findings were reached about which method was superior; both proved workable and some valuable lessons were learned.

FAA is preparing a draft Notice of Proposed Rule Making (NPRM), which will present both the administrative method and the auction method for comment. This should have been released by the time that this article is published.

Brander's points will now be discussed in the order in which they were raised.

1. Slots used at one airport are linked to slots used at other airports. Therefore, the suggested procedure is too narrow and does not meet the needs of the air transportation system as it now exists.

It is true that every scheduled operation at a quota airport is linked to a scheduled operation at some other airport. But only four airports have quotas, and for two of those the quota applies only during 5 h of the day. Thus, the majority of flights that require a slot at one end do not require a slot at the other end.

However, the problem of getting slots at both ends of some flights does exist. The existing scheduling committees (which have met the needs of the industry for over 10 years) solve the problem in this way. The quota airports are handled sequentially, beginning with the hardest to resolve (DCA) and ending with the easiest to resolve (JFK). Usually, the schedule at DCA is not completely resolved in the time allotted. In that case, the DCA committee resumes negotiations after the other airports' schedules have been resolved. In any case, there is provision for turning in unusable slots and obtaining unused slots after negotiations are closed. I would handle this problem in just that way.

2. The Geisinger approach to slot allocation is overly protective of the existing carriers and discriminates against new entrants.

New entrants do not compete with incumbents but are given a set of slots by exemption. The current thinking is that four slots would be a reasonable number. It could be 8, 16, or 100. The process itself does not discriminate.

3. There is a bias in favor of airlines that have a large number of current slots.

Yes, there is such a bias. In fact, if we neglected exempted slots and if all airlines had an equal measure of passenger service, they would all get their current allocations. The current allocation is the starting point and deviations are made only as passenger service differs and then only in modest amounts. The airlines with more slots do risk losing a larger number of slots in the process, however.

The reasons for this bias are as follows: (a) The current allocation is recognized as an investment that an airline has made in developing markets and providing service capacity; (b) the measure of service is an average made over the current schedule and is not valid for gross variations (many more or many fewer slots) from that schedule; and (c) turbulence caused by sudden and drastic changes in allocations would be harmful to everyone.

Nevertheless, if service differentials persist, significant changes in allocations could occur after repeated applications of the procedure (every six months).

4. Airlines that have a large number of slots have to propose fewer alternative slot plans proportionately than do airlines that have a small number of slots.

This is true. Moreover, the number of variations mathematically possible increases much faster than linear proportion to the number of slots. But the problem is that preparing alternative slot plans is a great burden to the airline schedulers, and the airlines that have many slots are faced with serious real-life constraints that counteract their supposed flexibility. FAA tests revealed the need to ask for as few alternatives as possible.

5. Airlines that have many slots will receive a disproportionate share of slots during the prime hours and get an advantage in increasing their service measure.

A limit is now placed on the number of slot requests that each airline can make in any hour. This limit is proportional to the total number of slots allocated to the airline. FAA tests revealed that this limit should be applied only for the problem hours.

6. A slot auction offers overwhelming advantages.

The objective of this paper was not to debate the relative merits of alternative allocation methodologies but rather to set forth one of many alternatives and stimulate public discussion thereof.

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Method for Forecasting General Aviation Activity

FRANK R. WILSON AND HAROLD M. KOHN

This paper describes a study of the method used to develop demand-estimation models for itinerant and local movements of general aviation aircraft. The study area consisted of seven airports in the Maritime Provinces of Canada (New Brunswick, Nova Scotia, and Prince Edward Island). Confidential data on aircraft movements were made available from the Aviation Statistics Centre for this study. Econometric models were developed for each airport separately, and one system model was developed for all traffic that flows on the 49 links between the seven airports. The approach used generation-distribution-type models in contrast to the pure generation models attempted by others and found to be only marginally successful. Cross-section demo-

graphic, economic, and system data for the base year 1975 were used. The adequacy of these models is analyzed in a series of statistical and intuitive tests. The model calibrated on link flows produced marginally acceptable results. Although the model is not recommended for detailed planning, it represents the first known attempt in Canada to calibrate, by using actual data, a model to forecast general aviation activity. In this context the work can be considered a departure point for the development of general aviation forecasting techniques for the Canadian transportation environment.

The movement and storage of aircraft, their servicing, and the handling of passengers and cargo associated with them are assumed to be the principal functions of an airport. Other land uses are complementary or supplementary. Operations in the airspace adjacent to and at airports that have a large passenger volume cater to the large aircraft that operate scheduled air services. However, a significant portion of the aviation system service demands associated with these airports is composed of other types of aircraft activity.

Considerable attention has been directed to the forecasting of the service demands that arise from commercial airlines operations, which is understandable because this activity produces the major economic impact of civil aviation. Although they do not produce the reliable results often desired, current techniques and estimates of future passenger demand are nevertheless the aspect of airport activity forecasting that appears so far to be accepted most readily by planners. These techniques also give some indication of the price elasticity of passenger traffic.

Forecasts of the demand for goods movements by air are generally not considered as reliable as those for passenger demand because of the close coupling of service supply to the passenger demand. It has been well established that air-cargo service availability depends on surplus aircraft space on passenger flights. Pricing practices tend to stimulate the market for air cargo in areas in which such surplus space exists. Therefore, the independent predictions of air-cargo service are generally not so reliable as are forecasts in which all cargo operations can be identified.

The most-difficult (and apparently the least-reliable) aircraft activity forecasts are those related to general aviation. Despite rising fuel prices and the general economic slowdown in recent years, the general aviation industry in North America has continued to grow and prosper. In 1978, U.S. manufacturers delivered about 18 000 general aviation aircraft that had a value of $1.78 billion. This represented 19.2 percent more billings and 5.3 percent more unit output than in 1977 (1). Canada imported slightly more than 500 general aviation aircraft in 1978. Canadian ownership of general aviation aircraft has grown phenomenally: It has risen at a rate of slightly more than 12 percent per year from approximately 2150 in 1960 to 15 000 in 1977.

Many firms and institutions in Canada own and operate general aviation equipment. It is estimated that approximately 100 corporations own jets and that there are hundreds of corporately owned piston- and turbo-powered propeller craft. There are literally thousands of other privately owned jets and propeller-driven aircraft (2).

There are, of course, a large number of smaller aircraft owned and operated purely for the joy of flying. Expense does not appear to be a major consideration. The joy of flying has contributed to the sales of aircraft to individuals and to flying clubs; flying is as much a sport and hobby as is stamp collecting and photography.

However, the economic gains and growth of the general aviation industry have also produced additional pressures on air-traffic control, safety, and airport congestion. More than half the civil aviation activity in Canada consists of general aviation. At Malton and Dorval International Airports, for example, general aviation accounts for roughly one-third of all itinerant movements. Several major Canadian and U.S. airports have become congested with both air carriers and general aviation to the level that a series of satellite airports have been built exclusively for use by general aviation. Buttonville Airport serves this purpose in the Toronto area, Pitt Meadows in the Vancouver area, and White Plains in the New York City area. At other Canadian airports, general aviation accounts for the majority of itinerant aircraft movements.

Increasing pressures on the existing and future aviation infrastructure dictate that reliable forecasts be made available to planners. Not only is it important to provide adequate airport and airside capacity, it is also vital that adequate safety standards be maintained in congested areas in which there exists a mix of large commercial aircraft and the smaller, slower, and increasingly greater numbers of general aviation aircraft.

This discussion has so far centered on forecasting itinerant aircraft movements. Local movements around an airport are normally even larger than itinerant movements. If an airport has a flying school or club, a large number of aircraft movements take place locally. These, together with the itinerant aircraft movements, make general aviation the largest segment of civil aviation in terms of volume. Table 1 contains data on local movements for various years at selected airports in the Atlantic Provinces of Canada compared with itinerant movements for base year 1975.

PREVIOUS WORK

There has been a limited amount of work done on developing general aviation forecasting models. These have been completed primarily in the United States by the Federal Aviation Administration (FAA) and there have been several works published in the literature. The usual approach has been to develop time-series trip-generation models on an individual-site basis. In Canada, most general aviation forecasts have been no more sophisticated than time-trend analysis.

Two studies that were carried out by FAA represented the most extensive econometric modeling exercise that pertained to general aviation at that time. These two studies were entitled Forecasting General Aviation Activity at Federal Aviation Administration Facilities: An Econometric and Time Series Analysis, by A.M. Schwartz, and A Recursive Forecasting Model of General Aviation Activity Levels with Policy Implications for Alternative Cost (Fuel) Scenarios, by J.E. Tom and S.G. Vahovich (these reports are not available to the public). These models employ a complex multiequation, simultaneous-regression, two- and three-stage, least-squares econometric model to forecast general aviation. This technique permits more explanatory variables to enter the model and equations, each of which may describe a certain behavioral aspect. These can then react with each other in a cause-and-effect relationship.

The Schwartz model was used as a basis for the development of the model described in this paper. Unfortunately, the Schwartz model cannot readily be calibrated in Canada due to the difficulty of collecting data for many of the variables.

Table 1. Number of local aircraft movements for various years versus itinerant movements for 1975.

Airport	Itinerant Movements, 1975	Local Movements 1975	1974	1973	1972	1971
Charlottetown	11 559	18 652	4 008	5 647	10 782	7 134
Fredericton	20 763	31 059	23 957	19 711	15 466	20 168
Halifax	15 657	35 947	39 428	32 777	30 360	51 725
Moncton	22 599	81 632	79 871	70 788	57 574	57 480
Saint John	16 356	27 603	27 518	15 555	14 771	10 608
Sydney	6 913	9 196	9 646	9 096	7 296	2 276
Yarmouth	5 187	–	672	1 090	39	96
Bathurst	375	3 863	753	1 199	9 475	189
Charlo	1 447	4 760	3 077	3 281	2 770	2 205
Deer Lake	3 139	41	102	–	2	16
Edmunston	559	1 257	94	702	2 292	2 443
Stephenville	3 472	363	3	4	62	2
St. John's	8 461	11 716	7 364	14 496	15 895	19 467
Gander	14 169	8 634	10 735	13 139	15 809	36 768

DEFINITION AND DATA BASE

In both the industry and the literature, there is considerable confusion and controversy about the definition of general aviation. There is no standard or universally accepted definition for the term. The difficulty in arriving at a mutually acceptable definition is often the result of different study objectives.

For planning purposes, general aviation must be defined as all civil aviation other than scheduled and charter operations. Scheduled-aviation space requirements are readily determined. One normally excludes charter from general aviation for two main reasons: (a) the majority of this traffic is, in effect, scheduled and (b) it is not thought of conceptually as typical general aviation. Military aviation is excluded since this sector of aviation generally frequents military bases and uses military navigational facilities. Of course, there are several airports (e.g., Fredericton in New Brunswick) that do experience military activity because of their proximity to major Canadian Air Force bases. However, the military's use of civilian facilities is limited, so studies on general aviation have excluded this component.

Despite the fact that movements of aircraft are being forecast, it must be remembered that, in essence, it is movements of people that should be forecast. Load-factor data are readily available for translating scheduled and charter passenger forecasts into aircraft movements, but these data are not available for general aviation.

Confidential data were made available from the Aviation Statistics Centre (ASC) in a form consistent with the use of the preferred trip-generation-distribution approach. The data in this paper are an aggregate of the raw data, and it is not possible to trace any particular aircraft movement to a specific time, place, or owner. Therefore the confidentiality of the data has been maintained.

The raw data made available from ASC were computer outputs in which each airport in Canada that has a control tower is included. Each airport report consists of two parts--one that lists aircraft trips to the airport and one that lists trips from the airport. It is based on a last-stop, next-stop system. These are not entirely true origin-destination (O-D) data, but they were the only data available with respect to where the aircraft were operating. Nonetheless, the reliability or workability of the model is not jeopardized, because the system is being described in terms of aircraft flow between airports. Furthermore, a large percentage of general aviation trips are short, because the aircraft are generally small and have limited range. Therefore the last-stop, next-stop data are significantly close to true aircraft O-D data.

The data base for each airport is extensive. For this reason, it was decided to limit the itinerant-model development work in the study to seven Maritime Province airports--Charlottetown, Fredericton, Halifax, Moncton, Saint John, Sydney, and Yarmouth--for the base year 1975.

Aircraft movements to and from airports were broken down by aircraft type and further disaggregated into 21 classifications. Each aircraft movement was classified by sector and category.

In choosing the data to be used in the study, scheduled, charter, and military movements were eliminated. Approximately 20 000 data entries were used. For the aircraft that leave from the seven test airports, the movements were summed for each node pair by aircraft type and by travel sector within each classification. The process was repeated for the aircraft that arrive at the seven airports, and the two totals were added. This produced a two-way trip table of flows for each node pair.

The most-disaggregate level of data collection produced 375 nodes scattered throughout North America and Europe. By using the Financial Post magazine's survey of markets, 70 catchment areas were defined. The catchment area of an airport was defined as the major geographical area from which the airport attracted business. O-D trip tables for each of the 70 areas were produced, and the data were used for model calibration.

In the development of the model, forecasts were attempted for two types of aircraft movements--itinerant and local. Within the itinerant class, a model was built for each of the seven airports as well as one model that incorporated all airports. The latter model was an attempt at forecasting on a systems basis (i.e., on a node-to-node basis).

Since data on economic variables were available on a metropolitan basis for major Canadian cities and their respective airports as well as for the catchment areas, two sets of calibration data were collected. One set used catchment-area data for each node, whereas the other replaced the catchment-area data with metropolitan-area data for those nodes at which these data were available. The latter data set therefore used data from both catchment and metropolitan areas.

Several of these catchment areas contained major metropolitan areas that influence an airport, and there could exist other airports within the greater area. For example, British Columbia as a provincial catchment area remained unchanged in both data sets. The Moncton catchment-area population was greater than that of only the metropolitan area, and therefore it consisted of the geographic area that made up its catchment area. In the combined data set, the Moncton metropolitan-area population replaced the catchment-area population.

MODELS

By using the FAA model as a starting point, several formulations of the model were tested based on the availability of data for the independent variables. The initial formulation of the models tested is presented below in Equations 1, 2, 3, and 4. The final models selected are presented in Equations 5 and 6 (the variables used are listed in Table 2).

Equations 1 and 2 present the initial models

Table 2. Variables used in models.

Variable	Definition
LCL	Local general aviation aircraft movements
ITN	Itinerant general aviation aircraft movements (two-way total flow for each node pair)
i,j	Origin (i)-destination (j)
a,b	Coefficients
BA	Based aircraft
W	Weather index
FSD	Dummy for flying schools
POP	Population of catchment area
INC	Per-capita income of catchment area
RS	Per-capita retail sales of catchment area
IRI	Income rating index of catchment area
MRI	Market-rating index of catchment area
TOAD	Dummy variable for type of airport
USD	Dummy variable for United States
FD	Dummy variable for foreign areas
APD	Dummy variable for Atlantic provinces
AD	Dummy variable for seven maritime airports
DIST	Distance
CPOP	Population of metropolitan and catchment areas
CINC	Per-capita income of metropolitan and catchment areas
CIMR	Market-rating index of metropolitan and catchment areas
CRS	Per-capita retail sales of metropolitan and catchment areas
CII	Income-rating index of metropolitan and catchment areas

developed based on catchment areas. The model for local general aviation aircraft movements on a node basis is as follows:

$$LCLi = a_1 + b_1BAi + b_2Wi + b_3FSD + b_4POPi + b_5INCi + b_6RSi + b_7IRIi + b_8MRIi \quad (1)$$

The model for itinerant general aviation aircraft movements on a link basis is as follows:

$$ITNij = a_2 + b_9POPi + b_{10}POPj + b_{11}INCi + b_{12}INCj + b_{13}RSi + b_{14}RSj + b_{15}IRIi + b_{16}IRIj + b_{17}MRIi + b_{18}MRIj + b_{19}TOAD + b_{20}USD + b_{21}FD + b_{22}APD + b_{23}AD + b_{24}DISTij \quad (2)$$

Equations 3 and 4 present the initial models developed based on metropolitan areas. The model for local general aviation aircraft movements on a node basis is as follows:

$$LCLi = a_3 + b_{25}BAi + b_{26}Wi + b_{27}FSDi + b_{28}CPOPi + b_{29}CINCi + B_{30}CIMRi + b_{31}CRSi + b_{32}CIIi \quad (3)$$

The model for itinerant general aviation aircraft movements on a link basis is as follows:

$$ITNi = a_4 + b_{33}BAi + b_{34}CPOPj + b_{35}CINCi = b_{36}CINCj + b_{37}CRSi + b_{38}CRSj + b_{39}CIMRi + b_{40}CIMRj + b_{41}CRSi + b_{42}CRSj + b_{43}TOAD + b_{44}USD + b_{45}FD + b_{46}APD + b_{47}AD + b_{48}DISTij \quad (4)$$

The above equations (and operational signs) present only the conceptual model and not individual independent-variable hypotheses. In fact, some variables were run in various multiple combinations.

Research on local movements has been limited in past studies of forecasting general aviation movements at an airport. Most of the emphasis has been placed on itinerant movements, since these place a greater demand on sophisticated air-traffic-control systems and facilities. Most local movements are training flights, and many can be associated with flying schools and clubs. It has been stated many times that local movements not only are a function of flight training, but also depend on good flying weather, since many local movements are conducted under visual flight rules (VFR) and require suitable weather. With this in mind, a model was postulated that included a variable for weather and a dummy variable for flying schools. Other variables included were population, per-capita income, retail sales, income- and market-rating indices, and based aircraft for both catchment-area data and metropolitan-area data.

It is reasonable to expect that explanatory variables for itinerant and local movements may only be the same in specific circumstances. Itinerant movements can involve trips for specific purposes and thus general aviation could be considered a passenger mode. Business trips would fall in this category, as would most government trips. Some itinerant movements would be cross-country training, which might be more difficult to explain by means of the usual socioeconomic variables. Local movements are normally training and might have an explanatory variable similar to that for itinerant training. Unfortunately, there are almost no data on trip purpose for either itinerant or local trips.

The list of airports selected was restricted by the availability of based-aircraft data. These data, which are collected on an ongoing up-to-date basis, were obtained late in 1975 from the Atlantic Regional Office of Transport Canada.

Independent variables formulated in the model included based aircraft, a dummy variable for flying schools, and a weather index based on VFR flying-weather percentages. The airports used for the local-movement model were listed in Table 1.

ANALYSIS AND RESULTS

Itinerant-Movement Model

Figure 1 depicts the calibration procedure used in the development of the model for itinerant-aircraft movements. Both linear and log-linear transformations of the format data were used to test the model on the seven Maritime Province airports.

The log-transformation form for the model produced the best model from a statistical viewpoint. The values of the coefficient of determination were of the order of 0.6. Generally, little correlation between the independent variables was observed, and the signs associated with the coefficients were as expected. Even with R^2-values of the order of 0.6, very erratic residuals were produced. By using various dummy variables and combinations of variables, it was not possible to significantly reduce the magnitude of the residuals to a level acceptable for a forecasting model. Table 3 contains a comparison of values for observed and estimated itinerant-aircraft movements for the Moncton Airport by using the log-transformation form of the model and combined catchment- and metropolitan-area data. The model yielded an R^2-value of 0.63. The F- and t-statistics for the forecasting equation were significant at the 95 percent level. The node model for itinerant-aircraft movements did not produce highly reliable estimates when it was applied to all 70 catchment areas.

It should be emphasized that it was not the intention of the study to maximize the R^2 but rather to minimize the differences between the observed and the estimated trip values. The values of the coefficient of determination were useful as a guide to the expected reliability of the model; as the R^2-value rises, the difference becomes smaller. For forecasting purposes on a link basis, in which each observation is a link, it is extremely important to minimize the value of the residuals. Only in this fashion can the model be expected to perform in any meaningful way. Since the model did

Figure 1. Calibration procedure for itinerant-aircraft movements.

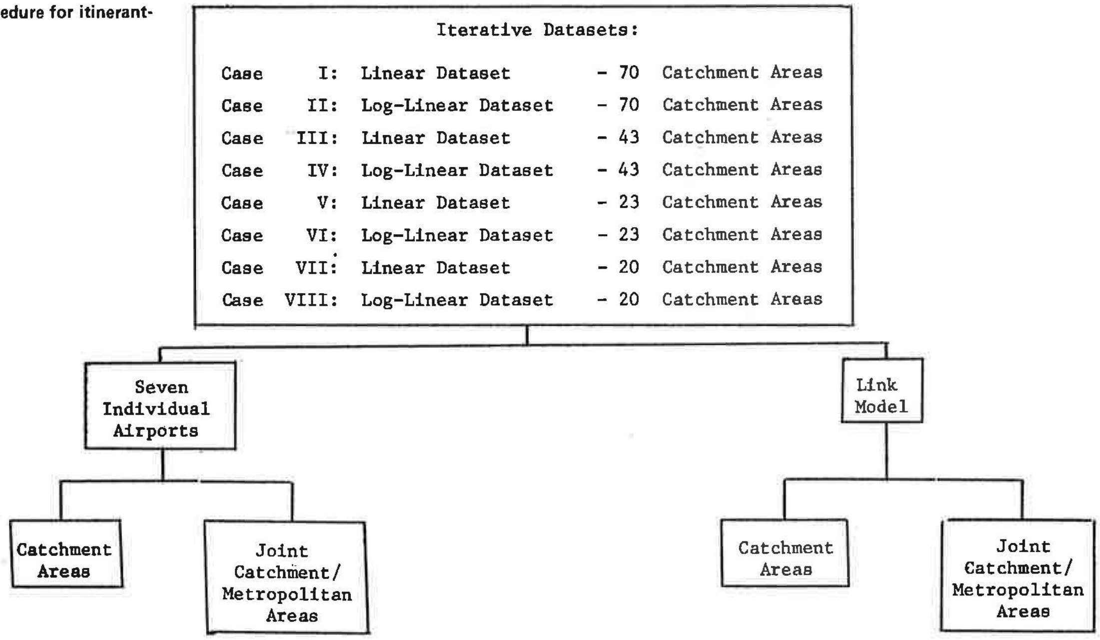

Table 3. Trip values for observed and estimated aircraft movements for node or airport model.

Node or Airport	Trip Values Observed Movements	 Estimated Movements	Percentage of Error
Deer Lake	37	25	-32
Stephenville	49	21	-57
Gander	84	23	-73
St. John's	71	28	-61
Halifax	2202	650	-70
Sydney	236	199	-16
Chatham	120	217	81
Charlo	231	69	-70
Fredericton	2081	696	-66
Saint John	1197	767	-36
Charlottetown	1354	718	-47
Massachusetts	25	27	8
New Jersey-New York	23	24	4
Maine	246	25	-89
Southeast United States	10	11	10
Canada (except areas specifically mentioned)	2841	49	-98
Metropolitan Toronto	50	53	-6
Eastern Ontario	111	16	-86
Metropolitan Montreal	210	103	51
Eastern townships	68	28	-59
Quebec	88	34	-61
Gaspesia	127	54	-57
House Harbour	96	33	-65
Greenwood	211	54	-74

not perform well with 70 catchment areas, a testing procedure was used that eliminated observations by removing those that made a relatively minor contribution to the trip values for total aircraft movements. The testing procedure indicated that by aggregating the catchment areas higher R^2-values (and thus lower residual values) could be obtained.

The original 70 catchment areas were first aggregated to 43, then to 23, and finally to 20. In each case, the linear and log-linear data base was tested for both the catchment area and the joint catchment and metropolitan conditions.

By using the 20 catchment areas, calibration on the basis of an individual airport or node did not produce acceptable results. This link model was tested by using the 20 catchment areas and produced marginally acceptable results when calibrated on the 49 links that serve the seven airports included in the study. The residuals shown in Table 4 indicate that, although this is the best model developed by using the most-recent link data available, the model could not be regarded as a highly reliable forecasting tool for planners.

The format for the 49-link model reduced from the general aviation models (Equations 2 and 4) is as follows:

$$ITNij^* = 89.08 - 0.64DIST + 4.31INC + 0.77RSI + 1.75MRI \qquad (5)$$

where ij* is itinerant trips outside the air-traffic-control zone that landed at point of origin, RSI is retail-sales index, and 89.08 is the constant. Related statistical data are $R^2 = 0.74$, SE = 0.89, F = 31.64, df = 4.44, and the coefficients and t-statistics listed below:

Coefficient	t-Statistic
0.64	0.69
4.31	0.43
0.77	0.21
1.75	0.13

Local-Movement Model

The local movements were calibrated for 14 individual Maritime Province airports by using linear and log-linear data for both the catchment area and the joint catchment and metropolitan areas. The final model selected from the initial models (Equations 1 and 3) was in the following form:

$$\text{Local trips} = 69\,545.25 + 29\,794FSD\ [4.23] + 874.07W\ [1.64] + 190.04BA\ [0.41] \qquad (6)$$

where the standard errors are in brackets.

Many of the airports show widely fluctuating counts. This is in part due to reporting difficulties. Many air-traffic controllers fill in the daily record sheet at the end of the shift by making an estimate of movements. This is especially true at the smaller airports and at those airports that are only radio controlled.

Unfortunately, although the exercise was quite interesting in terms of the variables that were

Table 4. Residual errors for the 49-link model.

Airport	Link	Trip Values: Observed Movements	Trip Values: Estimated Movements	Percentage of Error
Charlottetown	1 Halifax	707	609	-14
	2 Yarmouth	45	62	38
	3 Sydney	525	214	-59
	4 Fredericton	280	346	24
	5 Moncton	1258	512	-59
	6 Saint John	163	360	121
	7 Charlottetown[a]	5957	5 795	-3
Fredericton	8 Halifax	993	689	-31
	9 Yarmouth	82	128	56
	10 Sydney	69	206	199
	11 Fredericton[a]	8787	14 011	59
	12 Moncton	2169	709	-67
	13 Saint John	1852	1 133	-39
	14 Charlottetown	275	346	26
Halifax	15 Halifax[a]	3583	22 247	521
	16 Yarmouth	765	161	-79
	17 Sydney	409	357	-13
	18 Fredericton	899	690	-23
	19 Moncton	2030	824	-59
	20 Saint John	598	810	35
	21 Charlottetown	635	609	-4
Moncton	22 Halifax	2209	824	-63
	23 Yarmouth	352	105	-70
	24 Sydney	236	229	-3
	25 Fredericton	2081	709	-66
	26 Moncton[a]	9373	11 189	19
	27 Saint John	1198	741	-38
	28 Charlottetown	1354	512	-62
Saint John	29 Halifax	687	785	14
	30 Yarmouth	222	155	-30
	31 Sydney	55	211	284
	32 Fredericton	1780	1 133	-36
	33 Moncton	1245	741	-40
	34 Saint John[a]	6796	13 161	94
	35 Charlottetown	166	360	117
Sydney	36 Halifax	408	357	-13
	37 Yarmouth	21	43	105
	38 Sydney[a]	2473	4 619	87
	39 Fredericton	62	206	232
	40 Moncton	230	229	0
	41 Saint John	54	211	291
	42 Charlottetown	552	214	-61
Yarmouth	43 Halifax	436	161	-63
	44 Yarmouth[a]	3485	676	-81
	45 Sydney	11	43	291
	46 Fredericton	51	129	153
	47 Moncton	144	105	-27
	48 Saint John	102	155	32
	49 Charlottetown	13	62	377

[a] Itinerant trips outside air-traffic-control zone that landed at point of origin.

identified as being significant, the results were not particularly encouraging and the R^2-values were relatively low.

The dummy for flying schools and the weather index very often were the first two variables to enter. In the linear formulation, these two variables combined to produce an R^2 of 0.57. Numbers of aircraft based at the airports entered next, and the marginal increase in the R^2 was 0.02.

The metropolitan linear data produced results that had little improvement. The maximum R^2 produced was 0.61. Table 5 presents the residual-error analysis. These results were to be expected, since the observed trip data ranged from 41 to more than 80 000 trips.

In the log-linear regressions, the socioeconomic variables were entered with the more-interesting explanatory structural variables of based aircraft, population, and weather, and these combined to produce an R^2 of 0.62. The income variables then entered with the reverse sign from that which would be expected.

Table 5. Residual-error analysis of best model developed for local movements at the node or airport level.

Airport	Observed Trips	Predicted Trips: Linear	Predicted Trips: Log-Linear
Deer Lake	41	7 980	376
Stephenville	363	12 328	405
Gander	8 634	5 635	17 581
St. John's	11 716	23 217	30 570
Halifax	35 947	37 803	46 520
Yarmouth	672	-5 102	804
Sydney	9 196	1 268	2 120
Charlo	4 760	3 726	1 190
Fredericton	31 059	41 742	66 455
Moncton	81 632	45 676	16 407
Saint John	27 603	39 518	19 008
Edmundston	1 257	10 454	3 204
Bathurst	3 863	11 187	5 826
Charlottetown	18 652	-38	3 375

DISCUSSION OF RESULTS

This paper has presented the method and results from the first known attempt to calibrate a general forecasting model on both a node and a link basis by using Canadian data recorded at the airport level. Similar work has been carried out in the United States and, very recently, Transport Canada has begun similar work.

The premise was accepted at the beginning of this study that forecasting general aviation in the manner described here would not be as precise as developing forecasts of passenger flows and then converting these flows to aircraft movements as is done for commercial aviation. When the passenger-forecasting approach is used, it is hypothesized that passengers are subject to economic and behavioral forces that direct them to use air transport as a mode of travel. However, there do not exist in Canada (or for that matter in the United States) reliable data on the volume of movements by individuals on an O-D basis for general aviation. Furthermore, the data on a passenger basis do not exist at the station-activity level. Trip-purpose data are not available. Such data could be compiled through user and pilot surveys of general aviation, but even for a region of Canada such surveys would be extremely expensive.

There are a number of reasons why the results obtained were not so reliable as required for detailed planning functions. Some of these reasons include the fact that a considerable portion of general aviation is recreational flying, and it is very difficult to find a socioeconomic indicator for this type of travel. The use of seven Maritime Province test airports may have restricted the model in that the main general aviation traffic routes in Canada were not included (for example, those routes that connect and center around Montreal and Toronto). Even so, a model in which the central nodes were Montreal and Toronto (if it were successful) would not necessarily be reliable in the less-dense traffic areas such as the Maritime Provinces. It is reasonable to suggest that one model would not necessarily work for all parts of the country.

The type of model used in this study does not explain fully the complex relationships between particular links due to specialty uses of general aviation (for example, between a head office and its regional counterpart, business links, government links, etc.). Data on travel at this level are simply not available without expensive and extensive surveys. To go one step farther, travel-demand forecasting has not progressed to the stage at which the behavior of individuals can be rationalized. Forecasting and modeling is still a crude process. It has been said that a forecast model is a muddled set of assumptions on an abstract piece of behavior.

The link model calibrated on the 49 links from the seven Maritime Province airports can be considered to produce marginally acceptable results. The statistical parameters associated with the forecasting model were significant at the 95 percent level.

The model, although not recommended for use in a detailed planning function, can be considered an acceptable departure point for the development of general aviation forecasting techniques for the Canadian Air Transport environment. The data supplied by Statistics Canada should be made available to other researchers so that development in this area can continue. The procedures for estimating commercial aviation activity are reasonably well advanced, and similar planning tools must become available for general aviation to enable the total air-transport mode to be evaluated on an ongoing basis.

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Air Traffic Control Network-Planning Model Based on Second-Order Markov Chains

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A method designed to assess the impact of increased air traffic demand on flow rates in a network of en route air traffic control sectors is described. Given projected arrival and departure rates at airports within a given region, a second-order Markov-chain model is employed that has transition probabilities estimated from historical data. The technique is designed to serve as a planning tool and is demonstrated by using data from the New York Air Route Traffic Control Center.

The primary purpose of air traffic control (ATC) systems is to ensure the safe and efficient movement of air traffic. Given projected increases in traffic levels, it is important that a method be developed to predict the impact of additional demand on the system. In particular, the need to restructure existing sector boundaries depends on the distribution of flow in the current system.

As an example of the structure of ATC networks, the New York Air Route Traffic Control Center (ARTCC) consists of 32 sectors that cover the entire states of New Jersey and Delaware and parts of New York, Pennsylvania, Connecticut, and Maryland. The center controls en route traffic by dividing the low- and high-altitude airspace into sectors, each of which is handled by an individual controller who has an assigned communications frequency. Figure 1 shows the orientation of the low-altitude sectors. The high-altitude sectors are configured similarly and control traffic at or above 24 000 ft.

This paper describes a method designed to assess the impact of specified demand patterns on flow in the system. The approach is based on describing the sequences of sectors traversed by aircraft as second-order Markov chains. Although it is an approximation, the model provides a reasonable characterization of general system flow patterns with a simple-enough structure to allow for adequate parameter estimates. The need for a second-order Markov chain for terminal areas rather than a first-order chain as proposed earlier (1) is due to a lack of unidirectionality in the flow through many of the en route sectors.

The paper begins with a general formulation of the ATC system as a directed network and then considers characterizations of traffic generation and sector sequences. The use of the method in predicting system flows is discussed. Throughout, the techniques described are applied to the New York ARTCC.

NETWORK STRUCTURE

To represent an ATC system, let the sectors be rep-

Figure 1. New York ARTCC low-altitude sector control boundaries.