Increased Seating Capacity

Airlines are trying to improve the average number of available revenue seats per departing flight, which in turn will reduce the number of departing flights and the quantity of fuel consumption. It was assumed that the increase in available revenue seats starting in 1980 would occur in the same airports as in the previous scenario, with the addition of Lynchburg Airport. The following conditions at these airports were anticipated for 1990:

Airport	Seats Available	Percentage Increase per Year
Charlottesville	100	2.385
Dulles International	170	2.116
Lynchburg	90	2.257
Norfolk	140	1.967
Richmond	125	2.569
Roanoke	120	3.150

RESULTS OF ADDITIONAL SCENARIOS

The results of the additional scenarios are shown in Table 5. Again, the model's outputs respond logically to the conditions under consideration. The projected jet fuel consumption increases the most under the scenario for competition between airports. One reason for this result is that the more-competitive airports, which are the large airports in Virginia, would be attracting more passengers, which would result in more departing flights and consequently more fuel consumption. Also, these large airports have a higher rate of fuel consumed per departing flight, which adds to the total increase in jet fuel consumption.

Aviation gasoline is considered only under one scenario, introduction of commuter air service, which shows a small amount of increase in such fuel consumption. The introduction of commuter air service is expected to have little effect (as the results show) on aviation fuel consumption, because there would be relatively small numbers of departing flights and, in addition, the amount of fuel consumed per departing flight by small commuter aircraft is small.

The scenario for expansion of Piedmont routes produced a slight increase in the amount of jet fuel consumption. On the other hand, increased seating capacity and improved efficiency of fuel consumption would have a sizeable impact on the reduction of jet fuel consumption.

In conclusion, the amount of aviation fuel consumption in Virginia is primarily affected by the economic condition of the state and the nation. In addition, airline policies have a great effect on the amount of jet fuel consumption in the state.

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Estimating the Market Share of International Air Carriers

STEVEN R. GORDON

United States flag carriers and aviation authorities are currently participating in a large number of activities that promise to alter the structure of the international air-transport network. There is a pressing need to develop methods for estimating the share of traffic that U.S. carriers can expect to attract under the various alternatives being considered. To meet these needs, a new method called the international quality-of-service index (IQSI) has been developed. It is derived from the quality-of-service index (QSI) method developed by the staff of the Civil Aeronautics Board for domestic-route cases and augments the old QSI method by considering (in addition to frequency, aircraft type, and number of stops) the impact on market share of citizenship loyalty to flag carriers. Use of IQSI essentially eliminates the biases inherent in the old QSI method and reduces the average prediction error by more than 25 percent.

The U.S. international air-route system is in a state of flux. Sections of the system have been dramatically modified in recent Civil Aeronautics Board (CAB) regulatory proceedings. Recently concluded bilateral negotiations on international air rights between the United States and several major foreign powers have greatly affected both existing and potential route structures of U.S. and foreign flag carriers. The merger of Pan American and National airlines is likely to result in further changes to the system.

All evidence points to a continuation of the present state of flux. Several important bilateral negotiations are currently under way, and new international-route cases seem to appear before CAB as fast as the old ones can be resolved.

One of the most-important tasks in analyzing and selecting among alternative route structures is to estimate the resultant division of traffic between U.S. and foreign flag carriers. The division of traffic has a direct bearing on the profitability of U.S.-flag-carrier services on affected routes and indirectly on which services will be offered, the net benefit to the public, and the ultimate viability of the U.S. flag system as a whole.

Although the need for a reliable means of estimating air-passenger route-specific traffic is clear and pressing, the best method now available is deficient in various respects. This method--commonly referred to as the quality-of-service index (QSI)--was developed by the staff of CAB for application in domestic-route proceedings (such as the

investigation of Reno-Portland/Seattle nonstop service, May 1970) and, over a period of years, has gained acceptance in the decision processes of the board. It is also being used increasingly in the internal planning processes of the carriers for analyzing the profitability of alternative new routes and for assessing possible merger partners. The method assigns standard weights to flight frequencies (number of weekly flights) operated with individual aircraft types. Larger and faster aircraft are weighted more heavily than smaller and slower aircraft to accord with presumed passenger preferences. Higher weights are given to nonstop than to one-stop flights; higher weights are given to one-stop flights than to multistop flights. The weighted-flight-frequency data are then used for two purposes:

1. To estimate the share of passenger traffic that will be captured by individual flights and combinations of flights and
2. To estimate the change in passenger traffic that results from a change in the available market services.

The QSI method is deficient for application to the international sector for the following reasons:

1. The existing estimating relationships are based on the somewhat archaic domestic experience in the late 1960s before extensive wide-body operations and on the generally limited information on later models of then-operational aircraft types.
2. The existing estimating relationships are not well calibrated to long-haul market experience. Relatively short-haul domestic market data are dominant in the determination of standard weights, which results in an incorrect evaluation of the deterrent values of stops and connections and of the importance passengers attach to comfort and speed factors.
3. The method does not deal with operations of the supersonic Concorde or the Boeing 747SP.
4. The method gives no explicit recognition to the citizenship composition of air passenger demand or to the preference of citizens for services of national air carriers. This is a major shortcoming in view of observed preferences.

In the light of these identifiable problems and the requirements of carriers and U.S. authorities that participate in route cases and bilateral negotiations, a review of the existing passenger-estimating relationships for international services has been performed. As a result, a new method--called the international quality-of-service index (IQSI)--has been developed, and it has almost twice the predictive power of the QSI method. It differs from the QSI method primarily by using different weights for aircraft types and number of stops, by recognizing passenger preferences for their own flag carrier or carriers, and by accounting for the difficulties faced by fifth-freedom carriers in attracting a proportional share of the market.

DESCRIPTION OF IQSI METHOD

The IQSI method is a procedure that can be used to estimate international scheduled-carrier market shares. In order to apply the method to any market, the market's citizenship composition (U.S. citizens versus aliens) and the pattern of air service (frequency by aircraft type, by number of stops, and by carrier) it receives must be known. For retrospective estimation, citizenship composition can be obtained from U.S. International Air Travel Statistics, published monthly by the U.S. government, and patterns of air service can be obtained from the Official Airline Guide, published semimonthly by the Reuben Donnelley Corporation. For forecasting purposes, citizenship composition may be estimated from past trends or by using more-sophisticated techniques, and patterns of service must be part of the specification of the future scenario.

The IQSI method is simple to apply. It consists of the following four steps:

1. Compute IQSI values for each carrier based on the service it offers,
2. Reduce IQSI of the fifth-freedom carriers by 40 percent,
3. Allocate a portion of the U.S. passengers to U.S. carriers and a portion of the foreign passengers to the flag carriers of the foreign country according to the citizenship factors shown in Table 1 (in which NA indicates that either regional or nondirectional factors may be used), and
4. Divide the remaining (unallocated) passengers among the carriers in proportion to their IQSIs.

Step 1 of the computation of IQSI is the same as it is for the computation of CAB's domestic QSI except that different weights are used for aircraft type and number of stops, as shown below (CAB has not derived QSI weights for the B-747SP or for the supersonic Concorde; 1.50 is the QSI weight for the DC8-63):

Item	IQSI Weight	CAB QSI Weight
Aircraft		
Boeing 747	2.25	1.85
Boeing 747SP	2.15	NA
Three-engine wide body	1.50	1.50
Four-engine narrow body	1.00	1.00
Supersonic Concorde	1.59	NA
Number of stops		
0	1.00	1.00
1	0.42	0.55
2	0.31	0.40
3 or more	0.02	0.03

Each flight is assigned an IQSI value equal to the product of its weekly (or monthly) frequency, the IQSI weight associated with its aircraft type, and the IQSI weight associated with the number of stops it makes en route. IQSI values of all flights by a carrier are summed to derive the IQSI value for the carrier. Table 2 illustrates this procedure for Air France service from Paris to New York, November 1976.

Table 3 presents a hypothetical scenario for service from New York to Rio de Janeiro, slightly modified for illustrative purposes. In step 3 of the IQSI method, passengers may be allocated to carriers (on the basis of citizenship factors) in one of two ways. If the U.S.-flag and foreign-flag carrier shares of QSI are relatively independent of direction (to or from the United States), the nondirectional citizenship factors of Table 1 may be used, as illustrated in Table 4. The resultant market shares (U.S. share = 0.408, foreign = 0.515, fifth-freedom = 0.077) are averages over both directions of travel. If market shares in each direction of travel are desired or if the IQSI shares of the carriers differ significantly between travel to and from the United States, the market

Table 1. Citizenship factors for use in IQSI method.

Country or Region	Departing United States		Arriving United States		Nondirectional	
	U.S. Flag	Foreign Flag	U.S. Flag	Foreign Flag	U.S. Flag	Foreign Flag
Argentina	0.168	0.320	0.139	0.095	0.157	0.213
Australia	-0.318	0.200	-0.216	0.230	-0.281	0.218
Belgium	-0.055	0.743	NA	NA	-0.021	0.690
Bolivia	-0.590	0.576	-0.410	0.420	-0.470	0.497
Brazil	0.023	0.259	0.075	0.182	0.045	0.238
Caroline Islands	0.913	-0.551	0.930	-0.542	0.919	-0.546
Chile	0.067	0.365	0.069	0.178	0.061	0.272
Colombia	0.001	0.039	-0.041	0.142	-0.018	0.090
Costa Rica	-0.083	0.522	NA	NA	-0.032	0.310
Denmark	-0.093	0.575	-0.020	0.098	-0.054	0.349
Ecuador	0.043	0.140	0.036	0.002	0.094	0.071
El Salvador	-0.051	0.188	0.015	0.217	-0.015	0.205
France	-0.019	0.468	0.130	0.415	0.061	0.441
Germany	0.123	0.555	0.251	0.306	0.187	0.439
Greece	-0.104	0.684	-0.016	0.445	-0.032	0.570
Guatemala	0.232	0.055	0.169	0.008	0.196	0.026
India	0.024	0.594	0.002	0.676	-0.018	0.660
Iran	-0.134	0.746	NA	NA	-0.070	0.832
Ireland	0.003	0.531	0.044	0.294	0.021	0.430
Israel	-0.259	0.680	-0.178	0.887	-0.222	0.768
Italy	0.205	0.238	0.290	0.127	0.248	0.173
Japan	0.214	0.286	0.140	0.225	0.177	0.258
Mariana Islands	0.617	-0.500	0.538	-0.509	0.579	-0.503
Mexico	-0.048	-0.135	-0.043	-0.048	-0.046	-0.090
Morocco	0.087	0.153	NA	NA	0.062	0.149
Netherlands	-0.051	0.732	NA	NA	-0.028	0.681
New Zealand	-0.017	0.477	-0.064	0.592	-0.032	0.500
Nicaragua	-0.077	0.662	-0.004	0.488	-0.052	0.670
Pakistan	-0.514	0.797	-0.086	0.582	-0.332	0.767
Panama	0.502	0.002	0.342	0.054	0.418	0.033
Peru	0.261	-0.033	0.199	-0.253	0.230	-0.186
Philippines	0.069	0.227	-0.122	0.287	-0.031	0.258
Poland	0.123	0.602	-0.066	0.656	0.081	0.719
Portugal	-0.113	0.424	0.049	0.271	-0.001	0.324
Senegal	-0.496	0.431	0.570	-0.131	0.226	0.041
South Africa	-0.187	0.722	NA	NA	-0.100	0.757
South Korea	0.147	1.000	0.455	0.237	0.441	0.108
Spain	0.147	0.223	0.193	0.094	0.155	0.177
Switzerland	-0.039	0.650	0.065	0.175	0.019	0.436
Tahiti	-0.061	0.384	-0.053	0.185	-0.059	0.302
Taiwan	0.070	0.701	-0.126	0.728	-0.032	0.720
Thailand	-0.261	0.728	-0.019	0.461	-0.247	0.640
USSR	-0.361	0.797	-0.136	0.884	-0.241	0.813
United Kingdom	0.126	0.185	0.155	0.090	0.140	0.137
Venezuela	0.125	0.169	0.341	0.049	0.203	0.116
Central America	0.081	0.051	0.061	-0.008	0.069	0.023
South America	0.066	0.148	0.056	0.063	0.061	0.104
Europe	0.082	0.335	0.138	0.177	0.107	0.257
Africa	-0.049	0.247	0.189	-0.158	0.063	0.125
Middle East	-0.304	0.763	-0.163	0.873	-0.260	0.805
Far East	0.104	0.325	0.034	0.295	0.069	0.310
Oceania	-0.199	0.389	-0.199	0.381	-0.201	0.388

Table 2. Illustrative computation of IQSI.

Flight No.	Aircraft Type	No. of Stops	Monthly Frequency	IQSI Weight for Type	IQSI Weight for Stops	IQSI
3	B-747	1	14	2.25	0.42	13.23
15	B-707	0	29	1.00	1.00	29.00
77	B-747	0	30	2.25	1.00	67.50
Total						109.73

must be disaggregated by direction of travel, and the directional citizenship factors of Table 1 must be used. Table 5 illustrates this technique for same scenario as that used in Table 4. The market shares are shown below.

U.S.	Foreign	Fifth-Freedom
0.406	0.515	0.078
0.478	0.451	0.071
0.334	0.580	0.086

The citizenship factors in Table 1 are displayed alphabetically by country. For countries with no past competition between U.S. carriers and carriers of the country of interest, no citizenship factors could be derived. If passengers in the country of interest are expected to behave as their neighbors do, the regional citizenship factors found at the end of Table 1 may be used. If, instead, the analyst has a priori knowledge of citizenship behavior, predetermined values may be substituted. Finally, with no knowledge of the likely passenger behavior, citizenship factors of 0.0 should be used.

Positive citizenship factors imply that passengers from the given country fly on their own flag carrier more often than would be indicated by its IQSI share; this exhibits a form of loyalty to the flag carrier and explains the procedure of allocating some of the passengers to their national flag carrier before dividing the remainder according to IQSI. Negative citizenship factors imply that passengers are more likely to fly a foreign flag carrier than would be indicated by its share of IQSI. Reasons for such behavior vary; they range from negative citizen perception of their own flag carrier to ethnic interest in the foreign flag. (This might explain, for example, the negative citizenship factor for U.S. citizens who fly to Israel.) The application of a negative citizenship

factor requires an imaginary allocation of a negative number of passengers to the country's flag carriers and consequently an increase in the number of unallocated passengers, who will then be divided among carriers according to IQSI shares. This procedure is illustrated in Table 6 for a hypothetical scenario of a flight from New York to Tel Aviv (the U.S. market share is 0.025 and the foreign-flag share is 0.975).

DERIVATION OF IQSI METHOD

To develop and validate the IQSI method, a data base

Table 3. Hypothetical service scenario, New York to Rio de Janeiro.

Carrier Flag	Direction	Aircraft Type	No. of Stops	Monthly Frequency	IQSI
U.S.	To U.S.	B-707	0	28	28.00
		B-747	0	28	63.00
				Subtotal	91.00
	From U.S.	B-707	0	28	28.00
		B-747	1	28	26.46
				Subtotal	54.46
	Total				145.46
Brazil	Each direction	B-707	0	32	32.00
		DC-10	0	26	39.00
				Subtotal	71.00
	Both directions				142.00
Fifth-freedom	Each direction	B-707	0	24	24.00
	Both directions			60 percent of each direction	14.40
				60 percent of both directions	28.80
Total	To U.S.				176.40
	From U.S.				139.86
	Both directions				316.26

Table 4. Illustration of passenger allocation, nondirectional method.

			Allocation Factor by Flag				Passengers Allocated by Flag		
Citizenship	Direction	Allocation Step	U.S.	Foreign	Fifth-Freedom	Unallocated Passengers	U.S.	Foreign	Fifth-Freedom
U.S.	Both	Preallocation[a]				178 200	0	0	0
		By citizenship[b]	0.045			170 181	8 019	0	0
		By IQSI[c]	0.460	0.449	0.091	0	78 283	76 411	15 487
Alien	Both	Preallocation[a]				233 800	0	0	0
		By citizenship[b]		0.238		178 156	0	55 644	0
		By IQSI[c]	0.460	0.449	0.091		81 952	79 992	16 212
Total	Both	Postallocation					168 254	212 047	31 699

[a]Hypothetical passenger volumes are about 10 percent above 1976; New York-Brazil traffic by citizenship.
[b]Source of citizenship factors is Table 1.
[c]Source of IQSI factors is Table 3.

Table 5. Illustration of passenger allocation, directional method.

			Allocation Factor by Flag				Passengers Allocated by Flag		
Citizenship	Direction	Allocation Step	U.S.	Foreign	Fifth-Freedom	Unallocated Passengers	U.S.	Foreign	Fifth-Freedom
U.S.	To U.S.	Preallocation[a]				89 100	0	0	0
		By citizenship[b]	0.075			82 417	6 683	0	0
		By IQSI[c]	0.516	0.402	0.082	0	42 527	33 132	6 958
Alien	To U.S.	Preallocation[a]				116 900	0	0	0
		By citizenship[b]		0.182		95 624	0	21 276	0
		By IQSI[c]	0.516	0.402	0.082	0	49 342	38 441	7 841
U.S.	From U.S.	Preallocation[a]				89 100	0	0	0
		By citizenship[b]	0.023			87 051	2 049	0	0
		By IQSI[c]	0.389	0.508	0.103	0	33 863	44 222	8 966
Alien	From U.S.	Preallocation[a]				116 900	0	0	0
		By citizenship[b]		0.259		84 623	0	32 277	0
		By IQSI[c]	0.389	0.508	0.103	0	32 918	42 989	8 716
Total	Both	Postallocation					167 382	212 337	32 281
Total	To U.S.	Postallocation					98 552	92 849	14 599
Total	From U.S.	Postallocation					68 830	119 488	17 682

[a]Hypothetical passenger volumes are about 10 percent above 1976; New York-Brazil traffic by citizenship.
[b]Source of citizenship factors is Table 1.
[c]Source of IQSI factors is Table 3.

Table 6. Illustration of passenger allocation with negative citizenship factors, nondirectional method.

			Allocation Factor by Flag				Passengers Allocated by Flag		
Citizenship	Direction	Allocation Step	U.S.	Foreign	Fifth-Freedom	Unallocated Passengers	U.S.	Foreign	Fifth-Freedom
U.S.	Both	Preallocation[a]				78 788	0	0	0
		By citizenship[b]	−0.222			92 613[d]	−16 825	0	0
		By IQSI[c]	0.195	0.805	0	0	18 060	74 553	0
Alien	Both	Preallocation[a]				30 784	0	0	0
		By citizenship[b]		0.768		7 142	0	23 642	0
		By IQSI[c]	0.195	0.805		0	1 393	5 749	0
Total	Both	Postallocation					2 628	103 944	0

[a]1976 travel between New York and Israel.
[b]Source of factors is Table 1.
[c]IQSI factors are approximately those for August 1976.
[d]Note that the number of unallocated passengers has increased due to the imaginary allocation of -16 825 passengers to the U.S. flag carrier. The sum of allocated and unallocated passengers must equal the original number of passengers.

Table 7. Sample computation of citizenship factors.

Market	U.S. Citizens	Non-U.S. Citizens	Monthly Frequency	Aircraft Type	Stops	QSI
U.S. carrier flights						
Geneva-New York	451	311	12	4NB	0	12.000
Zurich-New York	1136	594	24	4NB	0	24.000
Total	1587	905	36			36.000
Swiss carrier flights						
Geneva-New York	817	727	13	4WB	1	12.285
Zurich-New York	2852	2664	30	4WB	0	67.500
Geneva-New York	361	443	11	4WB	0	24.750
Zurich-New York	373	447	12	4WB	1	11.340
Zurich-Boston	1111	790	28	3WB	0	42.000
Zurich-Chicago	804	701	24	3WB	1	15.120
Total	6318	5772	118			172.995
Total	7905	6677	154			208.995

Note: Aircraft types are abbreviated as follows: 4NB = four-engine narrow body; 4WB = four engine wide body; 3WB = three engine wide body.

was constructed by merging, for each flight number, passenger-volume and citizenship data collected by the U.S. Immigration and Naturalization Service (INS) and data on air-carrier schedules published in the Official Airline Guide. The merged data include the monthly frequency, the volume of U.S. citizens carried, the volume of foreign citizens carried, the type of equipment used, and the number of stops en route. The data were organized into four files--February, May, August, and November 1976. The May, August, and November files were used for model estimation and the February file was used for model validation. The files included data from all countries (except Canada and Caribbean points) that received competitive single-plane service from the United States. Canadian and Caribbean markets were excluded on the basis of their similarity to domestic rather than international travel.

Estimation of IQSI Weights

The first step was to obtain an initial estimate of citizenship factors. This estimate was derived by using the CAB QSI weights and the method described in the following section.

A computer program was then written to apply the IQSI method to the data to estimate, for each country, the market share of the U.S. carrier or carriers, the foreign-flag carrier or carriers, and the fifth-freedom carrier or carriers. This program was applied to the August data file several times and the IQSI weights were changed between runs to improve the fit between actual and predicted market shares. The IQSI weights that provide the best fit were given in the section that described the IQSI method. These weights were then used to reestimate the citizenship factors. Further sensitivity analysis on the IQSI weights, by using the new citizenship factors, resulted in no change to the IQSI weights.

The computer program to compare predicted with actual market shares was also responsible for the incorporation of the 40 percent reduction of fifth-freedom IQSI into the method. Without this reduction, fifth-freedom traffic was overestimated, on the average, by nearly 100 percent, no matter what IQSI weights were used. The reduction of fifth-freedom IQSI by 40 percent eliminated this bias.

Because of the small number of flights performed by the supersonic Concorde and the Boeing 747SP during the months analyzed, it was impossible to perform sensitivity analyses on IQSI weights for these aircraft types. Instead, markets served by these aircraft were isolated and weights were calculated so as to best predict the market share for the aircraft in the identified markets. This resulted in estimated IQSI weights of 1.59 for the Concorde and 2.15 for the B-747SP.

Estimation of Citizenship Factor

Let K be the fraction of U.S. passengers in a given market who will fly on the U.S. carrier or carriers regardless of its IQSI share. The remaining fraction (1 - K) is divided among flights according to IQSI. Let p be the number of U.S. passengers in the market; q, the U.S. IQSI share; and n, the number of U.S. passengers who use the U.S.-flag carrier. Then

$$n = Kp + q(1 - K)p \qquad (1)$$

or

Table 8. Predictive ability of alternative methods.

Statistic	Method	Flag of Carrier: U.S.	Foreign	Fifth-Freedom	All Carriers
Sum of residuals	1	2 583	−30 940	28 357	
	2	3 243	−28 600	25 357	
	3	14 360	−19 868	5 507	
	4	−2 033	3 942	−1 909	
Sum of squared residuals	1	5 422	6 450	3 734	15 606
	2	5 331	6 202	3 360	14 893
	3	5 267	5 713	1 158	11 638
	4	3 077	4 350	1 317	8 744
Average residual	1	0.005	−0.057	0.052	
	2	0.006	−0.053	0.047	
	3	0.026	−0.036	0.010	
	4	−0.004	0.007	−0.004	
Square root of average squared residual	1	0.100	0.109	0.083	0.098
	2	0.099	0.107	0.079	0.095
	3	0.098	0.098	0.046	0.084
	4	0.075	0.089	0.049	0.073
Average market share		0.418	0.516	0.064	0.333

$$K = (n - qp)/(p - qp) \quad (2)$$

We can compute K for foreign carriers and passengers in a similar fashion by letting n be the number of foreign passengers who fly on the foreign-flag carrier; p, the number of foreign passengers in the market; and q, the foreign IQSI share.

Note that K can never exceed unity but that it can fall below zero if n is less than qp, that is, if the fraction of U.S. passengers who use a U.S. carrier is less than that carrier's share of the IQSI (or similarly for foreign passengers and carriers).

Table 7 illustrates how citizenship factors are computed. The example shown is for travel from Switzerland to the United States in November 1976. To calculate K for U.S. passengers, set n equal to 1587, q to 0.172 (36 divided by 209), and p to 7905. This results in a K of 0.035. Similarly, setting n to 5772, q to 0.828, and p to 6677 results in a K for Swiss passengers of 0.212.

Citizenship factors were computed as described above for the months of May, August, and November 1976 (results by month are available from the author). These factors were then averaged to derive the figures in Table 1. Note that citizenship factors for passengers returning to their own country are almost always greater than they are for passengers leaving their own country. Two reasons are hypothesized for this behavior: One is that passengers are eager to immerse themselves, when they start on a trip, in the culture of the nation they are to visit; conversely, by the time they are to return home, these passengers have satisfied their desire for a foreign culture and are eager to hear their own language and eat their national foods. A second possible reason is that the period between the making of reservations and the making of trips is shorter for the trip abroad than it is for the trip home (since most reservations for round trips are made at the point of origin). Consequently, passengers are more likely to encounter difficulty in making reservations for the flight of their choice on the trip abroad than on the trip home. It follows that the trip abroad is more likely to be distributed according to carrier capacity (and IQSI) than according to citizenship. The theory that capacity may in fact affect citizenship factors gains some support in the slightly lower citizenship factors observed in the peak month of August compared with those for the off-peak months of May and November. However, citizenship factors are sufficiently stable between months (generally varying by less than 0.1) to support the conclusion that psychological or behavioral patterns cause their directional variations.

VALIDATION

A computer program was written to predict the market shares of U.S., foreign, and fifth-freedom carriers for every market in the data base in both directions of travel. The program estimated market shares in the following four ways (hereafter called methods 1 through 4):

1. According to CAB method for domestic service,
2. Same as method 1 except that IQSI weights were used,
3. Same as method 2 except that fifth-freedom carrier IQSI shares were reduced by 40 percent, and
4. By applying citizenship factors and the 40 percent reduction of fifth-freedom IQSI.

These market shares were then compared with actual market shares, and the residual (the difference between the estimate and the actual) was computed. The residual and the squared residual in each market were weighted by the number of passengers in the market to account for the relative importance of correctly estimating market shares in major versus minor markets. Weighted totals and averages of the residual and squared residual were then computed for U.S. carriers, foreign carriers (excluding fifth-freedom carriers), fifth-freedom carriers, and all carriers.

The program was applied to the data for the months of May, August, and November (the months for which the method was calibrated) and for the month of February, which was used to validate the methodology. The February 1976 results are displayed in Table 8.

In each of the months, method 4, the IQSI method described above, produces a sum of squared residuals equal to approximately one-half that produced by method 1, the CAB domestic method. This is probably the best measure of fit, since the sum of squared residuals is an indication of the variance of the estimate around the actual value. In all months, method 3 (the same as method 4 except without the citizenship factors) also produces a substantial improvement over method 1 in terms of the sum of squared residuals. In general, its sum of squared residuals falls two-thirds of the way between methods 1 and 4 (closer to method 4).

Method 4 also produces substantially better average residuals than any of the other methods.

The average residual is a measure of the bias of the method. For example (as shown in Table 8), method 1 generally underestimates the market share of the foreign carrier by 0.057 and overestimates the market share of the third-country carrier by 0.052. Thus, a fifth-freedom carrier's market share of 0.01 would probably be estimated as 0.06, and a foreign carrier's market share of 0.55 would probably be estimated as 0.49. Methods 2 and 3 are not much better in this respect. By contrast, method 4 in no month biased any carrier's market share by more than 1.1 percentage points. Its bias is almost always far less than 1 percentage point.

Note that the sum of the biases in any method is always zero. If the actual market shares are x, y, and z and the estimated market shares are X, Y, and Z, the sum of the biases $[(X - x) + (Y - y) + (Z - z)]$ equals $(X + Y + Z) - (x + y + z) = 1 - 1 = 0$.

The square root of the average squared residual is an indication of the average magnitude of the error (difference between actual and predicted results). For example, if one method overestimates market share by 0.1 in one market and underestimates it by 0.1 in another, its average bias (average residual) is nil but its square root of the average squared residual is 0.1. If another method overestimates market share by 0.06 in one market and underestimates it by 0.02 in another, its average squared residual is 0.045. Whether the second method is better or worse than the first would, in this case, be open to question, since it produces more bias but a closer prediction. Among the methods examined, however, there is no question which is the better one, since method 4 performs better than any of the others in reducing both bias and absolute error.

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Forecasts of Passenger and Air-Cargo Activity at Logan International Airport

ROBERT MELLMAN, MICHAEL NELSON, AND JANE PIRO

This paper summarizes the results of a recently completed aviation-forecasting project conducted for Logan International Airport, Boston's major metropolitan air facility. Independent procedures are developed for forecasting certificated air-carrier (domestic and international), commuter, general aviation, and air-cargo traffic. Data are drawn from several sources, which include airport records and Federal Aviation Administration and Civil Aeronautics Board publications. To the greatest extent possible, multiple-regression techniques are employed to identify the factors responsible for historic changes in activity levels. Simple forecasting models are then used to predict aviation activity under alternative scenarios; these show that air-passenger and air-cargo volumes are likely to increase at the rate of approximately 5 percent per year. The exact growth rate will depend most heavily on changes in regional income and on costs and fares. Growth in aircraft operations will be lower, due to projected increases in airplane sizes and load factors but will still be significant. In addition to their primary use in planning at Logan, the results shed light on broad issues in aviation forecasting. One important implication is that the effects of rate and route deregulation on activity at major airports are likely to be minor in comparison with changes in economic conditions and fuel prices.

The long-term planning decisions now being made by airport authorities strongly depend on expectations of growth in aviation activity over the next two decades. There is currently considerable uncertainty whether the future will be characterized by the robust growth in airline activity observed from 1960 to 1969 and 1975 to 1978 or whether the experience of the last few years is a bubble that will burst and the commercial aviation industry will return to the modest secular growth rates of 1969-1975. Identifying the determinants of growth in the air-passenger and air-cargo industry is necessary for making reliable forecasts of airport activity. This paper summarizes the results of a recently completed aviation-activity-forecasting project conducted for Logan International Airport, Boston's major metropolitan air facility. Forecasting procedures have been developed independently for each of the major types of airport passenger activity and operations: certificated air carrier (domestic and international), commuter air, and general aviation (GA). A separate forecasting method has also been developed for air-cargo operations. For each type of service, statistical methods are employed wherever possible to isolate the factors that have caused variation in historical activity levels from available Logan-specific data. Scenarios of plausible future levels of these causal factors are then employed to derive activity forecasts over the next 20 years. [The consequences that result from alternative scenarios of future conditions have also been examined by Charles River Associates (CRA) (1).] These forecasts are explicitly demand oriented and do not incorporate the effects of potential capacity limitations.

Aside from the practical application of these forecasts to the work of the Massachusetts Port Authority (Massport) planning department at Logan, the forecasting models estimated are of broader interest for several reasons:

1. The past two years have been marked by