United Kingdom and the United States are not used in Nigeria.

The differences in the three case studies are that the Nigerian study involved journeys of less than 1 hr and that passengers may not have found it necessary to choose an airport with a longer access travel time, because total trip time would certainly increase. On the other hand, the airport studies in the United States and the United Kingdom involved both domestic and international passengers. Passengers in those studies were stratified into business and nonbusiness passengers (and international leisure passengers in the UK study). Thus travelers had to consider the flight frequencies and air fares available at each airport because of the long-haul nature of their journey.

CONCLUSIONS

Disaggregate behavioral airport choice models can provide an important policy tool for airport planners, managers, and decision-makers. Although relatively new, the advantages of such models over other models in forecasting ability and accuracy make them more suitable in airport choice modeling to help ensure the balance of the economic equation between travel demand and supply.

Because of the high level of investment characterizing the civil aviation industry, and because the industry is highly susceptible to political, economic, and other external influences, air traffic forecasting is a useful tool in airport planning. It can be used to determine airport shares, levels of service, and consequent desirable levels of investments—especially in a developing country such as Nigeria. Finally, this research has demonstrated that the catchment area concept is not valid in Nigeria. Airports do in fact compete. This supports the findings in the United States and the United Kingdom in separate studies by both Harvey (*2*) and Benchemam (*8*). However, the results suggest that the regional populations should be considered when deciding on the level of investment and level of service because airports will, in most cases, be expected to serve "local" demands, at least in the short run.

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