Forecasts of Aviation Fuel Consumption in Virginia

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Aviation fuel shortages and their impact on airline services and fuel-tax revenues have encouraged transporters, suppliers, and state agencies to look more closely at future aviation fuel consumption. This paper, the work for which was sponsored by the Virginia Division of Motor Vehicles, determines forecasts for aviation fuel consumption in Virginia under various socio-economic and airline-policy conditions. The forecasting method is an econometric model that consists of 17 basic components; the major components are population and economy. The state population and economic conditions are considered the major forces that affect travel behavior, airline service, and, in turn, aviation fuel consumption. The model clearly distinguishes between operations of air carriers and of general aviation. General aviation local operations and their itinerant piston-powered operations are considered to consume only aviation gasoline, whereas the remaining aviation operations consume jet fuel. A separate model was developed for each air-carrier airport, whereas an aggregated state model was built for general aviation operations. The scenarios tested include high gasoline prices, rising consumer price index for all goods, high air fares, improved fuel-efficient aircraft, and many other factors. The results show that aviation fuel consumption continues to increase but at different rates, which depend on the economic conditions in the state. Airline policies were also found to affect the amount of jet fuel consumption greatly.

Since 1950, there has been a steady rise in intercity travel by most major modes--private automobile and common carrier (rail, bus, and air). Among the common carriers, air travel increased from 14.2 percent in 1950 to nearly 85 percent in 1978 according to the Air Transport Association Facts and Figures of 1979. The growth in aviation is expected to continue, especially because of the recent deregulation of the airlines, the cut in air fares, and the provision of different air services.

At the state level, similar trends have been realized. In the last decade, aviation activities in Virginia have been growing at a considerable rate. In 1967, there were 1 773 814 domestic enplaned passengers, 1311 licensed aircraft, and 4991 licensed pilots. In 1977, there were 3 066 299 domestic enplaned passengers, 2465 licensed aircraft, and 10 724 licensed pilots. Concurrent with the growth in aviation activities is the growth in the demand for aviation jet fuel. The amount of aviation jet fuel consumed in Virginia had increased from 118 003 671 gal in 1968 to 210 547 896 gal in 1978.

However, the recent rise in fuel prices and the limited availability of aviation fuel have created a substantial impact on the Virginia air transportation system, so that many flights have had to be cancelled or rerouted. The Division of Motor Vehicles (DMV) of the commonwealth of Virginia is in charge of collecting the state tax revenues for fuel, which includes aviation fuel. They sponsored the work of determining the state's future demand for aviation fuel under various scenarios and the associated tax revenues in order to aid in the proper scheduling and allocation of future expenditures in this area.

Thus, we have developed a computerized econometric model for DMV to forecast aviation fuel consumption and its associated tax revenues. This paper also examines and discusses the impacts of alternative future scenarios such as high gasoline prices, rising inflation, and changing airline policies.

MODELING APPROACH

There are two major kinds of aviation fuel--aviation jet fuel and aviation gasoline. Aviation jet fuel is consumed mostly by air carriers and partly by general aviation (GA) aircraft with turbine-powered engines. Because of these two distinct kinds of fuel, aviation activities were separated into air-carrier and GA activities.

In determining air-carrier activities, each air-carrier airport is considered individually to encompass its own distinct characteristics and environment. An aggregated state model that jointly addresses all the air-carrier airports was eliminated from consideration, because it obscures the variability among the different airports and is not sensitive to the future conditions at each airport. There are now 11 air-carrier airports in Virginia: Charlottesville, Danville, Dulles International, Hot Springs, Lynchburg, Newport News, Norfolk, Richmond, Roanoke, Staunton (Shenandoah Valley), and Washington National. For purposes of tax revenue, Washington National Airport will not be considered in the model, since there is a state agreement that declares aviation fuel consumption at this airport to be nontaxable.

GA activities in Virginia take place at 84 airports. Similarly, for purposes of tax revenue, the model did not consider the GA activities at Washington National Airport. An aggregated state model that combined the GA activities at all airports was developed in this case because building a separate model for each individual airport was found unnecessary and the availability of data at each airport was limited. Since the quantity of aviation fuel consumption is directly related to the amount of aircraft operations, the model then focused on forecasting the number of aircraft operations in Virginia. Historically, GA operations at airports that had or did not have towers were not growing at the same rate. This fact led to the categorization of GA operations into towered and nontowered operations. Also, at each GA airport, two major types of operations were considered--itinerant and local.

MODEL STRUCTURE

The forecasting model is an econometric model that consists of 17 basic components, as shown in the flowchart in Figure 1.

The model was developed under the assumption that population and economic factors are the major forces that affect travel behavior, aviation fuel consumption, and (in turn) potential for tax revenue. This is clearly depicted in Figure 1, in which both population and economy are directly or indirectly related to each component of the model. Both are shown to affect air-carrier enplaned passengers and GA operations. Air-carrier enplaned passengers were converted to air-carrier departing flights by determining the number of enplaned passengers per departing flight, which is the multiplicative result of the seat-load factor and the available revenue seats. These departing flights were directly related to air-carrier jet fuel consumption. GA operations were classified into itinerant and local operations. All local operations were considered to be piston-powered operations, which consume aviation gasoline. All itinerant operations were considered to be both turbine- and piston-powered operations, which consume aviation jet fuel and aviation gasoline,

Figure 1. General relationships of aviation-fuel-consumption model.

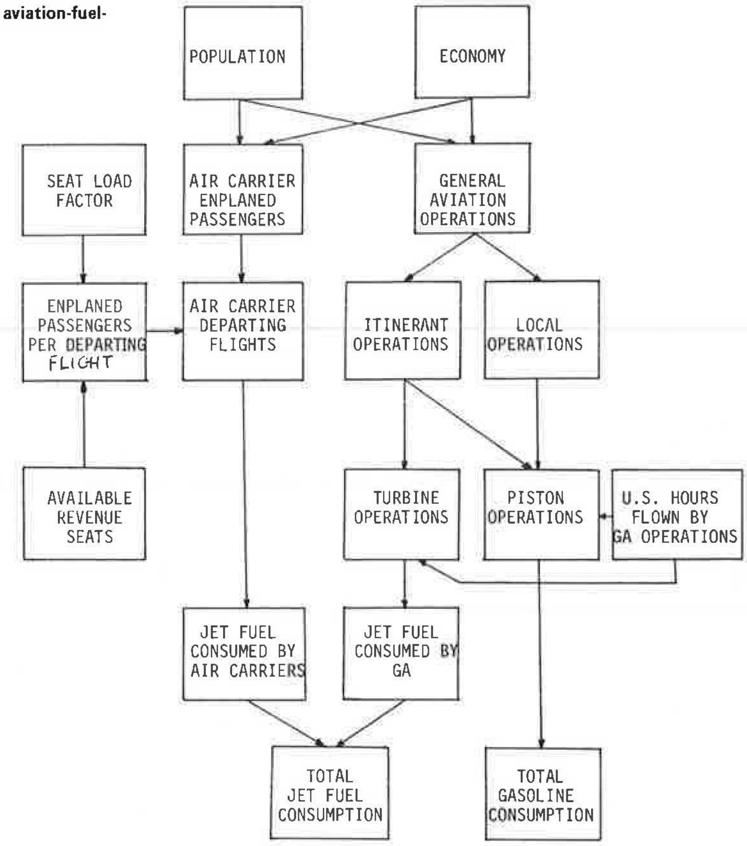
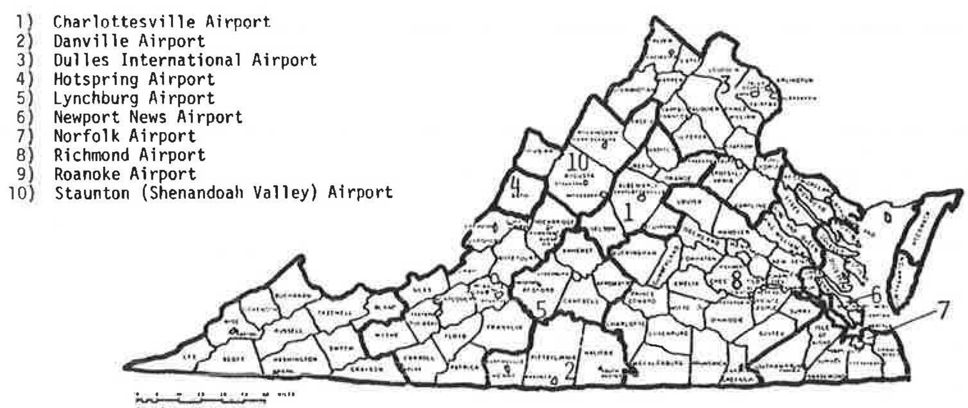


Figure 2. Airport service areas.



respectively. Total aviation jet fuel consumption is the sum of the consumption of both air-carrier jet fuel and GA jet fuel. Aviation gasoline consumed by GA piston-powered operations represented the total aviation gasoline consumption in Virginia. Aviation fuel-tax revenues were then easily determined by multiplying the aviation fuel consumption by the tax rate.

AIR-CARRIER DOMESTIC ENPLANED PASSENGERS

In determining the aviation jet fuel consumption at each air-carrier airport, the number of domestic enplaned passengers at each airport annually was forecast first. The number of enplaned passengers was considered to be influenced by the following variables: (a) service-area population, (b) service-area real per-capita personal income, (c) average air fare per revenue passenger mile, and (d) cost of 1 mile of automobile operation. The airport service areas are defined by the Division of State Planning and Community Affairs of the commonwealth of Virginia as the counties and cities located roughly within a radius of 60-70 miles from each airport. The service areas for each airport are shown in Figure 2. The real per-capita personal income is expressed on the base-year (1967) value. That is, real per-capita personal income for any particular year is equal to per-capita personal income of that year multiplied by the ratio of the consumer price index (CPI) for all goods in the base year to the CPI for all goods in that particular year. The cost of 1 mile of automobile operation was obtained from secondary sources (1). The

Table 1. Forecasting equations for air-carrier airports.

Airport	Forecasting Equation	R^2
Charlottesville	CHAPAS(I) = -143 438.3 + 1.411 92CHAPOP(I) + 6709.274[ACPM(I)/USFARE(I)]	0.943
Danville	DANPAS(I) = 10 049.59 - 747.0708USFARE(I) + 171.9913ACPM(I)	0.363
Dulles International	DULPAS(I) = -971 783.3 + 0.905 08DULPOP(I) + 191.2122DULPCI(I) + 37 462.33 [ACPM(I)/USFARE(I)]	0.987
Hot Springs	HOTPAS(I) = 5206.287 + 1.0791HOTPCI(I) -788.0317USFARE(I) + 180.9274ACPM(I)	0.217
Lynchburg	LYNPAS(I) = -106 442.6 + 0.7303LYNPOP(I) + 0.3440LYNPCI(I) + 30 602.15 [ACPM(I) ÷ USFARE(I)] - 12 162.02LYNDUM(I)[a]	0.873
Newport News	NEWPAS(I) = 84 478.09 + 0.185 75NEWPOP(I) + 54.045NEWPCI(I) - 19 939.13USFARE(I)	0.791
Norfolk	NORPAS(I) = -1 963 571 + 2.903 97NORPOP(I) + 143.2402NORPCI(I) - 12 720.67USFARE(I)	0.897
Richmond	RICPAS(I) = -52613.4 + 0.7574RICPOP(I) + 57.2030RICPCI(I) + 7581.388ACPM(I)	0.915
Roanoke	ROAPAS(I) = 640 679.1 + 0.7845ROAPOP(I) + 191.531ROAPCI(I) + 38 254.93 [ACPM(I)/USFARE(I)]	0.981
Staunton	STAPAS(I) = 11 777.796 + 0.005 06STAPOP(I) + 1.592STAPCI(I) + 3846.426[ACPM(I) ÷ USFARE(I)]	0.187

[a]LYNDUM(I) = dummy variable that represents the reduction of daily flights by Piedmont Airlines (prior to 1974 = 0; in 1974 and thereafter = 1).

average air fare per revenue passenger mile was obtained from the Civil Aeronautics Board (CAB) reports to Congress for various years.

The number of domestic enplaned passengers at each airport was considered to be a linear function of the above four socioeconomic variables. The typical relationship between the dependent variable (domestic enplaned passengers) and the independent variables at each airport by using the multiple-linear-regression technique is anticipated to be as follows:

$$XPAS(I) = a + b * XPOP(I) + c * XPCI(I) + d * [ACPM(I)/USFARE(I)] \quad (1)$$

where

- XPAS(I) = number of domestic enplaned passengers at airport X in year I,
- XPOP(I) = population who live in airport X service area in year I,
- XPCI(I) = real per-capita personal income of population in airport X service area in year I,
- ACPM(I) = cost of 1 mile of automobile operation in year I,
- USFARE(I) = average air fare per revenue passenger mile in year I, and
- a, b, c, and d = regression parameters.

All the independent variables in the above equation should display positive correlation with the dependent variable. That is, if population or real per-capita personal income or both increase, the number of enplanements at that airport should increase. Similarly, the ratio ACPM/USFARE should have a positive coefficient, because if USFARE decreases with respect to ACPM for the same length of trip, it should induce the traveler to use air service more often.

Unfortunately, the equation developed for some airports did not contain positive coefficients for all the parameters; thus the logical relationship was not represented correctly. In these cases, different combinations of the independent variables were employed, and those variables that provided the most-logical contributions were selected to represent the forecasting equations. The forecasting equations for all air-carrier airports considered are shown in Table 1. They were developed by using time-series data from 1967 to 1977.

Most of the equations displayed a high coefficient of determination (R^2), except for those for Danville, Hot Springs, and Staunton, where R^2 was quite low--0.363, 0.217, and 0.187, respectively. These airports had experienced fluctuations in the number of enplaned passengers over the last decade due to fluctuations in flight services and schedules and other economic conditions that the hypothesized equation was not able to capture. In spite of the low R^2-values, the plots of the residuals for these airports showed that the estimates were converging toward the actual data in the last five years. This positive indication plus the inability to produce better equations with the available data forced us to use the equations developed.

As stated earlier, aviation fuel consumption is dependent on the number of departing flights and the average amount of fuel consumed per departing flight. To translate the already-determined number of annual enplaned passengers at each airport into departing flights, the average number of available revenue seats and average-seat-load factor per departing flight had to be determined first.

Average Number of Available Revenue Seats per Departing Flight

The average number of revenue seats per departing flight at each airport in year I [XSEAT(I)] was determined by using the following relationship:

$$XSEAT(I) = \Sigma_j \Sigma_k [A_{jk}(I)] [XB_{jk}(I)] / \Sigma_j \Sigma_k XB_{jk}(I) \quad (2)$$

where $A_{jk}(I)$ is the number of revenue seats per average departing flight by aircraft type (k) and by air-carrier group (j) in year I and $XB_{jk}(I)$ is the number of departing flights by aircraft type (k) and by air-carrier group (j) at airport X in year I. The A-values were obtained from CAB reports from 1971 to 1977. The B-values were obtained for the seven years from airport activity statistics published jointly by CAB and the Federal Aviation Administration (FAA).

Average-Seat-Load Factor per Departing Flight

An average-seat-load factor per departing flight at each airport for year I [XLF(I)] was determined by dividing the average number of enplaned passengers per departing flight at each airport by the average number of available revenue seats per departing flight [XSEAT(I)]. The number of enplaned passengers per departing flight was calculated by dividing the number of annual enplaned passengers at each airport by the total number of departing flights at that particular airport. Historical data for these two figures were available for each airport. Thus, average number of revenue seats and average-seat-load factors per departing flight at each airport were calculated for the years 1971-1977. These two figures were then projected into the future for the horizon year based on past trends.

Annual Number of Departing Flights at Each Airport

The annual number of departing flights at each airport [XOPN(I)] was then determined by dividing the annual number of enplaned passengers [XPAS(I)] by

the average number of available revenue seats per departing flight [XSEAT(I)] and the average-seat-load factor per departing flight [XLF(I)] at that particular airport:

$$XOPN(I) = XPAS(I)/[XSEAT(I)]\ [XLF(I)] \quad (3)$$

Fuel Consumed per Departing Flight

In this model, the amount of fuel consumed per departing flight was considered to be the product of the average gallons of fuel consumed per block hour [$GALR_{jk}(I)$] and the total block hours [$BLOCK_{jk}(I)$] from ramp to ramp of average departing flights by aircraft type (k) and by air-carrier group (j). The latter value was determined as follows:

$$BLOCK_{jk}(I) = LENGTH_{jk}(I)/SPEED_{jk}(I) \quad (4)$$

where $LENGTH_{jk}(I)$ is the average stage length (miles) from ramp to ramp per departing flight by aircraft type (k) and by air-carrier group (j) in year I, and $SPEED_{jk}(I)$ is the average ramp-to-ramp speed (mph) per departing flight by aircraft type (k) and by air-carrier group (j) in year I. $LENGTH_{jk}(I)$, $SPEED_{jk}(I)$, and the average amount of fuel consumed per block hour [$GALR_{jk}(I)$] were obtained from CAB operating-cost and performance reports for the years 1971-1977. Thus, the average amount of fuel consumed per departing flight for these years by aircraft type (k) and by air-carrier group (j) in year I [$GALT_{jk}(I)$] was calculated by multiplying $BLOCK_{jk}(I)$ by $GALR_{jk}(I)$.

The average amount of fuel consumption per departing flight at each airport for year I [XFUEL(I)] was determined next by using the following relationship:

$$XFUEL(I) = \Sigma_j \Sigma_k\ [GALT_{jk}(I)]\ [XB_{jk}(I)] / \Sigma_j \Sigma_k XB_{jk}(I) \quad (5)$$

The above figure for XFUEL(I) was determined for each year from 1971 to 1977 and projected to the horizon year by using the trends of the seven years of data.

Finally, the total annual aviation jet fuel consumed at airport X was determined by multiplying the average amount of fuel consumed per departing flight at airport X (XFUEL) by its annual number of departing flights (XOPN). The total annual air-carrier jet fuel consumption in Virginia was then obtained by summing this value over the 10 air-carrier airports studied.

GA OPERATIONS

Several socioeconomic variables in Virginia are considered to influence GA operations. Among them are (a) the number of certified pilots, (b) the number of active GA aircraft, (c) the manufacturing investment, and (d) the CPI for gasoline. These socioeconomic variables were used in a series of multiple-linear-regression equations to determine the parameters of the estimating equations for GA operations. Future value of these independent variables had to be exogenously projected and then used as inputs into the model. In that respect, a regression analysis was also performed on the number of certified pilots and the number of active GA aircraft. The manufacturing investment and the CPI for gasoline were obtained from existing sources (1), which forecast their values to the year 1990.

There are four types of certified pilots: student, commercial, private, and airline. Airline pilots who operate air-carrier aircraft were not considered to influence the GA operations; the three other types were. In this model, each of the three types of pilot was forecast individually by using basically two independent variables--Virginia population and the corresponding national value of the variable under consideration. The national figures were obtained from the FAA statistical handbooks for the years 1967-1978. The projected value of these figures was also obtained from an FAA publication (2). The forecasting equation for student pilots in Virginia [VASPLT(I)] is as follows:

$$VASPLT(I) = -8123.678 + 0.001\,731\ VAPOP(I) + 0.017\,73 USSPLT(I) \quad (6)$$

where

VAPOP(I) = population in Virginia in year I,
USSPLT(I) = number of student pilots in the United States in year I, and
$R^2 = 0.730$.

The forecasting equation for commercial pilots in Virginia [VACPLT(I)] is as follows:

$$VACPLT(I) = -23\,085.52 + 0.005\,347 VAPOP(I) + 0.011\,51 USCPLT(I) \quad (7)$$

where USCPLT(I) is the number of commercial pilots in the United States in year I, and $R^2 = 0.907$.

Similarly, the forecasting equation for Virginia private pilots [VAPPLT(I)] is as follows:

$$VAPPLT(I) = -9091.199 + 0.002\,32 VAPOP(I) + 0.010\,48 USPPLT(I) \quad (8)$$

where USPPLT(I) is the number of private pilots in the United States in year I, and $R^2 = 0.881$.

The number of active GA aircraft in Virginia was considered to be dependent on the number of GA pilots in Virginia, on Virginia real per-capita income, and on the number of active GA aircraft in the United States. A series of multiple-linear regressions that used various combinations of the above variables was examined and analyzed. The equation that displayed the strongest relationship (statistically as well as theoretically) was chosen:

$$VAAAC(I) = -1121.012 + 0.1179 VAGAPL(I) + 0.2845 REAPCI(I) \quad (9)$$

where

VAAAC(I) = number of active GA aircraft in Virginia in year I,
VAGAPL(I) = number of GA pilots (student, private, and commercial pilots only) in Virginia in year I,
REAPCI(I) = Virginia real per-capita personal income in year I, and
$R^2 = 0.943$.

Once the forecasts of the socioeconomic variables that influenced GA operations in general were obtained, they were used in the GA operations forecasts at two categories of airports, towered and nontowered. This division of airports was found necessary because the growth rates of GA activities in these two types of airport were quite different.

Towered Airports

Two types of GA operations occur at towered airports--itinerant and local. Each of these operations was forecast separately. In itinerant operations, all independent variables were considered except the number of student pilots who perform mostly local operations (for training purposes). A series of multiple-linear regressions was performed between the dependent variable and the

independent variables, which resulted in the selection of the following equation:

$$TOWITI(I) = 158\,972.8 + 75.8859VAAAC(I) \quad (10)$$

where TOWITI(I) is the number of itinerant operations at towered airports in Virginia in year I, and R^2 = 0.716.

Similarly, in local operations, all independent variables were considered except for the number of commercial pilots. Only private and student pilots were considered to perform local operations. The best forecasting equation was found to be as follows:

$$TOWLOC(I) = 32\,634.65 + 49.2940VAAAC(I) + 116.3042MFGINV(I) \quad (11)$$

where

TOWLOC(I) = number of local operations at towered airports in Virginia in year I,
MFGINV(I) = amount of manufacturing investment in Virginia in year I ($000 000s), and
R^2 = 0.700.

Nontowered Airports

Again, the forecasts for two types of GA operations at nontowered airports in Virginia (itinerant and local) were developed individually.

Itinerant operations at nontowered airports were considered to be influenced by the same socioeconomic variables that influence such operations at towered airports. The selected forecasting equation is as follows:

$$NOTITI(I) = 51\,347.61 + 177.2526VAAAC(I) + 56.2954MFGINV(I) \quad (12)$$

where NOTITI(I) is the number of itinerant operations at nontowered airports in Virginia in year I, and R^2 = 0.968.

Similarly, local operations were regressed against the same independent variables as those used in towered airports, and the best forecasting equation developed is as follows:

$$NOTLOC(I) = 117\,985.2 + 531.1408VAAAC(I) \quad (13)$$

where NOTLOC(I) is the number of local operations at nontowered airports in Virginia in year I, and R^2 = 0.954.

Both equations developed for nontowered airports are superior to those for towered airports because of the uniformity of the existing data. Besides, nontowered airports account for the most GA operations in the state--about 75 percent.

As stated earlier, the total GA itinerant operations, which take place at towered and nontowered airports, were considered to be both turbine-powered and piston-powered operations, which consume aviation jet fuel and aviation gasoline, respectively.

To determine the number of turbine-powered itinerant operations, the following relationship was adopted:

$$JETITI(I)/ITINT(I) = TURBIN(I)/[TURBIN(I) + PISTON(I)] \quad (14)$$

where

JETITI(I) = number of turbine-powered itinerant operations in Virginia in year I,
ITINT(I) = total GA itinerant operations in Virginia in year I,
TURBIN(I) = number of hours flown by GA turbine-powered operations in the United States in year I, and
PISTON(I) = number of hours flown by GA operations in the United States in year I.

The data and the forecasts for the two variables TURBIN(I) and PISTON(I) were obtained from the FAA statistical handbooks and the FAA aviation forecasts (2), respectively.

The piston-powered itinerant operations at all airports were simply determined by subtracting the turbine-powered itinerant operations from GA itinerant operations.

The GA local operations are composed of those operations at both towered and nontowered airports. Because local operations are mostly short-distance operations, they were assumed to be GA piston-powered operations, which consume only aviation gasoline.

Thus, the total GA piston-powered operations are composed of GA local operations and piston-powered itinerant operations.

GA FUEL CONSUMPTION

To translate GA operations into fuel consumption, a trend method was used in the case of piston-powered operations and a ratio method (which compared Virginia consumption with national consumption) was used in the case of turbine-powered operations.

The former method involved a simple linear regression between GA gasoline consumption as the dependent variable and GA piston-powered operations as the independent variable. The equation developed is as follows:

$$VAGAS(I) = 3\,551\,434 + 1.068\,14GAPIOP(I) \quad (15)$$

where VAGAS(I) is the amount of GA gasoline consumption in Virginia in year I, and GAPIOP(I) is the number of total GA piston-powered operations in Virginia in year I. VAGAS was considered to represent the total quantity of aviation gasoline consumed in Virginia because there is a relatively small amount of aviation gasoline consumed by air carriers.

Since no data were available on the amount of GA jet fuel consumed in Virginia, the following ratio method that compares Virginia and the United States was used to determine the GA jet fuel consumed in Virginia:

$$GAJET(I)/[VAGAS(I) + GAJET(I)] = USGAJT(I) \div [USGAGS(I) + USGAJT(I)] \quad (16)$$

where

GAJET(I) = number of gallons of GA jet fuel consumption in Virginia in year I,
USGAJT(I) = number of gallons of GA jet fuel consumption in the United States in year I, and
USGAGS(I) = number of gallons of GA gasoline consumption in the United States in year I.

USGAGS and USGAJT were both obtained from an FAA publication (2). GAJET was then added to air-carrier jet fuel consumption to yield the total aviation jet fuel consumption in Virginia. Aviation fuel consumption in Virginia (from DMV motor-fuel tax reports) is shown in Table 2.

SCENARIOS

One of the advantages of using an econometric model for forecasting is its flexibility for testing

alternative future scenarios. A scenario is referred to here as a future condition in which the underlying assumptions of the model fail to hold true. The original conditions used in developing the model (base-case conditions) are presented in Table 3. The scenarios tested adequately cover the key elements and assumptions under consideration.

Sagging Economy

The originally projected rate of increase for manufacturing investment is 8.6 percent per year. If there is a slowdown of economic growth, aviation fuel consumption and consequently the tax revenues will be adversely affected. To test the hypothesis, a rate of increase of 8.0 percent per year was employed instead.

High Gasoline

In this scenario, CPI for gasoline will increase at 8.5 percent per year rather than 6.4 percent as was used in the base case. This scenario is of particular importance due to the uncertainty of the future gasoline supply and its price.

Table 2. Aviation fuel consumption in Virginia.

	Aviation Gasoline (gal 000 000s)		Aviation Jet Fuel (gal 000 000s)	
Year	Actual	Forecast	Actual	Forecast
1971	5.193	5.26	170.769	173.35
1972	5.286	5.44	174.813	177.02
1973	5.598	5.57	174.890	181.75
1974	6.247	5.59	184.297	180.78
1975	5.986	5.67	170.641	182.54
1976	6.010	5.81	178.654	185.26
1977	6.055	5.93	200.957	200.71
1978	6.290	6.12	210.648	204.77
1979		6.35		208.05
1980		6.58		211.99
1981		6.78		214.55
1982		6.96		217.32
1983		7.12		219.44
1984		7.30		221.82
1985		7.49		224.17
1986		7.67		226.72
1987		7.85		228.53
1988		8.03		230.64
1989		8.21		233.19
1990		8.40		235.52

Rising CPI for All Goods

Historically, the rate of inflation periodically rises at a faster rate than it does during average economic activity. It was decided to explore the impact of rising inflation on aviation fuel consumption. Thus, CPI for all goods (CPIALL) was assumed to increase at 8.5 percent per year rather than at 6.0 percent per year as in the base case.

High Gasoline and Rising CPIALL

It is very true that the high price of gasoline will simultaneously raise the cost of living. In this scenario, both CPIALL and CPI for gasoline (CPIGAS) were assumed to increase at 8.5 percent per year.

Rising CPIALL and High Air Fares

Rising inflation will induce airlines to raise the air fare in order to cope with the high cost of goods. In this scenario, CPIALL and air fares were assumed to increase at 8.5 and 6.5 percent per year, respectively.

RESULTS OF SCENARIOS

The results of the scenarios are shown in Table 4. Although they are self-explanatory, it would be beneficial to review some of the more-interesting results.

Aviation jet fuel consumption decreases under all but one scenario, high gasoline, which indicates the influence of adverse economic conditions. The high price of gasoline, according to the model, has had more influence on the operating cost of automobiles (ACPM), which in turn has induced intercity travelers to shift from automobiles to air carriers. The result is a greater number of departing flights and consequently a greater amount of fuel consumption.

Similarly, aviation gasoline consumption decreases under all but that same scenario. Since the model did not contain the price of gasoline as an explanatory variable to GA operations, it did not influence fuel consumption. However, it is expected that this variable will gain more importance in the future.

ADDITIONAL SCENARIOS

Several additional scenarios were performed to reflect all possible aviation conditions in Virginia and their impact on fuel consumption. They are discussed separately because some of the inputs to

Table 3. Base-case conditions at Virginia airports.

	Percentage Increase per Year at Airport										
Variable	All	CHA	DAN	DUL	HOT	LYN	NEW	NOR	RIC	ROA	STA
CPI											
Gasoline	6.4										
All goods	6.0										
Parking	5.75										
Air fare per revenue passenger mile	5.5										
Manufacturing investment	8.60										
Per-capita personal income (service area)		8.2	8.5	9.0	8.7	8.2	8.8	9.0	8.7	8.6	8.2
Available revenue seats per departing flight		1.8	0.46	1.15	0.46	1.61	1.37	1.97	2.15	2.71	0.46
Seat-load factor per departing flight		2.126	2.456	3.274	2.477	3.145	2.233	1.473	1.375	2.627	3.691
Fuel consumed per departing flight		2.435	2.343	1.945	2.486	3.576	1.331	2.352	1.258	3.168	3.096

Note: Airports are abbreviated as follows: CHA, Charlottesville; DAN, Danville; DUL, Dulles International; HOT, Hot Springs; LYN, Lynchburg; NEW, Newport News; NOR, Norfolk; RIC, Richmond; ROA, Roanoke; and STA, Staunton.

Table 4. Projected aviation fuel consumption for 1990 for each scenario.

Scenario	Jet Fuel Consumption (gal 000 000s)	Gasoline Consumption (gal 000 000s)
Base case	235.51	8.40
Sagging economy	235.47	8.38
High gasoline	236.77	8.40
Rising CPIALL	196.33	8.12
High gasoline and rising CPIALL	197.50	NA
Rising CPIALL and high air fares	194.71	NA

Table 5. Projected aviation fuel consumption for 1990 under base-case and additional scenarios.

Scenario	Jet Fuel Consumption (gal 000 000s)	Gasoline Consumption (gal 000 000s)
Base case	235.51	8.40
Introduction of commuter air service at specific airports	235.28	8.45
Expansion of Piedmont routes	236.08	NA
Improved efficiency of aircraft fuel consumption	225.76	NA
Competition between airports	238.12	NA
Increased seating capacity	224.15	NA

these scenarios are partly or totally performed outside the model. These scenarios are (a) introduction of commuter air service at specific airports, (b) competition between airports, (c) expansion of Piedmont routes, (d) improved efficiency of aircraft fuel consumption, and (e) increased seating capacity. The assumptions and the inputs under each scenario are presented first, and the results are discussed later for the sake of brevity.

Introduction of Commuter Air Service

The commuter air service is proposed to serve the airports of Danville, Hot Springs, Lynchburg, and Newport News.

At present, the number of air-carrier enplaned passengers at Danville and Hot Springs airports is declining. These two airports are exclusively served by Piedmont Airlines; it is assumed in this model that service will be terminated at either or both airports if the annual number of enplaned passengers drops below 1000. The termination of Piedmont service is expected to result in the introduction of commuter air service. It was also assumed that the number of users of commuter air service would reach 1500 at both airports in the first servicing year after termination of Piedmont service and would increase at 10 percent per year thereafter.

At Lynchburg Airport, Air Virginia is currently providing commuter air service, even when the number of enplaned passengers is still on the rise. At this airport, it was assumed that commuter air service would attract and accommodate up to 1800 passengers per year from 1980 to 1990.

Similarly, at Newport News Airport, a commuter service was assumed to replace Piedmont Airlines and to service nearby hub airports. This commuter service will attract an average of 2000 passengers per year from 1980 to 1990.

The aircraft used by commuter airlines are usually light and small. In this model it was assumed that PA-31 and Short 330 would be the representative aircraft; these have a two-piston engine and a two-turboprop engine, respectively. It was also anticipated that 50 percent of the users of the commuter air service will fly on Short 330s, and the remaining 50 percent will fly on PA-31s. The amount of fuel consumed per departing Short 330 or PA-31 flight was found to be 48.81 and 35.67 gal, respectively.

Competition Between Airports

Some air-carrier airports in Virginia have direct competitors in terms of better flight schedules and frequencies or facilities or both. One way of analyzing the competition within the model is to change the service area and the corresponding catchment-area population of the competitive airports.

In this scenario, it was anticipated that Charlottesville Airport would lose Fredericksburg to Dulles Airport, which has better facilities and flight schedules. It is assumed that Roanoke Airport would gain Bedford from Lynchburg Airport and Staunton Airport would lose its northern half of Page County to Dulles. Similarly, it was assumed that Norfolk Airport would attract Hampton and Richmond Airport would gain Williamsburg and James City and Gloucester Counties from the Newport News Airport service area.

Expansion of Piedmont Routes

Piedmont Airlines is in the stage of expanding and opening new routes. The expansion will affect air-carrier fuel consumption. It was assumed that only Norfolk, Richmond, Roanoke, and Dulles International airports would be affected by these route expansions. The opening and expanding of new routes (starting in 1980) will increase the stage length per departing flight, which thus affects the amount of fuel consumed per departing flight. After careful analysis and study of the existing flight schedules, flight frequencies, and stage lengths, it is expected that the amount of fuel consumed per departing flight at the above airports will increase from the base-case condition as follows:

Airport	Percentage Increase per Year
Dulles International	0.18
Norfolk	0.60
Richmond	0.60
Roanoke	0.60

Improved Efficiency of Aircraft Fuel Consumption

The limited availability and high price of aviation fuel are expected to entice the airlines to use more fuel-efficient airplanes. It was assumed that only Dulles, Norfolk, Richmond, and Roanoke airports, which are served by relatively large jet aircraft, would be affected by these fuel-efficiency improvements, starting in 1980. This scenario anticipates that the following gallons of fuel consumed per departing flight and the increase from the base case would be as follows in 1990:

Airport	Fuel Consumed (gal)	Percentage Increase per Year
Norfolk	2100	1.426
Richmond	1500	0.606
Roanoke	1400	2.459
Dulles International	6300	1.627

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

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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