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.

ACKNOWLEDGMENT

I wish to gratefully acknowledge the assistance of Michael Meadows, who helped write the computer programs and create the data files on which this research is based. Also, I am grateful for the support of the U.S. Department of Transportation (DOT), which funded this research; however, I wish to emphasize that the findings and conclusions presented in this paper are not necessarily fully congruent with DOT studies or with present official policy. Finally, let me thank Nathan Simat and other members of Simat, Helliesen and Eichner, Inc., for their contribution to various aspects of the study design and interpretation of results.

Publication of this paper sponsored by Committee on Aviation Demand Forecasting.

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

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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

substantial deregulation of rates and routes for both air-passenger and air-cargo traffic. There is general interest in the size of the effects of deregulation as they relate to other influences on the level of air-service demand.

2. Because Boston is a major city that has large sectors of each class of air service represented, forecasts specific to Logan may be indicative of likely trends elsewhere.

3. A large number of air-travel forecasting models were developed during the late 1960s that proved inaccurate, grossly overestimating future growth. It is of general interest to learn why these models performed poorly and how a model estimated on more-recent data compares with these models.

4. The air industry has moved to a relatively complicated and demand-sensitive pricing structure. It is important to know whether simple price measures such as average yield perform well in multiple-regression forecasting models or whether a more-complex series of price terms is needed to capture the range of prices that faces different customers.

FORECASTING PROCEDURES FOR PASSENGERS

Logan experienced double-digit growth in passenger traffic on certificated and commuter carriers from 1965 to 1970, a dramatic slowdown from 1970 to 1975, and a return to robust growth from 1975 to 1978. Because both international certificated and domestic commuter traffic were growing from a small base, their initial growth rates were especially large. The growth rates in annual numbers of flights generally mirrored the passenger growth rates, though the rates for 1970-1975 were much lower due to the introduction of wide-body jets.

The forecasting system developed is based primarily on a statistical examination of 1965-1978 data. Although including earlier data would have provided more data points, it would have been extremely difficult to isolate the effects of the introduction of jet aircraft on consumer attitudes toward and use of air travel. This examination is therefore confined to the jet era.

International and Domestic Certificated Carriers

Model Development

The models of certificated air-carrier passenger activity are estimated by using multiple-regression techniques. Many explanatory variables were considered for inclusion; the most basic of these is the population of the Boston area. All other things being equal, a larger population should produce more travel into and out of Boston. Another candidate variable is inflation-adjusted income, since numerous other studies have related air travel to income growth. A third important economic indicator is a cyclical variable, such as an index of capacity use, which may act as a measure of consumer sentiment. The inflation-adjusted level of air fares is another obvious candidate for inclusion; for long-range forecasts, one should also test the significance of the age distribution of the population if one believes that different age groups have inherently different propensities to travel by air. Finally, the occupational mix of the population in the Boston area may also be of interest, since it is well known that some groups travel extensively on business, whereas others make no business trips by air at all.

Mention should also be made of variables purposely not included in the demand models. We do not consider supply-side limitations such as runway or terminal capacity since this study is intended to produce unconstrained-demand forecasts for use by airport authorities. Frequency of air service is not included since discrete additions of flights to certificated-carrier markets are likely to produce only minor service-quality changes in an airport as large as Logan. The effect of changes in the relative performance of alternative modes is not included either. Relative travel times have remained roughly constant over the past 15 years and will be assumed to remain at or about current levels. Finally, the model ignores many possible short-term influences on air traffic, since it is intended to be long-term in orientation. For example, it is assumed that interruptions in fuel supply are temporary and that in the long run there will be adequate fuel supplies, although perhaps at a much higher price.

International Carriers

There are three basic types of international traveler at Logan. The first travels from Boston directly abroad; the second travels from some other point in the United States to Boston to connect with an international flight; the third travels from Boston to another gateway and then connects with an international flight. In a May 1979 study, Civil Aeronautics Board (CAB) origin-destination data, CAB portion-of-international-journey data, and Massport international-passenger data were used by CRA to break down Boston international travel into these three categories (see Table 1).

The level of direct Boston international travel grew rapidly from 1965 to 1971 and has grown more slowly since. Conversely, use of Boston as an international gateway has increased considerably since 1973 and by 1978 such use accounted for 22 percent of the total number of Boston international enplanements. This increase has undoubtedly been influenced by the growing congestion at Kennedy International Airport in New York and the marketing efforts of Massport. The congestion at Kennedy combined with changes in service levels from Boston has also led to a 60 percent decline in the use of other gateways by Boston travelers between 1973 and 1978.

The procedure used to forecast international passenger activity at Logan begins by predicting Boston-originating international travel. It is then assumed that the percentage of Boston travelers who

Table 1. Number of passengers by category of international traveler.

Year	Type of Traveler A	B	C
1965	60 000	30 000	316 552
1966	80 000	47 500	375 952
1967	150 000	64 999	500 433
1968	210 000	82 499	547 717
1969	210 000	99 999	689 666
1970	210 000	117 499	870 433
1971	192 632	134 998	959 515
1972	206 842	152 498	1 160 344
1973	243 666	148 214	1 267 773
1974	186 565	253 115	1 187 778
1975	194 131	220 739	1 023 175
1976	169 982	261 458	1 206 481
1977	141 370	321 877	1 254 821
1978	98 153	398 477	1 385 701

Note: A = Boston international travelers who use international gateway other than Logan; B = travelers from outside Boston region who use Logan as international gateway; C = Boston travelers who fly abroad directly from Logan.

use other gateways (7 percent in 1978) continues to decline. To forecast international enplanements at Logan, such travelers must be subtracted from the Boston-originating total. Projections of non-Boston-originating passengers who use Boston as a gateway are then added to this subtotal. This procedure yields the total number of passengers who board international flights in Boston.

The left-hand variable in the basic forecasting equation is the true number of Boston-originating travelers. This represents international travel that originates in Boston regardless of gateway choice. Because this variable is specific to the Boston region, it should be primarily dependent on Boston region-specific factors. For forecasting purposes, we have chosen the regional definition of Boston used by the Bureau of Economic Analysis of the U.S. Department of Commerce; this region includes eastern Massachusetts, southern New Hampshire, and Rhode Island. Although this may be geographically slightly larger than the true Logan service area, past demographic and economic data and future projections are readily available for this region, and changes in this region's activity levels should correspond nearly perfectly with changes in the actual Logan market.

As outlined above, variables tested as possible explanatory factors for Boston international air travel included population, income, occupation mix, age mix, cyclical capacity use, and air fares (inflation-adjusted yield per international passenger mile). Well-known technical problems exist with use of this last variable since yield is not a fixed-weight price index. However, the problems are not thought to be as severe in this case, and no practical alternatives exist (2). Across a variety of alternative model specifications, variable combinations, and variable definitions, it was found that population, income, and fare levels prove to be the primary determinants of the volume of air travel. Independent of changes in population, income, and air fares, other potential determinants of international air travel are not statistically significant.

The reason for this finding is the extremely high correlation between regional income and regional international air travel, displayed in the correlation matrix in Figure 1, which uses Pearson correlation coefficients and the following variables: BOSNYPC, Boston-originating international air passengers per capita; RARIT, real average yield per international passenger mile (cents per mile in 1967 dollars); RINCPC, real Boston regional income per capita (thousands of 1967 dollars); CAPFRB, Federal Reserve Board index of capacity use; and AGEMXPC, percentage of Boston-region population 25-49 years of age. The correlation between international air travel (BOSNYPC) and real income (RINCPC) is extraordinarily high (0.97). The air-fare variable (RARIT) also has a high negative correlation with international air travel (-0.68). After changes in population, income, and air fares have been accounted for, there is little change in air travel left to be explained by other variables. It is therefore concluded that the following, rather simple forecasting model will prove reliable:

$$\text{BOSNYPC} = -33.31 + 431.3\ [146.0]\ \log(\text{RINCPC}) - 239.9\ [93.2]\ \log(\text{RARIT}),$$

where $R^2 = 0.96$ and the standard errors are in brackets. The choice of a specification with the log of variables only on the right-hand side is appropriate for a market characterized by extremely rapid growth in its early years followed by maturation. At the 1978 levels of the model's variables, the income elasticity of demand is 1.7 and the price elasticity is -0.94.

Domestic Carriers

In the domestic travel-forecasting procedure, a model is used to project true Boston domestic originations. The travelers who use Logan for a domestic portion of an international journey are then added to derive total domestic enplanements. As in the international travel model, socioeconomic variables specific to the Boston region defined by the Bureau of Economic Analysis are used. The same set of variables--population, income, air fares, occupation mix, age mix, and a cyclical variable--was tested for their explanatory power by using annual data from 1965 to 1978. In addition to average yield per passenger mile (RARDT) on domestic flights, a consumer price index (CPI) for air travel was tested. The Bureau of Labor Statistics CPI for air travel is based on a fixed-weight sample of air-carrier routes and, for that reason, is a theoretically superior price index. However, the sample of routes is not comprehensive and the measure did not perform so well as did the yield variable. Overall, across a large set of alternative model specifications, population, income, and air-fare levels again proved to be the dominant determinants of air travel. Other variables had coefficients that were extremely sensitive to model specification and that were, in most specifications, statistically insignificant. The correlation between domestic travel and income is 0.95 and between domestic travel and yield is nearly -0.97. These two variables by themselves explain nearly all the year-to-year variations in domestic travel, and a forecasting model based on these two variables can be expected to provide reliable forecasts:

$$\log(\text{PDCEP}) = 0.5597 + 1.4757\ [0.79]\ \log(\text{RINCPC}) - 0.700\ [0.54]\ \log(\text{RARDT}),$$

where

R^2 = 0.96 and the standard errors are in brackets,
PDCEP = Boston-originating domestic passengers per capita, and
RARDT = real average yield per domestic passenger mile (cents per mile in 1967 dollars).

Figure 1. Correlation matrix: regional income and regional air travel.

	BOSNYPC	RARIT	RINCPC	CAPFRB	AGEMXPC
BOSNYPC	1.0000	-0.6759	0.9697	-0.5354	-0.3909
RARIT	-0.6759	1.0000	-0.6358	0.3904	0.6881
RINCPC	0.9697	-0.6358	1.0000	-0.4867	-0.2474
CAPFRB	-0.5354	0.3904	-0.4867	1.0000	0.4376
AGEMXPC	-0.3909	0.6881	-0.2474	0.4376	1.0000

Table 2. Forecast of Logan trips.

Type of Trip	Number of Trips (000s) 1980	1985	1990	1995	2000
Domestic service					
Boston-based domestic	11 718	15 136	19 888	25 965	33 807
Boston-U.S.-international	+ 87	+ 70	+ 59	+ 71	+ 83
U.S.-Boston-international	+ 574	+ 1 155	+ 1 859	+ 2 995	+ 3 822
Total	12 379	16 361	21 806	29 031	37 712
International service					
Boston-based international	1 732	2 338	2 931	3 542	4 159
Boston-U.S.-international	- 87	- 70	- 59	- 71	- 83
U.S.-Boston-international	+ 574	+ 1 155	+ 1 859	+ 2 995	+ 3 822
Total	2 219	3 423	4 731	6 466	7 898

Because the model is estimated in log-log form, the coefficients are elasticities. The income elasticity of domestic travel is estimated to be 1.48 and the price elasticity, -0.70. Once again, this model forecasts pure domestic travel. The number of travelers who use Logan on a domestic leg of an international trip must be added to this subtotal to arrive at the number of domestic enplanements.

Baseline Scenario

The baseline scenario consists of forecasts of population, income, and air fares. The population and income projections are provided by CRA market service, which supplies regional disaggregation to the University of Maryland national macroeconomic model. The population of the Boston region is projected to grow at a rate of only about 0.6 percent per year, which is lower than that of the rest of the country. The baseline economic forecast shows that inflation-adjusted income per capita is growing at the following annual rates:

Years	Percentage of Growth
1978-1980	2.10
1980-1985	2.21
1985-1990	2.62
1990-2000	2.50

By comparison, U.S. real income per capita grew at the higher rates of 2.71 percent per year from 1960 to 1970 and at 4.20 percent per year between 1970 and 1973 (3, p. 383). However, the growth rate of income per capita from 1973 to 1978 was less than 1 percent per year. The baseline forecast assumes that long-term economic growth will be neither so robust as during the 1960-1973 period nor so weak as during the 1973-1978 period. Growth is expected to be slower than in the past because the easy-growth gains from urbanization, greater investment in education, and the large-scale entrance of women into the labor force have already occurred. Conversely, growth is expected to be more robust than in the past five years because a repeat of the worst postwar recession on record and a quadrupling of oil prices is not anticipated during every five-year period in the future.

However, the baseline forecast does allow for considerable growth in energy prices over the next two decades. Since energy accounts for less than 10 percent of total national final demand (4, p. 8) and because the consensus of energy modelers is that higher energy prices need not cripple long-term growth (5), the baseline economic-growth scenario is consistent with much higher real-energy prices and represents a realistic appraisal of future long-term economic growth.

Real domestic air fares declined at a rate of 2.7 percent per year over the entire 1965-1977 period and dropped nearly 7 percent between 1977 and 1978.

The baseline case assumes that air fares will continue to decline in relation to all other goods and services but that the rate of decline will be much less than that during the 1965-1977 period. The following specific changes in average yield per passenger mile relative to the overall inflation rate are assumed. (Since this paper was prepared prior to 1979 fuel-price increases, 1978-1980 fare declines are probably overstated, but long-term results are robust with respect to this short-term change.)

Years	Percentage of Change
1978-1980	-2.5
1980-1985	-1.8
1985-2000	-1.5

In this scenario, increases in average plane size, route rationalization, minor further increases in load factors, and the introduction of more-fuel-efficient jets are expected to more than offset real fuel-price increases. The assumption that the energy problem becomes one of high prices rather than limited supply is implicit.

Finally, the baseline case implicitly assumes that people will continue to want to travel (i.e., that no new invention or pastime will change broad personal attitudes toward travel) and that electronic communications will not replace the business need for person-to-person contact.

Baseline Passenger Forecasts

The baseline scenario leads to the baseline Boston-region air-travel forecast shown in Table 2 (calculated by CRA, May 1979). The numbers in the first row of the domestic and international categories represent Boston originations rather than enplanements. Enplanements are derived by accounting for the use of Boston as a gateway by passengers from other regions and the use of other international gateways by Boston travelers. The use of other gateways by Boston-originating international travelers declined from 30 percent in 1967 to 6.6 percent in 1978. Because of the increasing congestion at Kennedy and better air service at Logan, it is assumed that this percentage will fall to 5 percent by 1980, 3 percent by 1985, and 2 percent from 1990 to 2000.

Use of the Boston international gateway by residents of other regions has increased about 20 percent per year in recent years. The baseline case assumes that the annual growth rate is 20 percent from 1978 to 1980, 15 percent from 1980 to 1985, 10 percent from 1985 to 1995, and 5 percent from 1995 to 2000. (Inasmuch as the use of the Boston gateway depends on the level of Massport marketing activity, this portion of air-traffic growth may be considered a policy variable.) To calculate total Logan domestic passengers we add Boston-U.S.-international and U.S.-Boston-international travel to the Boston-based domestic travel. To calculate Logan international travel, we start with Boston-based international travelers, subtract those who use other gateways, and add travelers from elsewhere who use Boston as a gateway.

Baseline Operations Forecasts

Given forecasts of annual passenger volumes, it is possible to derive forecasts of aircraft operations by establishing likely average airplane sizes and load factors.

Based on estimates made by the Boeing Company regarding growth in the average seating capacity of certificated domestic aircraft divided by the 1977 average of 124.2 seats per airplane, the following values are derived:

Year	Average Increase, Seats per Plane
1977	1.00
1980	1.17
1985	1.30
1990	1.32
1995	1.37
2000	1.43

This analysis shows relatively rapid growth in average airplane sizes during the years 1977-1985 as wide-body airplanes become more dominant. Beyond 1985, the projections show a more-stable average airplane size. Of course, these projections are only an educated guess, because post-1985 airplanes have not yet been ordered. More-rapid growth in airplane sizes after 1985 must be considered a strong possibility, particularly in the presence of prolonged fare competition.

It is assumed that average load factors at Logan will approach an upper bound of 64 percent as follows: 1977, 50.5 percent (actual); 1980, 61 percent; 1985, 63 percent; and 1990-2000, 64 percent. Beyond 1980, the assumption is implicit that large-discount off-peak fares will continue to be offered and that airlines will tend to avoid low load-factor segments as the contribution per passenger declines in the presence of fare competition.

Domestic

The baseline operations forecasts are calculated as the projected number of passengers divided by the product of base-year (1977) passengers per flight, the ratio of future-year to base-year airplane size, and the ratio of future-year to base-year load factor. The projected domestic passenger volumes and calculation of growth in the number of domestic certificated flights (as calculated by CRA in May 1979) appear in Table 3.

The 1980 figure may be an underestimate that reflects the assumption of a more-rapid upgrading of the air fleet than may actually occur at Logan. However, the long-term trend is clear. The number of domestic certificated flights will stay relatively stable until 1985 and then increase significantly due to the slow increase in average airplane size thereafter.

International

While the above method could theoretically be used to project the number of international flights, a significant number of international passengers use foreign-flag carriers for which load-factor data are not available. Therefore, less-precise estimates of future international flights are made under the following two assumptions:

1. On the average, airplane sizes on international flights will grow two-thirds as much as airplane sizes on domestic flights. This assumption is made because roughly half the international flights already use wide-body aircraft.
2. On the average, international load factors will grow by 15 percent more than domestic load factors because there are fewer peak-hour and time-of-day problems involved in scheduling international flights.

These assumptions allow us to construct in Table 4 projections of numbers of international flights that correspond to the estimates of domestic flights in Table 3, given baseline scenario passenger projections. These calculations (made by CRA in May 1979) show that the number of international flights will more than double between 1980 and 1995 and will grow faster than domestic flights.

Caveats

While the calculations of number of flights for domestic and international travel provide our best forecast, there are two reasons why they may prove to be biased upward. First, current estimates of future airplane types and sizes based on current orders of the airlines lead to the assumption of a

Table 3. Estimates of certificated domestic flights at Logan, 1977-2000.

Variable	1977[a]	1980	1985	1990	1995	2000
Domestic passengers (000s)	9906	12 379	16 361	21 806	29 031	37 712
Base-year passengers per flight	59.0	59.0	59.0	59.0	59.0	59.0
Growth in no. of seats per airplane	1.00	1.13	1.31	1.31	1.36	1.42
Growth in load factor	1.00	1.21	1.25	1.27	1.27	1.27
No. of flights	167 898	153 451	169 347	222 151	284 884	354 434

[a]Data for 1977 are actual data.

Table 4. Estimates of international flights at Logan, 1977-2000.

Variable	1977[a]	1980	1985	1990	1995	2000
International passengers (000s)	1634	2219	3423	4731	6466	7898
Base-year passengers per flight	85.8	85.8	85.8	85.8	85.8	85.8
Growth in seats per airplane	1.00	1.08	1.20	1.20	1.24	1.28
Growth in load factor	1.00	1.24	1.29	1.31	1.31	1.31
No. of flights	19 040	19 312	25 772	35 076	46 393	54 897

[a]Data for 1977 are actual data.

rather gradual trend in average airplane size after 1985. However, there is a chance that fare competition will lead to greater production and use of larger aircraft, which would lower projections of the number of flights.

The second cause for possible upward bias is that we project an equilibrium load factor of 64 percent. This seems to be in the middle of a range of projections that extend from below 60 percent to 70 percent. More-sophisticated peak-load pricing or airline scheduling practices or both may be able to bring the average load factor higher. A combination of larger airplanes and higher load factors could significantly reduce the number of projected flights in future years. Even under these more-liberal assumptions, however, aircraft operations at Logan would be projected to grow substantially.

Commuter Air Service

In recent years, the commuter air market has experienced extremely rapid growth in New England in general and at Logan specifically, as well as across the rest of the United States. This growth has been aided by abandonment of some routes by certificated carriers, broader acceptance of favorable joint interline fares with the larger carriers, more-favorable financial treatment by lending institutions, and greater awareness of the commuter lines by the flying public. In future years, certificated carriers are unlikely to abandon many more routes, not many more unserved pockets of latent demand will surface for commuters, and growth will no longer be from a small base, so growth rates should decline. During the next 5-10 years, expansion is also likely to be severely constrained by a national shortage of suitable aircraft. Although we expect the commuter industry to continue to grow more rapidly than the certificated carriers, growth will become more difficult and passenger growth rates such as the 40 percent observed from 1977 to 1978 will not be sustained.

In a market environment of rapid growth but expected maturity and external constraints, formal econometric models often fail to provide a satisfactory forecasting tool. [An example of an econometric forecast of 1988 Boston commuter activity made in 1977 that had already been exceeded by 1979 is reported in a 1977 Federal Aviation Administration (FAA) report (6).] Instead, the method chosen for this study examines each segment between Logan and other airports served by each commuter airline and uses the experienced judgment of John W. Drake, a consultant to the aviation and air commuter industry, to forecast commuter air activity. The method and results are described in much greater detail in a CRA publication (1).

It should be noted that the air commuter designation excludes Air New England, which recently became a certificated carrier. Because Air New England was omitted from the above analysis of certificated carriers, the latter part of this section projects growth for Air New England alone.

Baseline Passenger Forecasts

Existing Routes

Four key market factors are taken into account in the forecasts of air commuter activity on existing segments: (a) traffic type (feeder versus local), (b) equipment type, (c) potential service improvements, and (d) carrier competition.

Based on a detailed consideration of these factors, the following aggregated forecasts of number of air commuter passengers per year at Logan were developed: 1977, 267 478; 1990, 650 182; and 2000, 1 405 671. These levels represent a 7.1 percent compounded annual growth rate from 1977 to 1990 and an 8.0 percent annual rate from 1990 to 2000.

Because of the extremely high annual growth rate observed during 1978, it might appear that these forecasts are somewhat low. However, an analysis of the commuter traffic growth during 1978 shows that much of the growth was due to extremely aggressive and nonsustainable expansion by only two firms. Given this consideration, the forecasts of commuter traffic will arbitrarily incorporate a 15 percent gain for 1979, a 10 percent gain for 1980, and then interpolate a constant-percentage growth rate between the forecasts given for 1980 and 1990 and for 1990 and 2000.

Although the judgmental technique for forecasting commuter growth rates provides conservative passenger growth rates relative to recent history, forecast long-term growth is nonetheless robust. Commuter passenger traffic at Logan in 1990 is forecast to be nearly 2.5 times the 1977 level, and by the year 2000, traffic will be more than five times the 1977 level. The reader should remain aware, however, that these projections are inherently softer than the certificated forecasts.

Air New England

Though legally a certificated carrier, Air New England has a route structure similar to that of a large regional commuter line and was therefore omitted from the projections for certificated carriers. However, since Air New England currently serves nearly as many passengers as all commuter lines combined, its inclusion is critical.

Unfortunately, it is always risky to make long-term market projections for a single air carrier or individual firm in any industry. Differences in managerial efficiency between Air New England and its competitors could cause significant redistributions of commuter-type activity among firms. Therefore our forecasts, which are based on the current traffic of Air New England and relationships between its growth and the growth of true commuter traffic, should produce accurate forecasts for the commuter-type market as a whole, though the firm-specific disaggregation should be treated with caution.

The resulting CRA forecast of total Logan commuter-passenger traffic is presented in Table 5. (In both Tables 5 and 6, the reader should treat the market total projections as more reliable than the commuter-Air New England market disaggregation.)

Commuter Air-Carrier Operations

Passenger forecasts have been translated into aircraft movements on a segment-by-segment basis through application of a number of standard industry practices regarding service frequency, equipment choice, and so forth (1).

CRA projections of total operations by passenger commuter airlines are given in Table 6. Due to use of larger airplanes and to improving load factors, it is anticipated that commuter operations at Logan will grow much less rapidly than will passenger volumes. Still, by the year 2000, they will be more than double the 1978 levels.

General Aviation

GA activity is the most difficult segment of the Logan air passenger market to forecast. Forecasting difficulties arise first from concerns about the

Table 5. Forecast of commuter-passenger traffic at Logan.

	Number of Passengers (000s)			
Year	Existing Commuters	New Routes	Air New England	Total
1978	327	0	369	696
1980	414	17	441	872
1985	519	25	568	1112
1990	650	36	736	1422
1995	956	55	1032	2043
2000	1406	74	1427	2907

Table 6. Forecast of commuter-passenger flights at Logan.

	Number of Flights (000s)			
Year	Existing Commuters	New Routes	Air New England	Total
1978	50	0	27	77
1980	55	3	28	86
1985	60	4	31	95
1990	65	5	35	105
1995	84	6	43	133
2000	108	7	52	167

accuracy of historic GA time-series data specific to Logan, since it is believed that inconsistent procedures for tabulating empty arrivals, flybys, etc., may have been employed. Unfortunately, more-reliable recent data are contaminated by significant levels of local helicopter traffic. These factors greatly reduce the validity of statistical models of itinerant GA activity based on Logan data. The use of statistical models is further hindered by the relatively unique character of Logan GA traffic, which restricts the transferability of results derived from other data. Therefore, it was concluded that scarce resources ought not to be devoted to statistical model development.

Instead, the GA forecast is made on the basis of trend extrapolation. GA operations increased by 5.4 percent annually between 1973 and 1978, a period that included the most severe postwar recession. We forecast a baseline growth of 5.6 percent per year for GA activity from 1978 to 1985, 5 percent per year from 1985 to 1990, and 4 percent per year from 1990 to 2000. The rate of growth of GA activity is expected to be dampened by further improvements in commuter air service to smaller cities.

Rocks and Zabronsky have given an example of a set of GA forecasts that allows for capacity constraints (7).

This forecast is defined as one that assumes that GA activity will be unconstrained by Logan's capacity or policies. In fact, it is highly likely that some form of constraint on the growth of GA traffic will have to be imposed within the next two decades. Such constraints might take the form of higher landing fees, time-of-day restrictions, or a slot-reservation system.

The following levels of GA operations at Logan are forecast:

Year	No. of Flights
1978	53 542
1980	60 160
1985	80 507
1990	102 570
1995	125 011
2000	152 095

FORECASTING PROCEDURES FOR CARGO

The air-cargo forecasts are based on actual cargo tonnages and growth trends at Logan during the 1960s and 1970s. Future air-cargo demand at Logan is projected by using a two-part model: (a) a set of single-equation air-cargo demand functions estimated separately for several subcategories of cargo and (b) a set of split ratios that are used to allocate the projected totals to types of aircraft and to enplanements and deplanements.

Model Development

The demand for air-freight movements depends on the level of general economic activity, regional specialization in activity conducive to air freight, air-freight rates, the quality of air-freight service, and the price and quality of freight services provided by competing modes. Quality-of-service considerations include scheduled frequency, speed of the mode, capacity offered, reliability of delivery service, and probability of loss and damage.

Although theoretical considerations argue for estimating and using a fully specified air-cargo model as a Logan planning tool, practical considerations have led us to develop a more-streamlined model. Therefore, the basic forecasting model projects air-cargo demand on the basis of future economic growth and air-cargo rates only. [See the CRA report (1) for a detailed description of the estimated equations.] It has been found that demand for all types of cargo is significantly affected by regional income levels and by cargo rates. The income and price elasticities of the several cargo categories estimated are presented below as calculated by CRA in March 1979:

	Elasticities	
Cargo Category	Price	Income
Domestic freight and express		
Total	-1.68	0.68
Certificated carrier	-1.74	0.56
International freight and express (average)	-2.89	1.62

Since the econometric model provides a basis for the forecast of total tonnage only, separate estimates were made of the split between enplanements and deplanements and the proportion of tonnage in all-cargo freighters. These estimates were based on historical data at Logan and comparisons with forecasts for other major airports.

Baseline Scenario

As was the case in the passenger forecasts, it is necessary to define a baseline set of future conditions. The rate of income growth projected for the New England region (the assumed Logan service area for cargo) in the baseline scenario is consistent with that projected for the Boston area in the passenger forecasts given earlier. Real rates are expected to decline by an annual average of 2.0 percent from 1978 to 1985, and thereafter at 0.8 percent per year due to the combined effects of projected increased load factors, increased containerization, improved terminal technology, economies of scale, and the introduction of new specialized systems. (As in the case of passenger fares, cargo rates in 1980 are probably understated due to recent fuel-price increases. However, long-term results are robust with respect to this short-term change.) This equals an average annual decline of 1.1 percent from 1978 to 2000. In

Table 7. Forecast of Logan air-cargo tonnage, 1978-2000.

Type of Service	Cargo (tons) 1978 Actual	1980	1985	1990	1995	2000
Domestic freight and express						
Certificated carrier						
Arrival	60 660		91 308	107 534		145 560
Departure	75 894		109 568	129 040		174 670
Total	136 554	153 066	200 876	236 574	276 810	320 230
Commuter service						
Arrival	2 541		5 858	8 843		17 037
Departure	2 517		5 858	8 843		17 037
Total	5 058	6 730	11 716	17 686	25 412	34 074
International freight and express						
Arrival	18 154		29 107	34 691		47 560
Departure	29 603		43 660	52 036		71 340
Total	47 757	55 078	72 767	86 727	102 864	118 900
Domestic mail						
Arrival	19 282		22 645	23 188		23 644
Departure	21 923		22 645	23 188		23 645
Total	41 205	42 883	45 290	46 376	46 938	47 289
International mail						
Arrival	1 740		3 008	4 047		7 145
Departure	2 041		3 532	4 751		8 388
Total	3 781	4 660	6 540	8 798	11 919	15 533
Total, all types of service	234 355	262 417	337 189	396 161	463 943	536 026
Total, all-cargo freighters[a]	86 077	93 945	113 970	126 375	139 183	151 695

Note: Data for 1978 come from Green Sheets supplied by Massport Aviation Department. Data for other years are calculated from simulations made by CRA, March 1979.

[a]Included in the total above.

general, it is assumed that no dramatic changes will occur in the structure of the industry, the nature of supply constraints that face Logan operations, or the political environment in which the industry operates.

Baseline Forecasts

The cargo projections presented in Table 7 forecast that cargo and mail tonnage will more than double by the year 2000, from 234 000 tons in 1978 to 536 000 tons in 2000. The figures suggest that the explosive growth rates of the 1960s are not likely to be seen at Logan during the next two decades, though tonnages will not stagnate, as was the case in the recession of the mid-1970s.

The growth in traffic projected for domestic cargo at Logan is nearly identical to FAA and American Public Transit Association national projections. Because domestic cargo constitutes 75 percent of all freight and express at Logan, the forecast implies that Logan's share in the national air-cargo market should remain roughly constant over the forecast period. The growth in international cargo at Logan is projected to be lower than the national average due to the relative maturity of the Logan market.

SUMMARY

Passenger counts and air-cargo tonnage at Logan are expected to grow at about 5 percent annually during the next 20 years. This is roughly the average of the 1960-1978 period taken as a whole. We expect that the number of aircraft movements will grow more rapidly than they did during the 1960-1978 period. This more-rapid growth will occur because there will not be an increase in average airplane size comparable with that which occurred when wide-body jets were introduced and because a growing percentage of air operations will be performed by relatively small commuter aircraft. We conclude that air traffic will grow neither so rapidly as during 1960-1969 nor so slowly as during 1969-1975.

The greatest uncertainty in the forecast is related to the rate of secular economic growth. A 1 percent difference in this rate translates into about a 30 percent difference in the year 2000 air activity forecasts. A second major uncertainty concerns the rate of increase in aviation fuel prices. Since fuel costs are now greater than 20 percent of total operating costs for airlines, differences in future energy price trends can have significant effects. Energy price forecasts for the year 2000 that differ by a factor of 2 result in air activity forecasts that differ by nearly 20 percent.

Some uncertainty is also introduced by reductions in rate and route regulation. However, although this issue is far from settled, it appears that the uncertainty for airport planners relating to future activity levels is much less than the uncertainty caused by different economic-growth and fuel-price scenarios. Off-peak discount pricing is already extensive, load factors are already up, and certificated airplane orders that can be filled for roughly the next five years are already placed. Although it is not difficult to believe that competitive strategies can increase load factors and reduce costs per passenger even further, likely scenarios do not show that the impact on certificated passenger traffic is likely to be major in comparison with other effects.

There is one sector, however, in which airline regulatory reform is already severely affecting the airport planning process. This is air-commuter passenger traffic. Regulatory reform has allowed certificated carriers that have large airplanes and infrequent service to be replaced in smaller cities by commuter carriers that have more frequent service and smaller airplanes. In addition, regulatory changes have included legislated interline fares that make feeder commuter-air connecting service to full-fare certificated flights extremely inexpensive. Partly as a result of these changes, commuter passenger traffic at Logan increased by 40 percent between 1977 and 1978.

Such volatility in the presence of not previously experienced changes is, of course, difficult to forecast, and many projections made in the mid-1970s dramatically underestimated growth of commuter traffic. However, aside from this type of unforeseeable effect, many earlier (i.e., late 1960s) forecasts systematically overpredicted future activity. Although this paper does not detail an explanation of these inaccuracies, the analysis undertaken in this study isolated two principal causes. First, economic growth was projected to be much higher than the actual experience of the 1970s. Second, early forecasting models had income elasticities that are now believed to be too high and air-fare elasticities that are believed to be too low.

Another finding during the course of the study has been the limited amount of consistent and reliable data available for site-specific forecasts. Differences in the categorization of activity between data sources and between available and desired data items often constrain modeling efforts. For example, the adequacy of average yield as an explanatory variable in demand-forecasting equations during years when the rate schedule is complex and demand oriented was subject to some doubt. Although we found that average yield provides an adequate measure of fare levels and find no evidence of large backcasting residuals when it is used, the unavailability or the known inaccuracies and biases of data that measure both activity levels and causal factors often make informed judgment an appropriate forecasting tool.

ACKNOWLEDGMENT

The forecasting project reported here was funded by the Massachusetts Port Authority under a planning grant from the Federal Aviation Administration. We would like to acknowledge the assistance provided by Mitchell Kellman and Cynthia Kagno of Charles River Associates. The opinions and conclusions expressed or implied in the paper are ours and are not necessarily those of the Transportation Research Board, the National Academy of Sciences, or the Massachusetts Port Authority.

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Publication of this paper sponsored by Committee on Aviation Demand Forecasting.

Forecasting Method for General Aviation Aircraft and Their Activity

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This paper describes the formulation and application of a general aviation (GA) forecasting model within the context of the North Central Texas regional airport system planning process. The objective of the model was to provide a means of forecasting registered county-level GA aircraft ownership and the activity of those aircraft (hours flown) that allows public policymakers and planners to assess the impact of policy and economic growth alternatives on GA demand. The bottom-to-top econometric and time-series model developed through this effort achieved these objectives with statistical results that varied across the 19 counties and four aircraft types. Finally, a feature of this model uncommon to other GA forecasting models is that the demand for aircraft is specified to be (among other things) a function of the demand for air travel (hours flown).

The North Central Texas Airport System Plan, adopted by the Regional Transportation Policy Advisory Committee (RTPAC) on November 16, 1974, presented the findings of a comprehensive two-year analysis of existing and future activity in the 19-county area defined by the North Central Texas and Texoma state planning regions. The plan identified existing airport facilities, forecast aviation demand through the year 1990, and recommended the staged development of a system of public airports (to include improvements to both proposed and existing airports) to meet that demand.

With the adoption of the plan, efforts of the RTPAC staff focused on assisting local governments in plan implementation. In addition, efforts were made to update the plan in response to changing conditions within the aviation community and within local communities. An outgrowth of these efforts was a realization that the technical planning process underlying the system plan did not allow for a rapid, comprehensive response to technical or policy issues that were raised by elected officials, airport managers, and the general public.

For example, a major issue raised by groups opposed to new airports was whether there was a need