MODEL FOR ESTIMATING REGIONAL AIR PASSENGER TRAVEL DEMANDS

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The model developed by this research uses empirically determined relations between total travel and regional socioeconomic activity as the basis for estimating the pattern of intercity travel by all modes. Origin-destination surveys of both intercity highway traffic and air passenger traffic together with census data provide the basis for determining these relations. A comparison of costs for air travel versus surface travel between each pair of communities within the study area provides the basis for estimating the modal split. Comparisons of estimated air travel and observed air travel for all Texas cities with commercial air passenger service in 1967 indicate that the model provides reasonable estimates of air passenger travel generated by individual communities. Although discrepancies between estimated and observed volumes do exist and future refinement of the model may be warranted, it is recognized that the potential demand for air travel is not the only factor used in resource allocation decisions. Social, political, and economic factors will unquestionably continue to influence decisions concerning the development of the air transportation system.

•UNTIL recently, there has been little air transportation planning activity at the state or regional level. However, recent developments in the aviation industry, including increased federal emphasis on regional air system planning and rapid growth of the third-level carrier systems, have brought the need for more refined and powerful tools for estimating regional air travel demands sharply into focus.

Techniques that have been applied at the local level and at the national or international level have been oriented to the large cities and do not provide suitable information for decisions concerning services and facilities at the small communities. A recent draft of a planning document prepared by the Federal Aviation Administration emphasizes the need for more refinement in the techniques for air transportation planning. In discussing methods for the estimation of regional demand for air passenger service, this document suggests that, "This is a fertile area for research. . . which remains as a future effort" (1).

PURPOSE AND SCOPE OF THIS STUDY

The purpose of this research is to develop and test the feasibility of a technique or model for estimating the magnitude and geographical distribution of demand for commercial air passenger travel. The term "demand" is frequently associated with the price-quantity relation. As applied to the model developed in this study, however, demand simply refers to the volume of traffic that would be generated under a specified set of relative prices, transportation system configuration, and pattern of regional socioeconomic activity. Because the nonhub airports and their connecting routes constitute vital components of the statewide air transportation system, this model is intended particularly for estimating potential demand at communities that currently have

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no commercial air service or have only limited service. However, it is also intended to apply to communities with well-established service.

Particular attention has been given to developing the model so that it is sensitive to the influence of the quality of air service on the volume of air travel generated, particularly for smaller communities with no air service or with only limited air service; the impact of changes in service to one community on the demand for and economic viability of service to nearby communities; and the complementarity between air transportation and other modes.

DESCRIPTION OF THE MODEL

Summary of Operational Characteristics

Figure 1 shows the general operation of the model. Essentially, it operates by first estimating magnitude and distribution of all intercity travel (irrespective of mode) generated by the region being studied. It then estimates the modal split for each city pair on the basis of comparative costs (which include both direct out-of-pocket costs and time costs). Travel cost calculation allows for variations in the traveler's income, trip purpose, and number of persons traveling together. Finally, the model tabulates the total number of air trips on each link of the air network.

Network Delineation

In delineating zones for this analysis, the entire United States is subdivided into a series of zones. The state or region for which the travel estimates are desired (e.g., Texas) is subdivided in greatest detail. The smallest geographic unit used in testing the model was the county. At greater distances, larger zones were used as shown in Figure 2.

The air transportation network, represented for this analysis as a series of links and nodes, is based on the route descriptions given elsewhere (2). It is, of course, simplified and shows detailed linkages only within the area of interest (Texas) but also includes linkages between Texas and other major cities.

In developing the model, it was assumed that intercity passenger travel is limited to two modes: commercial airline and private automobile. Because of the relatively small percentage of passengers carried by bus, rail, and water, this assumption is appropriate for areas such as Texas. (Trip generation factors developed for this model exclude general aviation travel.) Because of the ubiquity of the highway system, it was further assumed that the highway network is continuous (i.e., it is not described by a series of links and nodes but by only the coordinates of the cities representing each zone). The coordinates provide the basis for calculating the mileage between any pair of cities and for estimating the travel costs.

Estimation of Total Intercity Travel

Three principal sources of data provide the basis for estimating the pattern of total intercity travel: the U.S. Census of Transportation (3), the annual Origin-Destination Survey of Airline Passenger Traffic (4), and various origin-destination surveys from the urban transportation studies for the study region.

The principal application of the census data is in describing the characteristics of the trips and trip-makers (i.e., trip purpose, income, and so forth) although the census does provide information relating to the amount of travel by individuals. The origin-destination data, on the other hand, provide more relevant information on the total magnitude and the spatial distribution of travel. Table 1 gives the trip generation characteristics determined for the study area.

The technique employed here for estimating the distribution of travel consists of enumerating all possible destinations (or origins) for trips produced at a given base zone (in this case, a county). Each of these possible destinations (or origins) is assigned a factor that indicates its attractiveness to trips to or from the base zone. These factors, multiplied by the total number of trips produced at the base zone, give the number of trips between the base zone and each other zone. By repeating this

Figure 1. Analysis of commercial air passenger demand.

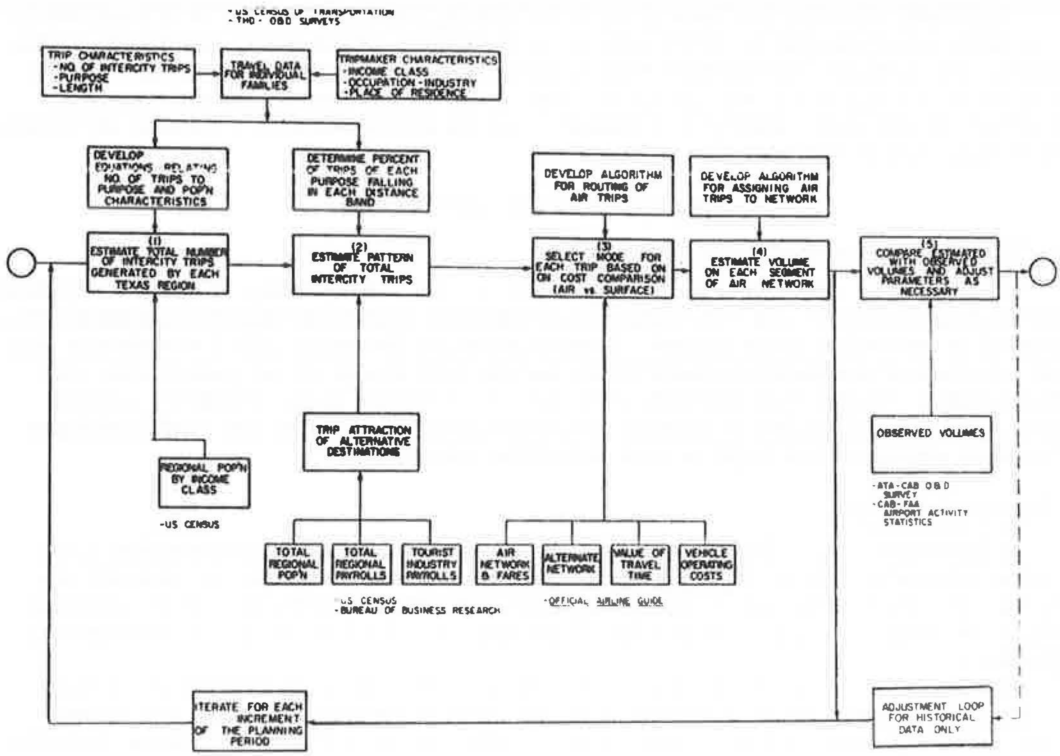


Table 1. Intercity travel by air and highway for selected Texas communities.

City	Estimated Population (1967)	100 to 199 Miles Total Trips	100 to 199 Miles Trips/ Person	200 to 499 Miles Total Trips	200 to 499 Miles Trips/ Person	500 to 999 Miles Total Trips	500 to 999 Miles Trips/ Person	>1,000 Miles Total Trips	>1,000 Miles Trips/ Person
Population of More Than 100,000									
El Paso	334,134	1,428,808	3.94	754,259	2.07	965,474	2.67	340,311	0.94
Population of 20,000 to 100,000									
McAllen	79,006	221,678	2.75	340,230	4.03	46,355	0.59	55,974	0.71
Sherman-Dennison	51,576	398,653	7.75	241,995	4.68	184,581	3.58	14,637	0.28
Victoria	42,645	714,520	16.75	82,100	1.93	11,050	2.59	16,560	0.39
Borger	25,286	32,110	1.27	123,090	4.88	70,850	2.81	3,425	0.13
Temple	34,300	226,320	6.60	118,630	3.46	33,800	0.99	9,720	0.28
Killeen	26,500	125,800	4.75	57,500	2.17	39,100	1.48	47,900	1.81
Paris	25,200	67,670	2.68	182,210	7.22	10,320	0.41	350	0.01
Total	284,513	1,786,751	6.28	1,145,755	4.03	396,066	1.39	148,566	0.52
Population Less Than 20,000									
Port Lavaca	11,950	115,000	9.63	17,350	1.45	3,340	0.28	3,340	0.28
Childress	6,560	125,500	19.15	38,800	5.93	11,180	1.71	7,220	1.10
Athens	8,046	340,000	28.60	84,500	10.50	19,280	2.40	1,330	0.17
Mineral Wells	12,451	126,400	10.20	209,000	16.85	39,300	3.17	20,350	1.64
Stamford	5,418	291,500	53.90	166,200	30.75	10,800	1.99	1,350	0.25
Levelland	11,700	72,300	6.19	28,300	2.42	16,220	1.39	0	0
San Marcos	14,700	243,000	16.53	130,200	8.84	2,090	1.42	6,270	0.43
Total	70,825	1,203,700	17.00	674,350	9.53	102,210	1.44	39,860	0.56
Grand totals	689,472	3,419,259	4.97	2,574,364	3.74	1,463,750	2.13	528,747	0.77

analysis and using each zone within the study area as the base, the pattern of total travel is obtained. This procedure is shown in Figure 3.

Travel patterns for different trip purposes can be expected to differ. For example, on a nationwide basis, business travel will be strongly oriented to the concentration of business activity in the Northeast. Trips for recreation and entertainment will be more concentrated along routes leading to vacation centers such as Las Vegas or Miami, and the distribution of trips made to visit family or relatives can be expected to closely parallel the national distribution of population.

In synthesizing the travel patterns, the model provides for separate estimates for three trip purposes. These are given in Table 2 together with the socioeconomic activity measures used to indicate the relative attractiveness of a region for trips of each purpose. Table 2 also gives the distribution of travel by purpose for each of three income classes used in developing the multipurpose trip table.

Modal Choice Analysis

A traveler's choice of mode for a given intercity trip can be approximated by comparing the costs of the trip via the alternative modes available and then selecting the mode or combination of modes for which the perceived cost is the least. In the strictest sense, the true travel costs include calculable costs such as vehicle operating costs, air fare, and travel time costs and psychic factors such as convenience, security, safety, and personal preference.

The effects of psychic factors on choice of mode cannot be readily evaluated but, to some degree, can be expected to offset each other (i.e., one person's preference for air travel will be offset by another's prejudice against air travel). Furthermore, for business travel, which accounts for a large segment of the commercial air travel market, the choice of mode can be expected to be much more sensitive to calculable costs than to personal preferences. Indeed, the choice will frequently be made by the employer rather than the traveler. It would, therefore, appear that the error resulting from assuming that the net effect of these psychic factors is zero will not seriously affect the validity of the analysis.

The cost of travel by automobile between two points consists of two principal components: vehicle operating cost and value of passenger travel time. Vehicle operating cost is calculated from the distance between the two cities or nodes being considered. An average perceived operating cost of $0.05 per mile is used in this analysis because it represents approximately the fuel, maintenance, and repair costs. For business travel, a higher rate would be more appropriate; however, the value of travel time associated with business travel is relatively high. Thus, the time cost represents a larger fraction of the total cost, and the choice of mode is relatively insensitive to the rate used in calculating vehicle operating cost for business travel. The allocation of this cost among all passengers making a particular trip can be accounted for by considering the distribution of person-trips by size of the travel party in estimating the surface travel cost. Data from the U.S. Census of Transportation (3) provide the basis for this allocation.

In calculating the passenger time costs, this analysis assumes that value of travel time is directly related to the traveler's annual salary and to the purpose of the trip. Factors used to estimate these values as as follows:

Trip Purpose	Value of Travel Time
Business and conventions	Twice hourly salary rate
Personal business	Hourly salary rate
Recreation and entertainment	None

Average annual income for each class is taken as follows:

Income Range	Assumed Average Income
Less than $5,999	$ 3,000
$6,000 to $9,999	$ 8,000
More than $9,999	$15,000

In allowing for the fact that the value of travel time may differ for different persons traveling together (i.e., value of time for children is very low), the model calculates travel time costs on the basis of the following assumptions:

1. For business travel, all persons traveling together value their time equally; and
2. For all other purposes, the full value of time applies for the first person, one-half of this value for the second person, and one-fourth of the full value for all other persons.

Air Travel Costs

Figure 4 shows the scheme used for calculating the cost of an air trip. Any trip may consist of all or a portion of these segments. Thus, the cost of the trip is a function of the routing. On the other hand, the routing selected for a particular trip is a function of costs; therefore, both must be determined iteratively. In calculating these costs, appropriate factors are included to allow for terminal impedances and other costs encountered in traveling by air. These include both time and out-of-pocket costs.

Trip Routing

Figure 5 shows the operation of the algorithm used to determine the least cost routing through the transportation network. This describes the trip in terms of both automobile and airline travel. It operates iteratively and is an integral part of the modal choice analysis.

Assignment of Trips to the Network

The output of this analysis is a tabulation of air trips along each link of the network. The output also includes the total number of air trips generated at each city within the analysis area. Highway trips, however, are not identified.

MODEL TEST

Data Base Used for Testing Model

In testing the model, 1967 was used as the base year for comparison. Estimates of 1967 air passenger volumes were compared with data from the 1967 survey (4). The 1967 estimates represent the output from the demand analysis based on socioeconomic data for 1967 and the approximate configuration of the air transportation system at that time.

Comparison of Results

In general, it is to be expected that a generalized model would be more reliable for estimating the pattern of long-distance air travel than for short-haul travel. Beyond a certain distance, the relative attractiveness of alternative destinations seems to be little affected by distance. Linkages between specific cities or regions are of a general nature and do not describe specific ties such as between large trading centers and the outlying communities.

On the other hand, factors affecting the pattern of travel and the traveler's choice of mode for the short-haul market are more varied and difficult to completely describe in a generalized model. State capitals or other major governmental or institutional centers generate significant amounts of air commuter traffic. Similarly, major financial centers appear to be the focal point for "single-day" air travel from the surrounding areas. In certain circumstances, where topographic constraints impose major discontinuities on the highway system, there is also a greater tendency for short-distance travelers to use air.

Figures 6 and 7 show the comparisons between observed and estimated air travel volumes for long-haul (interstate) and short-haul (intrastate) air travel respectively. (These comparisons are displayed on a logarithmic scale for convenience.)

Figure 2. Delineation of external regions.

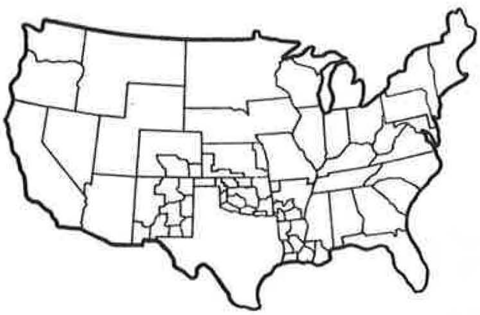
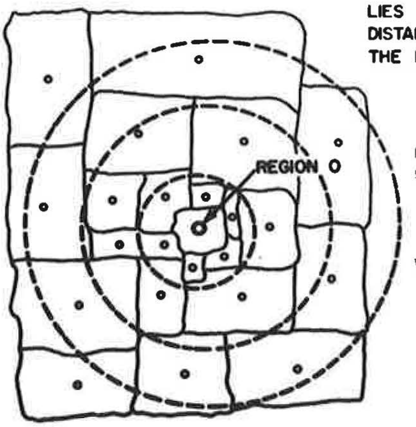


Table 2. Distribution of travel (percent) for each income level.

Trip Purpose	Associated Attractiveness Factor	Family Income Level: Less Than $6,000	Family Income Level: $6,000 to $9,999	Family Income Level: More Than $9,999
Business and conventions	Total taxable payrolls[a]	9.7	13.4	24.7
Visit friends and relatives and personal business	Total population	55.3	46.0	33.4
Recreation and entertainment	Hotel and motel payrolls[a]	35.0	40.6	41.9

[a]Payroll data refer to payrolls subject to social security taxation during the first quarter of the year. These data are taken from County Business Patterns, U.S. Bureau of the Census, 1967.

Figure 3. Method for estimating distribution of total travel.



The number of trips of purpose k generated by the base zone 0 and attracted to any other zone d is given by

$$T_{odk} = (R_{jk})\left(\frac{A_{dk}}{\Sigma A_{ijk}}\right)P_o$$

where

R_{jk} = trip generation rate for distance interval j and purpose k (Tables 1 and 2),
A_{dk} = socioeconomic descriptor representing the attractiveness of zone d for trips of purpose k (Table 2),
A_{ijk} = socioeconomic descriptor for purpose k and zone i within the distance band j, and
P_o = population of base zone 0.

Figure 4. Components of cost for air trip.

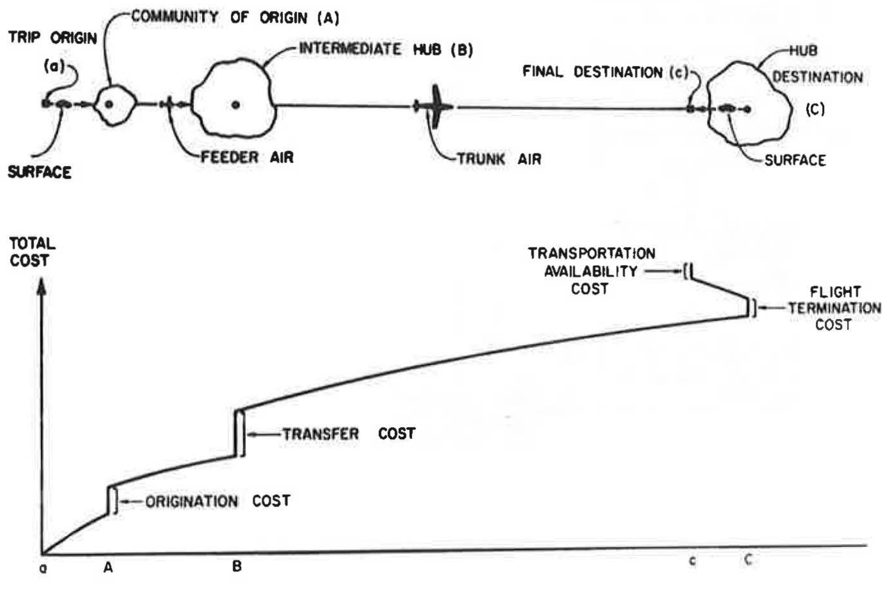


Figure 5. Algorithm for selecting least cost routing through air network.

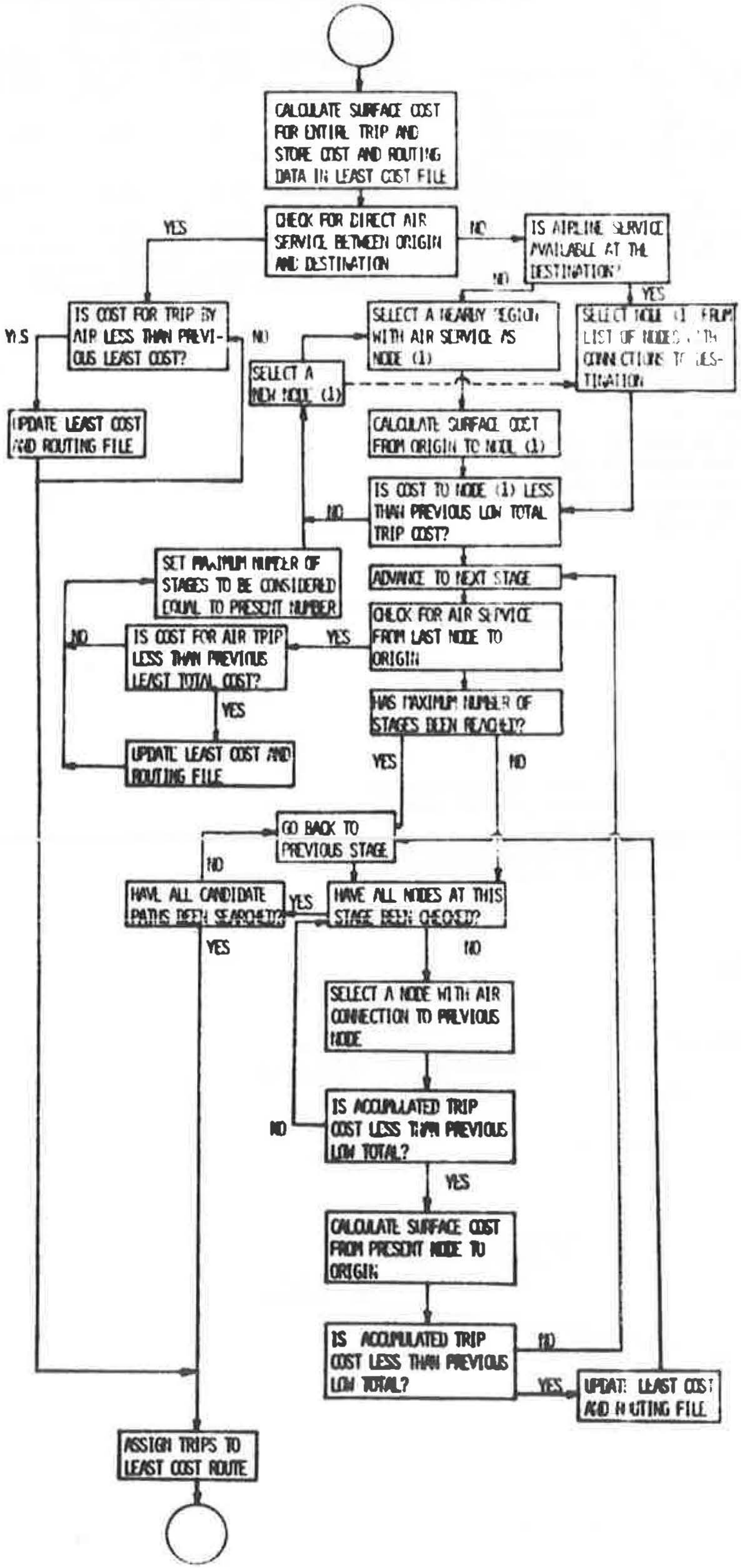


Figure 6. Comparison of estimated and observed interstate air passenger trips for 1967.

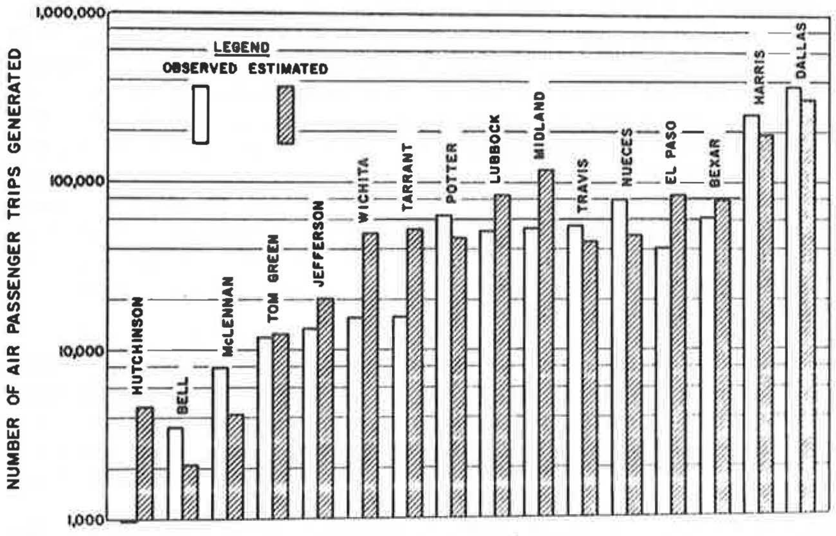
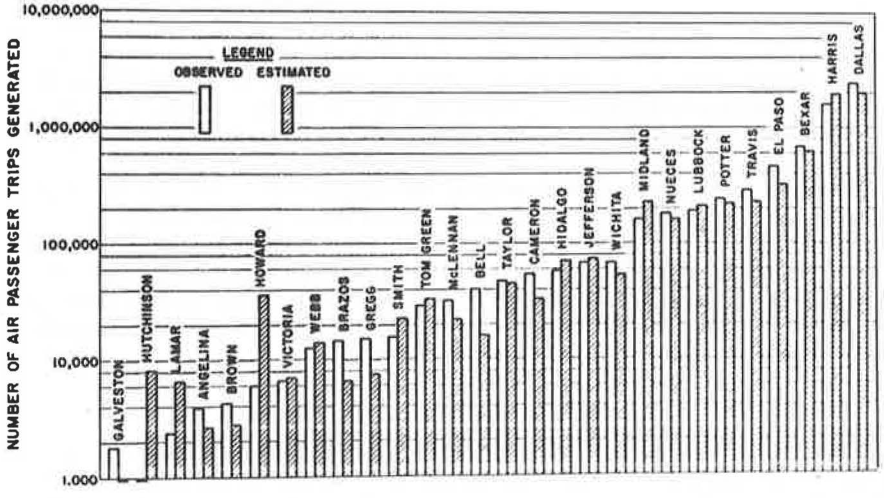


Figure 7. Comparison of estimated and observed intrastate air passenger trips for 1967.



Examination of the comparisons for interstate travel indicates relatively close agreement between observed and estimated travel volumes for the larger urban areas. For smaller areas, the relative variation is greater but is generally explainable. For example, the fact that observed travel is higher than the estimated levels for Wichita and Bell counties can be attributed largely to the major military installations in these areas. Similarly, the state capital and a major university in Travis County and another major university in Brazos County explain the low estimated volumes for thses areas.

Close proximity to other airports of greater or comparable size accounts for estimating variation for Hutchinson, Cameran, and Hidulgo counties. Significant underestimation of traffic at Galveston occurs because Galveston is separated from the nearby Houston Intercontinental Airport by Galveston Bay, which increases the relative attractiveness of the Galveston-Houston air connection for trips originating in Galveston.

For several counties in the West Texas plains area (i.e., Lubbock, Midland, Tom Green, and Howard), per capita income is relatively high, and there is generally a high propensity to travel. However, general aviation activity in this area is also considerably above average. It would, therefore, appear that many candidate air travelers in this area substitute general aviation for commercial air travel. (Wide separation of communities and lack of concentration of travel between them inhibit development of a viable commercial air service that can satisfy the existing demand.)

The comparison for intrastate air travel indicates generally similar patterns as for the interstate travel, but the relative variation appears to be somewhat greater. However, the fact that the short-haul (intrastate) travel accounts for only about one-fourth of the total air travel generated by this area lessens the significance of this greater variation.

Errors in the origin-destination data used as the basis of comparison represent another potential source of variation between the observed and estimated volumes. These observed air travel volumes are actually estimated from a 10 percent sample of ticket coupons. In addition to sampling errors, the fact that information contained on the tickets frequently does not exactly describe the traveler's actual trip introduces an indeterminate bias into the observed data.

Much of the variation previously identified could be significantly reduced by "fine tuning" of the model. Possible improvements include the development of trip generation relations that more accurately reflect the effect of character and level of economic activity on a region's trip generating potential and the refinement of the network description to more precisely account for discontinuities in the highway system in regions of detailed study. Even in its present form, however, the estimates appear adequate for providing general system development criteria.

SUMMARY

This research has developed a model for estimating the magnitude and geographic distribution of air travel demands at the regional level. The model represents, to a large degree, a synthesis of the basic concepts and relations used by previous techniques. However, it permits examination of the following factors that are especially important for planning a regional air transportation system and have not generally been integrated in previous models:

1. The influence of the level of air service provided to a community on the volume of air travel generated, particularly for small communities with no air service or with only limited service;
2. The impact of changes in service to one community on the demand for and economic viability of service to nearby communities; and
3. The complementarity between air transportation and other modes.

Comparison of estimated air travel volumes and observed volumes indicates that the method provides reasonable estimates of air passenger demand. Although there are discrepancies between the observed and estimated air passenger volumes, these discrepancies are not generally serious, and the likely sources of such errors are apparent. Further refinement of the model may ultimately be desirable to reduce these discrepancies, but the procedure in its present form provides useful information for the planning and development of a statewide or regional air transportation system.

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