General Aviation Forecasts for System Planning

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Consistent, reproducible forecasting models for general aviation activity at airports are important in statewide airport planning since more than 80 percent of the operations at major airports are by general aviation aircraft. During the state airport system planning process in Iowa, current general aviation forecasting tools were evaluated and a survey was designed to study the aviation operations at several airports where continuous count data were not available. The methodology developed for forecasting annual general aviation operations, passenger enplanements, and peak-hour movements are discussed. Data for 1971, 1975, and 1976 were available from several nontowered and towered airports and indicate that general aviation operations per based aircraft declined at both classes of airports. The general aviation operation models, developed from 1975 survey data, predicted operations in 1976 within 7 percent; the differences were not statistically significant.

A primary objective for the development of state and national airport system plans is to provide for the orderly and timely development of a system of airports adequate to meet air transportation needs. Within this framework a major component of analysis is the development of aviation activity forecasts that are used to identify airport development and air navigation facility needs, airspace use, and air traffic control procedures. Annual and peak-hour operations and passenger enplanements by air carrier and general aviation aircraft are principal factors in determining these needs.

Although the greatest financial needs may occur at those airports that provide certificated air carrier service, that service is a small portion of the total airport activity. Even at the 430 major airports that have Federal Aviation Administration (FAA) control towers, the data indicate that, on the average, approximately 80 percent of all operations are by general aviation aircraft. At most of the other approximately 12 000 airports in the country, general aviation aircraft constitute the entire operational activity.

For airport system planning purposes the air-carrier activity is well documented, and a reasonable historical data base can be established at most air carrier airports. General aviation activity, however, is not well documented, and consistently applicable estimating procedures have not been established. In this paper we discuss some basic parameters and forecasting methodologies that have been used to estimate general aviation activity and discuss the forecasting procedure used in the development of the Iowa State Airport Plan (1, 2). The changes that have occurred in aviation activity and the sensitivity of the forecasting model to the changes are evaluated.

GENERAL AVIATION FORECASTING METHODOLOGIES

The absence of a satisfactory data base for general aviation operations at all sizes of airports imposes one of the greatest handicaps to the development of forecasting models. If adequate information were available, the operations at a local airport could be analyzed for correlation with community factors such as population, income per capita, employment, and gross sales; with aviation factors such as airport quality, based aircraft, and registered pilots in the county; and with regional or system characteristics such as degree of isolation. Since adequate data are not available, however, the activity forecasts in smaller communities are most frequently based on some form of trend extrapolation from national forecasts or FAA guidelines. Several of the forecasting techniques that have been used for state or national system studies are discussed here.

One forecasting approach is the use of average data offered as a guide by FAA. FAA data on operations per based aircraft, given below, combined with an estimate of based aircraft are used to forecast aircraft operations. (The metropolitan area is the area under the influence of the central city of a standard metropolitan statistical area.)

Airport Type	Annual Operation	Metropolitan Areas	Nonmetropolitan Areas
Airline served	Itinerant	600	300
	Local	600	300
General aviation only	Itinerant	400	200
	Local	600	300

A second approach uses national growth rates and is based on the forecasts of flight hours by general aviation aircraft. Forecasts of aviation flight hours by aircraft type (3) based on reported flight hours for the registered aircraft are developed annually by FAA. The hours flown forecasts are combined with the estimate of hours per flight by aircraft type and the number of aircraft by type at the airport to derive an estimate of annual operations.

One modification of the procedure involves adjustment of the state projections based on relative state and national population and increase in the number of aircraft. Specific community factors, however, are not addressed in these forecasts.

In a third forecasting approach, at least one state recognized the value of incorporating local parameters into the estimating relations, but because of time and financial constraints the data on operations could not be obtained (5). Instead, estimates of operations were obtained from the Airport Master Record (Form 5010-1) maintained by FAA. The operation data on Form 5010-1 are themselves estimates that are frequently based on data such as those given in the tabulation above or on estimates made by the local airport manager. Further, the estimates are frequently not given on the forms, and gaps in the data result.

One of the most comprehensive efforts to evaluate the relations between community factors and general aviation operations was accomplished under the sponsorship of FAA (4). An objective of that study was to develop a nonsurvey method for estimating activity at nontowered airports. One phase was concerned with models to develop total operations, and a later phase dealt exclusively with general aviation operations. Operational data were obtained from activity reports at towered facilities, from FAA survey audits conducted at tower-candidate airports, and from similar surveys conducted by the research agency at general aviation airports. Aviation characteristics and community characteristics were obtained primarily from Form 5010-1 and from the census bureau's city-county data book respectively.

More than 50 factors were considered to be potentially important in explaining variations in annual operations.

The investigators developed regression models that were reported to be statistically valid for estimating activity at nontowered airports throughout the country. As an indication of variables found to be significant in that study, the final equation for estimating general aviation itinerant operations at nontowered airports included airport land area, number of single-engine based aircraft, registered aircraft in the county, state registered aircraft per 100 000 population, hours flown, and an airport facility index that described the airport quality.

Although this modeling effort produced equations that met standard statistical tests, some reservations regarding the use of the model for system planning remain. For example, itinerant operations at an airport were predicted to decrease with an increase of airport size. Likewise, local operations were predicted to decrease with an increase in the number of single- and multi-engine based aircraft. These relations are logically inconsistent and are not borne out by the observed data. Further, the hours-flown variable used in the itinerant model must itself be estimated, even in the base year, because of nonreported flight activity. During the entire planning period we felt that the hours-flown variable would be at least as difficult to forecast as the dependent variable. Finally, when the model was used to estimate general aviation operations at selected towered and nontowered airports in Iowa, the predictive models consistently overestimated operations at the nontowered facilities and underestimated operations at the towered facilities.

GENERAL AVIATION FORECASTS FOR IOWA

In Iowa, more than 400 airports have been identified, of which 116 are publicly owned and 93 are privately owned but open to the public. Only 9 of the airports provide certificated air-carrier service, and even at those airports general aviation aircraft accounts for more than 80 percent of all operations. Thus, when state airport system planning studies were undertaken, one of the primary concerns was the adequacy of the forecasting techniques for general aviation operations. It was felt that the existing methodologies did not adequately represent variations in activity because (a) the data base did not represent the many smaller airports, (b) the community characteristics and growth potential were often not accounted for, or (c) the relations among variables had not been adequately determined.

This paper summarizes the procedures used in the development of forecasts for general aviation operations and passenger enplanements. Pertinent inventory and analysis techniques developed for the 1972 and 1976 system plans are discussed (1, 2). The models developed address the limitations as listed above, but only the final factors used are described. Many other factors that strongly related to general aviation total and itinerant operations were originally considered, but were not used in the final phase because they led to inconsistent relations or were insensitive to changes that occur during the planning period.

The models discussed relate primarily to 1975 base-year data, but frequent references are made to the 1972 operations so that traffic growth patterns can be discussed.

Forecasts of Registered Pilots

The variables explicitly used in the operation models were pilots registered in the county and aircraft based in the county. Historical and current data regarding the statewide total and the county distribution of pilots and aircraft were obtained from the Aeronautics Division, Iowa Department of Transportation (formerly Iowa Aeronautics Commission). Forecasts of future pilot registrations in the state were developed by using national forecasts and a step-down approach that accounts for variations between U.S. and Iowa population and economic growth.

The distribution of pilots among the counties was found to be closely related to population of the county. However, more populous counties tend to have less than a proportionate share of the pilots in the state. The forecasts of county distributions were made by accounting for the population growth of each county relative to the state growth and adjusting this value by the relative share of pilots in each county in 1975.

Forecasts of Based Aircraft

Statewide and county estimates of aircraft were developed in a similar manner. A further allocation of aircraft to the individual airports was required for the operation forecasting models. Available data indicate that the residence area of an owner is not necessarily associated with the site at which the aircraft will be based. Selection of a site for basing an aircraft may be affected by factors such as hangar space and rental rates, availability of navigational aids, and runway length and condition. An aircraft may be based several kilometers from the owner's place of residence in order to have access to the more attractive features. As a result, some airports may attract a larger number of aircraft than are registered in the county and other airports may not attract as many aircraft as are registered in the county. In forecasting future based aircraft, we assumed that a quality system throughout the state would remove much of the attractiveness differential among airports by the end of the long-range period. Thus, in the long run, the number of based aircraft in a county should be more nearly equal to the registered aircraft in that county.

A growth curve was used in which the ratio of based aircraft to registered aircraft would asymptotically approach 1.0. Based aircraft for the base year were taken from site surveys conducted at all principal public-use airports. In the 1975 update plan the ratio of 1975 based aircraft in the county to 1975 registered aircraft in the county was calculated for each county. Then 1995 county based aircraft were estimated according to the following equation:

$$BA(95) = B^{1/3} \times \text{(1995 registered aircraft in county)} \qquad (1)$$

1985 county based aircraft were estimated to be

$$BA(85) = B^{1/2} \times \text{(1985 registered aircraft in county)} \qquad (2)$$

1980 based aircraft were assumed to be the average of 1975 and 1985 values.

If there was more than one system airport in the county, the county based aircraft were proportioned among system airports by using the same relative ratio that existed in 1975.

This general procedure provided an overall assignment methodology. Second iteration adjustments, however, were incorporated as decisions were made as to which airports would be retained in the state system plan. Virtually all future growth in aircraft was assumed to occur at those airports. If an airport was not to be included in the system, adjustments were made in the allocation process, which considered factors such as surface travel time to alternative sites and registered pilots in the competing areas. After final adjustments, more than 95 percent of the general aviation fleet had been assigned to the system airports by the end of the long-range period.

Base Data for Forecast Models

Because accurate data regarding aircraft operations are available only for airports with traffic control towers, we selected 15 airports, representing the range of operations expected in Iowa, to be surveyed 16 h/d for 1 week during the summer of 1975. These 1-week counts are not representative of an average annual week, and additional data from the records maintained by the FAA traffic control towers were used to expand the 1-week counts. The monthly tower reports from the five Iowa control towers and the towers in Omaha, Nebraska, and Moline, Illinois, were obtained for 1972, 1973, and 1974. The monthly variations in general aviation itinerant, local, and total operations were used to develop monthly factors for converting 1-week counts to average weekly counts. The composite monthly factors are given in Table 1. Statistical tests generally indicated that the monthly factors remained constant throughout the years and that the factors were relatively constant from city to city. Assuming that the monthly variations in general aviation operations at the nontowered airports are comparable to the variations at the towered airports, we used these factors to expand the weekly counts to annual operations.

The data from 14 of the surveyed airports (one site was considered to be an outlier) were eventually combined with general aviation data from the 5 towered airports. Before these data were used in a combined model, however, the homogeneity of variances of the groups was established. We found that the groups could be combined only if a transformation was made. A logarithmic transformation was found to be statistically acceptable and was used. The final models were based on 19 observations.

General Aviation Total Operations

Several community and aviation system characteristics were evaluated for inclusion as explanatory variables in the operation models. Strong linear correlations existed between operations and other factors such as population, employment, gross sales, based aircraft, number of families with incomes of $15 000, and registered pilots in the county. All of these variables, however, are highly intercorrelated and do not independently explain variations in the operation data. Incorporation of all factors in a demand model would result in intuitively incorrect, if not statistically invalid, models. Instead, the interdependent nature of these factors was accounted for in the final model by forming multiplicative interaction variables. The best overall forecasting equation for total general aviation operations was

$$\log(\text{annual total operations}) = 2.614 + 0.501 \log(\text{based aircraft} \times \text{county pilots}) \quad (3)$$

This model explained 88 percent of the variation in the data, and the errors were randomly distributed. Forecasts derived from this equation were generally found to be reasonable. However, in smaller communities within largely metropolitan counties, the large number of pilots caused unreasonably high forecasts. In this case a model considering the direct effect of community population and based aircraft was developed. This model was satisfactory for estimating the operations in the smaller communities.

General Aviation Itinerant Operations

Itinerant operations were also highly correlated with several other factors, particularly population. Larger communities that serve as regional centers increased the attractiveness of the area to individuals throughout Iowa and adjoining states, thus tending to increase the proportion of itinerant operations at the airports. Of course, the propensity for flights is directly related to the number of aircraft and pilots in the service area. The latter factors were dominant in the model formulation. The final model was

$$\log(\text{annual itinerant operations}) = 1.865 + 0.605 \log(\text{based aircraft} \times \text{county pilots}) \quad (4)$$

This model explained more than 95 percent of the variation in itinerant operations, and the errors were randomly distributed. The impact of service area population appears to be adequately measured by variations in county pilots.

Adjustment Factors for Unique Community Characteristics

Previous experience indicates that, regardless of the statistical strength of a forecasting model, some communities possess unique economic or locational characteristics that are impossible to incorporate in a statewide model of aeronautical demand. To account for these unique characteristics, each professional staff member evaluated each community that was considered to experience some greater or lesser potential for travel that could conceivably not be accounted for in the statewide model. Multiplier factors for itinerant and total operations were calculated from these ratings. All ratings were completed before any operational data were obtained from field surveys. In this way the data could not interfere with or bias the staff ratings. The majority of the adjustment factors resulted in changes of 5 percent or less. The maximum community factor changes were approximately 20 percent.

EVALUATION OF FORECASTS AND FORECASTING MODELS

The activity counts taken at the 15 airports in 1975 repeated similar counts taken in 1971 at 8 airports and provided an opportunity to assess the changes in general aviation operations. The data supplement our knowledge about annual operations as measured at the air traffic control towers.

The number of operations per based aircraft is commonly used as a basis for comparing levels of operations at airports of differing size or at the same airport as the number of aircraft at the facility changes over time. This rate is expected to increase because increasing prices of aircraft and increasing navigational equipment requirements prompt aircraft owners to use their craft more intensively to justify the increased capital costs. The operations per based aircraft at all airports with air traffic control towers declined during the period (Table 2). At the smaller airports the trends were not as consistent, but overall a decrease was noted. The weighted average operations per based aircraft decreased 26 percent at all airports, from 840 in 1971 to 620 in 1975, and 15 percent at nontowered airports, from 776 in 1971 to 670 in 1975.

The Iowa Department of Transportation continued to monitor activity in 1976, and preliminary summaries show that the operations per based aircraft were fewer in 1976 than in 1971 at 5 nontowered airports and fewer in 1976 than in 1975 at 4 nontowered airports.

All factors that might have contributed to this reduction are not known, but the forecast models indicate that one of the principal factors is the reduced growth rate of registered pilots. Between 1972 and 1975 aircraft registrations increased by 9.4 percent, while the number of registered pilots declined by 2.8 percent.

Another factor is the percentage of itinerant operations. At the 8 nontowered airports, 26 percent of operations were itinerant in 1971 and 36 percent in 1975. Itinerant operations represent a larger portion of the total primarily because of the reduced growth rate of local operations, which is a reflection of the declining number of new pilots throughout the state.

These observations are based on short-term counts and are subject to the random variations occurring in those counts. Unfortunately, sufficient survey data are not now available to analyze this variation. A measure of the ability of the forecasting model to predict operations in spite of these variations is, however, afforded by portions of the 1976 data that are available. On the average, the models developed from the 1975 data underpredicted total and itinerant operations at 9 airports by about 6.5 percent. A t-test for paired differences indicated that these differences were not statistically significant at the 95 percent confidence level.

GENERAL AVIATION PASSENGER AND PEAK-HOUR FORECASTS

Peaking characteristics and general aviation passenger enplanements were developed primarily from the 7-d count data, hourly data from control towers, air taxi observed data, and estimates from airport managers and operators. Although the estimates are subject to high variability, they provide a sufficiently accurate estimate for statewide system evaluation. Master planning efforts would require more detailed analysis.

Table 1. Adjustment factors for seasonal variation in general aviation operations.

Month	Itinerant	Local	Total
January	1.22	1.29	1.25
February	1.21	1.18	1.20
March	1.02	1.02	1.02
April	1.00	0.98	0.99
May	0.90	0.89	0.89
June	0.82	0.86	0.84
July	0.83	0.76	0.80
August	0.83	0.82	0.83
September	0.94	0.90	0.93
October	0.95	1.00	0.97
November	1.21	1.27	1.24
December	1.42	1.51	1.46

Table 2. Annual general aviation operations per based aircraft.

Airport Type	City	1971	1975
Nontowered	Charles City	700	960
	Clinton	1030	620
	Fairfield	880	1200
	Fort Dodge	1140	1330
	Osceola	510	760
	Sac City	700	530
	Shenandoah	550	430
	Spencer	570	540
Towered	Des Moines	860	600
	Dubuque	680	610
	Sioux City	780	610
	Waterloo	1330	1060

Air Taxi Operations

General aviation itinerant operations include the number of air taxi operations. However, since the passenger volumes tend to be greater on air taxi flights than on regular flights, terminal area requirements would increase as air taxi operations increased. Air taxi operations tend to increase as community size increases, but data for determining the extent of these operations are extremely limited. Figure 1 shows the degree of variation evidenced in the surveys. Data from air carrier airports depict a reasonably consistent pattern, but these airports in Iowa are associated only with communities having more than 30 000 population. Estimates obtained from smaller cities tend to be proportionately higher because of the demand for additional air taxi service in smaller cities where scheduled service is not available, the optimism of local operators, or some combination of these and other factors. At any rate, estimates for a given city size show ranges that could vary by about an order of magnitude and can serve only as a guide. Data for specific airports would be most useful to estimate these operations.

In Iowa, the control tower data base was used in forecasts of air taxi operations for air carrier airports. For other airports, the estimate was obtained from a hand-fitted average line developed from the local operators' and managers' estimates, as shown in Figure 1.

General Aviation Passenger Enplanements

General aviation passengers include all passengers on private, air taxi, and air commuter aircraft. The number of passengers on nonscheduled certificated air carriers is significant in Des Moines, Cedar Rapids, and Waterloo but still less than 2 percent of all air carrier passengers at those airports. These passengers were simply included in the total enplaned passengers by commercial aviation.

General aviation passengers were calculated to be 1.5 times the general aviation itinerant operations, except at locations where air taxi potential seemed to be most significant, i.e., in communities of 10 000 or more population. At those locations, air taxi passengers were estimated separately. The range of air taxi loads was from 2.0 to 3.0 passengers per itinerant operation. General aviation passengers were then calculated as

$$\text{Total general aviation passengers} = (\text{estimated passengers per air taxi operation}) \times (\text{air taxi operations}) + 1.5\,(\text{itinerant operations} - \text{air taxi operations}) \quad (5)$$

General Aviation Peak-Hour Operations

The pattern of peak-hour operations was determined from field survey counts and various airport planning forecasts. The observed peak-day and peak-hour data are given in Table 3; Figure 2 shows the relation between annual operations and peak-hour operations. The line depicting a 20 percent peaking factor for the average survey data is also shown as a lower bound. A hand-fitted curve of the data points was used for estimating peak-hour operations.

Peak-hour passengers were calculated to be 1.5 times peak-hour itinerant operations except in communities with high air taxi operations. In those areas a weighted figure of 1.7 passengers per itinerant operation was used.

CONCLUSIONS

The forecasting procedures used to estimate general aviation activity have ranged from judgmental estimates to detailed econometric models. In nearly all instances, the information used to determine annual operations at nontowered airports is synthesized from national projections or is developed from incomplete data obtained at the local level. More complete activity data were collected in surveys in Iowa cities ranging in population from 3000 to 35 000 to supplement tower data available in cities ranging in population from 60 000 to 200 000. These data, combined with community and aviation-related factors, served as the base for developing forecasting models of air travel in Iowa.

The models used to estimate general aviation total and itinerant operations were able to explain quite well (coefficient of determination of 0.88 and 0.95 respectively) the variations in operations among different airports in 1975. Whether the models can predict growth at a specific airport over time cannot, of course, be completely judged at this time. Changes in operations must be sensitive to changes in the explanatory variables in the model. The two explanatory factors, registered pilots and based aircraft, are certainly not the only factors that affect growth, but the interaction of these variables is highly significant. Other factors such as employment or population can statistically explain variation between cities at a point in time, but general aviation changes over time will not respond quickly to a change in these parameters. Inclusion of these factors in the model would be intuitively correct, but would simply confound the forecasting tool.

A measure of the ability of the models to estimate changes in operations during a short time period was provided by the data collected in 1976. The models predicted the annual operations within 6.5 percent of the survey estimates. These estimates were not statistically different.

The peak-hour and passenger enplanement forecasts were based on data and factors from several sources, but a primary source was the short-term counts. As a base for making statewide estimates, these data are felt to be sufficiently reliable although subject to large but unknown variations. A subject of future research should be the acquisition of data covering an extended time period at selected general aviation airports. Peak-hour or monthly variations are often assumed to follow the same pattern at general aviation airports as at control-tower airports. The fact that an estimating equation using data from several towered airports where continuous counts were available and data from several tower-candidate and smaller airports where 1-week counts were available could not satisfactorily estimate operations in Iowa suggests that more information is needed.

Figure 1. Trends of air taxi operations.

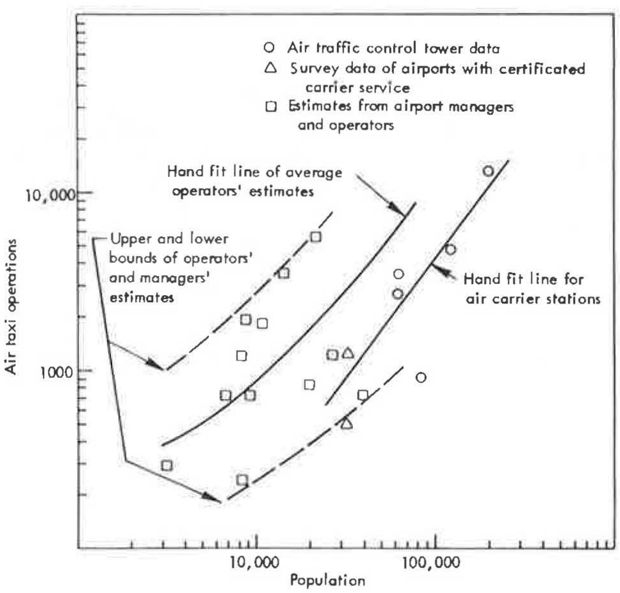

Figure 2. General aviation peak-hour operations.

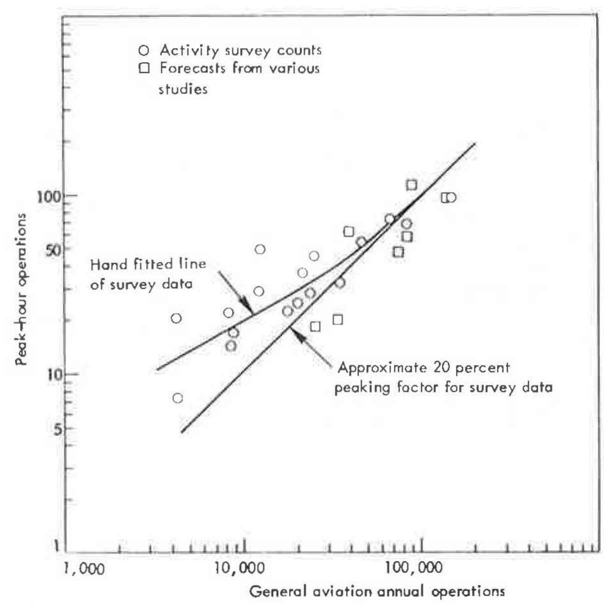

Table 3. Peak-hour and peak-day general aviation operations.

City	Peak-Hour Operations	Peak-Day Operations	Annual Operations	Peak-Hour/ Annual	Peak-Day/ Annual
Algona	16	46	8 700	0.001 84	0.005 29
Charles City	27	100	20 200	0.001 34	0.004 95
Clinton	24	96	19 900	0.001 21	0.004 82
Council Bluffs	36	123	21 400	0.016 80	0.005 75
Decorah	43	101	14 000	0.003 07	0.007 21
Fairfield	44	125	24 000	0.001 83	0.005 21
Fort Dodge	39	191	35 900	0.001 09	0.005 32
Keokuk	15	64	15 300	0.000 98	0.004 18
Manchester	20	26	4 220	0.004 74	0.006 16
Marshalltown	31	150	32 000	0.000 97	0.004 69
Orange City	28	60	12 000	0.002 33	0.005 00
Osceola	14	42	8 440	0.001 66	0.004 98
Sac City	7	19	4 340	0.001 61	0.004 38
Shenandoah	21	40	8 160	0.002 57	0.004 90
Spencer	21	94	17 700	0.001 19	0.005 31

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Abridgment

Survey of Ground Transportation at the Dallas-Fort Worth Regional Airport

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This paper describes a survey of ground transportation at the Dallas-Fort Worth Regional Airport (DFW) conducted on May 16 and 20, 1975. For purposes of the survey, trips were classified as follows: (a) trips made by air passengers and visitors in private automobiles, (b) trips made on public transportation, and (c) trips made by employees. Each of the three classes of trips was investigated separately. This paper describes the methodology and physical performance of the travel survey and some of its findings.

OVERVIEW OF DFW GROUND TRANSPORTATION SYSTEM

Highway Access

Automobile access to DFW is provided by several distinct roadway systems, the most important of which is the north-south spine highway, which passes through the center of the airport. The spine highway system is composed of a multilane public roadway flanked on both sides by a physically separated service road system.

Access via the public roadway is controlled by means of control plazas at the north and south entrances to the airport, each consisting of eight control booths. Control booths on inbound parkway lanes issue parking tickets; outbound booths collect parking fees.

The system of service roads is used mainly by employees and commercial, maintenance, and service vehicles. The service roads branch from the spine highway just outside the control plazas at each end of the airport.

Public Transportation Access

Public airport transportation is provided by bus, limousine, and taxi services. A quasi-public corporation created by the cities of Dallas and Fort Worth, Surtran, has an exclusive franchise to provide express airport bus service. In addition, shuttle bus service is provided by various companies using small minibuses or vans.

EMPLOYEE TRAVEL SURVEY

Over 13 000 employees make daily work trips to and from DFW, thereby contributing significantly to the total traffic volume. A general classification of employees by type of industry and the number in each classification is shown below.

Industry	Number of Employees
Airlines	8 364
Air cargo	1 139
General aviation	100
Food service	1 406
Maintenance (excluding airline employees)	379
Security and police	378
Rent-a-car firms	268
Miscellaneous	1 334
Total	13 368

The miscellaneous category includes employees of the U.S. air mail facility, the Federal Aviation Administration, the Dallas-Fort Worth Regional Airport Board (excluding security and maintenance employees), and the Airport Marina Hotel.

The employee survey form requested information on street address, mode of travel, time of arrival and departure, sex, age, occupation, income, and previous airport employment. Survey forms were distributed to employees by their supervisors. Most survey forms were mailed to the employer; some were delivered by hand. The completed questionnaires were collected in