ANALYSIS OF AIR PASSENGER TRAVEL IN THE TWIN CITIES METROPOLITAN AREA

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This paper documents the socioeconomic and travel characteristics of the air passenger and quantifies the relationships of several variables to the air passenger trip generation within the Twin Cities area. The results of the analysis may then be used as input in determining development policy for future locations of new major airport facilities.

•THE NUMBER of air passenger trips in the United States has increased 3 times in the past 10 years to over 168 million trips in 1969. Forecasts are that air trips will continue to increase at the same rate until 1980. Besides this increase in the absolute number of air passenger trips, urban trips related to other airport uses are also increasing. Air passenger and air passenger-related trips will be concentrated in time and space because of larger aircraft and an increased demand for air travel.

Aircraft landing requirements have necessitated an increase in the space requirements of major regional airports to approximately 5,000 acres. Control over noise, air pollution, and land development are important locational factors for regional airports. As a result, new regional airports will have to be located farther from the urban areas in order to satisfy stringent locational requirements. To plan adequate facilities for the air traveler within the airport complex requires that more be known about air traveler characteristics. The Twin Cities area was used as a model in an analysis of the problem (1).

AIR PASSENGERS

Air passengers make approximately 30 to 40 percent of all daily trips to and from air terminals (2, 3). An in-flight survey of commercial aircraft entering and leaving the Twin Cities, conducted during the week of January 21-28, 1970, showed that a total of 91,996 air passengers traveled to or from the Twin Cities. These 91,996 air passenger trips were divided into various air terminal movements: 32,691 terminated in the Twin Cities Region, 20,049 transferred to other planes, 5,111 passed through on the same aircraft, and 34,145 originated in the Twin Cities region.

The 66,836 regional trips in the Twin Cities area were further divided into those trips inside of the study area, defined by 756 traffic analysis zones for which socioeconomic data were available, and those trips outside of the study area. During the survey week, 57,839 or 86.5 percent of the regional trips originated or terminated within the study area.

COMBINING ARRIVING AND DEPARTING PASSENGERS

The initial step in the analysis was to determine whether arriving and departing passengers had similar socioeconomic characteristics (4). If the characteristics were similar, then the arriving and departing passenger groups could be combined for further analysis. The respondents to the air-travel interview were categorized into 4 principal groups that were as follows: arriving residents, departing residents, arriving visitors, and departing visitors.

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These groups were further classified by the following characteristics: purpose of air trip, address type at origin or destination, mode of ground travel, and family income. These categories and cross classifications were then used to establish the similarity of arriving and departing passengers. The following discussions of the address type and income relationships is an example of the similarity that exists within the total air passenger population.

Address Type

The differences in address type between residents and visitors who arrive and depart from the airport are given in Table 1. Residents had the most trip ends at homes, whereas visitors had trip ends usually at hotels or motels. Visitors were also more likely to have trip ends at places of business than were residents. The comparison between arriving and departing passengers also indicated differences in distribution of address types. For residents, departing passengers were more likely to have their origin trip ends at their places of employment than those arriving. More than 90 percent of all arriving residents had trip ends at their homes as compared to 84 percent for departing residents.

For visitors, the greatest difference in land use categories for arriving and departing passengers was between hotels or motels and places of business. Arriving passengers were more likely to have their trip ends at hotels or motels than were departing passengers. However, departing visitors usually left from places of business. None of the other differences between arriving and departing visitors exceeded 2 percent. Therefore, as in the case of residents, pooling the distributions of land use categories for arriving and departing visitors did not distort the importance of the different land use categories.

Income

As given in Table 1, the maximum difference for any income category occurred in the $15,000 to $19,999 group and ranged from a low of 20.0 percent for arriving residents to 23.2 percent for departing visitors. All other differences among the 4 types of passengers were less than 3 percent. Even though residents and visitors had different characteristics when categorized by trip purpose, address type at origin or destination, and mode of travel, there was no evident reason to expect income distribution to be different for residents and visitors.

Number of Models Required

A summary of the resident and visitor air trips by the 2 major divisions of address type is given in Table 2. The residents have 90 percent of their trip origins at homes. It was assumed that the characteristics of the zone could represent the characteristic of the air passenger. An investigation indicated a similarity between the resident and visitor air passenger whose trips were home based; therefore, these 2 groups were combined.

More than 50 percent of the visitors' trips were associated with hotels or motels. The majority of remaining visitor trips were associated with non-home addresses. Because visitors with home-based trips were shown to have the essential characteristics of residents, the model for non-home-based trips could be based on the characteristics of hotels or motels rather than other land use characteristics.

Summary

Studying the various socioeconomic characteristics of all the air passengers showed that arriving and departing passengers were similar. The similarities allowed a pooling of the trips into larger groups. An analysis of these groups showed that essentially 2 models would explain the air passenger trip-generation characteristics: one for home-based air passenger trips, which accounted for 90 percent of all resident trips, and one for non-home-based air passenger trips, which accounted for 80 percent of all the visitor trips.

TABLE 1

AIR PASSENGER TRIPS BY INCOME AND ADDRESS TYPE

Income	Arriving							Departing						
	Home or Other Than Home	Hotel or Motel	Normal Work Place	Other Than Work Place	Other	Total	Percent of Total	Home or Other Than Home	Hotel or Motel	Normal Work Place	Other Than Work Place	Other	Total	Percent of Total
Residents														
$0-4,999	397		4		32	433	3.2	403	18	24		23	468	3.0
$5,000-9,999	1,134	14	77		40	1,265	9.1	1,481	10	40		88	1,619	10.3
$10,000-14,999	2,587	45	166		36	2,834	20.5	2,739	30	376	20	104	3,269	20.8
$15,000-19,999	2,490	31	196	4	38	2,759	20.0	2,821	47	451	18	66	3,403	21.6
$20,000-29,999	2,452	30	107	8	15	2,612	19.9	2,459	12	509	14	17	3,011	19.2
More than $30,000	2,269	39	176	12	34	2,530	18.3	2,100	53	360	31	51	2,595	16.5
Not given	1,280	20	56		28	1,384	10.0	1,160	19	136	3	40	1,358	8.6
Total	12,609	179	782	24	223	13,817		13,163	189	1,896	86	389	15,723	
Percent of Total	91.2	1.3	5.7	0.2	1.6		100.0	83.7	1.2	12.1	0.5	3.5		100.0
Visitors														
$0-4,999	221	68		15	99	403	3.1	271	123	10	10	71	485	3.8
$5,000-9,999	459	472	17	91	216	1,255	9.7	396	420	23	73	223	1,135	8.8
$10,000-14,999	468	1,398	38	359	284	2,547	19.8	592	1,166	50	432	263	2,503	19.5
$15,000-19,999	311	1,564	78	460	247	2,660	20.7	475	1,514	122	578	7,288	9,977	23.2
$20,000-29,999	235	1,619	17	448	211	2,530	19.6	265	1,332	84	583	173	2,437	19.0
More than $30,000	223	1,491	33	400	303	2,378	18.4	304	1,278	62	475	259	2,378	18.5
Not given	237	501	32	164	184	1,118	8.7	116	414	36	144	167	927	7.2
Total	2,154	7,108	215	1,937	1,477	12,891		2,469	6,247	387	2,295	1,444	12,842	
Percent of Total	16.7	55.1	1.7	15.0	1.5		100.0	19.3	48.5	3.0	17.9	11.3		100.0

TABLE 2

AIR PASSENGER TRIPS

Passenger	Trips		Total
	Home-Based	Non-Home-Based	
Residents	25,772	3,767	29,539
Visitors (hotel or motel)	0	13,354	13,354
Visitors (other)	4,624	7,757	12,381
Total	30,396	24,878	55,274

NONSPATIAL CHARACTERISTICS OF AIR PASSENGERS

The aggregate characteristics for arriving and departing travelers were grouped as follows: air trip purpose, address type at origin or destination, family income, and modes of ground travel.

Air Trip Purpose

Purposes of air trips for all passenger trips in the Twin Cities area are shown in Figure 1. Most trips were for business purposes, 33,827 trips, which were distributed equally between residents and visitors. "Manufacturing and wholesaling" and "personal or professional service" accounted for 63 percent of all business trips. The trip-purpose category with the next highest number of trips, 7,919, was "personal." One other interesting fact was that the January vacation trips of residents outnumbered the visitors by more than 3 to 1.

Address Type at Origin or Destination

Eighty-five percent of residents, or 45 percent of all air trips, started or ended trips at their homes. The origins or destinations of the 17,645 trips by visitors were from or to hotels or motels or someone else's home. Visitors tended to have more trip ends at hotels and more origins at other work places.

Family Income

The majority of people who flew during the test week had an annual family income more than $10,000. Individuals with incomes of more than $20,000 accounted for 40 percent of the air patronage.

The number of air trips made per year also increased with income. Those passengers who made 1 trip per year were twice as likely to have incomes of more than $10,000 than to have incomes of less than $10,000. Passengers were 7 times more likely to be in the over-$10,000 income group than to be in the under-$10,000 income group if they made 8 to 12 flights per year and 10 times more likely to be in the higher income group if they made more than 21 flights per year. When the income characteristics were cross correlated with trip purposes, the majority of low-income passengers were found to be either military personnel or students.

Modes of Ground Travel

Air passengers who drove their own cars or who were driven by someone else numbered 34,511 or constituted 62 percent of all ground trips. The second largest group of passengers who used taxis, airport buses, and limousines, accounted for an additional 25 percent of the trips. Car rental transportation was used by 4,764 air passengers, most of whom were visitors. Courtesy cars and public buses were used for 1.2 percent of all the ground trips made by airline patrons.

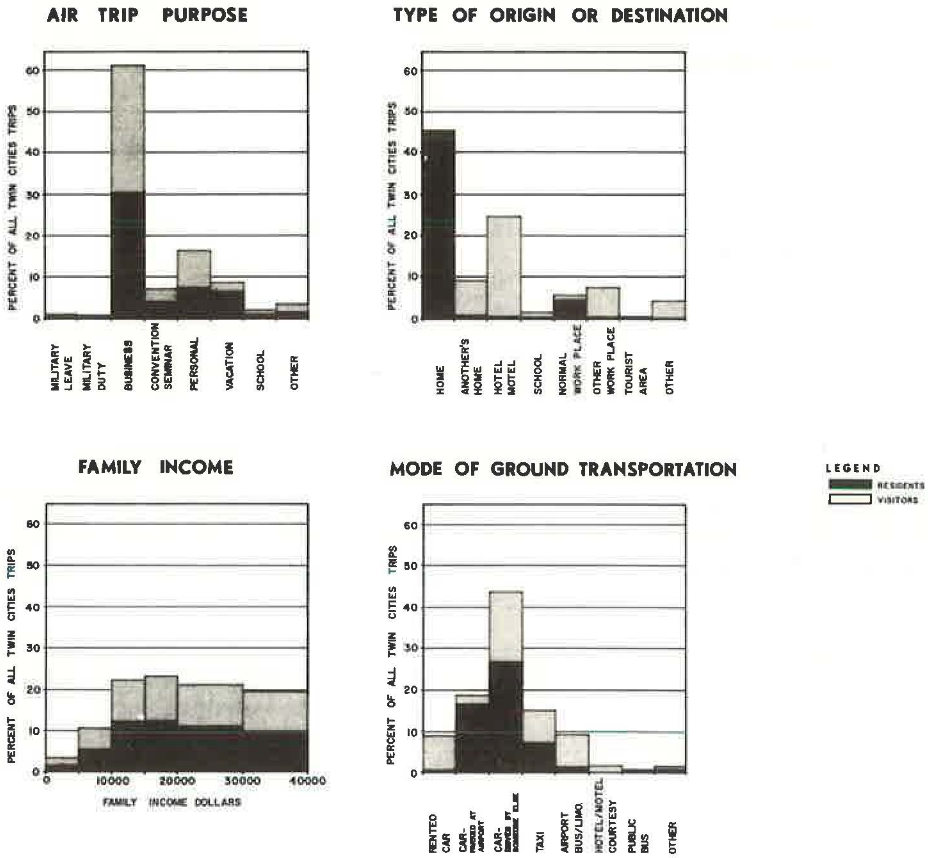

Figure 1. Travel characteristics of air passengers at Twin Cities Airport.

TRAVEL TIME CHARACTERISTICS OF AIR PASSENGERS

The average travel time for all air passengers, as shown in Figure 2, was 25.5 min. The travel times from each traffic analysis zone in the study area to the air terminal were obtained from the Minnesota Department of Highways computerized 1970 highway network system. The trip-length distribution for various types of trips is shown in Figure 2 and discussed in the following sections.

All Home-Based Trips

There were 30,396 air passenger trips, or 55 percent of all trips, that had a home base at 1 end. Within 10 min driving time from the air terminal, there were 1,400 air passenger trips, and this number increased at an average rate of 1,000 trips per minute for the next 20 min. The number of trips then decreased until at 50 minutes only 4 percent of air trips remained. Twenty-five percent of all home-based trips were within a 20-min travel time and 75 percent were within 34-min travel time to the terminal. The average trip for all home-based trips was 27.7 min.

Total Resident Trips

The distribution of travel time for total resident trips was generally similar to that for all home-based trips. It rose to a maximum of 1,500 trips at 22 min and then decreased to almost 0 trips at 50 min. At 22 min, 42 percent of the residents had

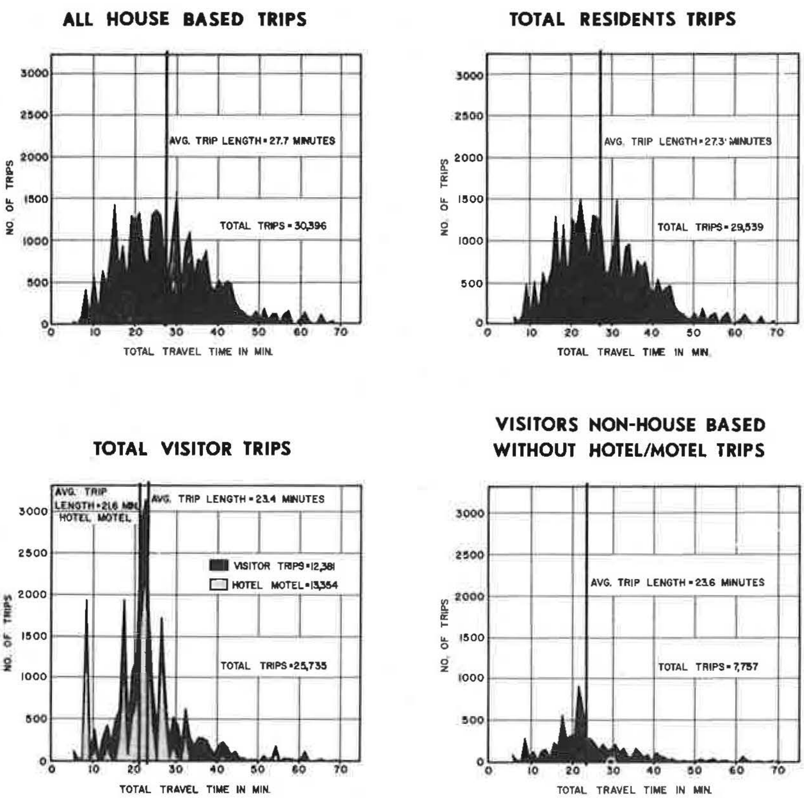

Figure 2. Travel time characteristics of air passengers at Twin Cities Airport.

completed their ground trips, and, at 50 min, 4 percent had yet to complete their trips. The average travel time for this set of air patrons was 27.3 min.

All Non-Home-Based Trips

The 7,757 non-home-based visitor trips increased to the peak of approximately 900 trips at 22 min. Beyond the peak, there was a rapid drop to a few hundred trips, and then a very gradual decrease to almost 0 trips at the outer reaches of the study area. The average travel time was 23.6 min, with 25 percent of all the trips being within 17 min and 80 percent being within 31 min of the terminal.

Total Visitor Trips

The major hotel areas adjacent to the airport were 8 min and the 2 city centers of St. Paul and Minneapolis were at 23 and 18 min respectively from the terminal. The remaining visitors trips were regularly distributed. They increased to a maximum of 23 min from the air terminal and then slowly decreased. The average trip time for the 13,354 hotel-based visitor trips was 21.6 min, and 90 percent of all hotel trips were within 27 min travel time. Of all remaining visitor trips, 25 percent were within 30 min, and the average trip time was 23.4 minutes.

AIR PASSENGER TRAVEL MODEL

The second objective of the analysis was the development of mathematical models to simulate the previously described travel patterns. The trip generation model estimates the number of air passenger trip ends in each traffic analysis zone based on the existing socioeconomic characteristics and travel to the airport. The equations are then used to estimate future air passenger origins and destinations throughout the metropolitan area on the basis of the forecast characteristics of the zone and a changing propensity of the population to use the air mode.

The variables used in developing the model must be those for which forecasts are available and reliable. The zonal variables with reliable 1985 forecasts in the Twin Cities are median family income, number of people, number of dwelling units, number of employees by selected industrial categories, and number of hotel or motel rooms. The characteristics of the air passengers are purpose of trip, address type, travel time to the airport, and income as previously indicated.

The minimum number of classes of air passengers, as previously explained, were determined to be a set of two—all home-based trips and all non-home-based trips. The resulting equations were obtained by a stepwise linear regression that used socioeconomic variables that were logically and statistically significant. The equations were then corrected for spatial distribution with the addition of a travel time function.

First Selection of the Important Independent Variables

As a first step in selecting which of the 13 independent variables to use in the equations, a simple correlation matrix was developed. The coefficient r is a measure of association between 2 variables, and the matrix gives the correlation coefficients for all combinations of variables. The existence of a strong relationship indicates a possible usable variable for the model. Investigation of the simple correlation matrix and numerous stepwise regression runs of home-based, non-home-based, and hotel- or motel-based air trips against all other variables indicated the following:

1. Non-home-based trips are highly related to the number of hotel or motel rooms (the best indicator) and to employment characteristics. A linear relationship was noted between these characteristics and non-home-based trips.
2. Two zones generated non-home-based trips that were not significantly related to the urban characteristics of the zone. These were motel areas adjacent to the southwest corner of the airport and the St. Paul CBD.
3. Areas farther from the airport have lower generation rates than those that are closer to the airport.
4. Home-based trips relate to economic groups. The zones where the median income was less than $11,000 had low air trip-making rates and zones where it was above $21,000 had high air trip-making rates.

Non-Home-Based Model

Stepwise regression analysis yielded the statistics for the non-home-based model given in Table 3. Dropping those variables with a t-value of less than 2.0 yielded the following equation:

$$T_{NHB} = 0.0108\ WM + 0.104\ R + 0.0311\ F + 0.0346\ GS + 1.145\ HM + 5.123$$

Home-Based Model

Running the standard stepwise regression to yield a model for home-based trips provided low coefficients of correlation. When the calculated values were compared with observed values, the low-income areas were estimated to be high and the high-income areas were estimated to be low. The next step was to compare the trip-making rates (air trips per 100 dwelling units) versus the median income for each traffic analysis zone. Then, the application of a modeling technique (5) that related trip length, density of trips, and socioeconomic variables would give the generalized relationship shown in Figure 3.

At least squares fit to each of the income ranges ($0-11,000, $11,000-21,000, and more than $21,000) resulted in the following equations:

$$T_{HB} = 2.5\ (DU/100)\ \text{for}\ I < \$11{,}000$$

$$T_{HB} = (-6.8 + 0.00089)\ I\ (DU/100)\ \text{for}\ \$11{,}000 \leq I \leq \$21{,}000$$

$$T_{HB} = 11.0\ (DU/100)\ \text{for}\ I > \$21{,}000$$

where

T_{HB} = home-based air passenger trips;
I = median family income in the zone, dollars; and
DU = number of dwelling units.

TABLE 3

NON-HOME-BASED MODEL VARIABLES

Variable	t-Value	r^2	Δr^2	Coefficient
Hotel or motel, HM	35.2	0.9800		1.145
Government service, GS	16.4	0.9857	0.0057	0.0346
Wholesale and manufacturing, WM	6.2	0.9869	0.0012	0.0108
Finance, insurance, and real estate, F	2.3	0.9879	0.0010	0.0311
Retail, R	2.2	0.9872	0.0007	0.104
Education and local government	1.2			
Transportation, utilities, and community	1.4			
Personal and professional service	1.1			

Travel Time Function

The ratio of the number of observed air trips to the number of calculated air trips was plotted against travel time to the airport for each traffic analysis zone for both home-based and non-home-based trips. A least squares fit was made to these points as shown in Figure 4. These travel time functions were incorporated into the model as a factor to be multiplied by the original equation.

K-Factors

As previously mentioned, zonal adjustments for 2 zones, the St. Paul CBD and a hotel or motel area near the airport, were necessary because of the orientation between the activities of the zones and those of the airport. The K-factor for the St. Paul CBD, which was 0.55, is chiefly explained by the nonairport use of the hotel or motel rooms. The motel zone close to the airport had a K-factor of 2.0.

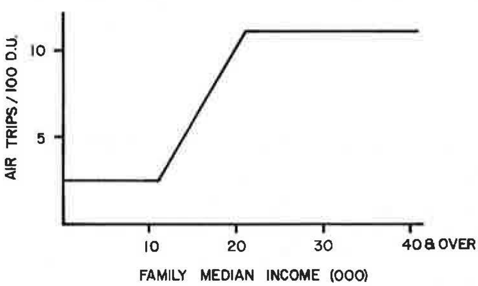

Figure 3. Trip generation model for air passenger trips originating from home.

Final Equations

The final trip-generation equations for existing conditions with the travel time function and K-factors were as follows:

1. Non-Home-Based Equations

$$T_{NHB} = (0.0108\ WM + 0.0104\ R + 0.0311\ F + 0.0346\ GS + 1.145\ HM + 5.123)\ (1.565 - 0.0217\ tt)\ K_j$$

where

K_j = 2.00 for zone 176, and
K_j = 0.55 for the St. Paul CBD.

2. Home-Based Equations

$$T_{HB} = 2.5\ (1.26 - 0.005\ tt)\ (DU/100) \text{ for } I < \$11{,}000$$

$$T_{HB} = (-6.8 + 0.00089)\ I\ (1.26 - 0.005\ tt)\ (DU/100) \text{ for } \$11{,}000 \leq I \leq \$21{,}000$$

$$T_{HB} = 11.0\ (1.26 - 0.005\ tt)\ (DU/100) \text{ for } I > \$21{,}000$$

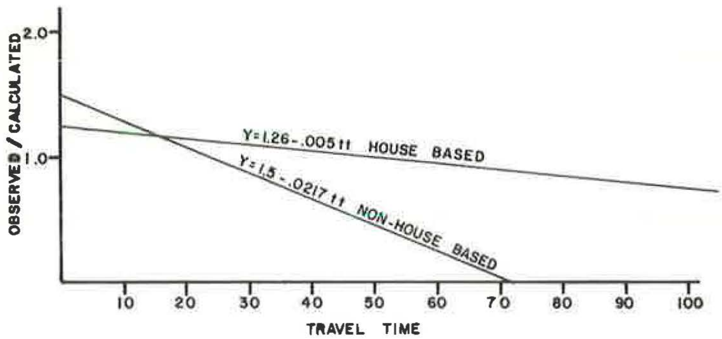

Figure 4. Air passenger travel time function.

Applying these equations to the base-year socioeconomic data resulted in the statistics given in Table 4. The low coefficient of correlation for the home-based trips resulted from the finding that the income of the air passenger was only weakly associated with the mean zonal income. The mean zonal income or some measure of the distribution of zonal income may yield a stronger relationship. The resulting non-home-based trip relationship was considered to be well within the limits of accuracy for trip generation.

APPLICATION OF THE MODEL

The air passenger accessibility study was one of many technical studies undertaken to help determine the most suitable location for a possible new air terminal for the Twin Cities (6). The 2 sites under consideration are shown in Figure 5. The northern site at Ham Lake is 18.5 miles north of the cities, and Farmington is 20.0 miles to the south. This section explains the modifications to the developed travel models necessary to account for an increased propensity to use aircraft and a changing travel time function.

Adjustment to the Travel Time Function

The non-home-based travel time function for the base year was (1.56 - 0.022 travel time). As a result, at 26 min, its effect is neutral and at 72 min, it reduces the number of trips to 0. Because both the Ham Lake and the Farmington sites will have longer travel times compared to Wold Chamberlain, the model that explained the existing situation must be adjusted to reflect this increase in travel time. The coefficient of travel time was adjusted by the ratio of the difference between the sum of all travel times to the new site and the sum of all travel times to Wold Chamberlain divided by the sum of all travel times to the new site. Mathematically, this is given as

$$\text{Adjustment} = \frac{\sum_{i=1}^{756 \text{ zones}} tt\ (\text{new site}) - \sum_{i=1}^{756 \text{ zones}} tt\ (\text{existing site})}{\sum_{i=1}^{756 \text{ zones}} tt\ (\text{new site})}$$

TABLE 4

APPLICATION OF TRIP-GENERATION EQUATIONS TO BASE-YEAR SOCIOECONOMIC DATA

Variables	Trips	
	Home-Based	Non-Home-Based
Observed trips	30,077	25,088
Calculated trips	29,937	24,600
r^2	0.47	0.96

This was done for the home-based and non-home-based equations. The resultant factors were as follows:

Location	Sum of Travel Times	Adjusted Factors
Ham Lake	37,591 min	0.402
Farmington	33,507 min	0.328

Adjustment Due to an Increased Propensity to Air Travel

The increase in air travel between 1970 and 1985 will be resulting from increases in employment, population, median income, and participation. This increased participation will be by people of the same 1970 and 1985 socioeconomic groups who fly more and also by those in lower socioeconomic groups. The non-home-based model as developed only takes into account the increases due to employment, hotel or motel rooms, and the like. Thus, with no adjustment, this model indicates that, if a zone increases employment from 1,000 to 2,000, the zone will produce air trips in 1985 similar to a zone that had 2,000 employees in 1970. The home-based model considers increased participation in the $11,000 to $21,000 range because the number of air trips increased with increased income in this range. All increased participation was adjusted by running the models adjusted with 1985 socioeconomic and travel time data. The 1985 forecast of total air passenger departures numbering 11,265,800 was made independently (7). This 1985 aggregate was used to develop a forecast for air travel in and out of the study area for

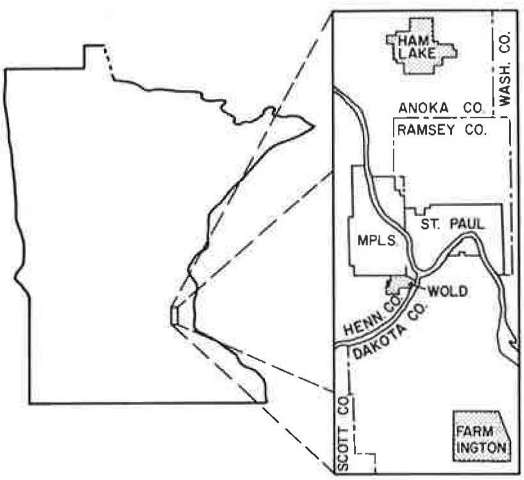

Figure 5. Existing and proposed major airport sites.

TABLE 5

1985 WEEKLY AIR TRIPS

Trips	Model-Unadjusted	Forecast	Ratio
Home-based			
Ham Lake	85,390	126,500	1.48
Farmington	87,415	126,500	1.45
Non-home-based			
Ham Lake	37,051	103,500	2.79
Farmington	44,774	103,500	2.31
Total	127,315	230,000	

the applicable week in January 1985. The ratio of the air travel found independently to the air travel obtained by the model was computed and applied to each coefficient. The corrections for increased participation are given in Table 5.

These 2 adjustments to the model made it possible to forecast the location and intensity of metropolitan area weekly air passengers for January 1985 for the Ham Lake and Farmington Airport sites.

External Air Travel

The preceding air passenger travel analysis was concerned with only the trips originating and terminating in the 756 zone study area. These trips accounted for 86.5 percent of all trips. The 8,997 air trips included in the area beyond the study area were treated in a different manner.

A growth factor technique was used to forecast the number and location of air trips in the outlying areas. If the assumption was true that the percentage of nonstudy area air trips in relation to all air trips remains constant over time, then the following relationships developed:

Air Trip End Location	Existing, 1970	Forecast, 1985
Study area	57,839	230,000
Outside of study area	8,997	35,780

Therefore, the nonstudy area air trips to or from Wold Chamberlain in the week of January 21, 1985, would be 35,780. Comparing this with the existing nonstudy area air trips yields a growth factor of 39.8 percent (35,780/8,997). This factor was multiplied by the existing air trips for each county on the assumption that distribution of air trips to the outlying counties would be similar to the existing distribution.

EVALUATION

The primary requirement of the results of the origin-destination survey and analysis was the comparison of the hours of travel by air passengers to each of the sites.

Study area travel

The air passenger hours of travel to each site are computed by multiplying the number of air passengers by the travel time to the particular airport for each traffic analysis zone and then summing the results for all zones.

The travel required for the forecast 230,000 study area weekly air passengers to reach the Ham Lake site was 184,063 hours. The travel required for the same number of air passengers to reach the Farmington site was 162,519 hours. Thus, 13.2 percent more travel time would be required for the study area air passengers to reach the Ham Lake than to reach the Farmington site. The average trip length of the air traveler to Ham Lake was 48.0 min as compared to the average trip length of the air traveler to the Farmington site, which was 42.5 min.

Nonstudy area travel

The hours of travel required for the air passengers from the outlying area was computed in a similar manner. The travel times from each Minnesota and Wisconsin county that had air trips to the Ham Lake and the Farmington sites were computed. The forecast air trips for each county were then multiplied by these travel times to arrive at the hours of travel by the passengers to each site. The results indicated that 4,329 more hours of travel would be required for the Ham Lake site than for the Farmington site.

All Travel in Region

The combined additional hours of travel that would be expended by air passengers in 1985 to access the Ham Lake site versus the Farmington airport site was 25,873 hours. This represents a 14.2 percent difference in travel hours for the week of January 21, 1985, as compared to the same week in 1970.

CONCLUSIONS

The development of an air passenger trip-generation model requires first that the characteristics of the population using air travel be analyzed and then the number of models be reduced to the minimum. The next limiting factor is the availability of base-year and forecast socioeconomic characteristics. In addition, the variables should allow for a differentiated propensity to air travel by various economic and social groups. For example, the availability of income data (8) for each traffic analysis zone satisfies this requirement. Stratification of income and employment are the most important variables.

The total air passenger trips must be obtained through an independent analysis and will act as a control total to allow revision of the trip generation equations to future air travel trends. If the objective of the study is to evaluate competing sites for a new air terminal, then adjustments should be made to the travel time function to allow for a change in the travel function.

The trip generation techniques developed in more general transportation studies may successfully be applied to commercial air passenger travel.

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REFERENCES

1. Twin Cities Airport Transportation Study. Bather-Ringrose-Wolsfeld, Inc., St. Paul, Minn., June 1970.
2. Keefer, L. E. Urban Travel Patterns for Airports, Shopping Centers, and Industrial Plants. NCHRP Rept. 24, 1966, 116 pp.
3. Air Transportation Analysis and Forecast. Regional Planning Commission, Franklin County, Columbus, Ohio, July 1969.
4. Corradino, J. C. The Philadelphia Airport Origin-Destination Survey—A Statistical Analysis. Highway Research Record 330, 1970, pp. 30-36.

5. Navin, F. P. D., and Schultz, G. W. A Technique to Calibrate Choice Models. Highway Research Record 322, 1970, pp. 68-83.
6. Newsletter. Metropolitan Council of the Twin Cities Area, Vol. 3, No. 5, St. Paul, Minn., July 1970.
7. Summary of Air Travel Demand Forecast for the Twin Cities Region. R. Dixon, Speas and Associates, working paper.
8. An Analysis of Airport Travel Demands, Lambert-St. Louis Municipal Airport. A. M. Voorhees and Associates, Inc., and Crawford, Bunte, Roden, Inc., Oct. 1969.