# Passengers' Choice of Airport: An Application of the Multinomial Logit Model

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**The authors sought to establish that airports do not have "catchment areas" as such and that air travelers make choices among available airports when they elect to travel. A model that describes this choice mechanism will permit airport systems to be planned on a more reliable basis. This work develops a model for passengers in central England based on data collected in 1975 and 1978 by the Civil Aviation Authority. The model chosen was one of discrete behavioral choice; the particular form that was successfully calibrated was the multinomial logit model. For business and inclusive tour travel, the most important variables of choice were access time to the airport and frequency to the chosen destination. For domestic and leisure trips there were three factors: air fare, access time, and frequency of available flights, in that order of importance. The calibrated model showed high agreement between observed and predicted market shares. The model was also found to be transferable to data from a separate survey of air travel from the London area. The model is expected to be of use to airport authorities and airlines in planning and determining business strategy in the increasingly competitive deregulated environment of air transport.**

It is not unusual for airports to be discussed in terms of "catchment areas," as if an individual airport served a particular area of a country. The concept of catchment would, perhaps, be valid if all air trips originating in a particular area invariably used the same airport, but this is not so. De Neufville *(1)* quite rightly pointed out the error of using this term in conjunction with airports because in many situations people can and do choose the airport they will use. Air trips are not invariably drawn to a single airport. If he has a choice of airport, the passenger is likely to choose on the basis of the perceived overall level of service he obtains from his selection. In a small country like the United Kingdom where there are many commercial service airports it is not possible to adhere to the belief in nonoverlapping airport catchment areas. Little research has, however, been carried out to obtain a better understanding of how trip makers choose among the services offered by competing airports. This is partly because carrying out research on airport selection is likely to involve time-consuming and costly passenger surveys.

In this work, after the factors that determine choice had been ascertained from a priori evidence, it was decided to construct a model based on the microeconomic theory of consumer choice instead of using a regression approach that would rely on a superficial correlation between observed data. In surface transport mode choice modeling, both in the urban and the interurban cases, discrete mode choice or behavioral models have been found preferable to and more transferable than the early aggregate models. It was believed that if a consumer choice model of this type could be built, it could be useful in forecasting the redistribution of passenger traffic among airports as new facilities and infrastructure or more services are added to the system or as other facilities, unsuitable for use on environmental or other grounds, are closed. It could also be helpful in determining the optimum location of new facilities. Furthermore, the model could be useful in forecasting the redistribution of traffic that might result from improvements in airport ground access (such as the construction of a high-speed rail system or a motorway), from the effect of shifting flights from one airport to another, or from the adoption of widely varying air fare policies. It is clear from the available literature that little work has been attempted in the field of airport choice in spite of the important implications that passenger choice has for demand and the consequent need for facilities. As air traffic continues go grow, there is a need for a much clearer understanding of how demand is shared among the components of a multiple-airport system and what factors are likely to be most effective in bringing about changes in demand shares among airports in such a system.

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## DATA REQUIREMENTS AND PREPARATION

The independent variables chosen from the outset of this modeling exercise were surface access time, frequency of flight service, and air fare. These variables had previously been the reasons most frequently cited by passengers for their selection of an airport in a survey carried out by the Civil Aviation Authority in 1978 *(2)*. Potentially, a large range of variables could enter into any choice model, but some variables are highly intercorrelated, and data are not always available for others. Tests were carried out on data for these three variables. They were found to be statistically independent one of another, and in combination it was found that they were capable of producing a highly significant model.

For each passenger the following data were required: surface origin, flight destination, age, day of the week on which trip was made, trip purpose, selected airport, travel time from surface origin to all competing airports, number of flights from the competing airports to the selected destination on that particular day of the week, and air fare from the competing airports to the selected destination. This sort of data is not routinely available from ordinary air transport sources. Specially organized airport surveys are generally prohibitively expensive because of the large sample size necessary to provide an adequate data base on individual airports or city pairs. Such data are, however, available from origin-destination surveys carried out periodically for the Civil Aviation Authority in the United Kingdom. The base survey data of the 1975 and 1978 surveys were made available to Loughborough University by the Civil Aviation Authority at the required level of individual trip records stored on computer tape *(2, 3)*. The analysis was carried out between 1983 and 1986. Although fare levels have changed considerably since the time of the surveys, use of the old data is valid because the model is one of behavioral choice that reflects fare levels at the time of travel. The logic of the model is unaffected by subsequent changes in the values of the variables used. A total of 40,000 passengers were interviewed for the 1975 survey and 91,086 for that in 1978. A survey of this scale was beyond the resources of this study, and the research was therefore dependent on the goodwill of the CAA in making their original trip records and associated origin-destination data available in magnetic tape format. For the purposes of this study 2,577 trip records were used. Air fare and flight frequency, which were not included in the CAA survey data, were obtained from the *ABC World Airways Guide (4)*.

Because of the availability of data in suitable form, central England was selected as the study area. The airports considered were Manchester, Birmingham, East Midlands, Luton (for inclusive tours only), and London's Heathrow. Subsequently, the following destinations were selected for purposes of analysis:

- Domestic: Belfast, Jersey, Glasgow, and Aberdeen;
- International: Dublin, Amsterdam, Frankfurt, and Brussels; and
- Inclusive tours: Palma, Alicante, and Ibiza.

Passengers were stratified on the basis of the following trip purposes:

- Domestic,
- International business,
- International leisure, and
- International inclusive tours.

It was reasoned that these four categories of passengers were likely to make different travel decisions.

Data relevant to the study included air passenger trip records (local origin, destination, airport used, flight number, trip purposes, and day of interview), frequencies of flight, air fares, and access time to the airports. These were necessary data both for the chosen airport and the rejected airports. As an example, for a passenger originating from a point somewhere in the city of Nottingham and flying to Amsterdam on a business trip from Manchester Airport on Thursday, the following were needed:

1. For the choice made:

- Computation of travel time from the point of origin in Nottingham to Manchester Airport.
- Determination from the pertinent *ABC World Airways Guide* of the number of flights leaving Manchester Airport to Amsterdam on Thursday as well as the economy air fare.

2. For the choices rejected:

- Computation of the respective travel times from Nottingham to Birmingham Airport, East Midlands Airport, and Heathrow Airport.
- Determination from pertinent *ABC World Airways Guide* of the number flights on Thursday to Amsterdam from Birmingham Airport, East Midlands Airport, and Heathrow Airport as well as the respective economy air fares.

## AIRPORT CHOICE MODEL

In previous attempts at modeling air transport trips at airports, the aggregate model approach was used. Airports have been regarded as centers of attraction of potential air trips generated in zones surrounding the airport. In recognition that zones that are remote from an airport in ground access terms will generate a low number of trips, the "propensity to fly" in these zones is depressed by a factor that reflects poor ground access. This approach is inevitable if aggregate or zonal models are used.

The development during the last 15 years of more sophisticated behavioral discrete choice models suggests an approach that is likely to be considerably more accurate, is capable of calibration with considerably fewer data than required for the aggregate approach, and is transferable from one area to another. Using the disaggregate approach, generation models can be built that will model the number of air trips generated throughout a region on the basis of the socioeconomic characteristics of the population and the provision of air service. These generated trips are then assigned to individual airports by a disaggregate airport choice model such as that proposed in this work. Earlier aggregate models have not been useful for examining the impact of changes in the availability and level of service of competing airports, either because they do not incorporate airport attributes as variables or because they perform poorly even when they do include such variables. These models do not consider that individual passengers can and do make choices about which airport to use.

The behavioral model employed in this research was, on the basis of experience with its use in both urban and interurban surface transport applications *(5)*, expected to provide a better approach to the problem under study. Discrete choice models of this type have been developed on the basis of stochastic choice using the hypothesis of random utility maximization. The most widely used of these models is the multinomial logit model (MNL):

$$P_{gk} = e^{V_{gk}} / \sum_{r=1}^{G} e^{V_{rk}} \qquad (1)$$

where

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

$V_{gk}$ = $a_1X_1 + \ldots + a_n X_n$ = representative function of the utility where $a_0, a_2 \ldots a_n$ = parameters to be estimated and $X_1, X_2 \ldots X_n$ = explanatory variables.

An important application of this formulation is that the ratio $P_{ik}/P_{gk}$ of choosing alternative $i$ over alternative $g$ is independent of the presence or absence of a third option, satisfying the equation

$$\text{Ln } (P_{ik}/P_{gk}) = V_{ik} - V_{gk} \quad (2)$$

This property, termed "independence from irrelevant alternatives" (IIA), is both the principal strength and the principal weakness of this model. It is a strength because it allows the introduction of new alternatives without reestimation of the model after a numerical functional form of $V$ has been established. It is a weakness because it requires that the alternatives be perceived as completely distinct and independent. A test based on conditional choice *(6)* was carried out for the four categories of passengers, and it can be concluded that in this study there is no violation of the IIA property. The MNL was, on balance, considered by the authors to be the most appropriate tool for modeling airport choice.

## CALIBRATION RESULTS

Separate models were calibrated for business, leisure, inclusive tour, and domestic air passengers by using an original computer program written by Ben-Akiva *(7)* based on a maximum likelihood technique.

Examination of the data, in conjunction with analysis of the earlier CAA survey results, indicated that a suitable form of the utility function of the model could be written in the form

$$V = a_1 \cdot TT + a_2 \cdot FREQ + a_3 \cdot FARE$$

where

$TT$ = travel time to the airport,
$FREQ$ = number of flights per day,
$FARE$ = air fare, and
$a_1, a_2, a_3$ = coefficients to be estimated in the calibration.

Statistical analysis of the data indicated that these variables were independent one of another.

In the first run, the fare parameter had the "wrong" sign for the business and inclusive tour categories (this parameter is expected to be negative). Thus the model was reestimated leaving out this variable for these two categories of passengers. The results of the calibration are given in Table 1. The likelihood ratio tests are much larger than the tabulated $\chi^2$ at the 99 percent confidence level, which implies an excellent fit. The likelihood ratio index values of 0.88, 0.92, 0.84, and 0.92 give evidence of this. Another goodness of fit measure is how well the model predicts the share of each airport. The data in Table 2 indicate that the predicted share of each airport was close to the observed share for all categories of passengers. Aggregate direct and cross elasticities were estimated to measure the responsiveness of airport choice to changes in the explanatory variables found significant at the 95 percent confidence level. Those are given in Tables 3–6.

TABLE 1 CALIBRATION RESULTS

| | Business | Leisure | Inclusive Tours | Domestic |
|---|---|---|---|---|
| $a_1$ (TT) | - 0.13605<br>(- 6.93)* | - 0.13788<br>(- 6.47)** | - 0.17787<br>(- 11.23)** | - 0.23254<br>(- 6.71)** |
| $a_2$ (FREQ) | 1.6607<br>(6.79)* | 1.07<br>(5.87)** | 2.069<br>(10.69)** | 2.6957<br>(6.61)** |
| $a_3$ (FARE) | -<br>- | - 1.2035<br>(- 4.23)* | -<br>- | - 0.74645<br>(- 5.22)* |
| Likelihood ratio test | 521.03 | 847.02 | 3123.67 | 1746.60 |
| Likelihood ratio index | 0.88 | 0.92 | 0.84 | 0.92 |
| $\chi^2$ (0.01, df) | 9.21 | 11.34 | 9.21 | 11.34 |
| df | 2 | 3 | 2 | 3 |

** significant at 99 per cent confidence level
* significant at 95 per cent confidence level
(t values shown in parentheses)

TABLE 2 OBSERVED AND PREDICTED SHARES

| | BUSINESS | | LEISURE | | INCLUSIVE TOURS | | DOMESTIC | |
|---|---|---|---|---|---|---|---|---|
| | Obs % | Pred % | Obs % | Pred % | Obs % | Pred % | Obs % | Pred % |
| MANCHESTER | 27.57 | 27.10 | 19.63 | 19.94 | 23.87 | 23.13 | 9.96 | 12.00 |
| BIRMINGHAM | 25.23 | 25.23 | 59.52 | 55.89 | 33.58 | 34.17 | 35.14 | 31.33 |
| EAST MIDLANDS | 15.42 | 17.29 | 13.90 | 17.22 | 34.84 | 36.62 | 53.00 | 54.17 |
| HEATHROW* | 31.78 | 30.27 | 6.95 | 6.95 | 7.71 | 6.08 | 1.90 | 2.49 |

*Luton for inclusive tours

TABLE 3 DIRECT AND CROSS ELASTICITIES—BUSINESS

| | Direct Elasticities | | | | Cross Elasticities | | | |
|---|---|---|---|---|---|---|---|---|
| | M | B | EM | LHR | B-EM-LHR | M-EM-LHR | M-B-LHR | M-B-EM |
| TT | -0.77 | -0.33 | -0.85 | -1.94 | 4.98 | 2.21 | 2.76 | 21.05 |
| FREQ | 0.31 | 0.26 | 0.24 | 1.79 | -4.33 | -3.49 | -2.12 | -26.87 |

TABLE 4 DIRECT AND CROSS ELASTICITIES—LEISURE

| | Direct Elasticities | | | | Cross Elasticities | | | |
|---|---|---|---|---|---|---|---|---|
| | M | B | EM | LHR | B-EM-LHR | M-EM-LHR | M-B-LHR | M-B-EM |
| TT | -0.22 | -0.19 | -0.67 | -4.38 | 3.23 | 1.90 | 2.56 | 18.74 |
| FREQ | 0.07 | 0.08 | 0.13 | 2.89 | -3.21 | -2.03 | -0.95 | -14.23 |
| FARE | -0.97 | -1.26 | -4.25 | -6.74 | 25.21 | 25.5 | 23.11 | 31.7 |

TABLE 5 DIRECT AND CROSS ELASTICITIES—INCLUSIVE TOURS

| | Direct Elasticities | | | | Cross Elasticities | | | |
|---|---|---|---|---|---|---|---|---|
| | M | B | EM | LUT | B-EM-LUT | M-EM-LUT | M-B-LUT | M-B-EM |
| TT | -1.73 | -0.52 | -1.38 | -7.20 | 6.97 | 2.79 | 5.29 | 11.83 |
| FREQ | 0.58 | 0.49 | 0.48 | 6.69 | -4.02 | -3.98 | -3.24 | -13.57 |

TABLE 6 DIRECT AND CROSS ELASTICITIES—DOMESTIC

| | Direct Elasticities | | | | Cross Elasticities | | | |
|---|---|---|---|---|---|---|---|---|
| | M | B | EM | LHR | B-EM-LHR | M-EM-LHR | M-B-LHR | M-B-EM |
| TT | -1.77 | -0.62 | -0.46 | -9.13 | 7.07 | 3.23 | 6.83 | 28.67 |
| FREQ | 0.42 | 0.28 | 0.21 | 8.72 | -4.41 | -3.51 | -3.39 | -27.38 |
| FARE | -1.96 | -0.87 | -0.62 | -3.68 | 10.63 | 12.48 | 12.21 | 8.28 |

## DISCUSSION OF RESULTS

It can be seen from the results that the a priori stratification of passengers into four categories, on the assumption that they make different travel decisions, was justified and that the variables expected a priori to be important were adequate explanatory variables. It is useful to measure for each category of passengers the relative importance of these variables as determinants of airport choice using the elasticity values given in Tables 3–6 and consequently to suggest some of the implications of these attributes as airport policy tools. The data in Tables 3 and 5 indicate that, for business and inclusive tour passengers, the absolute value of the direct elasticity of travel time is in all cases higher than the corresponding value of the direct elasticity of frequency of flights. From this result it can be concluded that the travel time variable is the dominant factor. Similarly, the data in Tables 4 and 6 indicate that the fare variable is the dominant factor for leisure and domestic passengers. These conclusions are summarized in Table 7.

TABLE 7 RELATIVE IMPORTANCE OF VARIABLES

| | Business-Inclusive Tours | Domestic-Leisure |
|---|---|---|
| 1st Dominant | TT | FARE |
| 2nd Dominant | FREQ | TT |
| 3rd Dominant | | FREQ |

For the British regional airports considered, it can be concluded from the elasticities tables that, as far as the passengers from the study area are concerned,

- A fare policy would give the best results in the attraction of more passengers if it were applied at Manchester Airport for domestic passengers and at East Midlands Airport for leisure passengers.
- An access improvement policy would give the best results in the attraction of more passengers if it were applied at Manchester Airport for domestic and inclusive tour passengers and at East Midlands Airport for business and leisure passengers.
- A frequency of flights policy would give the best results in attracting more passengers if it were applied at Manchester Airport for business, inclusive tour, and domestic passengers and at East Midlands Airport for leisure passengers.

It can therefore be concluded that Manchester Airport has the potential to develop into a "hub" airport. This finding supports the 1985 U.K. government White Paper on airport policies that states:

> The government is fully committed to maintaining and further developing Manchester airport as a gateway . . . for long-haul services, and as a domestic and European hub.

East Midlands Airport could also attract more passengers, particularly those on leisure trips, if the appropriate policies (i.e., lower fares) were applied. Birmingham Airport appears to suffer more from the proximity of the London airports.

The high values of the cross elasticities when there is a change in a variable characterizing Heathrow (Luton for inclusive tours) show that there is most scope for redirecting passengers originating from central England to the three regional airports. This measure could be considered by some in a negative light because there is a risk that connecting traffic at Heathrow might be lost to other European airports.

In work that will be reported in a later paper, the model was tested for transferability to another area of the United Kingdom using data collected in a subsequent survey by the Civil Aviation Authority. Pooled data and Bayesian updating techniques were used, and the model was found to be statistically transferable.

## CONCLUSIONS

Disaggregate behavioral models of airport choice provide an important new tool for the airport planner. Furthermore, the possibility of transferability in time and space (after applying an updating procedure) adds to their attraction.

The results showed that the multinomial logit model used for airport choice had good explanatory ability and was successful in predicting choices actually made. The predicted share for each airport was also close to the observed share for the four categories of passengers.

As already stated, the results justified the a priori stratification of passengers into four categories and confirmed some intuitive expectations such as that nonbusiness passengers are more concerned with accessibility and less concerned with flight frequency than are business passengers when choosing among airports.

Elasticity analysis was also conducted in this study. It showed that choice was not equally responsive to changes in its determinants and therefore access time, flight frequency, and air fare cannot be viewed as equal determinants of airport choice. The accessibility variable was more important than the frequency of flights variable for all passengers. The fare variable, found to be significant only for leisure and domestic passengers, is the most important determinant for these two categories.

It appears that by influencing these determinants, the planner or operator can shift traffic from one airport to another in order to have an airport system that is more economically or environmentally efficient. Air fare differentials can be effective in attracting leisure and domestic passengers from one airport to another. For the business traveler, changes in flight frequency are much more effective in changing airport choice.

Improvements in airport access can be an efficient policy tool for shifting passengers' choice of airport, regardless of trip purpose. Obviously, airport managers and airport planners are unlikely to have much influence over the scale of the regional road transport system and therefore often have little direct control over this variable. However, a major change in the road access system, brought about independently of airport needs, may have large and previously unpredictable effects on airport choice and therefore airport demand. A case in point is the recent completion of the London Orbital route in Britain, which was planned for general easing of traffic congestion in metropolitan London. Overnight it has made Gatwick Airport considerably more accessible to the Midlands and East Anglia. In the next few years this increased accessibility will have profound effects on the distribution of traffic among the London area airports.

Because the model predicts airport share, it could be used in forecasting the redistribution of passengers among airports if another airport were to be added to the system or, on the other hand, a decision were made to close one airport in a multiairport system. Because the test of independence from irrelevant alternatives was found to be valid, the model does not need to be reestimated if one or more airports are added to or dropped from the system under consideration. There is also strong evidence that the model is transferable outside the area of calibration.

In conclusion, it can be stated that disaggregate behavioral models of airport choice provide an important new tool for airport planners and operators. Although conceptually they are more difficult to comprehend than some of the simple models now in use, their advantages in accuracy and reduced data requirements argue strongly for their adoption. From the viewpoint of airport operators, the model demonstrates that traffic at an airport will increase disproportionately to population growth as flight frequencies increase, fares fall, and surface transport links serving the airport improve. These variables are, of course, not generally under the control of the airport authority, and the airport operator almost certainly will be required to provide increased capacity as favorable changes in these factors are produced by the airlines and by investment in ground access infrastructure. Equally important is that airport authorities struggling to maintain market share must ensure that they are not displaced in the marketplace by competing airports at which flight frequencies and fares are improved to attract business and leisure passengers, respectively.

The implications of the model for the airline operator are clear. Business traffic will be attracted to an airport only if ground access and flight frequency are adequate, and ground access time is far more important than flight frequency. For the leisure traveler, fare and access time are the most important factors, and an airline operating from a particular airport must compete on that basis.

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