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MONITORING THE EFFECTS OF THE DALLAS/FORT WORTH REGIONAL AIRPORT
VOLUME I: GROUND TRANSPORTATION IMPACTS

WILLIAM J. DUNLAY, JR. . . [et al.]
LYNDON HENRY
THOMAS G. CAFFERY
DOUGLAS W. WIERSIG
WALDO A. ZAMBRANO

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MONITORING THE EFFECTS OF THE DALLAS/FORT WORTH REGIONAL AIRPORT

VOLUME I: GROUND TRANSPORTATION IMPACTS

(SURVEY OF GROUND TRANSPORTATION PATTERNS AT THE DALLAS/FORT WORTH REGIONAL AIRPORT - PART II: ANALYSIS OF RESULTS AND DEVELOPMENT OF MODELS)

William J. Dunlay, Jr.
Lyndon Henry
Thomas G. Caffery
Douglas W. Wiersig
Waldo A. Zambrano

December 1976
Research Report

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16. Abstract

This report presents new conceptual and methodological approaches to developing models to interrelate airline schedules, airport-based employee work-shift schedules, and airport access ground traffic volumes in any time period for a given report.

The results of a survey of ground travel at the Dallas/Fort Worth Regional Airport are presented and analyzed. Specific ground transportation impacts of the installation of this relatively new airport are assessed.

Models are described which (1) express volumes of automobiles carrying airline passengers and visitors as a function of airline schedules and (2) transform existing or future employee work-shift schedules into estimates of incoming and outgoing employee vehicle volumes in any time interval. Preliminary research toward the development of a model to estimate public transit passenger volumes as a function of airline passenger volumes is also described.

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EXECUTIVE SUMMARY

AUTOMOBILE TRAFFIC

Automobile traffic patterns on airport access roadways depend largely on airline flight schedules and employee work-shift schedules. This report introduces and references mathematical models for estimating the volumes of automobile traffic entering and leaving an airport in any specified time period as a function of these schedules. The models can be used to obtain accurate estimates of traffic peaking characteristics. They can also be used to evaluate the effects of proposed changes in airline schedules or work hours on airport access congestion. Another application of the models is to transform demand forecasts, in the form of proposed airline schedules or estimates of future airport employment, into forecasts of the future airport access traffic demand due to air passengers and employees.

The purpose of this summary is to describe briefly the basic concepts and the application of the models to their potential users. Formal derivations of the models and the probability theory behind them are detailed in the main body of this report.

Previous Methods

The realization that patterns of airport access traffic are related to flight schedules and work shift schedules is not new. However, there have been very few formal attempts to express access volumes as an explicit function of these schedules.

Most methods of relating access traffic volumes to measures of airport activity used in previous airport planning studies have been simplistic. These methods range from using some standard or estimated number of peak hour automobiles per annual enplaned passenger to assuming that passenger and employee vehicles enter and leave the airport exactly at scheduled flight or work-shift times. Previous methods lack the precision and theoretical foundation necessary to accurately estimate short-term peaks in airport access traffic.

Koussios and Homburger[1] developed multiple-regression equations which express hourly volumes of access traffic and parking vehicles at San Francisco International Airport as a function of hourly volumes of enplaning and deplaning passengers.

Davidson, Martin, and Morton[2] used a unit hydrograph method to estimate traffic flow at an airport.

Air Passenger Traffic Volumes

The model proposed for estimating volumes of air passenger vehicles is based on the flight schedule, the number of originating and terminating passengers per flight and times at which the passenger vehicles enter and leave the airport relative to scheduled flight times. In particular, the distributions of the following four times are critical to the method:

(1) entering times of vehicles carrying originating air passengers,
(2) entering times of vehicles picking up terminating air passengers,
(3) leaving times of vehicles carrying terminating passengers, and
(4) leaving times of vehicles after dropping off originating air passengers.

Frequency distributions of the above entering and leaving times are used to estimate the probability that vehicles associated with a particular flight cross the airport boundary, i.e., enter or leave the airport, in a given time period. Using this probability along with information on the number of passengers on the flight and the number of passengers per automobile, one can estimate the average number of vehicles expected to cross the airport boundary in the given time period for a particular flight. To estimate the total average number of vehicles crossing the boundary in the period, one simply adds together for all flights the averages obtained as above for the individual flights. For example, suppose it is desired to estimate the access volumes in a particular 15-minute time interval of

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[1] Koussios, D., and W. S. Homburger, Vehicle Traffic Patterns at an Airport In Relation to Airline Passenger Volumes, University of California, Berkeley, ITTE Research Report No. 44, May 1967.

[2] Davidson, Martin, and Morton, "A Traffic Prediction Model for Brisbane Airport," Journal of the Australian Road Research Board, Vol. 3, No. 10, June 1969, pp. 24-35.

the peak hour. One would first estimate the expected number of vehicles entering and leaving for each flight operation that occurs near the selected time interval. These individual results would then be summed over all flights.

The report presents a complete set of formulas for estimating the expected number of vehicles entering and leaving an airport in any given time period. These formulas account for both air passengers who drive themselves to and from the airport and air passengers who are driven by someone else. Note that the latter case involves extra trips on the access roadways over and above the number of trips that would result if all passengers drove themselves to the airport and parked, namely, trips by vehicles coming to pick up passengers and trips by vehicles leaving the airport after dropping off passengers. This points to the necessity of determining the percent of air passengers who are driven to and from the airport by someone else; at the Dallas/Fort Worth Regional Airport (DFW) approximately 70 percent of air passengers fall into this category.[3]

Also presented in the report are formulas for estimating the day-to-day variation in the volumes of access traffic in a given time period and, in addition, some evidence that these volumes are normally distributed. In short, one can estimate the mean, variance, and probability distribution of the total volumes of air passenger traffic on airport access roadways in any selected period of the day.

The model was applied to the Dallas/Fort Worth Regional Airport using input data collected on (1) scheduled flight times, (2) originating and terminating air passengers per flight, and (3) the distributions of vehicle entering and leaving times.[4] In addition, estimates of traffic volumes obtained from the model were compared to actual field traffic counts of air passenger vehicles crossing the airport boundary at DFW. These comparisons are described in detail in the report. In general, the estimates were found to compare favorably with actual counts even in 15-minute time intervals. This ability to estimate short-term traffic peaks is the major advantage of the proposed model over previous methods.

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[3] Dunlay, W. J., et al., Survey of Ground Transportation Patterns at the Dallas/Fort Worth Regional Airport, Research Report 15, Council for Advanced Transportation Studies, The University of Texas at Austin, August 1975.

[4] Ibid.

Employee Traffic Volumes

The model for estimating volumes of employee vehicle traffic is very similar to the method described above for estimating air passenger traffic volumes. Employees enter and leave an airport according to their work-shift hours. By knowing the shift times, the number of employees per shift, employee vehicle occupancy, and the distribution of actual employee entering and leaving times relative to the work-shift starting and ending times, one can estimate the average number of employee vehicles entering and leaving the airport in a given time period for each shift. Traffic volumes associated with different nearby work shifts may overlap in the same time interval. Therefore, total average employee access volumes in a given period are obtained by adding together the average volumes for the different work shifts. The report also provides a means for estimating the variance in employee traffic volumes and evidence that these volumes are normally distributed. The employee traffic estimating model is almost identical in concept to the model described earlier for air passenger traffic.

The Dallas/Fort Worth Regional Airport was again used as a test case. Data on work-shift times, the number of employees per shift, employee vehicle occupancy, and the distributions of actual employee entering and leaving times were collected at DFW. These data were used in conjunction with the model described above to obtain estimates of employee traffic volumes in each 15-minute time interval of a typical week day. Actual traffic counts of employee vehicles were used to check the accuracy of these estimates. It is found that the estimates produced by the model compare favorably with actual traffic counts. Details on this application and the comparison of model estimates with traffic counts are given in the report.

Summary and Conclusions

Models are available for transforming existing or proposed airline schedules and employee work-shift schedules at an airport into estimates of the volumes of automobile access traffic in any time period. The general concepts underlying the methods have been presented in this summary. A more detailed description of the derivation of the models and their application to DFW is contained in the main body of the report. The models can be used to obtain more accurate estimates of short-term peaks in airport access traffic than have been possible to obtain using previous methods. They can also be used to evaluate the effects that alternative changes in airline schedules or airport employees' work hours may have on access traffic and parking congestion.

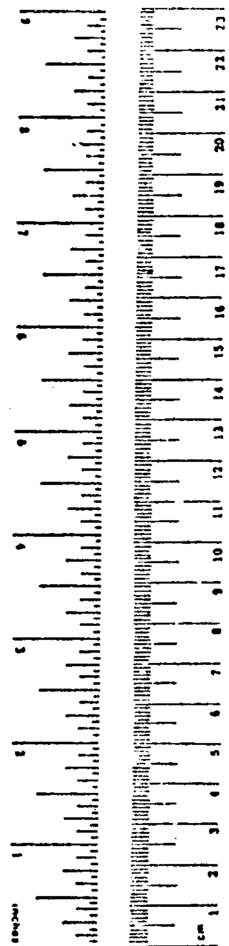
The models have been applied to only one major airport, DFW. It is hoped that further applications of the methods will be performed and reported for other major airports so that a better understanding of their accuracy and utility can be obtained.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

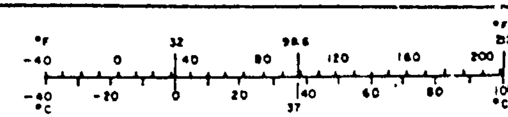


FIGURE 1. METRIC CONVERSION FACTORS

PREFACE

This is the 36th in a series of research reports describing activities and findings as part of the work done under the research report entitled, "Transportation to Fulfill Human Needs in the Rural/Urban Environment." The project is divided into six topics, and this is another report under Topic IIIB, "Monitoring the Effects of the Dallas/Fort Worth Regional Airport," per Contract No. DOT-OS-30093.

This project is sponsored by The Office of University Research, U. S. Department of Transportation.

W. J. Dunlay, Jr.
L. Henry
T. G. Caffery
D. W. Wiersig
W. A. Zambrano

December 31, 1976

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(1) Michael J. Sganga, Jr., Director of Planning, Dallas/Fort Worth Regional Airport Board;

(2) Ben Tonic and Richard Jarret of Surtran, Inc.;

(3) Ray E. Bayless, Director of Aviation, City of Austin;

(4) Gary P. Smith, Robert R. Heath and William M. Parker of the North Central Texas Council of Governments;

(5) Main Office and Fort Worth Office of the State Department of Highways and Public Transportation;

(6) The Center for Highway Research of The University of Texas at Austin.

In addition, we are grateful to the various employers and employees of the Dallas/Fort Worth Regional Airport for their cooperation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

I. INTRODUCTION

The broad purpose of this project has been to monitor changes in travel patterns caused by the installation, in January 1974, of a major new transportation facility, the Dallas/Fort Worth Regional Airport (Figure 1), located approximately halfway between the north Texas cities of Dallas and Fort Worth, which lie about thirty miles apart on an east-west axis (Figure 5). Specific project research has been focused on evaluating the airport's impact on ground transportation patterns, with a broader objective of developing methodological techniques for assessing the ground transportation impacts of new or expanded airport facilities in general.

Insufficient attention has been given to the airport/urban interface in the planning of new airports or the expansion of existing ones. This is evident from the fact that of the 20 busiest U. S. airports, 15 (which handle 56 percent of the total enplanements) are presently characterized by airport-access congestion.[5] A recent survey of airport officials showed that at least five major U. S. airports are currently experiencing serious-to-critical landside congestions, most notably access congestion.[6] In the past, the lack of adequate data and a validated analysis methodology has hindered objective studies of the relationship between ground access volumes and the level of airport activity.

The development of analytical models for estimating ground transportation from observable measures of airport activity has been interpreted as the most productive means of fulfilling the foregoing objectives. The lack of data on region-wide traffic volumes, before and after the opening of DFW, has restricted us to consider only the trip generation aspects of the new airport. Thus, within the general aim of assessing DFW's impact on ground transportation, our orientation has been toward the utilization of modeling techniques for inter-relating air and ground traffic as well as analyzing changes resulting from the shift in regional airport location from Love Field, the previous major

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[5] Wilbur Smith and Associates, Airport Access/Egress System Study, Final Report, DOT-TSC-OST-73-32, I, September 1973.

[6] U. S. Department of Transportation, The Airport/Urban Interface, Final Report, DOT-TSC-75-12, July 1974.

airport, located in northwest Dallas, to DFW. It has been expected that such models relating air traffic activity to ground transportation levels developed in this project will be useful tools for airport planners in the planning of airport ground-side facilities, in particular, access and parking facilities.

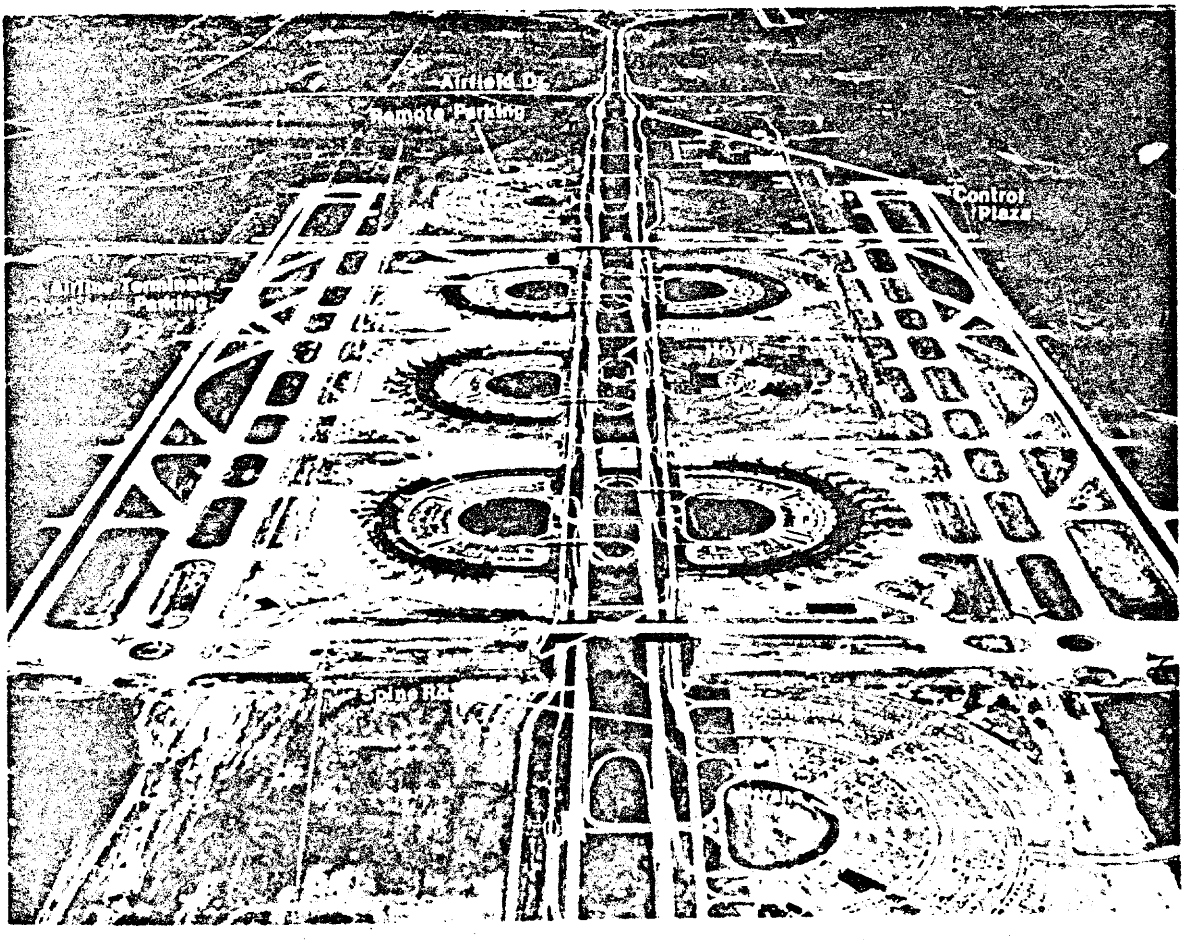

FIGURE 1.

Dallas/Fort Worth Regional Airport Showing
Principal Ground Transportation Features

II. DESCRIPTION OF DFW GROUND TRANSPORTATION SURVEY

INTRODUCTION

This chapter describes a survey of ground transportation at the Dallas/Fort Worth Regional Airport (DFW) conducted on May 16 and 20, 1975, and including two supplementary "mini-surveys" in November 1975 and May 1976. The primary purpose of the survey was to provide information on ground transportation that can be related to standard measures of air traffic activity and, thereby, obtain a better understanding of airport trip generation. The survey was also intended to allow an examination of the spatial distribution of off-airport trip ends to determine if there has been an identifiable change in the distribution of trip ends concomitant with the opening of DFW.

Scope

The survey of ground transportation at DFW was designed to obtain as complete a sample as possible of all trips beginning or ending at the airport. For purposes of the survey, trips were classified as follows: (1) trips made by air passengers and visitors in private motor vehicles (identified solely as "auto-users"); (2) trips made on Surtran, the primary transportation carrier; and (3) trips made by employees based at DFW. Each of these three classes of trips was investigated separately. The survey of the first component was accomplished via personal, oral interviews while the latter two survey components were of the written type distributed via prepared survey forms.

The May 1975 survey was restricted to two days because of financial constraints. Friday was chosen because many business trips terminate on that day and many weekend travelers leave Friday afternoon. Tuesday was the other day because it is a day when many business trips begin. These conclusions were reached in consultation with DFW authorities.

This chapter describes the methodology and actual physical performance of the travel survey. It also provides a preliminary analysis of the findings of the survey. Emphasis is on findings which reflect the airport's effect on ground traffic volumes.

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OVERVIEW OF DFW GROUND TRANSPORTATION SYSTEM

Ground transportation at DFW consists of a blend of personal motor vehicle traffic, public transit, para-transit, and even an intra-airport automated guideway transit system. This project was concerned exclusively with ground travel to and from DFW and not with circulation within the airport itself. Analysis of the patterns of travel eventually determined that movement to and from DFW could be conceptually segregated into the fairly distinct categories mentioned above: general-public motor vehicle traffic, Surtran (primary transit) traffic, and employee commutation.

Highway Access

Access to DFW by automobile 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 [Figures 2(a), 2(b) and 3]. Secondary access roads are located on the east and west sides of the airport. These minor roads are used mainly by vehicles visiting peripherally-located airport facilities, such as the administration building and the air freight complex. The spine highway system itself is composed of the multilane International Parkway and a physically separated service road system flanking the parkway on each side.

Access into DFW via International Parkway is controlled by means of "control plazas" at the north and south entrances to the airport, each consisting of eight "control booths" (Figure 3). Control booths on inbound Parkway lanes issue parking tickets; outbound booths collect parking fees based on length of stay at the airport as determined from the tickets. Between the north and south control plazas, International Parkway services the airline terminals and other airport facilities via access/egress ramps.

The system of service roads is used mainly by employees and by commercial, maintenance, and service vehicles which have business at the airport. The service roads branch from the spine highway just outside the control plazas at each end of the airport (Figures 2(a) and (b)).

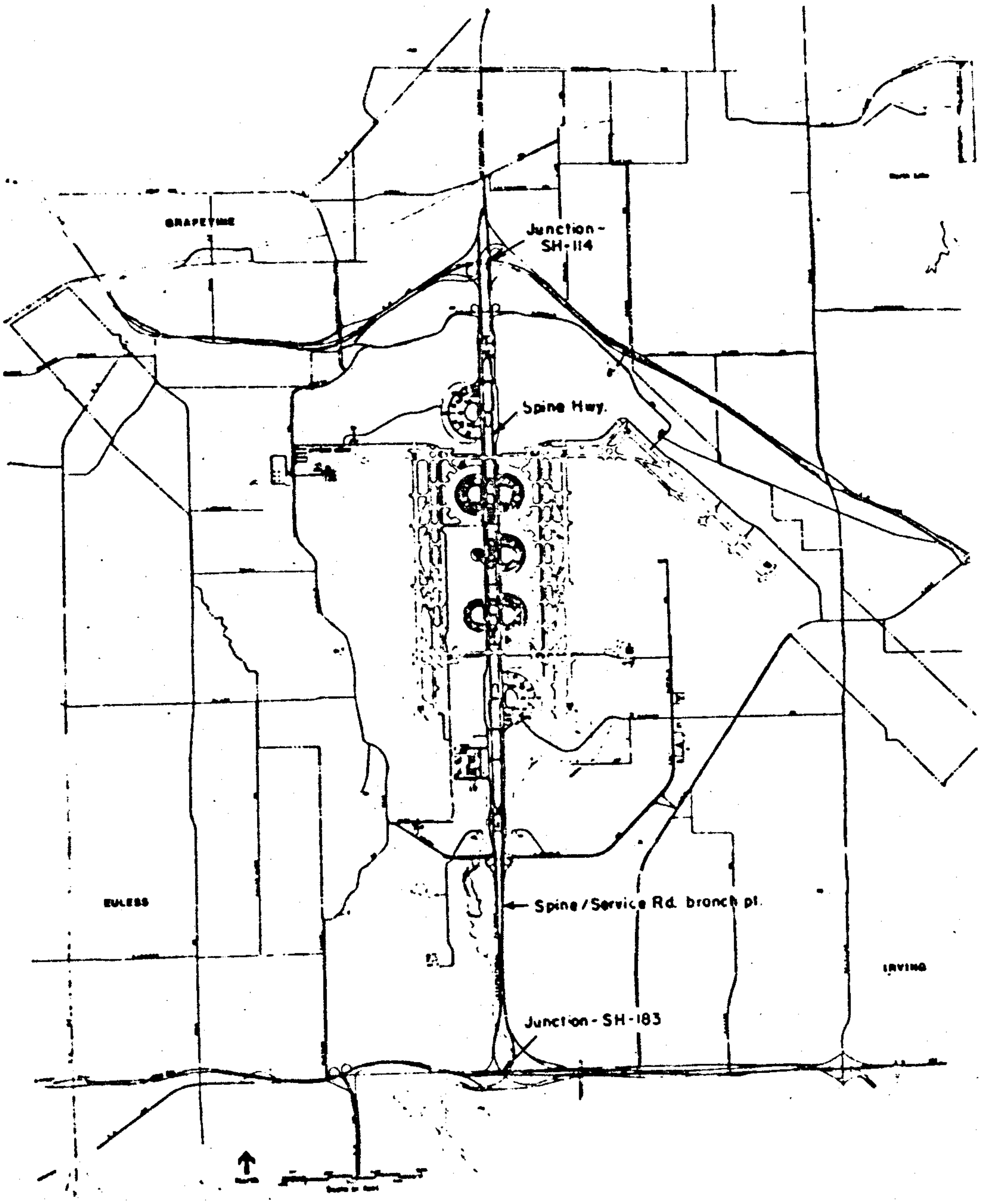

FIGURE 2(a). MAP OF DFW ROADWAY SYSTEM

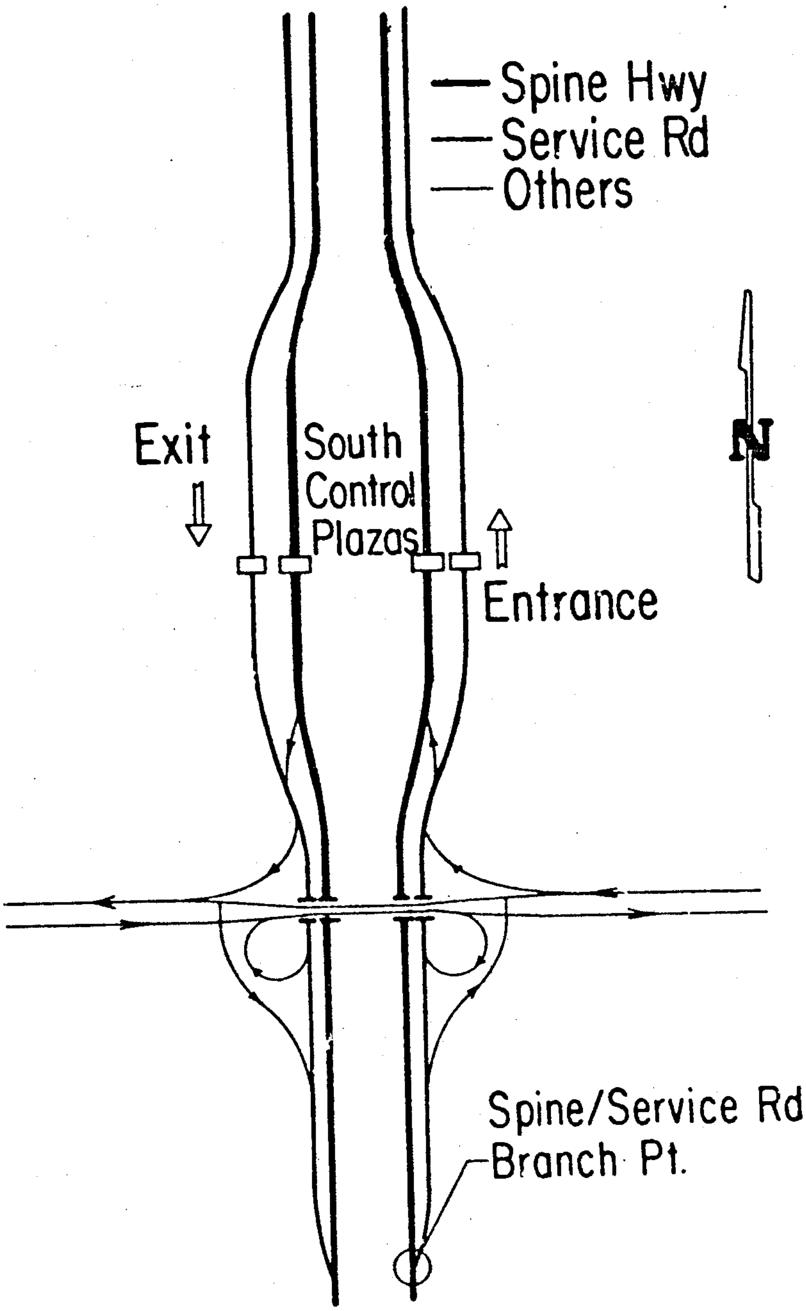

FIGURE 2(b). DETAIL OF DFW ROADWAY SYSTEM

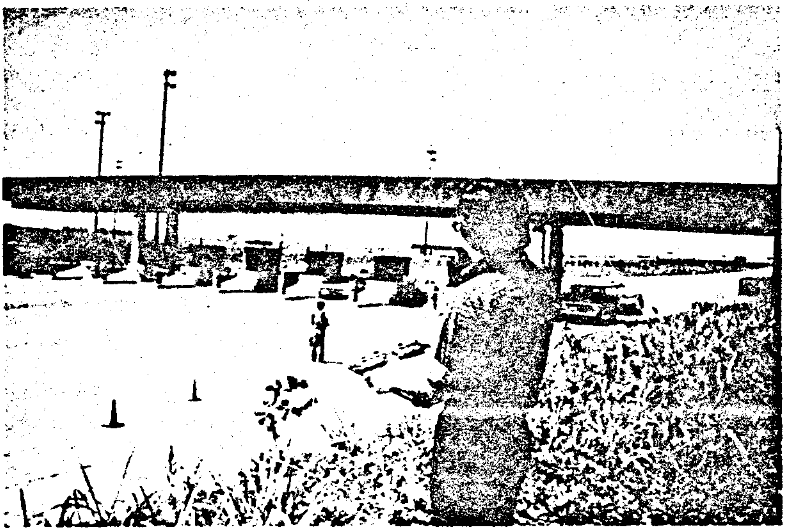

FIGURE 3. TYPICAL CONTROL PLAZA

(With Survey Personnel Shown)

Intra-Airport Transportation Other Than Highway

Intra-airport transportation service other than by private auto is provided mainly by the Airtrans System, consisting of about thirteen miles of grade-separated concrete guideways over which operate twenty-four passenger, electrically-propelled, rubber-tired vehicles controlled automatically by a central computer. Airtrans was originally designed to provide the basic intra-airport transport service for passengers and employees and also to carry baggage, mail, supplies, and trash. At the time of the survey, however, the system was carrying only airline passengers.

Public Transportation Access

Public transportation to and from the airport is provided by bus, limousine, and taxi services. Private taxi carriers may drop off patrons at the airport but are prohibited from picking up riders leaving the airport. Surtran Taxi, Inc., has the exclusive right to carry passengers away from the airport.[7] A quasi-public corporation, Surtran, created by the cities of Dallas and Fort Worth, has an exclusive franchise to provide express bus service to and from the airport for air passengers, visitors, and employees. Surtran is described in greater detail later in this report. In addition, shuttle bus service is provided by various hotel and rental car companies using small minibuses or vans that carry passengers in both directions between DFW and the owning establishments.

EMPLOYEE TRAVEL SURVEY

Background

The 13,000 employees making work trips to and from DFW contribute significantly to the total traffic volume. A general classification of employees by type of industry and the number in each classification are shown in Table 1.

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[7] Shaw, James T., "Dallas-Fort Worth Airport: Trail Dust to Star Dust?," unpublished thesis, San Francisco State University, May, 1974.

TABLE 1. NUMBERS OF EMPLOYEES BY TYPE OF INDUSTRY

1.	Airlines	8,364
2.	Air Cargo	1,139
3.	General Aviation	100
4.	Food Service	1,406
5.	Maintenance (excluding airline employees)	379
6.	Security and Police	378
7.	Rent-a-Car Firms	268
8.	Miscellaneous	1,334
	TOTAL	13,368

The "Miscellaneous" category of Table 1 includes 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. An attempt was made to send survey forms to all employees through their respective employers.

Previous Research

There have been a large number of past studies of airport travel patterns, but the employee component has received little attention. Where employee travel has been surveyed, it has usually been found that at least 80 percent of airport employee travel is by private auto.[8] One objective of our research has been to examine the modal split of employee travel between auto and Surtran at the Dallas/Fort Worth Regional Airport.

[8] Verve Research Corporation, Analysis of Airport Access Traffic, A Study and Forecast of Air Passenger Ground Access Traffic, Report No. 2: Bibliography and Summary of Relevant Literature, August 1974.

Robinson and Nordlie[9] have presented an origin/destination survey of Washington National Airport. In the employee survey part of that study, the following procedures were followed:

(1) From an alphabetical listing of all employees of organizations having more than seventy-five employees, a sample consisting of every eighth person was selected, and a weekly record of travel patterns was obtained for that sample by personal interview.

(2) For organizations with less than seventy-five employees, questionnaires were sent by mail with instructions to be followed in selecting employees for the sample to be interviewed.

(3) The informaton obtained from the employee survey included

(a) work hours,

(b) home address,

(c) type of vehicle,

(d) automobile occupancy,

(e) travel time (to and from the airport), and

(f) attitude toward travel time, i.e., feeling about the travel time.

Only summary comments about the results of the employee survey are given by Robinson and Nordlie.

Chance[10] has presented a study of how the different users of airport access highways create ground transportation problems. He shows graphs depicting the daily movement of people at six airports: San Francisco, Washington National, Dulles, Friendship, Los Angeles, and London Heathrow. In this study, the percentages of the total volumes represented by daily employees were derived deterministically from the starting and ending work shift times. No reference to the distributions of times at which airport employees actually enter or leave the airport relative to scheduled work shift times could be found.

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[9] Robinson, John P., and Peter G. Nordlie, A Survey of Local Origins and Destinations of Users of Washington National Airport, U. S. Department of Commerce, Report HS-RR-61-5-MS-b, February 1961, pp. 37-43.

[10] Chance, Merrit O., Airport Access and Ground Traffic Study Review, (Graduate Report, Institute of Transportation and Traffic Engineering, University of California, Berkeley, 1968) pp. 18-31.

The Employee Survey Form

The employee survey form consists of a short introductory paragraph followed by eleven questions (see Figure 4).

In designing the form, attention was paid to the subsequent task of coding the data for computer analysis. On each survey form, space was provided for the direct transfer of the responses to coding boxes; this greatly facilitated the subsequent keypunching operation. Employees' street addresses were converted to North Central Texas Council of Governments Regional Analysis Area (RAA) zones.

Survey Method

The distribution and collection of the employee survey forms proved to be a time-consuming task, because seventy-one different airport employers were contacted. Most survey forms were distributed through the mail. A letter of introduction was included to explain the purpose of the survey, together with a set of detailed instructions for distribution and collection. Also included in the packet of information sent to employers were copies of a bulletin board flyer, suitable for posting, which announced the study. The survey forms were distributed through the employee supervisors. Collection of the completed questionnaires was accomplished in exact reverse order of the distribution. The individual employee gave the form to his supervisor, who, in turn, returned the forms by mail in a prepaid mailing envelope provided in the original packet; for a few of the largest employers, the completed forms were picked up by project staff.

Sample Size

Of the 13,368 employee forms sent, 3,157 were returned, a 23.6 percent rate of return. This rate could have been increased with tighter controls over the collection/distribution process but at a greater cost.

Critical Evaluation of Employee Survey

Problems with the Employee Survey involved wording of certain questions, length, and the fact that the DFW Airport Board had recently conducted a survey of its own, which contained several similar questions. Thus, some employees

DALLAS / FORT WORTH AIRPORT
EMPLOYEE TRAVEL SURVEY

Dear DFW Employee:

This survey is being conducted for the purpose of increasing our knowledge of airport-related travel.

Information from these questionnaires will be used to prepare plans and programs for the future development of transportation services to the DFW Airport so we can provide you with the best possible service.

Please take a few minutes to fill out the following questions and give the form to your supervisor.

Thank you.

PLEASE DO NOT MARK IN THIS BOX.

1. WHAT IS YOUR PRESENT STREET ADDRESS? [1 2 3 4]

______ (Street No.) (Street name) (City or Town) (Zip)

OR

______ (Nearest Street Intersection) (City or Town) (Zip)

2. YOUR TRAVEL DISTANCE (PLEASE ESTIMATE) [5 6 7]

A. Approximately how many miles long would you guess your total trip to or from the airport to be?

About ________ miles. [8 9]

B. How many miles would your trip be to the old airport, Dallas Love Field? About ________ miles [10 11]

3. YOUR TRAVEL TIME (PLEASE ESTIMATE)

A. Approximately how many minutes does your total trip to or from the airport take?

About ________ minutes. [12 13]

B. How many minutes would a trip to Love Field take? About ________ minutes. [14 15]

4. TYPE OF VEHICLE TAKEN TO AND FROM WORK: [16]

___Driving my own vehicle ___Taxi

___Riding in a carpool ___SURTRAN

___Being dropped off by someone ___Other (Please specify)________

5. YOUR PREVIOUS AIRPORT EMPLOYMENT:

A. Did you work at Dallas Love Field before the opening of the new Dallas-Fort Worth Regional Airport? ______ Yes ______ No [17]

B. IF YES, have you changed your place of residence or do you plan to change because of your shift to the new airport? ______ Yes ______ No [18]
If you have moved, what was your previous street address?

______ (Street No.) (Street Name) (City or Town) (Zip) [19 20 21 22]

OR

______ (Nearest Street Intersection) (City or Town) (Zip) [23 24 25]

C. Type of vehicle taken to Love Field: [26]

___Driving my own vehicle ___Taxi

___Riding in a carpool ___Public bus

___Being dropped off by someone ___Other (Please specify) ________

6. TIME THAT YOU ARRIVE AND LEAVE WORK: [27 28 29 30]

A. What time did you arrive at the airport TODAY?________ A.M. / P.M. [31 32 33 34]

B. What time did your work shift start TODAY?________ A.M. / P.M. [35 36 37 38]

C. What time will you get off work TODAY?________ A.M. / P.M. [39 40 41 42]

D. What time will you leave the airport TODAY?________ A.M. / P.M. [43 44 45 46]

7. FREQUENCY OF YOUR TRAVEL:

Please check the days of the week you work at the airport. [47 48 49]

___Sunday ___Tuesday ___Thursday ___Saturday

___Monday ___Wednesday ___Friday

8. YOU ARE: ___Male ___Female [50]

9. YOUR AGE: (PLEASE CHECK ONE) [51]

___Under 21 ___35-44 ___55-64

___21-34 ___45-54 ___Over 65

10. YOUR OCCUPATION: (PLEASE CHECK ONE) [52 53]

____Professional ____Craftsman, Foreman ____Other Labor

____Clerical ____Technician/Operator ____Service (Please check one)

____Sales ____Maintenance food/airline/custodian

11. YOUR FAMILY INCOME IS: (PLEASE CHECK ONE) [54]

____Under $6,500 ____$13,000 - $20,000 ____$26,000 - $32,000

____$6,500 - $13,000 ____$20,000 - $26,000 ____Over $32,000 [55 56 57 58]

FIGURE 4. EMPLOYEE TRAVEL SURVEY FORM

may have been irritated by the necessity of executing yet another survey form. The travel survey was also relatively complicated, e.g., the questions asking for time and distance estimates.

A small number of respondents interpreted question 2 as asking for a round trip distance. This could easily have been avoided by specifying one-way distance. Also, a few respondents may have misinterpreted question 2B as asking for the distance between DFW and Love Field since they were filling out the form at DFW. It was possible to spot-check this error by locations of the two airports relative to their homes.

Question 4 could be improved by asking for the vehicle taken "most often" or "usually," as we got several multiple responses.

Another troublesome question was the one that requested employees to classify themselves by occupation (professional, clerical, sales, craftsman/foreman, technician/operator, maintenance, other labor, service). It was deemed preferable to give the respondent a check list for this purpose to avoid nebulous and illegible answers. However, it turns out that the wording of such a list may also be conducive to misinterpretation by the respondent. In addition, a question of this type actually solicits the respondent's perceived self-classification.

PUBLIC TRANSPORTATION (SURTRAN) SURVEY

Description of System

Access to DFW by public transit is provided via Surtran (SURface TRANsportation), an express bus system franchised b, the cities of Dallas and Fort Worth exclusively to serve the airport. Surtran buses operate to and from the airport from five outlying passenger terminals--three in Dallas, one in Fort Worth, and one in Arlington. The Surtran route configuration is shown in Figure 5.

Background

Surtran was created based on a recommendation contained in a feasibility study by Arthur D. Little & Co., which indicated a strong potential ridership

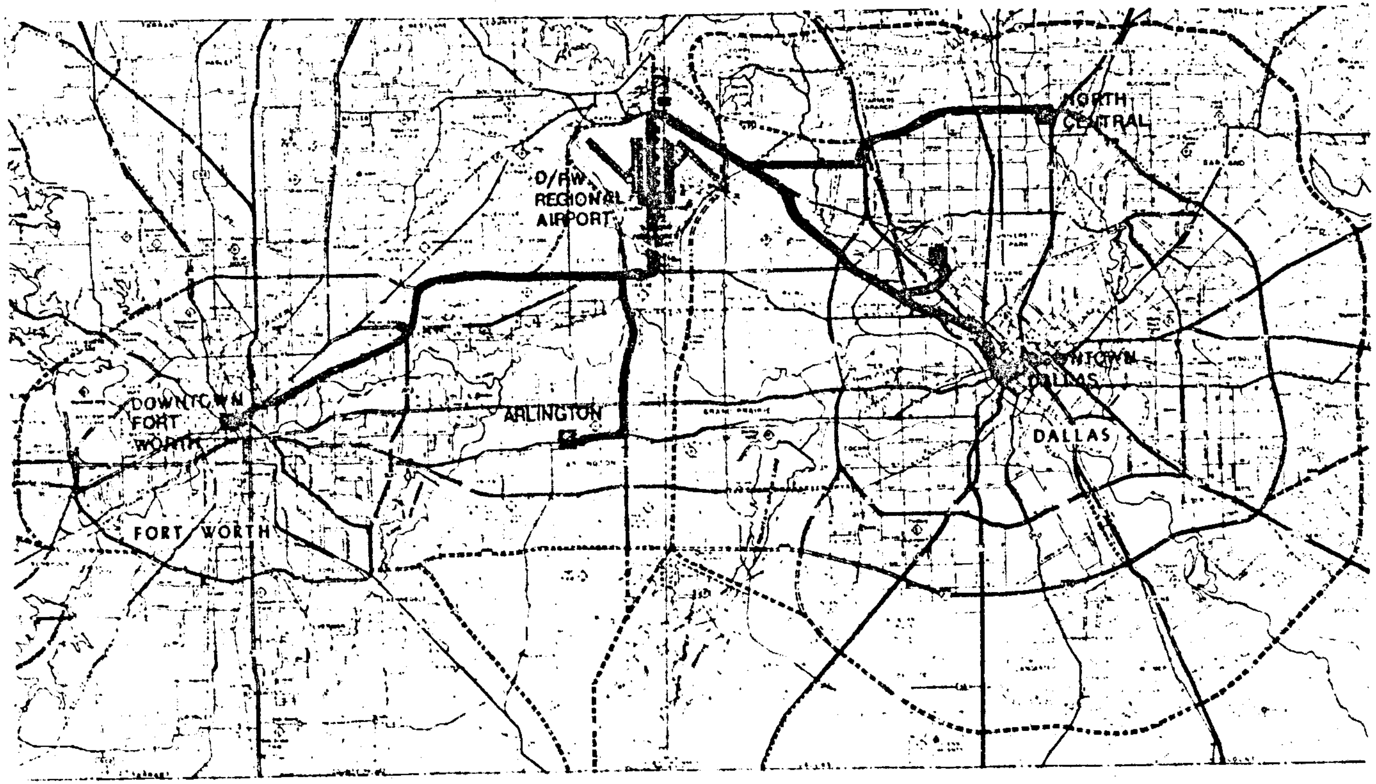

Figure 5. Surtran Route Map.

for express public transportation service to the airport.[11] A publicly owned system was selected, and the system is presently owned jointly by the cities of Dallas and Fort Worth. Initial organization and management of the system was undertaken by the Dallas Transit System and Fort Worth's city-owned Citran. Later, Surtran's own management was established, with offices in Arlington and a staff of approximately one hundred drivers, maintenance workers, ticket clerks, and other personnel.

Surtran ticket clerks dispense tickets at Surtran terminals (the outlying stations as well as at kiosks within the DFW airline terminals). Sale of Surtran tickets is subcontracted to hotels served in downtown Dallas and Arlington.

It was deemed important to survey Surtran riders for several reasons. First, they constitute a significant proportion of trips to and from the airport--about 3,000 daily passengers. Furthermore, demographic characteristics of Surtran riders may differ significantly from those of persons making auto trips to/from the airport.

Previous Public Transportation Surveys

No previous survey aimed specifically at public transit riders at Dallas Love Field could be found; the only related survey was an on-board survey of airline passengers, performed in 1969 by Alan M. Voorhees and Associates, in which a question on mode of travel was asked.[12]

Past studies of public transportation to airports contain very little detail on survey methods and materials. One noteworthy exception is the "Airport-Access-by-Transit Studies" in the New York area, conducted by the MIT Civil Engineering Systems Laboratory in 1970 through 1971.[13] The types of

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[11] Little, Arthur D., Inc., Public Ground Transportation for the Dallas-Fort Worth Regional Airport, Report to the Dallas-Fort Worth Regional Airport Board, August 1971.

[12] Voorhees, Alan M. and Associates, Inc., Air Passenger Survey Data Collection Program, Dallas Love Field Airport, Dallas, Texas, June 1969.

[13] De Neufville, Richard, "The Demand for Airport Access Services," Traffic Quarterly, October 1973.

data gathered in the MIT survey were similar to data of the DFW project, but the methods of administering the survey forms differed. The MIT group actually rode the buses with the riders and supervised the on-board completion of the survey form. In contrast, a strictly self-administered questionnaire handed out at ticket counters was chosen for the DFW survey in order to reduce manpower requirements. A 1968-69 Cleveland study utilized on-board airline passenger surveys, transit rider surveys, employee questionnaires, and interviews in parking lots and terminals.[14]

The Surtran Survey Form

The Surtran survey presented the challenging problem of designing a survey form which could be completed easily by Surtran riders while riding to or from the airport. These riders comprise a very diverse group in that they include airline passengers and airport employees who may be either residents or non-residents of the Dallas-Fort Worth area. The problem is further complicated by whether the bus is going to or from the airport. For these reasons, it was decided to design two separate forms, one for buses bound for the airport and the other for buses leaving the airport [see Figures 6(a) and 6(b)].

Survey Form Distribution and Collection

The method of purchasing Surtran tickets was conducive to handing out survey forms because, before boarding Surtran, a rider must purchase a ticket at a ticket counter. Therefore, it was decided to have ticket clerks hand out the forms to passengers and also provide pencils if necessary (not providing pencils might bias returns in favor of those who carry pencils). The rider then boarded the bus and completed the form while in transit; the survey form was printed on heavy paper to facilitate this on-board completion. Surtran drivers collected the forms as passengers left the bus.

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[14] De Neufville, Richard, et al., Airport and Air Service Access, U. S. Department of Transportation, March 1973.

surtran

DFW AIRPORT TRAVEL SURVEY

Dear Surtran Rider:

This survey is being conducted for the purpose of increasing our knowledge of airport-related travel.

Information from these questionnaires will be used to prepare plans and programs for the future development of transportation services to the DFW Airport so that we can provide you with the best possible service.

Please take a few minutes to fill out the following questions and give the card to your Coach Captain when you reach your final destination.

Thank you.

1 A WHERE IN THE DALLAS-FORT WORTH AREA WILL YOU FINALLY END YOUR TRIP AFTER YOU LEAVE SURTRAN?

____

(Street Name & Number, OR Nearest Intersection) (City or Town) (Zip)

OR

____

(Company Name or Business Location) (City or Town) (Zip)

B THE ABOVE ADDRESS IS

- ☐ Your home
- ☐ Someone else's home
- ☐ Your work place
- ☐ Another place of business
- ☐ Hotel/Motel
- ☐ Shopping
- ☐ Other (please specify) ____

C WHAT CITY OR TOWN ARE YOU A RESIDENT OF?

____

(City or Town) (State) (Zip)

D WHAT TYPE OF VEHICLE WILL YOU TAKE FROM THE SURTRAN TERMINAL? (Please Check One)

- ☐ City bus
- ☐ Limousine
- ☐ Taxi
- ☐ Drove my own vehicle
- ☐ Picked up by someone
- ☐ Other (please specify) ____________________

2\. YOUR TRAVEL DISTANCE (Please Estimate)

A Approximately how many miles would you guess your total trip to be from the airport to your final destination (as stated in question 1)? About ________ miles

B How many miles would your trip be from the old airport, Dallas Love Field, to your final destination? About ________ miles.

C How many miles is the trip from where you will get off SURTRAN to your final destination? About ________ miles. (If you are staying at a hotel where you will leave SURTRAN, check here ☐ and skip part D.)

D From where you will get off SURTRAN, is your final destination (Check one).
☐ very convenient, ☐ convenient, OR ☐ inconvenient for you

3\. YOUR TRAVEL TIME (Please Estimate)

A Approximately how many minutes will your total trip take from the airport to your final destination? About ________ minutes.

B How many minutes would a trip from Love Field have taken? About ________ minutes

4\. WHEN LOVE FIELD WAS THE MAIN AIRPORT, WHAT TYPE OF VEHICLE DID YOU USE MOST OFTEN? (Please Check Only One)

- ☐ City Bus
- ☐ Limousine
- ☐ Taxi
- ☐ Rent-A-Car
- ☐ Drove my own vehicle
- ☐ Picked up by someone
- ☐ Other (please specify) ____________________

5\. PURPOSE OF YOUR TRIP TO THE AIRPORT (Please Check One)

- ☐ Airline Passenger
- ☐ Greeting someone
- ☐ Seeing someone off
- ☐ Pick up an airline ticket
- ☐ Airport employee
- ☐ Business at airport
- ☐ Visitor
- ☐ Other (please specify) ____________________

6\. FREQUENCY OF YOUR TRAVEL TO THE AIRPORT

A How many times have you traveled to the new airport recently? About ________ times last month, OR ________ time last year.

B How often did you make trips to Love Field before the new airport opened? About ________ times per month, OR ________ times per year

C Do you still use Love Field now? ☐ Yes ☐ No
If YES, how often? About ________ times last month, OR about ________ times last year.
What type of aircraft do you fly? ☐ Commercial ☐ Private

(OVER)

FIGURE 6(a)
SURTRAN SURVEY FORM (FRONT)

7. FOR AIRLINE PASSENGERS ONLY

A. What airport did you fly from? ______________________________ (Airport and/or City)

B. What airline flight did you arrive on?
Airline (Please check one) Flight No. ________

- ☐ American
- ☐ Braniff
- ☐ Continental
- ☐ Delta
- ☐ Eastern
- ☐ Frontier
- ☐ Metroflight
- ☐ Mexicana
- ☐ Ozark
- ☐ Texas International
- ☐ Other (please specify) ______________

C. What time did your flight arrive? ________ ☐ A.M. ☐ P.M.

D. What was the purpose of your air trip?

- ☐ Business/employment
- ☐ Vacation
- ☐ Convention
- ☐ Personal Affairs
- ☐ Visiting family or friends
- ☐ Military
- ☐ School
- ☐ Other (please specify) ______________

E. Please indicate the duration of your air trip:

- ☐ 1 day
- ☐ 2 - 4 days
- ☐ 5 - 7 days
- ☐ 1 - 2 weeks
- ☐ 3 - 4 weeks
- ☐ Over 1 month

F. If you are a resident of the Dallas-Fort Worth area, how did you leave here? ☐ Flew out ☐ Drove out ☐ Other
If you are not a resident, how will you return home? ☐ Fly back ☐ Drive back ☐ Other

G. How many other people flew with you, in your party? ________

8. SURTRAN INFORMATION

A. How did you first find out about the services provided by SURTRAN?

- ☐ TV
- ☐ Radio
- ☐ Newspaper
- ☐ Display
- ☐ Brochures
- ☐ Ticket Booth
- ☐ Inflight Magazine
- ☐ Personal Recommendation
- ☐ Other (please specify) ______________

B. Why did you take SURTRAN? (Please rank the following in the order of importance to you.)

- _____ Avoid traffic
- _____ Avoid parking cost
- _____ Avoid confusion at airport
- _____ Avoid trip to airport for person delivering you
- _____ No auto available
- _____ Save time
- _____ Other (please specify) ______________

C. Is this your first trip on SURTRAN? ☐ Yes ☐ No

D. In the future—as a portion of all your trips to DFW Airport—will you ride SURTRAN on: (please check one)

- ☐ most of your trips
- ☐ some of your trips
- ☐ only a few of your trips
- ☐ won't be going back to DFW Airport

WHATEVER your response to the previous question, please tell us WHY?
____

9. YOU ARE: ☐ Male ☐ Female

10. YOUR AGE (Please Check One)

- ☐ Under 21
- ☐ 21-34
- ☐ 35-44
- ☐ 45-54
- ☐ 55-64
- ☐ Over 65

11. YOUR OCCUPATION

A. Position

- ☐ Professional
- ☐ Clerical
- ☐ Sales
- ☐ Craftsman/Technician
- ☐ Student
- ☐ Retired
- ☐ Service (circle one) food domestic other
- ☐ Other (please specify) ______________

B. Type of Industry

- ☐ Construction
- ☐ Manufacturing
- ☐ Transportation
- ☐ Wholesale/Retail Trade
- ☐ Communications & Utilities
- ☐ Public Administration
- ☐ Finance, Insurance, & Real Estate
- ☐ Education
- ☐ Military
- ☐ Other (please specify) ______________

12. YOUR ANNUAL FAMILY INCOME

- ☐ Under $6,500
- ☐ $6,500 - $13,000
- ☐ $13,000 - $20,000
- ☐ $20,000 - $26,000
- ☐ $26,000 - $32,000
- ☐ Over $32,000

FIGURE 6(b)
SURTRAN SURVEY FORM (BACK)

Critical Evaluation of Surtran Survey

Our initial data analysis indicates that the design of the survey form was satisfactory; little confusion was evident in the returned forms. However, it was found that part A of questions 2 and 3 would have been improved by specifying "DFW," rather than just "the airport." A few respondents apparently interpreted the question to refer to the airport at the other end of their flight. Similar confusion occurred in a few cases with part A of question 7. In question 8, which deals with factors affecting mode choice, very few people attempted to rank the alternatives listed; instead, most just checked off one or two items. Perhaps only the most important factor(s) should have been requested.

ROADSIDE SURVEY OF AUTOMOBILE USERS

Previous Research

Most past surveys of automobile travel by air passengers to and from major airports have used questionnaires distributed and completed on board the aircraft during flight.[15] Standard techniques for conducting such surveys have been compiled and synthesized by Barton Aschman Associates, Inc., in their Airport Travel Survey Manual.[16]

The same manual also describes roadside interview techniques similar to the one used in this research. The manual recommends that the personal interview technique be limited to airports "...where activity levels are low or

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[15] Corradino, Joseph C., "The Philadelpha Airport Origin-Destination Survey-A Statistical Analysis," Highway Research Record, No. 330, 1970; Port Authority of New York and New Jersey, New York's Domestic Air Passengers, February 1972 Thru January 1973, The Port Authority of New York and New Jersey/Aviation Economics Division; Port Authority of New York and New Jersey, New York's Transatlantic Air Passenger Market--May 1968 through April 1969, The Port of New York Authority/Aviation Economics Division, September 1970; Port of New York Authority, New York's Domestic Air Passenger Market June 1967 Through May 1968, The Port of New York Authority/Aviation Economics Division, December 1970; Voorhees, op. cit.

[16] Barton-Aschman Associates, Inc., Airport Travel Survey Manual, U. S. Department of Transportation, Washington, D. C., July 1973.

where trip makers to be surveyed are concentrated at a small number of points." The manual also points out that, "Personal interviewing is most applicable when certain aspects of the questionnaire cannot be understood by respondents, or when the line of questioning followed is dependent on the response to specific questions."[17] The selection of the roadside interview technique for the DFW survey of auto passengers was based, in part, on the above recommendations. Besides, it was felt that much of the information sought, e.g., auto occupancy, perceived time and distance, the specific route taken to and from the airport, and the times of entering and leaving, could best be determined from a personal interview on the roadside.

Consideration was given to handing out postcards to drivers as they entered the control booths and collecting cards as they left. It was estimated that the cost of postcards coupled with manpower for sending them out would be nearly double the cost of the roadside interview. Besides, the DFW Airport Board expressed the concern that persons handing out cards at the control booths would cause confusion at airport gates.

Scope of Roadway Survey

It was decided to limit interviews to vehicles on the outgoing lanes of the airport spine roads, i.e., interview vehicles only as they left the airport. This decision was made under the hypothesis that persons leaving the airport would be less reluctant to stop for an interview than persons on their way to catch a flight. Feedback from the interviewers suggested that the above hypothesis was correct.

Location of Interview Stations

Consideration was initially given to interviewing vehicles at the control plazas when they stopped to pay their parking fee. However, this method was rejected on the basis that unnecessary traffic congestion and other problems would be created at the affected control booths. Instead, it was considered preferable to locate the interview stations just outside the control plazas, placing one on each side of the outgoing spine roads at each end of the airport, for a total of four interview stations. This was the maximum number deemed appropriate given budgetary constraints and the physical configuration of the airport exits.

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[17] Ibid.

Physical Situation

Vehicles were interviewed at both ends of the airport between 6:00 a.m. and 10:00 p.m. as they exited from the control booths. Four interviewers, two flagmen and two traffic counters were stationed at each end of the airport. Figure 7 shows the physical setup of the interview lanes. Interviews were conducted in turnouts located about one hundred feet beyond the control booths. A sign identifying the survey was placed at the entrance to each interview lane, and traffic cones were used to channelize vehicles to the interview point (Figure 8).

The specific traffic lanes open through the control plaza varied throughout the day. Booth 1 was always open due to its use by Surtran buses and other larger vehicles. The other booths were opened as demand warranted, starting with Booth 2. During low volume periods, booths 1-4 were usually open, which required a setup of the left interview lane closer to these open lanes so that vehicles could be directed to the interview point without having to cross too many lanes (see Figure 7).

The Auto-User Interview Form

The auto-user interview form is shown in Figure 9. In designing this form, careful attention was paid to the phrasing of questions. When asking for destination, for example, it was felt important to first ask for the street address or hundred block and then, if these could not be ascertained, to ask for the nearest street intersection. In requesting the routes that drivers planned to take to their next destination, it was necessary to be very persistent in asking for the next street along the route because most drivers had a tendency to stop after giving two or three legs of their journey, which often left a significant distance away from their final destination unaccounted for.

Similarly, for questions on perceived time and distance, drivers frequently had to be coaxed to respond satisfactorily. In most cases, distance presented the most difficulty. The question on purpose of the air trip also required persistence, since many passengers did not distinquish between the given categories, e.g., that the "convention" category is distinct from the "business" one.

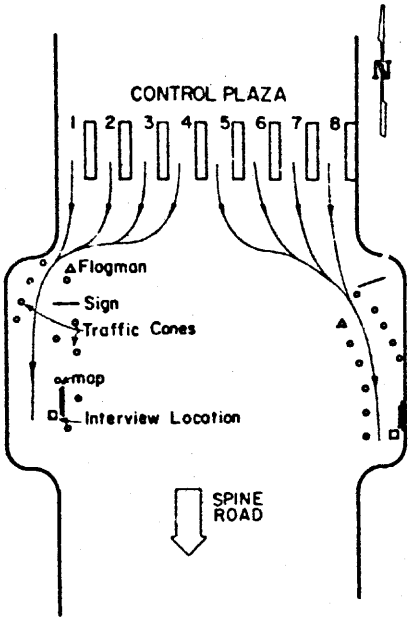


FIGURE 7. DETAIL OF INTERVIEW STATION

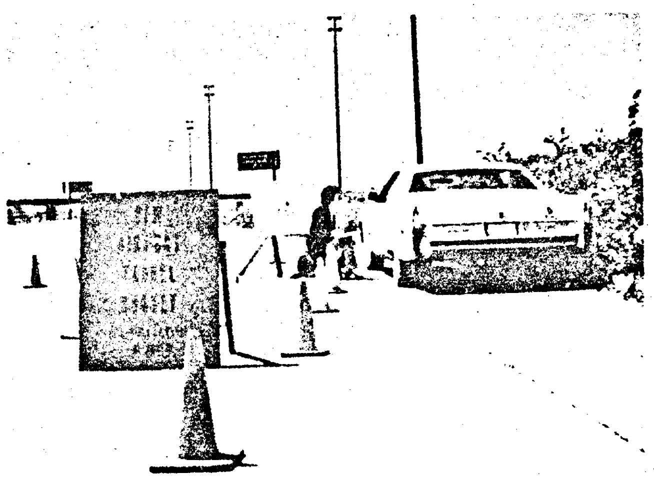


FIGURE 8. TYPICAL AUTO SURVEY STATION

SHORT FORM
DFW ORAL AUTO SURVEY

Surveyor Number ________

Time ________ AM / PM Number of CP's ________ M ________ F

Driver: ____ M ____ F

Type of Vehicle: ____ Private car ____ Rent-a-car

1 2 / 3 4 5 6 / 7 8 / 9 10

INTRODUCTION

1. Purpose of trip to airport?
   - ___ AP, alone
   - ___ Drop off AP
   - ___ Pick up AP
   - ___ Business at airport
   - ___ Pick up ticket
   - ___ Visitor
   - ___ Other (specify) ________

11

1. What city or town are you a resident of?

____

12 13 14

2. 1. Number of AP's ________ M ________ F
   2. What city are AP's residents of?

____

15 16 / 17 18 19

3. TRIP FROM AIRPORT
   1. What is your next destination?

____

____

20 21 22 23 / 24 25 26

   2. ___ Your home ___ Hotel
      ___ Someone else's home ___ Shopping
      ___ Your work place ___ Other (specify)
      ___ Another place of business ________

27

   3. How many miles? ________
   4. How many minutes? ________
   5. Route ________

28 29 / 30 31

4. TRIP TO AIRPORT
   1. Where did trip to airport start?

____

____

32 33 34 35

   2. ___ Your home ___ Hotel
      ___ Someone else's home ___ Shopping
      ___ Your work place ___ Other (specify)
      ___ Another place of business ________

36

5. 1. Time got to control booth: ________ AM / PM
   2. What kind of parking did you use?
      ___ Short-term ___ Curb
      ___ Remote

37 38 39 40 / 41

5. FREQUENCY OF AIRPORT USE:
   1. Times used DFW airport: ________ times last ☐ month ☐ year
   2. Times used Love Field before DFW opened: ________ times per ☐ month ☐ year
   3. Use Love Field now? ____ Yes ____ No
      ________ times last ☐ month ☐ year ☐ Private ☐ Comm'l
   4. How many miles to Love Field from next stop?
      ________ miles
   5. How many minutes? ________ minutes
   6. When Love Field was main airport, type of vehicle used most often?
      - ___ City bus
      - ___ Limousine
      - ___ Taxi
      - ___ Courtesy bus
      - ___ Drove own vehicle
      - ___ Dropped off by someone else
      - ___ Rent-a-car
      - ___ Other ________

42 43 / 44 45 / 46 47 / 48 49 / 50 51 / 52 53

6. AIRLINE FLIGHT INFORMATION
   1. Other airport: ________
   2. Flight number: ________
      ___ AA ___ EA ___ OZ
      ___ BN ___ FL ___ TI
      ___ CO ___ METRO ___ Other
      ___ DL ___ MX ________
   3. Purpose of air trip:
      ___ Business/Employment ___ Visiting
      ___ Vacation ___ Military
      ___ Convention ___ School
      ___ Personal Affairs ___ Other ________
   4. When return trip? ________ ☐ fly ☐ drive ☐ other?

54 / 55 56 57 / 58 59 60 / 61 62 / 63 / 64 65 66

7. PERSONAL DATA (AP'S AND D's)
   1. Occupation:
      D ________ Position Industry
      AP ________
   2. Age: ___ A. Under 21 ___ D. 46-55
      ___ B. 21-35 ___ E. 56-65
      ___ C. 36-45 ___ F. Over 65
   3. Family Income:
      ___ A. Under 6.5k ___ D. 20k - 26k
      ___ B. 6.5k - 13k ___ E. 26k - 32k
      ___ C. 13k - 20k ___ F. Over 32k

67 / 68 69 70 71 / 72 73 74 75 / 76 77 / 78 79 / 80 81 82 83 / 84 85 86 87

FIGURE 9. AUTO-USER SURVEY FORM

The procedure for asking the questions on age involved handing the driver and the air passenger a card containing ranges of age, each identified by a letter, A through F (see Figure 10). The respondents were asked to indicate the age category in which they were included by specifying the corresponding letter. A similar procedure was followed in asking for family income. This method worked very well and made answering these personal questions quite acceptable to the respondents.

Interview Rate and Sample Size

An average interview took approximately three to four minutes, depending on the purpose of the trip to the airport and the response pace of the driver. Additional time was needed, between interviews, to record the time of day and vehicle occupancy figures, and to recheck the form to see that all questions were completed and legible. Another element of the time interval between interviews was the time required to flag another vehicle into the interview lane; this was a function of delays at the control booths, slack periods in traffic flow, and the occasional refusal of drivers to be interviewed. The average interviewing rate was 8.4 interviews per hour per interviewer.

AGE

A.	Under 21	D.	46 - 55
B.	21 - 35	E.	56 - 65
C.	36 - 45	F.	Over 65

FIGURE 10. AGE CATEGORY CARD

On Friday, May 15, 1975, there were 278 interviews at the north end and 219 at the south end, for a total of 497 interviews. Tuesday, May 20, 1975, interview totals were 180 north and 209 south, for a total of 389 interviews. Combining the two days, a total of 886 interviews were conducted, which corresponded, approximately, to a five percent sample size, based on traffic counts made during the same time periods.

TRAFFIC COUNTS

Traffic counts were conducted to determine traffic volumes by direction and vehicle type on the various access roads to the airport. These data provide the basis for expanding the roadside interview sample to represent the entire population of vehicles entering and leaving the airport.

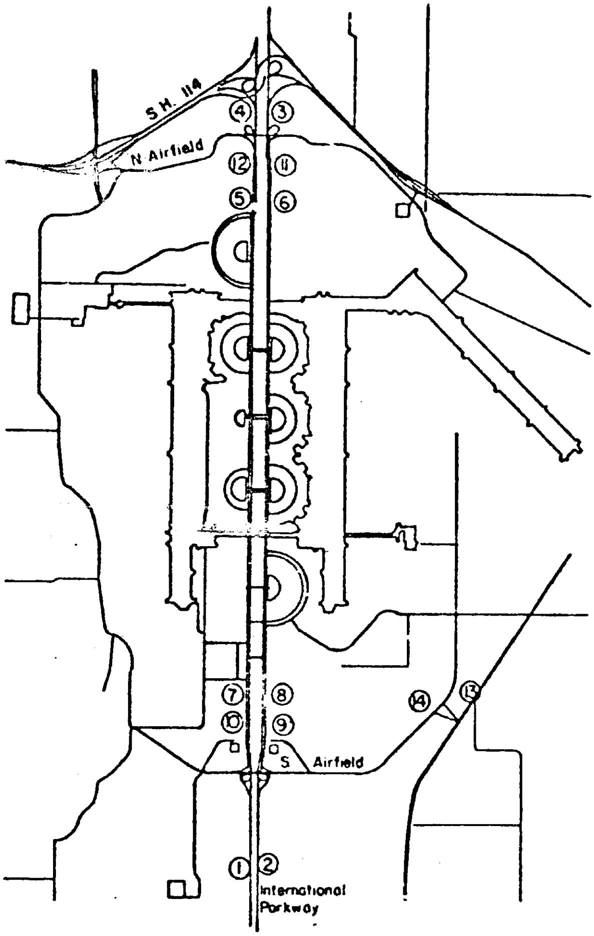
Both machine counts and manual counts were conducted. Manual counts were necessary for determining the classification of vehicles and for converting axle counts (machine counts) to vehicle counts; only passenger cars and private pickup trucks were being interviewed. Machine counts were used to obtain 24-hour volumes, as well as traffic volumes during the interview period (6:00 a.m. to 10:00 p.m.). The location of the machine counters (automatic tube type) is illustrated in Figure 11.

DATA REDUCTION AND STORAGE

Results from the various survey forms, traffic counts, and passenger counts were coded for computer input and stored on magnetic tape in the System 2000 Data Management Package. Through the use of System 2000, various data files were created for easy access. This also facilitated the definition of new data files, modification of existing files, and retrieval and updating of the data in these files.

AUSTIN TEST SURVEY

Many of the questions and techniques included in our survey had not been reported or tested in previous airport access surveys, e.g., interviewing only people leaving the airport, perceived time and distance questions, and questions on the routes taken by auto passengers. Therefore, it was decided to perform a preliminary study at Robert Mueller Municipal Airport in Austin,



STATION INDEX

1. South International Parkway South Bound (Exit)
2. South International Parkway North Bound (Entrance)
3. North International Parkway North Bound (Exit)
4. North International Parkway South Bound (Entrance
5. North International Parkway (Control Plaza) South Bound (Entrance)
6. North International Parkway (Control Plaza) South Bound (Entrance
7. South International Parkway (Control Plaza) South Bound (Exit)
8. South International Parkway (Control Plaza) North Bound (Entrance)
9. South Service Road-North Bound (Entrance
10. South Service Road-South Bound (Exit)
11. North Service Road-North Bound (Exit)
12. North Service Road-South Bound (Entrance)
13. South Airfield Drive (West Bound)
14. South Airfield Drive (East Bound

FIGURE 11. DEPLOYMENT OF MACHINE TRAFFIC COUNTERS

Texas, to test out the survey forms and procedures. This airport was chosen because of its proximity to The University of Texas at Austin campus.

Robert Mueller Municipal Airport was not served directly by a scheduled bus route at the time of the survey. Therefore, the equivalent of a Surtran rider survey could not be tested in Austin. Roadside interview and employee survey techniques were tested. The lack of a Surtran survey trial was not considered serious because most of the Surtran questions had very similar counterparts on the roadside interview and employee forms. This pilot study led to major improvements and refinements in our survey instruments and procedures.

III. DATA ANALYSIS

INTRODUCTION

The most salient findings of the DFW Travel Survey are presented in this chapter. For simplicity, the survey data of 16 May 1975 are referred to merely as "Friday" and 20 May 1975 as "Tuesday." In some cases, data were available only for 16 May 1975; therefore, that is identified for convenience as the "sample date." It must be emphasized that "auto-users" as applied herein refers to all users of personally-operated motor vehicles (mostly autos) and is applied for convenience only. "DFW Employees" has been used to identify all employees based at DFW, not simply employees of DFW itself.

COMPREHENSIVE RESULTS

This section summarizes pertinent findings relative to all three survey components considered in the aggregate. Each individual survey is discussed in detail in subsequent sections.

Air Passenger Traffic

Figures 12(a) and 12(b) and 13(a) and 13(b) illustrate originating and terminating air passenger volumes by hour of day for both survey dates, 16 May 1976 and 20 May 1976. These data are derived from information supplied to the project by the individual airlines (adjusted and interpreted in some cases by project staff). The illustrations show that peaking characteristics for the two separate days were quite similar.

In the travel survey, air passengers were requested to give their air trip origins or destinations (O/Ds). In order to discern the general patterns of air travel into and out of DFW, these O/Ds have been grouped into the following eight regions or categories:

(1) Texas: all exclusively intra-state O/Ds;

(2) States bordering on Texas: O/Ds to/from New Mexico, Oklahoma, Arkansas, Louisiana;

(3) Northeast states: Maryland, District of Columbia, Delaware, Pennsylvania and north to Maine;

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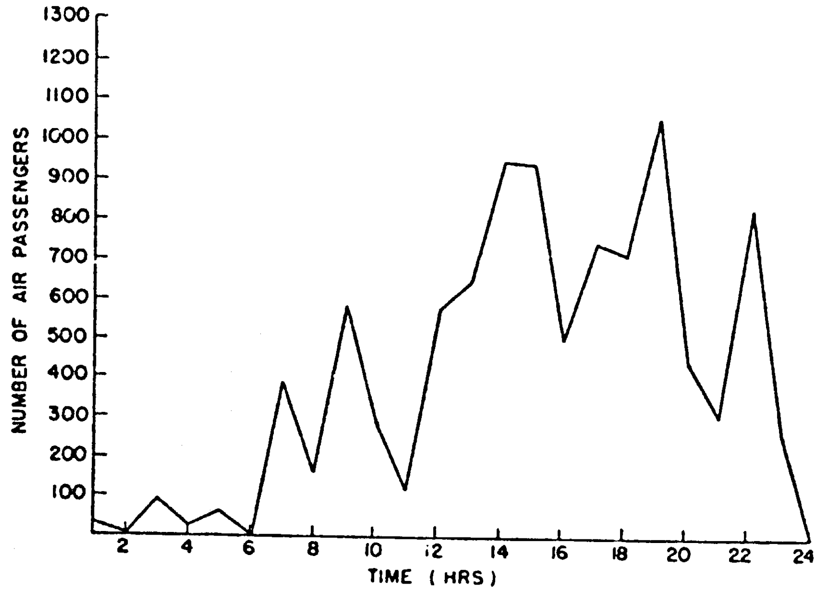
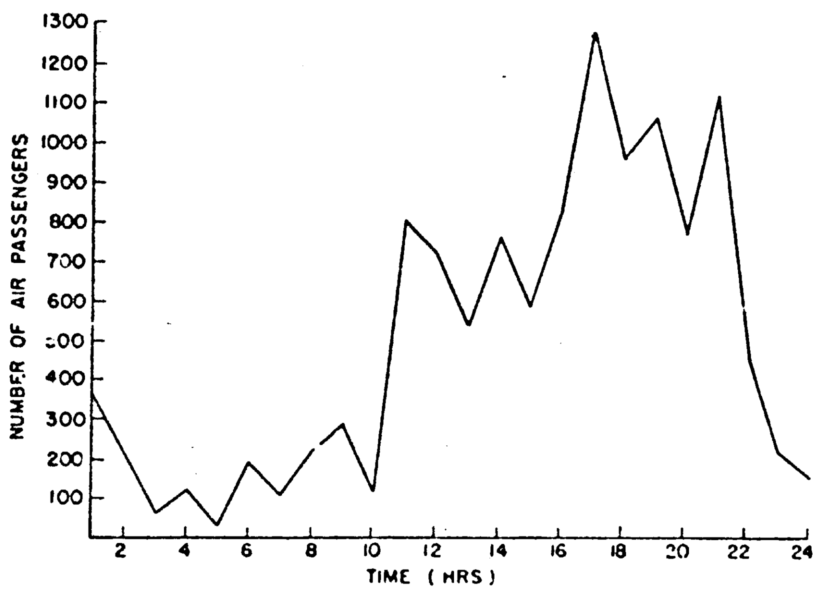
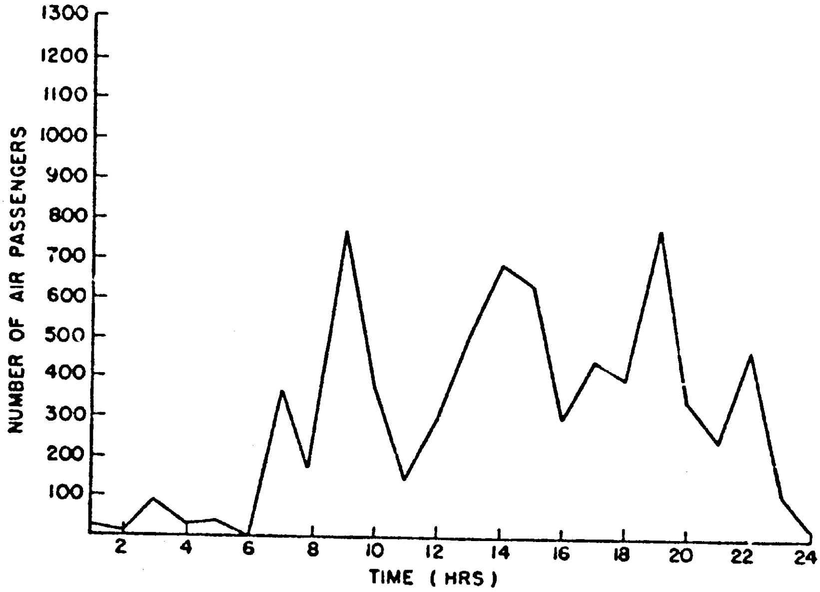


(a) ORIGINATING

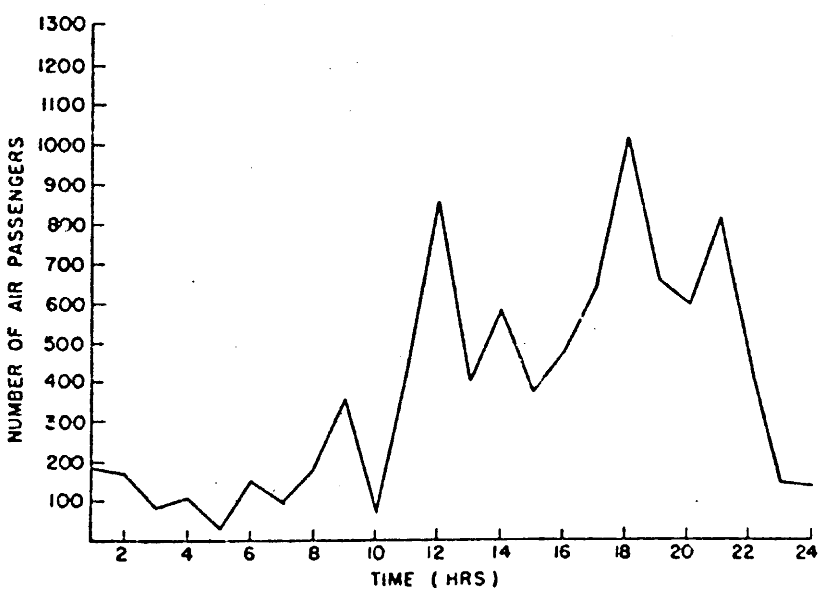


(b) TERMINATING

FIGURE 12. HOURLY DISTRIBUTION OF DFW AIR PASSENGERS, FRIDAY



(a) ORIGINATING



(b) TERMINATING

FIGURE 13. HOURLY DISTRIBUTION OF DFW AIR PASSENGERS, TUESDAY

(4) South and Southeastern states: Virginia, West Virginia, Kentucky, Tennesec, North and South Carolina, Mississippi, Alabama, Georgia, Florida;

(5) Midwest states: Ohio, Michigan, Indiana, Illinios, Wisconsin, Minnesota, Iowa, Missouri, North and South Dakota, Nebaraka, Kansas;

(6) Western states: Montana, Wyoming, Colorado, Idaho, Utah, Arizona, Nevada;

(7) Far west states: Washington, Oregon, California, Alaska, Hawaii;

(8) Out of United States: O/Ds to/from points outside of the fifty states, including Canada and Mexico.

The respective shares of total O/Ds to or from DFW and these eight O/D categories are given in Table 2. It can be noted that over one-third (35.0%) of DFW air passenger O/Ds are located either within Texas or its four border states (which might be considered as "short-haul" trips). Further, as exhibited in Table 3, eight major cities account for over one-third (36.7%) of total O/Ds.

Utilizing this O/D information, air passenger trips were then classified as either long-haul or short-haul (within a radius of roughly 500 miles). As shown in Table 4, there is significant difference between users of the two primary ground travel modes, Surtran versus auto, in terms of characteristic trip length. Surtran carries a much larger percentage of long-distance air passengers. Some of this difference might be attributed to the relatively greater number of non-residents using Surtran.

The proportionate purposes of air trips are tabulated in Table 5. It can be readily seen that some two-thirds of these trips are for "Business/Employment" purposes.

The duration of the air trip was also investigated for air passengers using both Surtran and automobile. Again, on the average, there was no significant difference between the modes (even though there was variation between the two survey days). For air passengers using Surtran, 22 percent were on one-day trips, 41 percent were on 2-4 day trips, 21 percent were 5-7 days, 11 percent were 1-2 weeks, and 5 percent of the passengers were on longer trips. This corresponds closely to the auto survey results. There was also similarity in the air passengers' mode of travel on the other long-haul leg of their trip. For both modes, 90 percent of the air passengers flew on their return trip, 7 percent drove, and 3 percent went by some other mode (train, intercity bus, etc.).

TABLE 2

REGIONAL DISTRIBUTION OF DFW AIR PASSENGER ORIGINS AND DESTINATIONS

O/D REGION	% OF TOTAL O/Ds
Texas	20.1
States Bordering on Texas	14.9
Northeast States	14.2
South and Southeastern States	13.9
Midwest States	18.4
Western States	5.9
Far West States	10.6
Out of U.S.	2.0

TABLE 3

CITIES WITH LARGEST SHARE OF ORIGINS AND DESTINATIONS

CITY O/D	% OF TOTAL O/Ds
Houston	6.1
New Orleans	3.8
New York City	5.[illegible]
Washington, D.C.	3.5
Atlanta	4.0
Chicago	5.9
Denver	3.0
Los Angeles	4.6
TOTAL	36.7

TABLE 4

DISTRIBUTION OF LONG-HAUL VERSUS COMMUTER AIR PASSENGERS, BY GROUND MODE

FLIGHT CLASS	SURTRAN	AUTOMOBILE
Long-Haul	71.5%	29.2%
Commuter	28.5%	70.8%

TABLE 5

PURPOSE OF AIR TRIPS

PURPOSE	% OF TOTAL
Business/Employment	67.7
Vacation	10.3
Convention	3.0
Personal Affairs	4.9
Visiting	10.3
Military	1.5
School	1.1
Other	1.2
TOTAL	100.0

Comparing the number of air passengers per party between Surtran and automobile users, shows that an observable difference exists. As illustrated in Figure 14, there is a slightly greater proportion of multiple-member groups using Surtran. Air passengers traveling alone made up 83 percent of auto-using air passengers but only 64 percent of those using Surtran. However, this difference may be somewhat artificial due to multiple responses from groups of air passengers.

No other significant differences in the characteristics of auto-using versus Surtran-using air passengers have been detected, except for residency in the Dallas/Fort Worth area, as exhibited in Table 6. (A resident is defined as a person who lives in the North Central Texas Nineteen-County Planning Region.) While Surtran-using air passengers are virtually equally divided between residents and non-residents, predominantly more auto-using air passengers tend to be residents. This is not surprising considering the out-of-town visitor's greater dependence on public transportation.

Ground Traffic

Table 7 gives the overall modal split determined from the data in terms of both person trips and vehicle trips. The "Automobile" mode includes both personally owned and rented vehicles. Also included in that designation are personally-owned trucks, e.g., pickups, campers, motor homes, and camping vans, as well as motorcycles. "Other buses, shuttle vans, etc." refers mainly to public transit vehicles owned and operated by hotels and car rental agencies for the convenience of their customers. The "Other" category refers to commercial vehicles.

From Table 7, it can be seen that some 46,380 vehicles entered and left DFW on the sample date. These correspond to 72,394 person trips to and from the airport. Surtran accounted for 4.2% of person trips but represented only 0.8% of the vehicular traffic due to the higher vehicle occupancy rates of Surtran buses compared to automobiles. The combination of Surtran, taxis, and the private special-purpose transit services carried 9.0% of the total person-trips to and from DFW.

Table 8 gives the contribution of each of the three surveyed DFW ground transportation components (employees, Surtran riders, and air passenger and visitor auto users) to the total ground traffic of the sample date. (Note that employees represent about one-fourth of the total person-trips to and

FIGURE 14

NUMBER OF AIR PASSENGERS IN PARTY BY GROUND ACCESS MODE

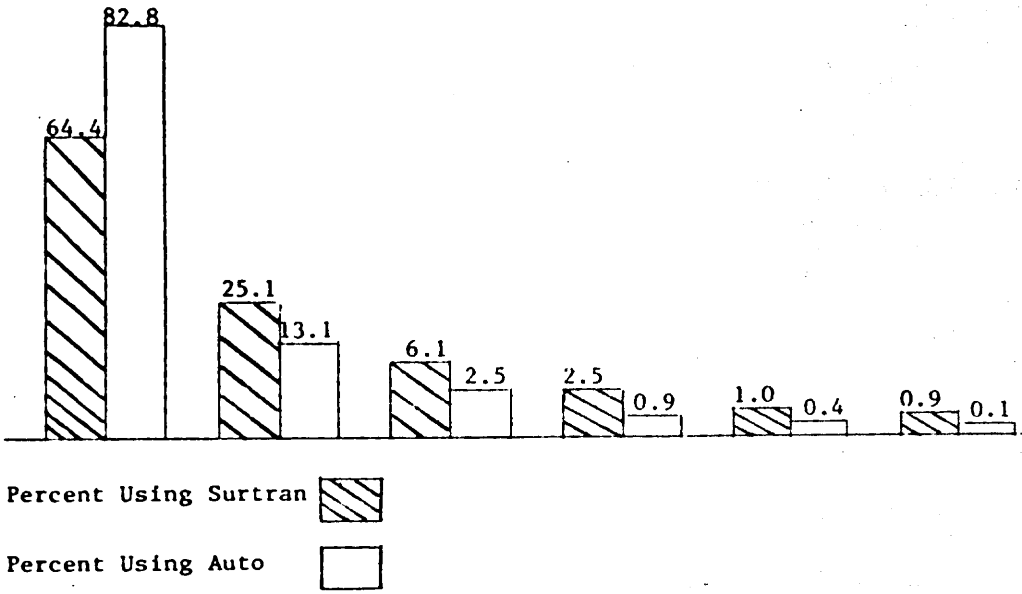


TABLE 6

DALLAS/FORT WORTH AREA RESIDENCY OF AIR PASSENGERS, BY MODE

RESIDENCY	SURTRAN	AUTOMOBILE
Resident	49.6%	58.4%
Nonresident	50.4%	41.6%

TABLE 7

DFW GROUND TRANSPORTATION MODAL SPLIT

Mode	Vehicle-Trips	Percent	Person-Trips	Percent
Automobile	43,133	93.0	64,992	89.8
Taxi	1,391	3.0	2,221	3.0
Surtran bus	393	0.8	3,035	4.2
Other buses, shuttle vans, etc.	813	1.8	1,301	1.8
Heavy trucks, other	650	1.4	845	1.2
TOTAL	46,380	100.0	72,394	100.0

TABLE 8

CONTRIBUTION TO DFW GROUND TRAFFIC BY MAJOR COMPONENT

COMPONENT	PERSON-TRIPS	PERCENT
Employees, service personnel, etc.	18,623	25.7
Surtran, taxis, other buses, etc. (excluding employees)	6,107	8.4
Auto-using general public	47,664	65.9
TOTAL	72,394	100.0

from DFW).

From the airline passenger data, it was determined that 22,384 air passengers originated or terminated their journeys at DFW on the sample date. The hourly distributions of these originating and terminating air passengers are illustrated in Figures 12(a) and 12(b). Note that the most pronounced peaking occurs for terminating passengers at about 16:00 hours [Figure 12(b)].

Table 9 presents the ground transportation modal split of air passengers only. Clearly, Surtran's share of air passengers is significantly higher (10.9%) than its share of total person trips (4.2%). In fact, all public transportation modes taken together account for 25.7% of the air passenger ground travel to or from DFW. Surtran's share of air passenger trips represents almost a tripling of the proportion of air passenger trips previously carried by equivalent bus services at Love Field before DFW opened.

The land use at off-airport ground trip origins is illustrated in Figure 15, segregated into Surtran and auto (personal motor vehicle) trips. Overall, this varies in a predictable manner because the Surtran categories include a relatively high proportion of non-resident business persons. This is particularly clear in the "your home" and "hotel or motel" categories.

In terms of airport use, air passengers riding Surtran fly roughly one-half as often as air passengers who use the automobile to access the airport. The median airport-use frequency for Surtran riders was eight times per year, as opposed to twenty times per year for auto users. No explanation factor could be found for this difference.

Demographic Characteristics of the Three Components of Travel

In all three component surveys, information on socio-economic characteristics such as age, income, and occupation were requested. It is interesting to compare these results among the three component groups.

Table 10 compares the proportional distribution of age categories. There is a tendency for employees to be slightly younger than the other two groups. Surtran riders are clearly older than the other categories, e.g., 39.1 percent over 45 years of age compared to 18.0 percent for employees and 31.1 percent for air passengers.

Table 11 compares the proportional distribution of occupational categories

TABLE 9

DFW GROUND TRANSPORTATION MODAL SPLIT FOR ORIGINATING/TERMINATING AIR PASSENGERS

MODE	PASSENGERS	PERCENT
Automobile*	16,626	74.3
Surtran bus	2,447	10.9
Taxi	2,088	9.3
Other buses, shuttles, etc.	1,223	5.5
TOTAL	22,384	100.0

*Includes personal light trucks, motorcycles, etc.

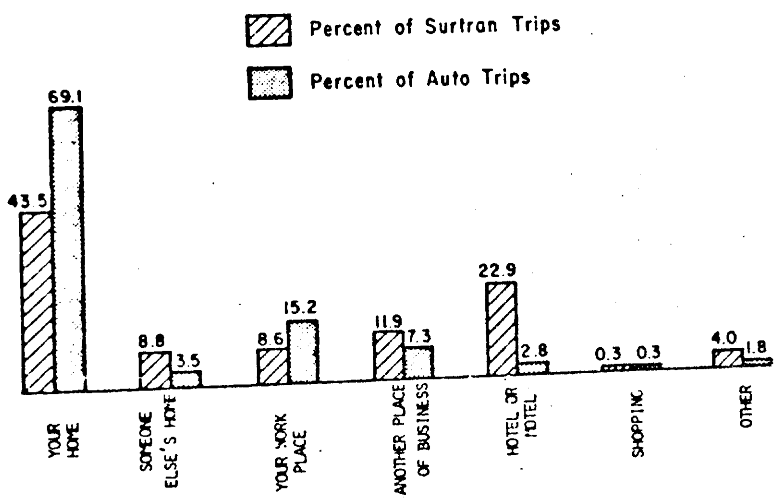


FIGURE 15
TYPE OF LAND-USE AT OFF-AIRPORT GROUND-TRIP END, BY MODE

TABLE 10

DISTRIBUTION OF AGE CATEGORIES FOR EACH SURVEY COMPONENT

Age Category	% Employees	% Surtran Riders	% Auto Users Driver	% Auto Users Air Pax
<21 years	7.8	3.3	7.8	4.7
21-34	50.0	31.6	44.5	35.9
35-44	24.2	26.0	22.3	28.3
45-54	13.5	24.2	17.9	22.0
55-64	4.3	10.7	6.5	5.9
$\geq$ 65	0.2	4.2	1.0	3.2
TOTAL	100.0	100.0	100.0	100.0

TABLE 11

DISTRIBUTION OF OCCUPATIONAL CATEGORIES
FOR EACH SURVEY COMPONENT

Occupational Category	% Employees	% Surtran Riders	% Auto Users Driver	% Auto Users Air Pax
Professional	31.6	60.9	43.1	51.9
Clerical	12.5	3.2	4.4	1.4
Sales	5.8	15.7	16.3	21.2
Craftsman/Foreman Technician/Operator	5.9	4.7	6.8	7.4
Maintenance	7.4	-	-	-
Service	24.9	1.4	2.4	1.4
Student	N/A	3.4	8.7	5.6
Retired	N/A	3.9	1.6	2.8
Housewife	N/A	2.6	14.0	5.5
Unemployed	N/A	0.4	1.3	1.4
Self-Employed	N/A	-	0.8	0.9
Other Labor	11.9	3.8	0.6	0.5
TOTAL	100.0	100.0	100.0	100.0

of the three groups of travelers. It can be seen that proportionately more Surtran riders and fewer employees tended to identify themselves as "Professional"; and substantially more employees tended to classify themselves in "Clerical" and "Service" categories.

Finally, in Table 12, the distributions of income categories of the different groups are compared. Surtran riders exhibited the highest income levels -- 62.1 percent in the \$20,000 per year or over bracket. Employees, on the other hand, indicated lower incomes -- 72.3 percent indicating family incomes of \$20,000 or less per year.

EMPLOYEE TRAVEL SURVEY RESULTS

Previous Love Field Employment

In order to assess the impact on airport-related employment of relocating the regional air facility from Love Field to DFW, the employees were asked to indicate whether they had previously been working at Love Field. Based on a response rate to this question of over 98 percent, it was found that 58 percent were former Love Field-based workers while 42 percent had been employed only at DFW.

Residential Distribution

Figure 16 shows the residential distribution of DFW-based employees by RAA zones. Overall, Dallas and its suburbs have the largest single share.

TABLE 12

DISTRIBUTION OF FAMILY INCOME CATEGORIES FOR EACH SURVEY COMPONENT

INCOME CATEGORY	% EMPLOYEES	% SURTRAN RIDERS	% AUTO USERS DRIVERS	% AUTO USERS AIR PAX
< \$6,500	12.9	4.3	10.8	8.1
\$6,500-\$13,000	30.5	11.9	17.7	12.0
\$13,000-\$20,000	28.9	21.7	26.5	19.8
\$20,000-\$26,000	13.3	25.1	18.8	21.7
\$26,000-\$32,000	6.8	16.3	9.7	13.6
> \$32,000	7.6	20.7	16.5	24.8

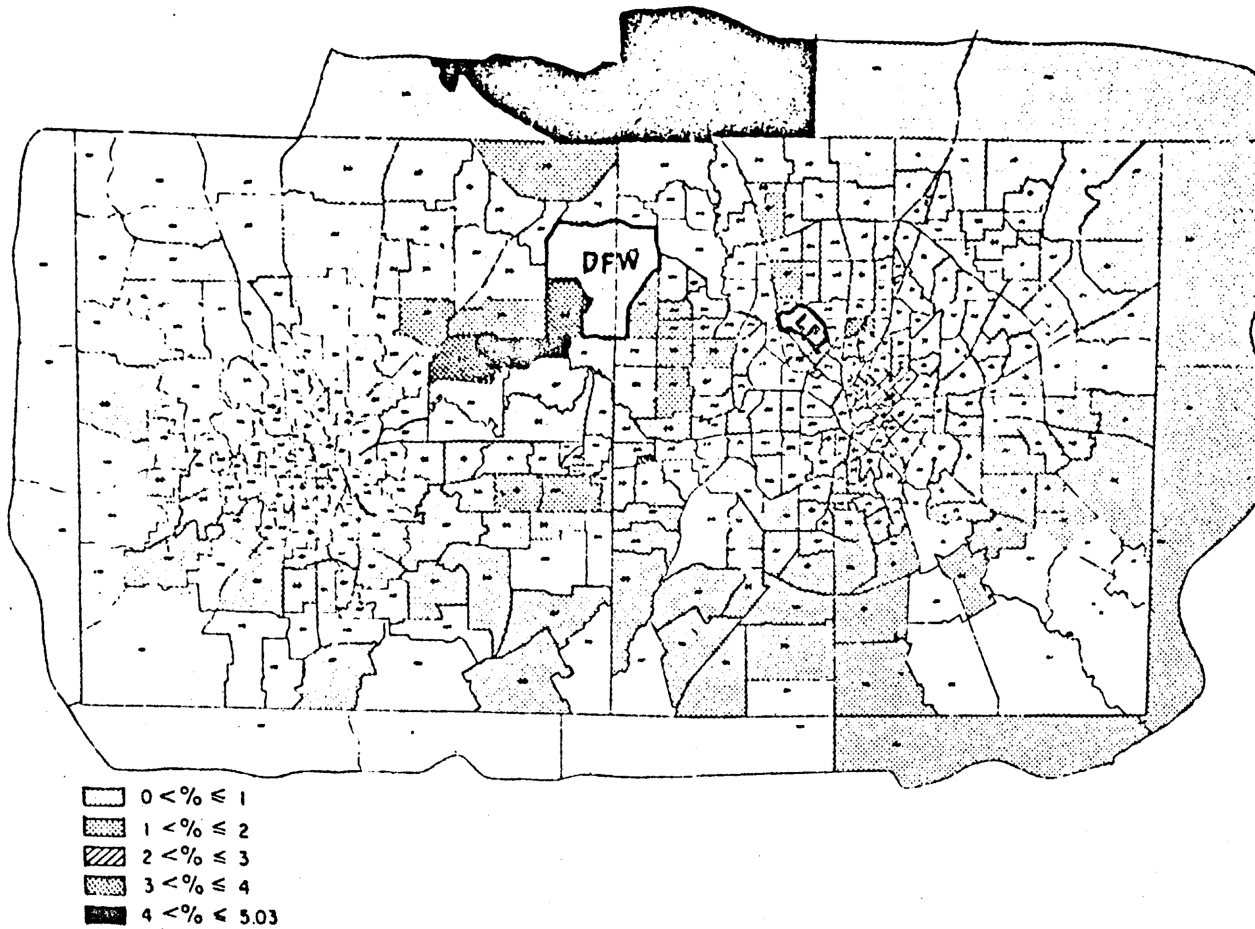


FIGURE 16. RESIDENTIAL DISTRIBUTION OF DFW-BASED EMPLOYEES BY ZONES

The residential distribution of DFW employees by RAA zone inside the intensive study area (ISA), broken down by employees who formerly worked at the Love Field Airport and those that did not, is illustrated by zonal maps in Figures 17(a) and 17(b).

Figures 17(a) and 17(b) reveal an interesting pattern of employee residential shifts that has resulted from the opening of the new airport. While previous Love Field workers reside predominantly in Dallas and its suburbs (Figure 17a), there is a pronounced westward shift of employee residence towards Fort Worth and the "Mid-Cities" area in the case of employees who did not previously work at Love Field (Figure 17b). This is undoubtedly due to the greater accessibility of DFW to more westerly residents. As the employee survey form indicates (Figure 4), the previous Love Field workers were asked whether they had relocated their residence because of the relocation of the area's major air facility from Love Field to DFW. Accordingly, 19.9 percent of the former Love Field workers indicated they had relocated their residence because of the shift of the major airport to DFW -- presumably a westward relocation for most. This implies that approximately 1,500 employees -- representing roughly 1,500 individual households or about 4,500 persons -- shifted their places of residence due to the changeover to DFW. These data suggest that changing the site of a major air facility does have a significant impact in terms of employee residential location.

Looking at employee residential distribution by cities inside the ISA (Table 13 and Figure 18), it is evident that Dallas had the single heaviest concentration, followed by Irving, Fort Worth, and Arlington. The differences in residential distribution of former Love Field versus non-Love Field employees (Table 14) is even more clearly represented in Figures 19(a) and 19(b), which decisively indicate that previous Love Field employees are concentrated more heavily in the Dallas area than those who did not work at Love Field. This, together with the zonal distribution data, corroborates the inference of a modest westward shift in employee residential patterns (see above) since the changeover from Love Field to DFW.

In Figure 20, the employees' residential distribution has been aggregated into the categories of the two large cities (Dallas and Fort Worth), their respective suburbs, the Mid-Cities communities lying in between Dallas/Fort Worth, and locations outside the ISA. As illustrated, some 40 percent of the

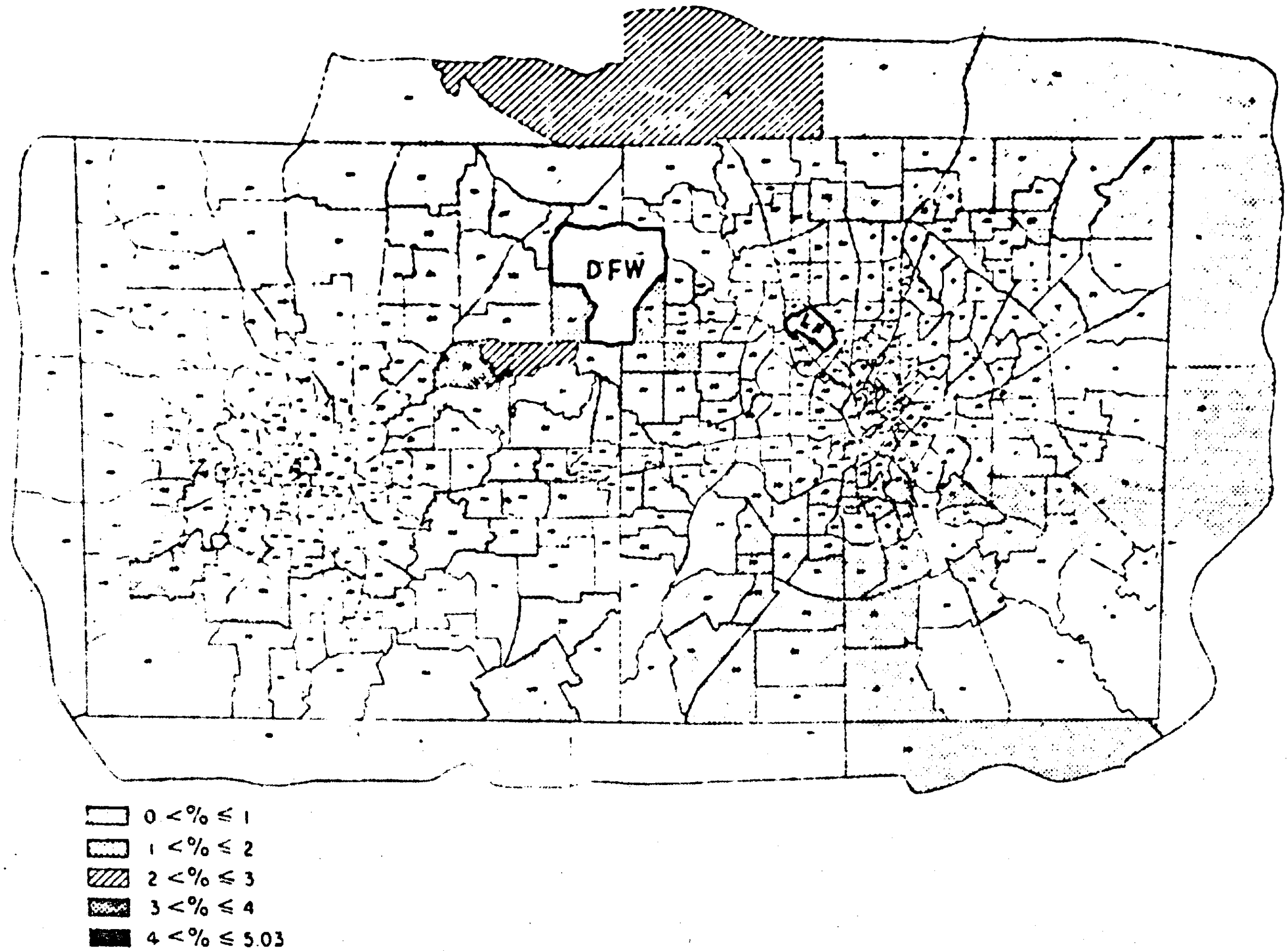


FIGURE 17(a)
RESIDENTIAL LOCATIONS OF DFW-BASED EMPLOYEES THAT FORMERLY WORKED AT LOVE FIELD AIRPORT, BY ZONES

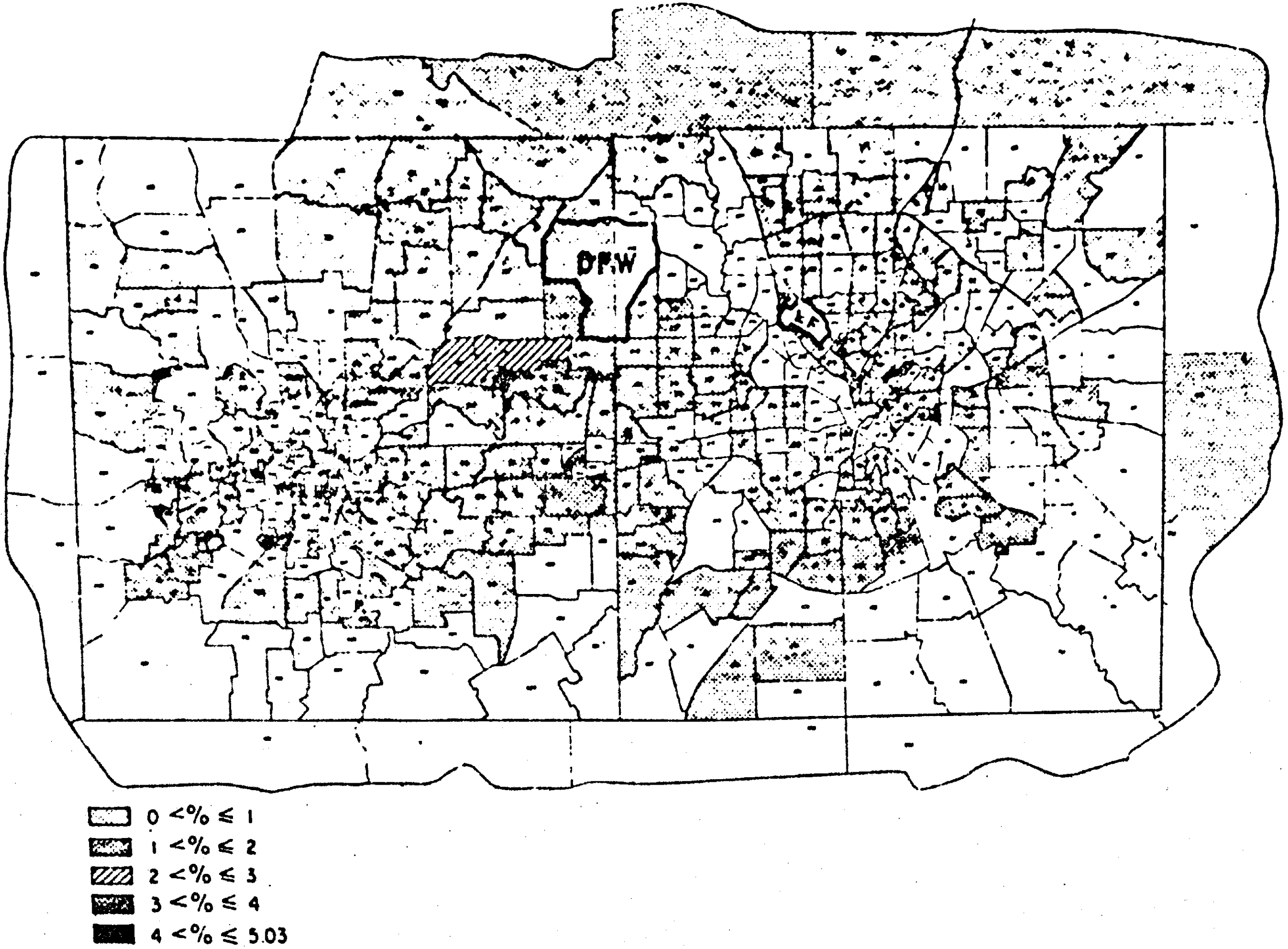


FIGURE 17(b)
RESIDENTIAL LOCATIONS OF DFW-BASED EMPLOYEES THAT DID NOT FORMERLY WORK AT LOVE FIELD AIRPORT, BY ZONES

TABLE 13

DISTRIBUTION OF DFW EMPLOYEES
BY CITIES INSIDE THE INTENSIVE STUDY AREA

CITY	SAMPLE FREQUENCY	PERCENT
Addison	7	0.22
Arlington	233	7.19
Azle	3	0.09
Balch Springs	4	0.12
Bedford	93	2.87
Benbrook	3	0.09
Blue Mound	4	0.12
Carrolton	74	2.28
Cedar Hill	5	0.15
Colleyville	28	0.86
Coppell	8	0.25
Dallas	801	24.71
Dalworthington Gardens	1	0.03
De Soto	13	0.40
Cuncanville	13	0.40
Everman	3	0.09
Euless	215	6.63
Farmers Branch	56	1.73
Fort Worth	257	7.93
Forest Hill	3	0.09
Garland	49	1.51
Grand Praire	88	2.72
Grapevine	93	2.87
Haltom City	20	0.62
Highland Park	2	0.06
Hurst	138	4.26
Hutchins	1	0.03
Irving	404	12.47
Keller	30	0.93
Kennedale	1	0.03
Lancaster	4	0.12
Mansfiled	3	0.09
Mesquite	25	0.77
North Richland Hills	59	1.82
Pantego	1	0.03
Richardson	33	1.02
Richland Hills	19	0.59
River Oaks	2	0.06
Sachse	1	0.03
Saginaw	2	0.06
Seagoville	1	0.03
Smithville	15	0.46
South Lake	9	0.28
University Park	18	0.56
Watauga	12	0.37
White Settlement	3	0.09
Wilmer	1	0.03
TOTAL	2,858	88.18

TABLE 14

DISTRIBUTION OF DFW EMPLOYEES BY CITIES INSIDE THE INTENSIVE STUDY AREA, ACCORDING TO PREVIOUS LOVE FIELD EXPERIENCE

CITY	FORMER LOVE FIELD WORKER			NON-LOVE FIELD WORKER		
	SAMPLE FREQUENCY	PERCENT OF TOTAL DFW EMPLOYEES	PERCENT OF DFW EMPLOYEES WITHIN CATEGORY	SAMPLE FREQUENCY	PERCENT OF TOTAL DFW EMPLOYEES	PERCENT OF DFW EMPLOYEES WITHIN CATEGORY
Addison	6	0.19	85.17	1	0.03	14.29
Arlington	71	2.19	30.47	158	4.86	67.81
Azle				3	0.09	100.00
Balch Springs	4	0.12	100.00			
Bedford	43	1.33	46.24	48	1.48	51.61
Benbrook	1	0.03	33.33	2	0.06	66.67
Blue Mound	3	0.09	75.00	1	0.03	25.00
Carrolton	62	1.91	83.78	10	0.31	13.51
Cedar Hill	2	0.06	40.00	2	0.06	40.00
Colleyville	14	0.43	50.00	14	0.43	50.00
Coppell	4	0.12	50.00	3	0.09	37.50
Dallas	622	19.19	77.65	175	5.40	21.84
Dalworthington (Gardens)				1	0.03	100.00
De Soto	9	0.28	69.23	4	0.12	30.77
Duncanville	8	0.25	61.54	5	0.16	38.46
Everman	1	0.03	33.33	2	0.06	66.67
Euless	93	2.87	43.26	113	3.49	52.56
Farmers Branch	45	1.39	80.36	11	0.34	19.64
Fort Worth	53	1.64	20.62	197	6.08	76.65
Forest Hill	1	0.03	33.33	2	0.06	66.67
Garland	40	1.2?	81.63	9	0.28	18.37
Grand Praire	30	1.20	44.32	49	1.51	55.68
Grapevine	45	1.39	48.39	47	1.45	50.54
Haltom City	5	0.16	25.00	14	0.43	70.00
Highland Park	1	0.03	50.00	1	0.03	50.00
Hurst	62	1.91	44.93	75	2.31	54.35
Hutchins	1	0.03	100.00			
Irving	230	7.10	56.93	169	?.21	41.83
Keller	17	0.52	56.67	13	0.40	43.33
Kenredale						
Lancaster	4	0.12	100.00			
Manfiled	3	0.09	100.00			
Mesquite	17	0.52	68.00	7	0.28	28.00
no. Richland Hills	15	0.46	25.42	42	1.30	71.19
Pantego				1	0.03	100.00
Richardson	24	0.74	72.72	9	0.28	27.27
Richland Hills	10	0.31	52.63	9	?.03	47.37
River Oaks	1	0.03	50.00	1	0.03	50.00
Sachse	1	0.03	100.00			
Saginaw	1	0.03	50.00	1	0.03	50.00
Seagoville	1	0.03	50.00			
Smithfield	9	0.28	60.00	5	0.16	33.33
South Lake	4	0.12	44.44	5	0.16	55.55
University Park	15	0.46	83.33	2	0.06	11.11
Watauga	4	0.12	33.33	8	0.25	66.67
White Settlement				3	0.09	100.00
Willmer	1	0.03	100.00			
TOTAL	1,592	49.09	5?.70	1,222	37.70	42.76

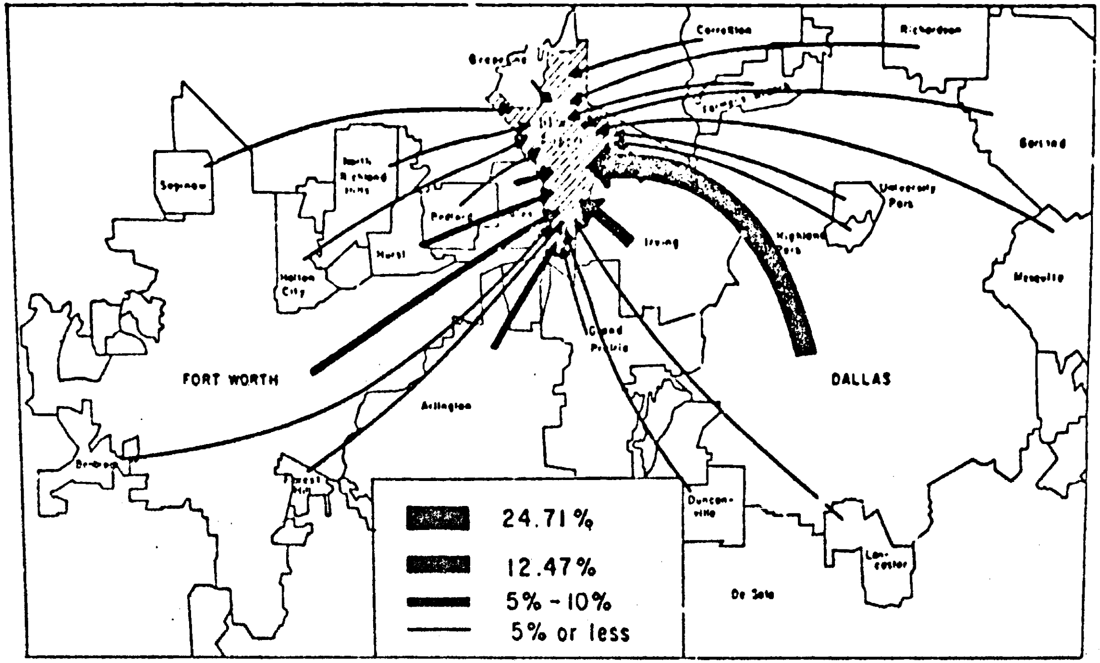
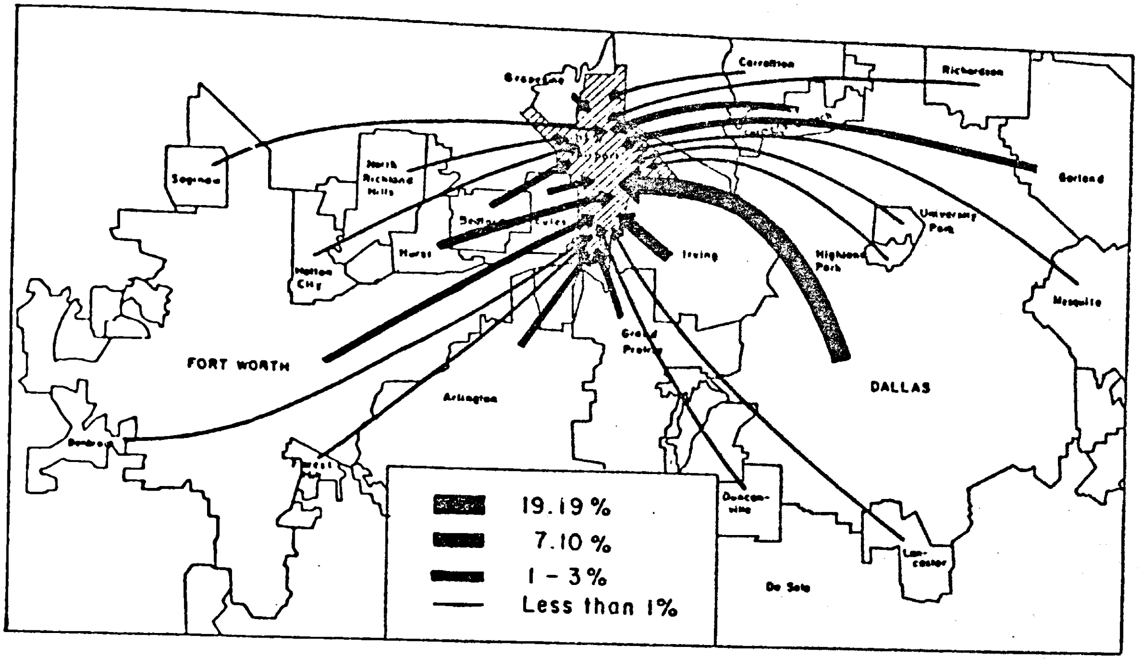
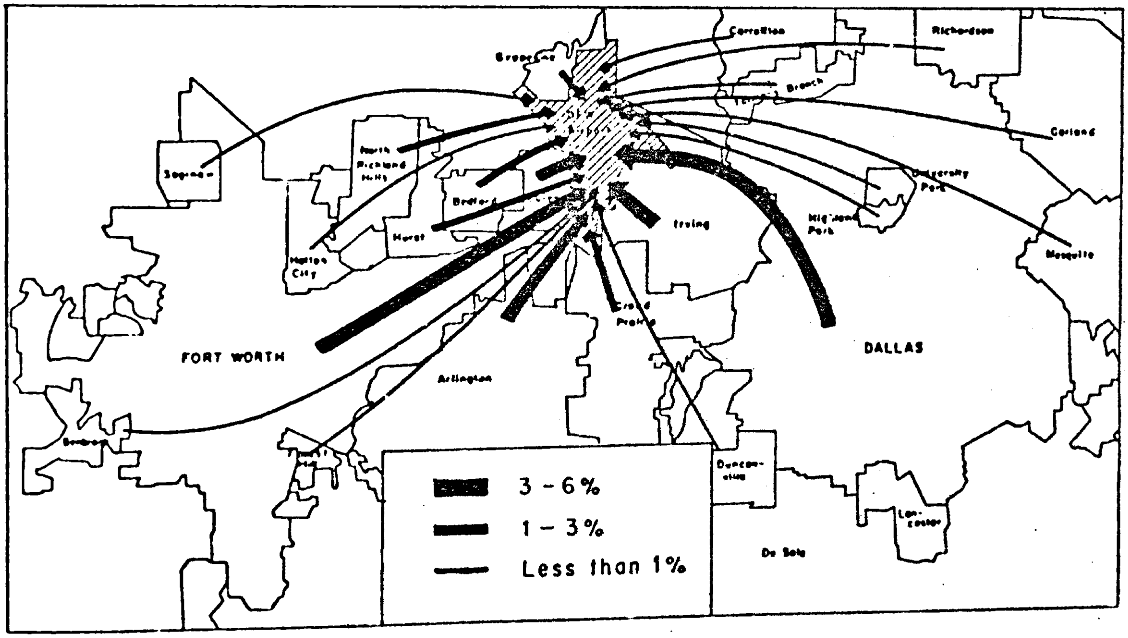


FIGURE 18. LOCATION OF DFW EMPLOYEES BY CITIES INSIDE THE INTENSIVE STUDY AREA



(a) FORMER LOVE FIELD WORKERS



(b) NOT FORMER LOVE FIELD WORKERS

FIGURE 19. LOCATIONS OF DFW EMPLOYEES BY CITIES INSIDE THE INTENSIVE STUDY AREA

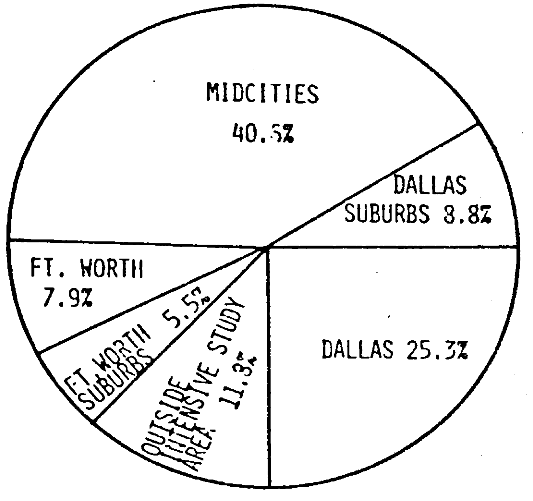


FIGURE 20
DISTRIBUTION OF DFW EMPLOYEES'
RESIDENTIAL LOCATIONS BY CATEGORIES

employees reside in the Mid-Cities communities, another one-third in Dallas or its suburbs, and some 13 percent (or about one in eight) in Fort Worth or its suburbs.

Employee residential distribution outside the ISA is presented in Tables 15 and 16. With the exception of the slightly heavier concentration of employees in Lewisville (about 3.5 percent compared with less than 1 percent for any other non-ISA community), no significant pattern is discernable.

Employee Travel Characteristics

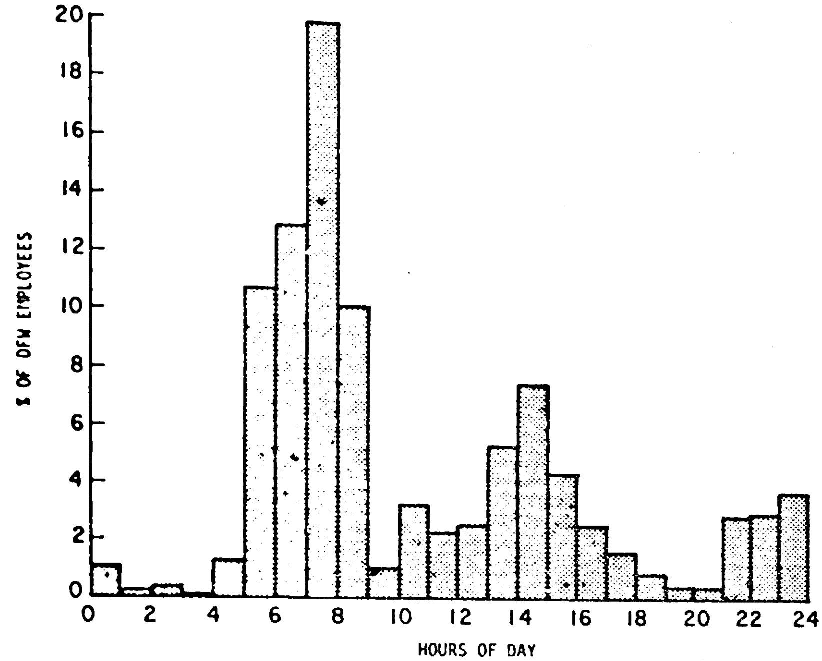
The distribution of employees' work shift starting and ending times is illustrated in Figures 21(a) and 21(b). While the largest concentrations occur during the typical periods of 07:00 - 08:00 and 16:00 - 17:00, there are other substantial concentrations at 14:00 - 15:00 and 22:00 - 23:00 which result in somewhat more evenly distributed traffic than if all shifts spanned the conventional 08:00 - 17:00 period.

TABLE 15
DISTRIBUTION OF DFW EMPLOYEES BY
CITIES OUTSIDE THE INTENSIVE STUDY AREA

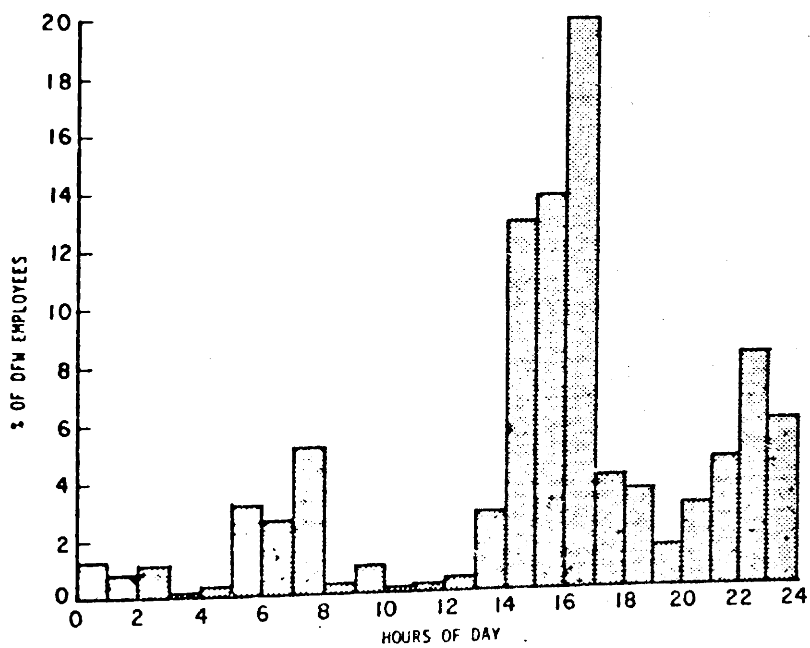
CITY	SAMPLE FREQUENCY	% OF TOTAL
Allen	2	0.06
Alvord	1	0.03
Argyle	7	0.22
Aubrey	1	0.03
Blue Ridge	2	0.06
Bonham	1	0.03
Bowie	1	0.03
Boyd	6	0.19
Bridgeport	4	0.12
Celina	2	0.06
Celeste	1	0.03
Cleburne	1	0.03
Clifton	1	0.03
Collinsville	1	0.03
Conroe	1	0.03
Decature	1,	0.03
Denton	31	0.96
Elmo	2	0.06
Ennis	2	0.06
Fairfield	1	0.03
Farmesville	1	0.03
Ferris	2	0.06
Flower Mound	2	0.06
Frisco	8	0.25
Gainsville	1	0.03
Granbury	1	0.03
Gordon	1	0.03
Greenville	1	0.03
Joshua	2	0.06
Justin	4	0.12
Highland Village	1	0.03
Kerns	1	0.03
Lake Dallas	6	0.19
Little Elm	1	0.03
Lewisville	113	3.49
Mabank	3	0.09
McKinney	9	0.28
Midlothian	1	0.03
Nevada	1	0.03
Nocona	1	0.03
Paradise	1	0.03
Plano	26	0.80
Pilot Point	2	0.06
Ponder	2	0.06
Poolville	1	0.03
Quinlan	1	0.03
RedOak	2	0.06
Rhome	1	0.03
Roanoke	30	0.92
Rockwall	3	0.09
San Marcos	1	0.03
Sanger	3	0.09
Sunset	1	0.03
Tioga	1	0.03
Valley View	2	0.06
Weatherford	3	0.09
Waxahachie	5	0.16
Wills Point	1	0.03
Whitewright	1	0.03
Wylie	4	0.12
TOTAL	320	9.87

TABLE 16
DISTRIBUTION OF DFW EMPLOYEES BY CITIES OUTSIDE THE INTENSIVE STUDY AREA, ACCORDING TO PREVIOUS LOVE FIELD EXPERIENCE

CITY	FORMER LOVE FIELD WORKER			NON-LOVE FIELD WORKER		
	SAMPLE FREQUENCY	% OF TOTAL DFW EMPLOYEES	PERCENT OF DFW EMPLOYEES WITHIN CATEGORY	SAMPLE FREQUENCY	% OF TOTAL DFW EMPLOYEES	PERCENT OF DFW EMPLOYEES WITHIN CATEGORY
Allen	2	0.06	100.00			
Alvord	1	0.03	100.00			
Argyle	6	0.19	85.71	6	0.03	14.29
Aubrey	1	0.03	100.00			
Blue Ridge	2	0.06	100.00			
Bonham	1	0.03	100.00			
Bowie	1	0.03	100.00			
Boyd	3	0.09	50.00	3	0.09	50.00
Bridgeport	2	0.06	50.00	2	0.06	50.00
Celina	2	0.06	100.00			
Celeste	1	0.03	100.00			
Cleburne				1	0.03	100.00
Clifton	1	0.03	100.00			
Collinsville	1	0.03	100.00			
Conroe				1	0.03	100.00
Decatur	1	0.03	100.00			
Denton	24	0.74	77.42	7	0.22	22.58
Elmo	2	0.06	100.00			
Ennis	2	0.05	100.00			
Fairfield	1	0.03	100.00			
Farmersville	1	0.03	100.00			
Ferris	1	0.03	50.00	1	0.03	50.00
Flower Mound	1	0.03	50.00	1	0.03	50.00
Frisco	5	0.16	62.50	3	0.09	37.50
Gainsville				1	0.03	100.00
Granbury	1	0.03	100.00			
Gordon	1	0.03	100.00			
Greenville				1	0.03	100.00
Joshua	1	0.03	50.00	1	0.03	50.00
Justin	1	0.03	25.00	3	0.09	75.00
Highland Village	1	0.03	100.00			
Kerns				1	0.03	100.00
Lake Dallas	4	0.12	66.67	1	0.03	16.67
Little Elm	1	0.03	100.00			
Lewisville	74	0.28	65.49	36	1.11	31.85
Mabank	2	0.06	66.67	1	0.03	33.33
McKinney	7	0.22	77.77	2	0.06	22.22
Midlothian	1	0.03	100.00			
Nevada	1	0.03	100.00			
Nocona						
Paradise				1	0.03	100.00
Plano	18	0.55	69.23	8	0.25	30.77
Pilot Point	2	0.06	100.00			
Ponder	1	0.03	50.00	1	0.03	50.00
Poolville	1	0.03	100.00			
Quinlan	1	0.03	100.00			
Red Oak	2	0.06	100.00			
Rhome				1	0.03	100.00
Roanoke	20	0.61	66.67	10	0.31	33.33
Rockwall	1	0.03	33.33			
San Marcos	1	0.03	100.00			
Sanger	2	0.06	66.67	1	0.03	33.33
Sunset				1	0.03	100.00
Tioga	1	0.03	100.00			
Valleyview	2	0.06	100.00			
Weatherford	1	0.03	33.33	2	0.06	66.67
Waxahachie	4	0.12	80.00	1	0.03	20.00
Wills Point	1	0.03	100.00			
Whitewright				1	0.03	100.00
Wylie	4	0.12	100.00			
TOTAL	219	6.76	68.44	94	2.90	20.39



(a) STARTING TIMES



(b) ENDING TIMES

FIGURE 21. DISTRIBUTIONS OF WORK SHIFT TIMES OF DFW EMPLOYEES

Table 17 gives the modal split of employee ground travel to and from DFW. It is evident that over 96 percent of DFW employees go to and from work by automobile compared with only 2.4 percent who use the Surtran express bus system. Given the reasonably high quality of the bus service, this seems a surprisingly low modal split for work trips; however, it probably reflects the rather high transit fare* in contrast to the relatively lower out-of-pocket cost of the automobile model plus "free" (actually subsidized) parking and other DFW motor vehicle facilities for employees.

To assess the significance of employee carpooling, data on vehicular occupancy were tabulated. Table 18 provides the results of this tabulation. From these results, it can be seen that nearly one-fourth of the employees engage in carpooling if such is defined as more than one occupant per car.

A prerequisite to the development of adequately predictive models is transforming the number of employees into the corresponding number of vehicles by multiplying by average vehicle occupancy. Data on vehicle occupancy were collected in a special survey during periods of peak employee traffic. Results are shown in Tables 19(a) and 19(b) for inbound and outbound employees. Note the variation in vehicle occupancy even in the peak period. The model estimates of traffic will obviously be sensitive to these conversion factors.

Travel Time/Distance

Employee travel time and distance were also surveyed, including data regarding Love Field for comparison. Employees were asked to estimate their distance and time to both airports; later, project staff computed actual distances and times using minimum-path analysis of the respondents' residential locations. Table 20 gives perceived versus actual distances and times of employee travel to DFW while Table 21 gives similar data for hypothetical travel to Love Field. Somewhat surprisingly, there is virtually no significant variation in either actual or perceived distance and time for employee travel to either airport. There is an appreciably higher percentage of employees living 5 miles or less from Love Field as compared with DFW. Also of interest is the relative accuracy of employees' distance and time estimations compared with the actual values.

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*At the time of the survey, employees paid a special price of $1.00; others paid $2.50.

TABLE 17

DFW-BASED EMPLOYEE MODAL SPLIT

Mode	Person-Trips	Percent
Automobile*	17,328	96.3
Taxi	18	0.1
Surtran bus	432	2.4
Other	216	1.2
TOTAL	17,994	100.0

*Includes personal light trucks, motorcycles, etc.

TABLE 18

DFW EMPLOYEE VEHICULAR OCCUPANCY (CAR-POOLING)

Number of Employees Per Auto	Percent of Autos
1	76.5
2 or more	23.5
3 or more	5.9
4 or more	1.9

TABLE 19

DFW EMPLOYEE VEHICLE OCCUPANCY

(a) DURING INBOUND PEAK

Half-Hour Interval	No. of Employees Per Vehicles
6:00 - 6:30 a.m.	1.45
6:30 - 7:00	1.36
7:00 - 7:30	1.15
7:30 - 8:00	1.35
8:00 - 8:30	1.25
8:30 - 9:00	1.25

(b) DURING OUTBOUND PEAK

Half-Hour Interval	No. of Employees Per Vehicles
2:30 - 3:00 p.m.	1.38
3:00 - 3:30	1.40
3:30 - 4:00	1.41
4:00 - 4:30	1.16
4:30 - 5:00	1.48
5:00 - 5:30	1.22
5:30 - 6:00	1.37

TABLE 20

DISTRIBUTION OF DFW EMPLOYEES' PERCEIVED VERSUS ACTUAL TRAVEL DISTANCES AND TIMES BETWEEN HOMES AND DFW

Distance Range (Miles)	% Employees in Range	
	Perceived Distance	Actual Distance
0-5 miles	6.6	1.0
6-10	18.0	21.3
11-15	22.9	26.3
16-20	18.0	19.4
21-25	13.6	14.6
26-30	11.0	8.0
31-35	5.1	6.2
36-40	1.9	1.6
41-60	1.9	1.5
Over 60	1.0	0.1
TOTAL	100.0	100.0

Time Range (Minutes)	% Employees in Range	
	Perceived Distance	Actual Distance
0-10 minutes	8.3	1.0
11-20	32.1	31.7
21-30	30.5	36.0
31-40	14.4	22.1
41-50	10.3	7.6
51-60	2.9	1.5
Over 60	1.5	0.1
TOTAL	100.0	100.0

TABLE 21

DISTRIBUTION OF DFW EMPLOYEES' PERCEIVED VERSUS ACTUAL TRAVEL DISTANCES AND TIMES BETWEEN HOMES AND LOVE FIELD

Distance Range (Miles)	% Employees in Range	
	Perceived Distance	Actual Distance
0-5 miles	10.2	9.0
6-10	19.2	25.4
11-15	18.3	13.3
16-20	16.2	22.3
21-25	11.4	14.7
26-30	9.6	7.5
31-35	5.5	3.6
36-40	3.6	2.4
41-60	4.9	1.8
Over 60	1.1	-
TOTAL	100.0	100.0

Time Range (Minutes)	% Employees in Range	
	Perceived Distance	Actual Distance
0-10 minutes	9.9	3.4
11-20	26.8	28.0
21-30	27.2	31.5
31-40	13.6	23.9
41-50	12.7	9.2
51-60	6.7	3.4
Over 60	3.1	0.6
	100.0	100.0

Employee Demographic Characteristics

The survey found that 65.0 percent of DFW employees were male and 35.0 percent female. Tables 10 through 12 above present a breakdown of DFW employees by age, occupation, and income, respectively. These latter three categories are further disaggregated into former Love Field employees and non-Love Field employees in Tables 22 through 24. The distribution of employees by sex is given in Table 25. It is interesting to note that the former Love Field workers are somewhat older -- in fact representing approximately 70 percent of all DFW employees over 34. In contrast, non-Love Field employees are younger, for example, constituting 88.1 percent of employees under 21.

As discussed in a previous report,[18] the necessary reliance on perceived self-classification as to occupation led to some problems (e.g., as to what constitutes a "professional" or "other labor" occupation); therefore, interpretation of these results must be cautious. It is probable, for instance, that there is considerable overlapping of identical occupations variously classified as "professional" and "service (airline)."

Somewhat clearer interpretation is offered by the occupational contrast between former Love Field and non-Love Field workers (Table 23). For example, there appears a clear tendency for predominantly more former Love Field workers to classify themselves as "Professional," "Sales," "Craftsman/Foreman," "Service (airline),"and "Service (auto rental)," while predominantly more non-Love Field workers tend to classify themselves as "Technician/Operator," "Other Labor," "Service (food)," "Service (custodial)," and "Service (hotel)."

These results, moreover, correlate logically with the responses as to income represented in Tables 12 and 24, in particular the contrast between former Love Field and non-Love Field workers evident in Table 24. It is apparent that non-Love Field workers have generally lower incomes, a fact consistent with the "Service (food)","Service (custodial)," and other lower-wage types of job categories in which they apparently predominate. Conversely, former Love Field employees' generally higher income levels tend to correlate with the "Professional," "Service (airline)," and other higher-income occupations in which they evidently predominate. From these results, it is speculatable that the bulk of new jobs created by the opening of DFW was in lower-income categories, while higher-income jobs predominantly tended to be filled by transferees in the same jobs from Love Field.

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[18] Dunlay, William J., Jr., et al., Survey of Ground Transportation Patterns at the Dallas/Fort Worth Regional Airport, Research Report 15, Council for Advanced Transportation Studies, UT-Austin, August 1975.

TABLE 22

DISTRIBUTION OF DFW EMPLOYEES BY AGE ACCORDING TO PREVIOUS LOVE FIELD EMPLOYMENT

AGE CATEGORY (Years)	% IN CATEGORY		% OF EMPLOYEES OF CATEGORY		
	FORMER LOVE FIELD EMPLOYEES	NON-LOVE FIELD EMPLOYEES	FORMER LOVE FIELD EMPLOYEES	NON-LOVE FIELD EMPLOYEES	TOTAL
Under 21	1.6	16.2	11.9	88.1	100.0
21 - 34	47.1	54.1	54.7	45.3	100.0
35 - 44	28.8	17.7	69.3	30.7	100.0
45 - 54	17.0	8.8	72.7	27.3	100.0
55 - 64	5.3	3.0	71.5	28.5	100.0
Over 65	0.2	0.2	57.1	42.9	100.0
TOTAL	100.0	100.0			

TABLE 23

DISTRIBUTION OF DFW EMPLOYEES BY OCCUPATION ACCORDING TO PREVIOUS LOVE FIELD EMPLOYMENT

OCCUPATIONAL CATEGORY	% IN CATEGORY		% OF EMPLOYEES OF CATEGORY		
	FORMER LOVE FIELD EMPLOYEES	NON-LOVE FIELD EMPLOYEES	FORMER LOVE FIELD EMPLOYEES	NON-LOVE FIELD EMPLOYEES	TOTAL
Professional	35.9	25.9	66.1	33.9	100.0
Clerical	11.3	14.1	52.9	47.1	100.0
Sales	7.1	4.0	70.9	29.1	100.0
Craftsmen/Foremen	2.4	1.9	64.2	35.8	100.0
Technician/Operator	2.5	5.2	39.6	60.4	100.0
Maintenance	5.9	9.3	47.1	52.9	100.0
Service (Food)	3.8	8.9	37.4	62.6	100.0
Service (Airline)	21.3	8.3	78.4	21.6	100.0
Service (Custodial)	0.4	2.2	21.6	78.4	100.0
Service (Auto Rental)	1.0	0.9	62.1	37.9	100.0
Service (Hotel)	-	2.2	-	100.0	100.0
Other Labor	8.4	17.1	40.8	59.2	100.0
TOTAL	100.0	100.0			

TABLE 24

DISTRIBUTION OF DFW EMPLOYEES BY INCOME ACCORDING TO PREVIOUS LOVE FIELD EMPLOYMENT

ANNUAL INCOME CATEGORY ($)	% OF ALL DFW EMPLOYEES IN CATEGORY		
	FORMER LOVE FIELD EMPLOYEES	NON-LOVE FIELD EMPLOYEES	TOTAL
< $6,500	3.3	10.0	13.3
$6,500-$13,000	16.7	14.4	31.1
$13,000-$20,000	18.9	10.0	28.9
$20,000-$26,000	8.9	4.4	13.3
$26,000-$32,000	4.5	2.2	6.7
> $32,000	5.6	1.1	6.7
TOTALS	57.9	42.1	100.0

TABLE 25

DISTRIBUTION OF DFW EMPLOYEES BY SEX ACCORDING TO PREVIOUS LOVE FIELD EMPLOYMENT

SEX	% IN CATEGORY		% OF EMPLOYEES OF CATEGORY		
	FORMER LOVE FIELD EMPLOYEES	NON-LOVE FIELD EMPLOYEES	FORMER LOVE FIELD EMPLOYEES	NON-LOVE FIELD EMPLOYEES	TOTAL
Male	68.5	60.4	61.0	39.0	100.0
Female	31.5	39.6	39.6	47.6	100.0
TOTAL	100.0	100.0			

Employee Characteristics by Mode of Work Trip

It is of interest to study the differences in characteristics between DFW-based employees using personal motor vehicles ("auto-users") and those who use Surtran buses for their work trips. Such an analysis may provide clues helpful to the understanding of modal choice decisions for this component of airport access travel.

In Table 26, employees are classified by sex under auto users and Surtran riders. Almost two-thirds of the auto-users are males; the reverse is true of the Surtran users, over 60 percent of whom are females. This contrasts strongly with the fact that only 22.0 percent of Surtran riders as a whole are females. In terms of previous Love Field employment, it can be seen that the proportion of each group is about the same.

Differences between residential patterns of auto-users and Surtran-users, shown in Table 27, reflect the characteristics of Surtran service. Surtran-riders are concentrated overwhelmingly in the two large cities, Dallas and Fort Worth, and the Dallas suburbs which are well served by, and thus more conveniently accessible to, Surtran. Auto-users, on the other hand, are far more dispersed with over half not located in the two large cities or their suburbs.

The previous mode of travel, before DFW opened, to and from Love Field for employees formerly based there also indicates an interesting differentiation. As shown in Table 28, over [illegible]0 percent of Surtran-users also used to use transit for their work trips to and from Love Field, compared with only about one percent of the current auto-users. It is also significant, however, that over 87 percent of [illegible] Field employees now using Surtran are "converts" from the automobile [illegible]

In Tables 29 through 31, auto-users and Surtran users are compared in terms of their age, occupation, and income. As indicated in Table 29, there is little difference in terms of age, although proportionally, more Surtran-users are under 21 years old.

Significant differences do emerge, however, as to occupation and income. As indicated in Table 30, proportionally more auto-users tended to classify themselves in the professional, clerical, sales, and craftsman/foreman/technician/operator categories while the proportion of employees classifying themselves in the service category was significantly higher for Surtran-users (41.6 percent contrasted with 24.4 percent of auto-users).

TABLE 26

COMPARATIVE CHARACTERISTICS OF AUTO-USING
VERSUS
SURTRAN-USING DFW-BASED EMPLOYEES

CHARACTERISTIC	PERCENT OF AUTO-USERS	PERCENT OF SURTRAN-USERS
Male	65.7	37.8
Female	34.3	62.2
Former Love Field Employees	58.0	56.0

TABLE 27

COMPARATIVE RESIDENTIAL LOCATIONS OF AUTO-USERS
VERSUS
SURTRAN-USERS

LOCATION	PERCENT OF AUTO-USERS	PERCENT OF SURTRAN-USERS
Dallas	24.5	51.3
Dallas Suburbs	8.8	14.5
Fort Worth	7.5	31.6
Fort Worth Suburbs	5.0	----
Mid-Cities	22.8	----
Other	31.4	2.6
TOTAL	100.0	100.0

TABLE 28

PREVIOUS TRAVEL MODE TO LOVE FIELD OF FORMER LOVE FIELD EMPLOYEES: AUTO-USING VERSUS SURTRAN-USING

PREVIOUS MODE TO LOVE FIELD	PERCENT OF AUTO-USERS	PERCENT OF SURTRAN-USERS
Auto	97.8	87.2
Transit	1.1	10.3
Other	1.1	2.6

TABLE 29

DISTRIBUTION OF AGE CATEGORIES AUTO-USING VERSUS SURTRAN-USING EMPLOYEES

AGE CATEGORY	PERCENT OF AUTO-USERS	PERCENT OF SURTRAN-USERS
Under 21 Years	7.7	12.2
21 - 34	50.0	47.3
35 - 44	24.2	21.6
45 - 54	13.5	12.2
55 - 64	6.6	6.8
65 and over	0.2	----
TOTAL	100.0	100.0

TABLE 30

DISTRIBUTION OF OCCUPATIONAL CATEGORIES: AUTO-USING VERSUS SURTRAN-USING EMPLOYEES

OCCUPATIONAL CATEGORY	PERCENT OF AUTO-USERS	PERCENT OF SURTRAN-USERS
Professional	31.8	23.6
Clerical	12.6	7.0
Sales	5.8	2.8
Craftsman/Foreman/ Technician/Operator	6.0	2.8
Maintenance	7.4	9.7
Other Labor	11.9	12.5
Service	24.5	41.6
TOTAL	100.0	100.0

TABLE 31

DISTRIBUTION OF INCOME CATEGORIES: AUTO-USING VERSUS SURTRAN USING EMPLOYEES

INCOME CATEGORY	PERCENT OF AUTO-USERS	PERCENT OF SURTRAN-USERS
Under $6,500	12.3	39.4
$6,500 - $13,000	30.6	24.2
$13,000 - $20,000	29.1	19.7
$20,000 - $26,000	13.4	6.1
$26,000 - $32,000	6.9	3.0
Over $32,000	7.6	7.6
TOTAL	100.0	100.0

As one would expect from the above results, the incomes of Surtran users are significantly lower than those of auto-users (Table 31). More than one-third (39.4 percent) of the Surtran-users earn $6,500 or less per year while only about one-eighth (12.3 percent) of auto-users are in that category.

In summary, Surtran-using employees at DFW are predominantly females between 21 and 44 years old earning $13,000 or less per year and living in one of the cities or suburbs. Auto-using employees, on the other hand, are mostly similarly-aged males earning more than $13,000 per year and living more in the Mid-Cities area and other areas.

SURTRAN PASSENGER TRAVEL SURVEY RESULTS

Ridership by Route

The total number of passengers riding Surtran during the survey was 3,035 for 16 May 1975 and 2,397 for 20 May 1975; this included air passengers, DFW airport employees, and non-air-passenger Surtran riders. On the average, over the two days, the Downtown Dallas route carried 33 percent of the riders, the North Central route 30 percent, the Fort Worth route 20 percent, the Love Field route 15 percent, and the Arlington route 2 percent.

The distribution of Surtran patronage by each of the five routes, and by day surveyed, is illustrated by the graph in Figure 22. Clearly, the Downtown Dallas and North Central Dallas routes together handle over 60 percent of total Surtran ridership.

As one would expect, the percentage on the Downtown Dallas route was slightly lower on Friday, May 16, than on Tuesday, as there are relatively fewer business air trips on Friday. Similarly, the North Central route, which serves mainly residential areas, shows a greater percentage on Friday than on Tuesday.

Origins/Destinations

DFW-bound riders (including employees) were asked to indicate the general location of their ground trip origins and outbound passengers were asked to indicate their destinations. This information was subsequently processed into accumulations by RAA zones. Figure 23 illustrates the pattern of total zonal trip-ends of Surtran riders determined by survey responses. Clearly, O/D's of Surtran users are much less dispersed and far more concentrated than those

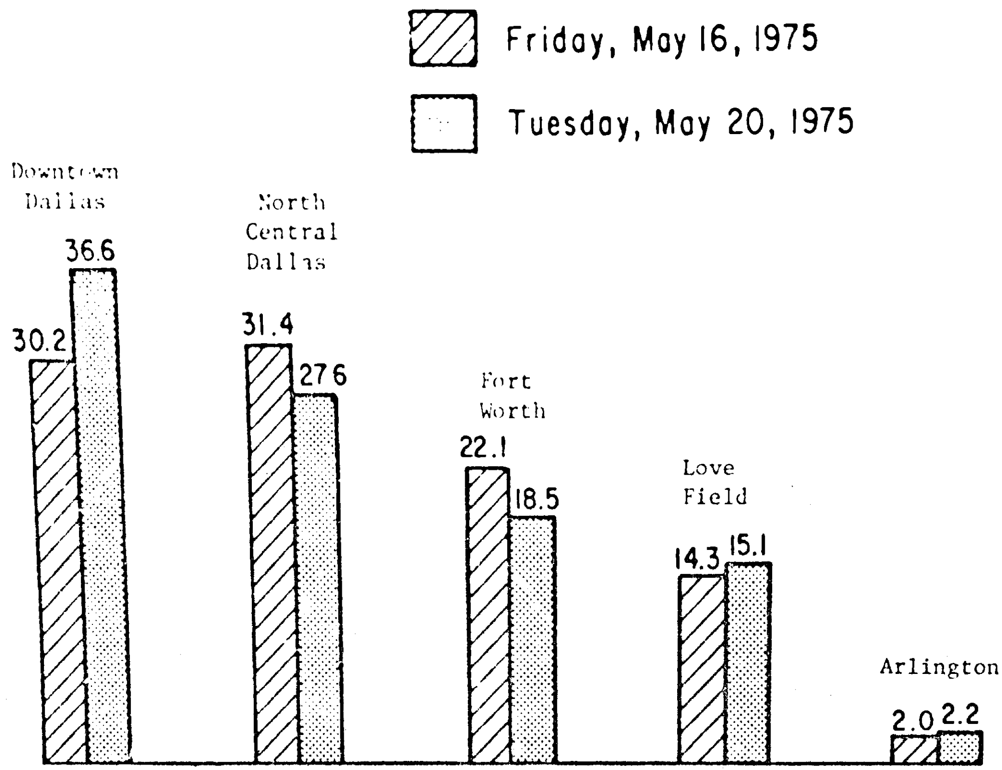


FIGURE 22. DISTRIBUTION OF SURTRAN RIDERSHIP PER ROUTE, BY SURVEY DATE

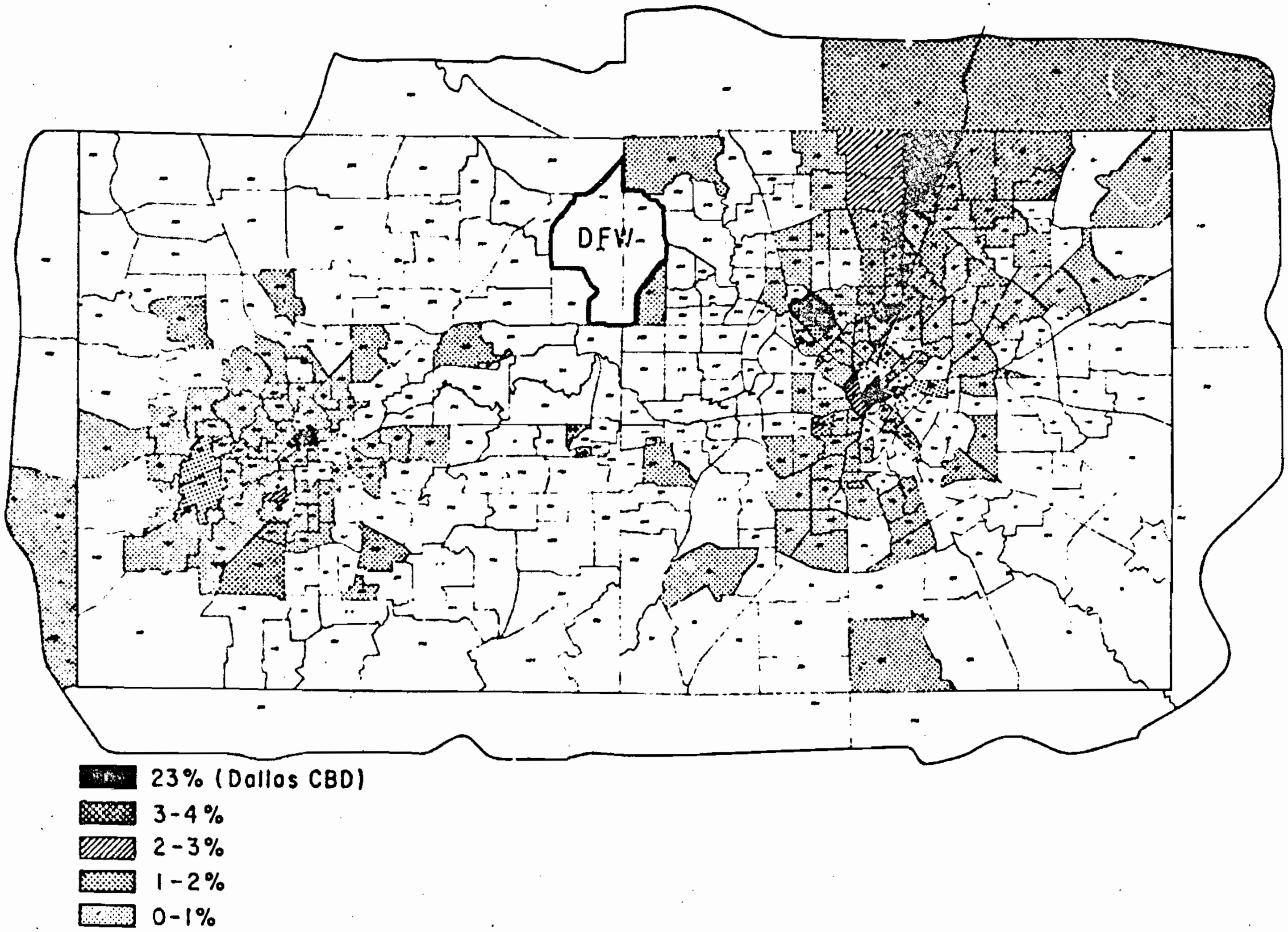


FIGURE 23. LOCATION OF SURTRAN PASSENGERS' TRIP-ENDS, BY ZONE

of auto users, as an example (cf. Figure 40).

An overwhelmingly high concentration of O/D's occurs to and from the Dallas CBD (solid dark area), in which Surtran provides virtual doorstep service for each of the major hotels. This high level of convenience, plus the fact that air passengers using local hotels probably would not tend to have private automobiles available, undoubtably helps explain the heavy usage of Surtran. This heavy concentration of trip-ends is approximately five times the heaviest single concentration for either of the other two components of DFW travel.

Figures 24(a) and 24(b) through 27(a) and 27(b) disaggregate the O/D results by origins and by destinations for passengers using each of the four major routes (excluding the lightly-used Arlington route due to inadequate sample size). For the North Central and Love Field routes -- providing park-and ride (P&R) facilities -- rider O/D's are relatively dispersed (heaviest concentration 12 percent) compared with the extremely heavy CBD concentration of O/D's (58 - 78 percent) for the Downtown Dallas route, with no P & R provided.

Two primary concentrations of trip ends are apparent, however: the Downtown Dallas CBD (already discussed) and the North-Central Dallas area. This would be expected from the ridership counts, as the two routes that service these areas account for approximately 63 percent of total Surtran riders.

There is considerable overlap in the service areas of the Downtown Dallas, North Central, and Love Field routes. Although the Downtown Dallas route is primarily oriented toward out-of-town business persons making trips to the Dallas Central Business District, and the North Central route is used mainly by Dallas area residents going between the airport and their homes, still there exists some overlap due to the multi-purpose trips, e.g., trips that combine business with visiting family or friends and trips with multiple origins/destinations.

Land Use

The proportions of different land uses at Surtran riders' off-airport O/D's are tabulated in Table 32. While the largest share of trips is to/from the passenger's own home, the high proportion of trips to/from hotels and motels (22.8 percent) is worth noting, especially in contrast with the relatively

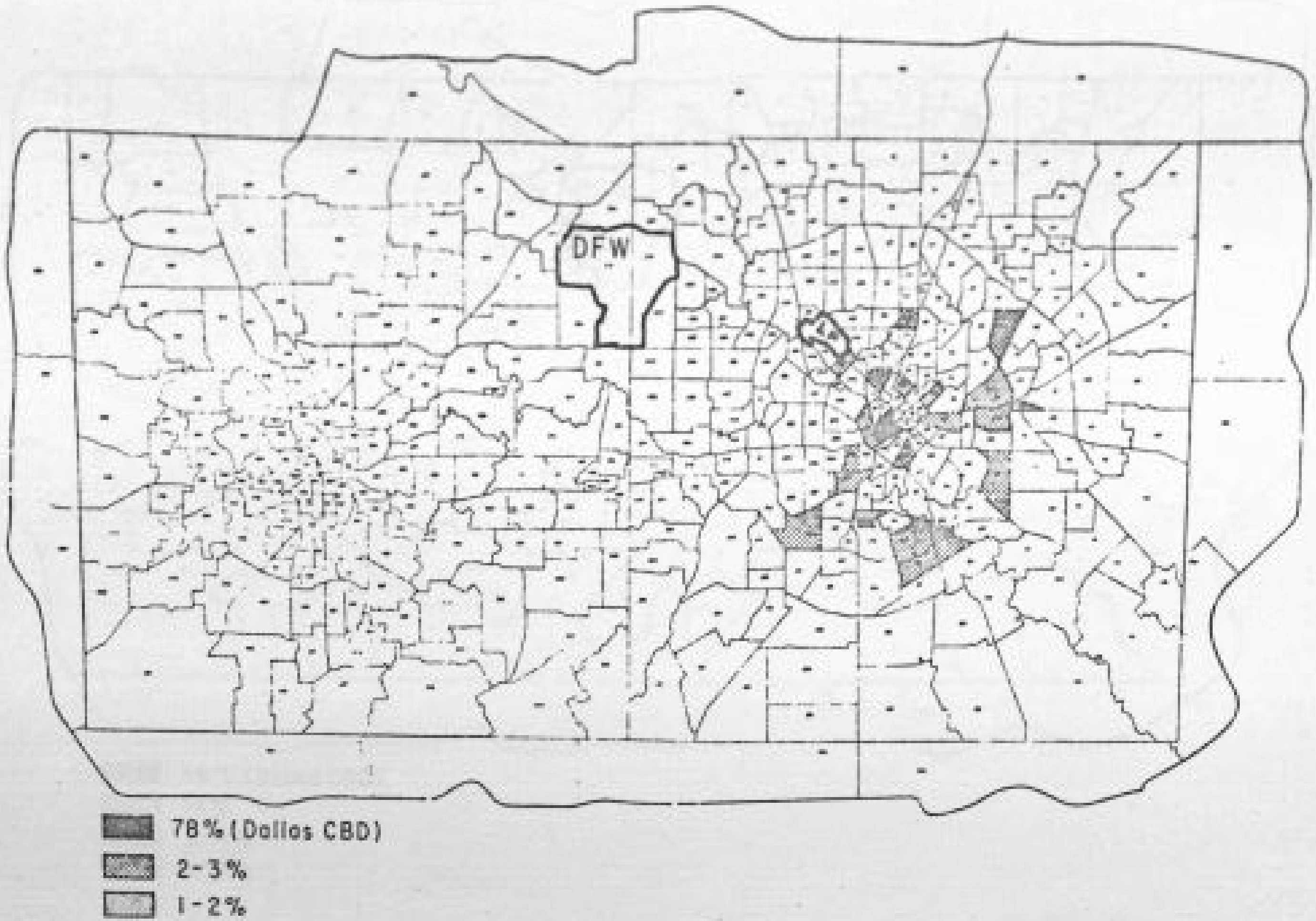


FIGURE 24(a). ORIGIN ZONES OF SURTRAN PASSENGERS, DOWNTOWN DALLAS ROUTE

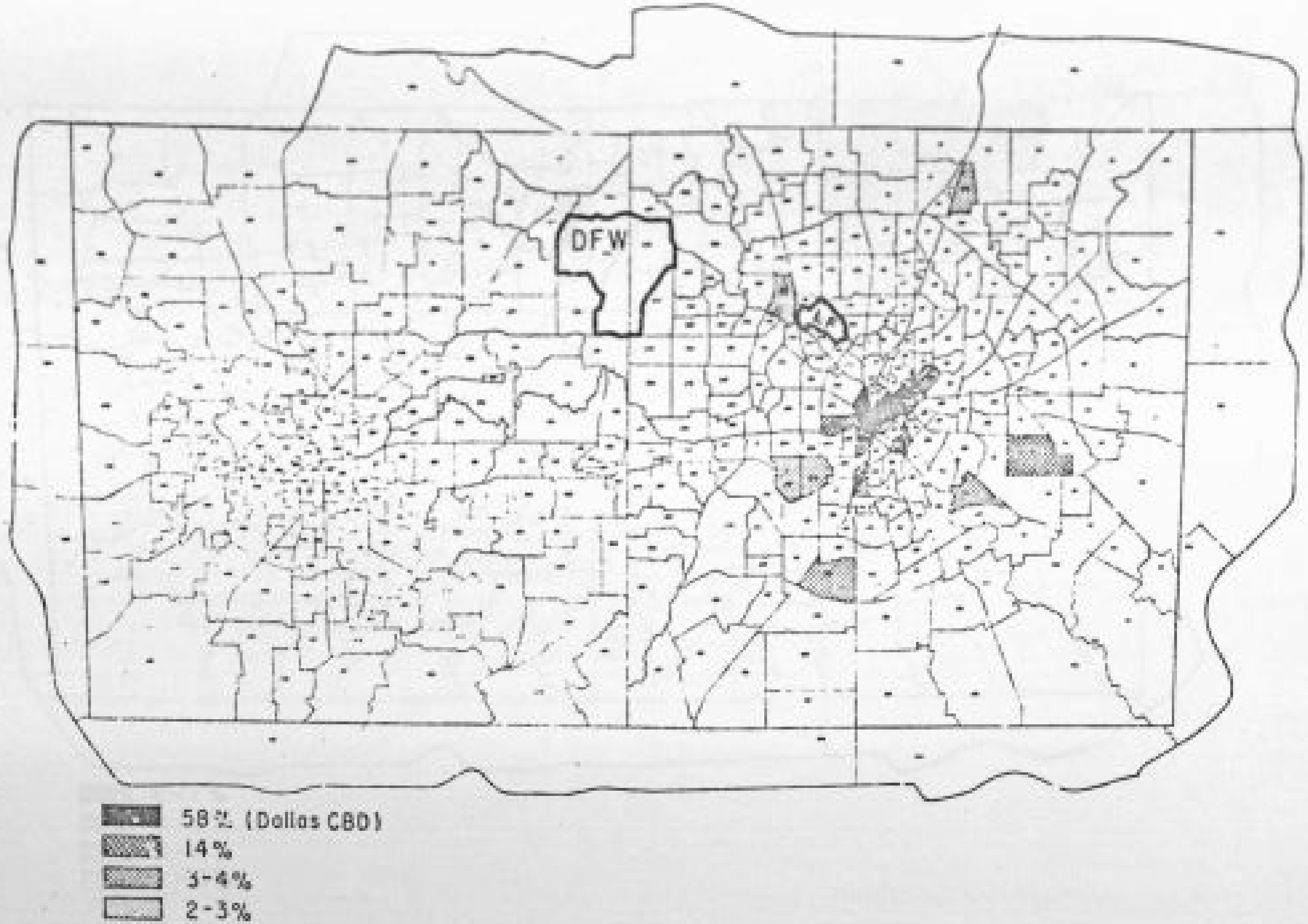


FIGURE 24(b). DESTINATION ZONES OF SURTRAN PASSENGERS, DOWNTOWN DALLAS ROUTE

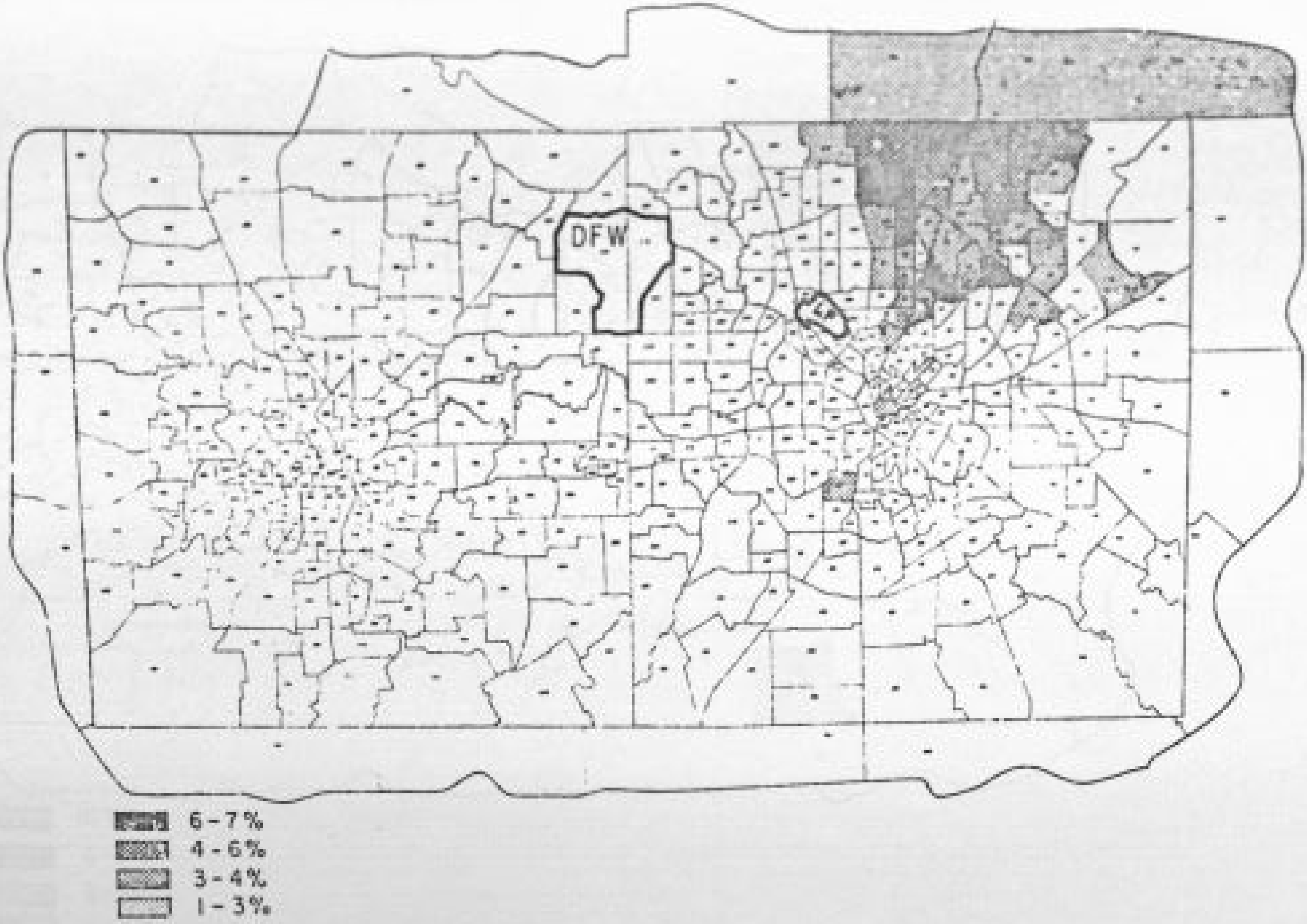


FIGURE 25(a). ORIGIN ZONES OF SURTRAN PASSENGERS, NORTH CENTRAL ROUTE

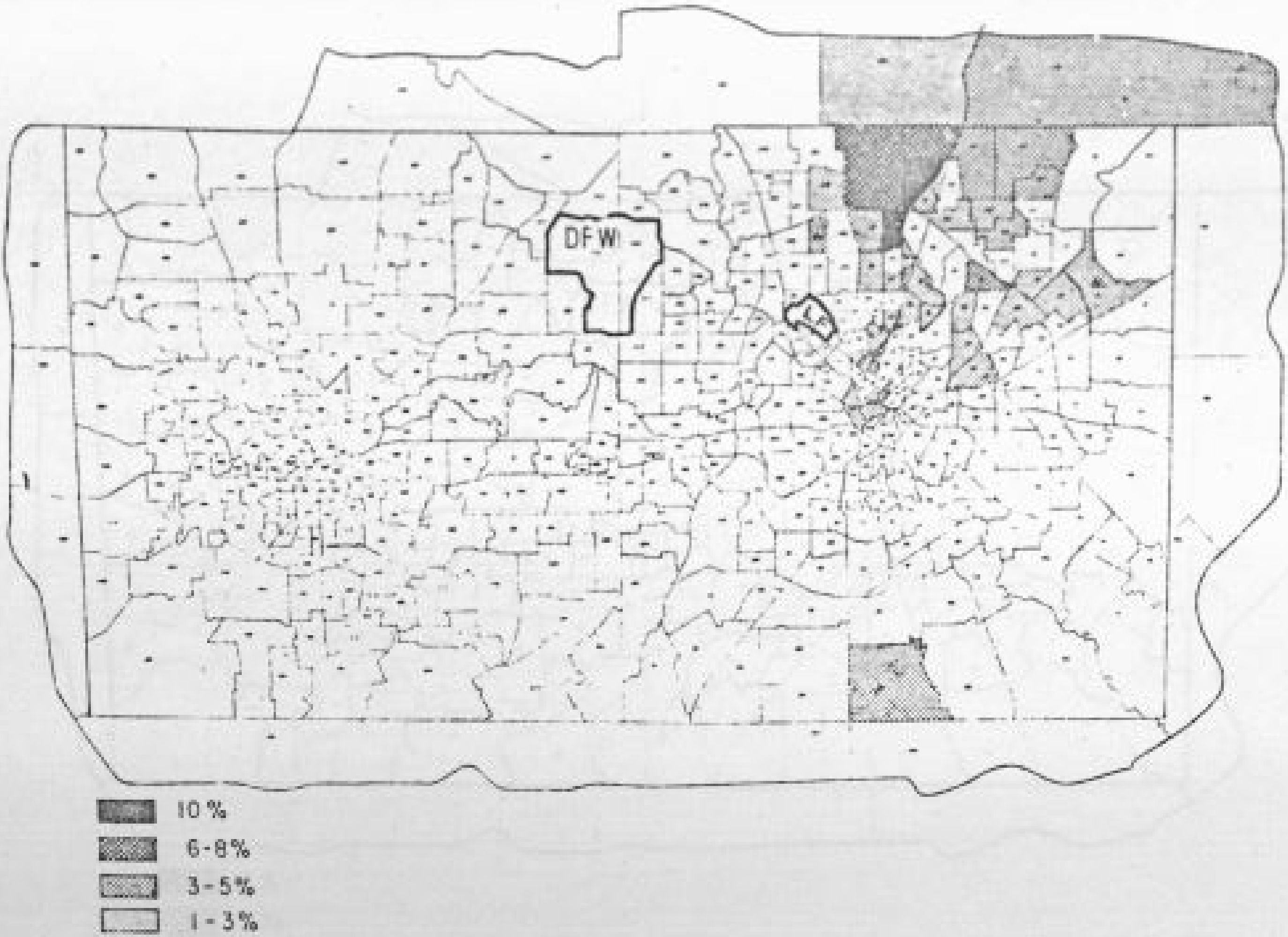


FIGURE 25(b). DESTINATION ZONES OF SURTRAN PASSENGERS, NORTH CENTRAL ROUTE

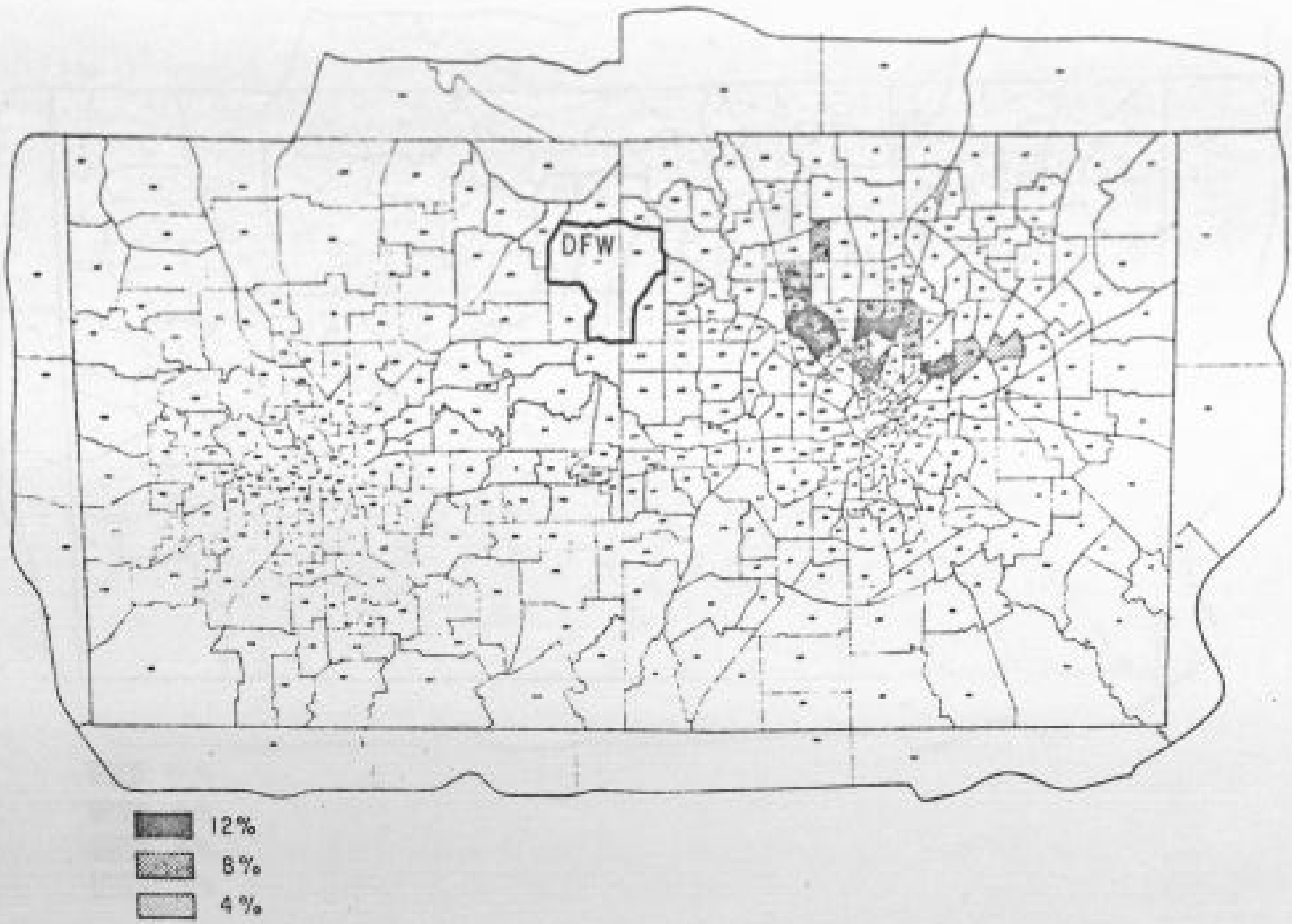


FIGURE 26(a). ORIGIN ZONES OF SURTRAN PASSENGERS, LOVE FIELD ROUTE

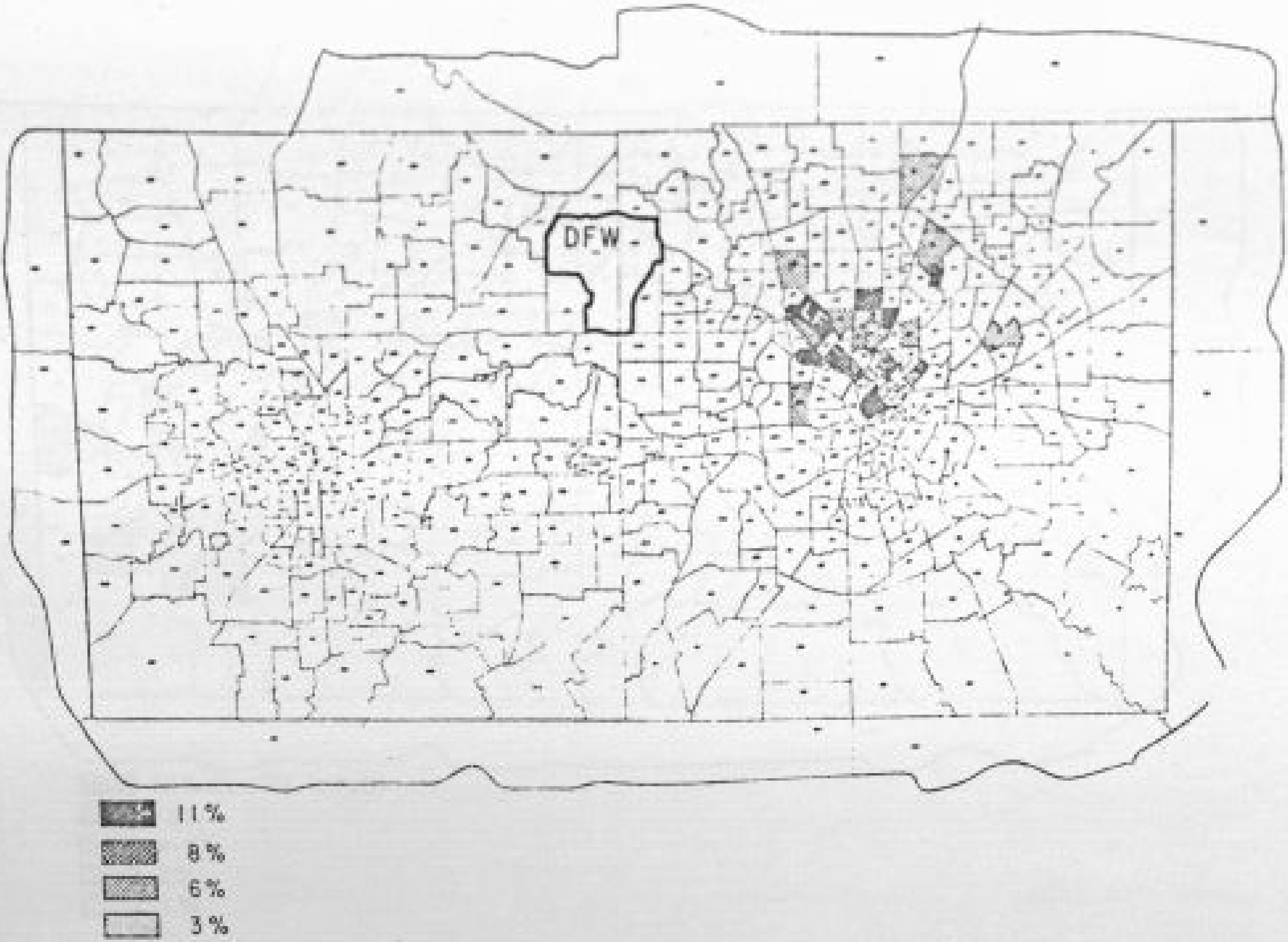


FIGURE 26(b). DESTINATION ZONES OF SURTRAN PASSENGERS, LOVE FIELD ROUTE

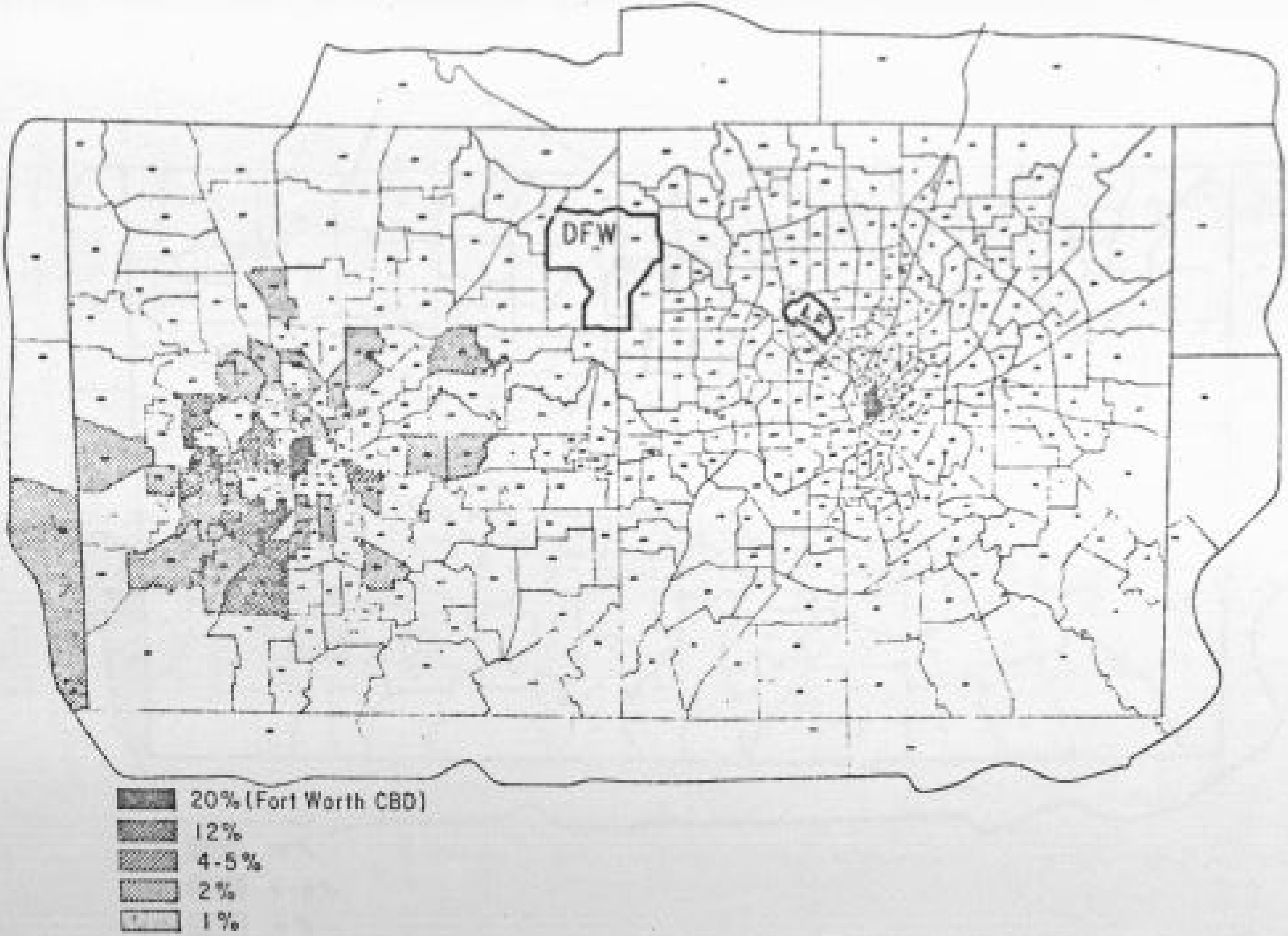


FIGURE 27(a). ORIGIN ZONES OF SURTRAN PASSENGERS, FORT WORTH ROUTE

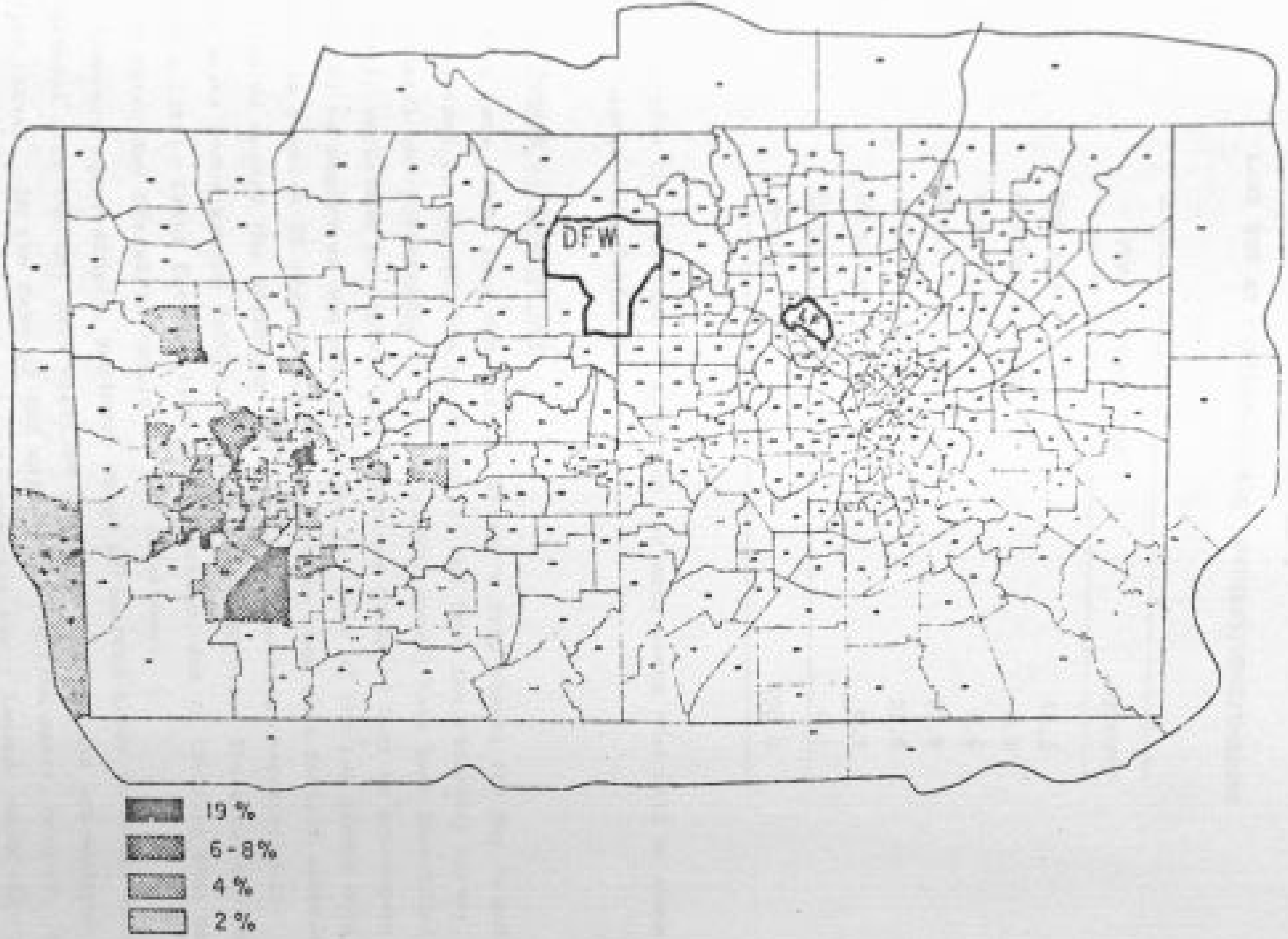


FIGURE 27(b). DESTINATION ZONES OF SURTRAN PASSENGERS, FORT WORTH ROUTE

TABLE 32

LAND USE AT SURTRAN-RIDERS' ORIGINS/DESTINATIONS

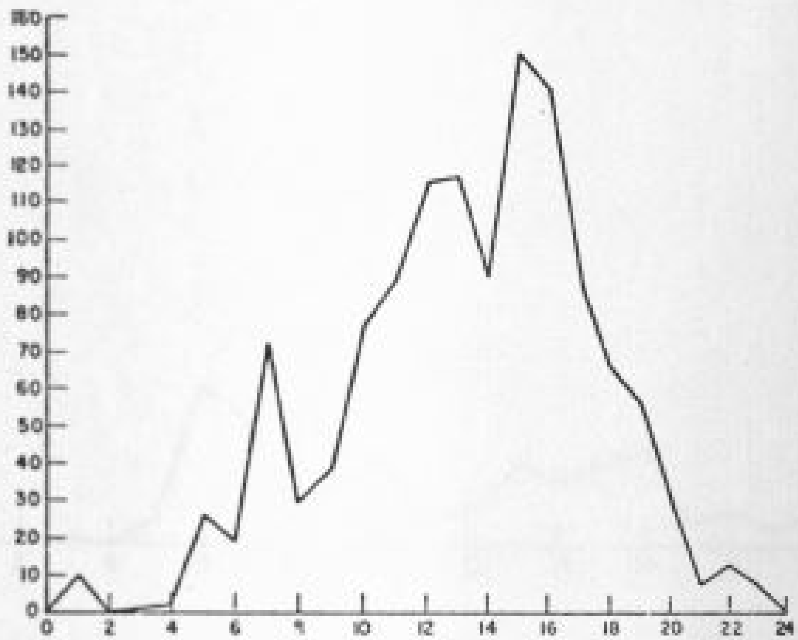
TYPE OF LAND USE	PERCENT
Own Home	43.5
Another's Home	8.8
Work Place	8.6
Other Business Place	11.9
Hotel/Motel	22.8
Shopping	0.3
Other	4.1
TOTAL	100.0

low proportion of this type of land use for auto users that will be shown later in this chapter (cf. Table 48).

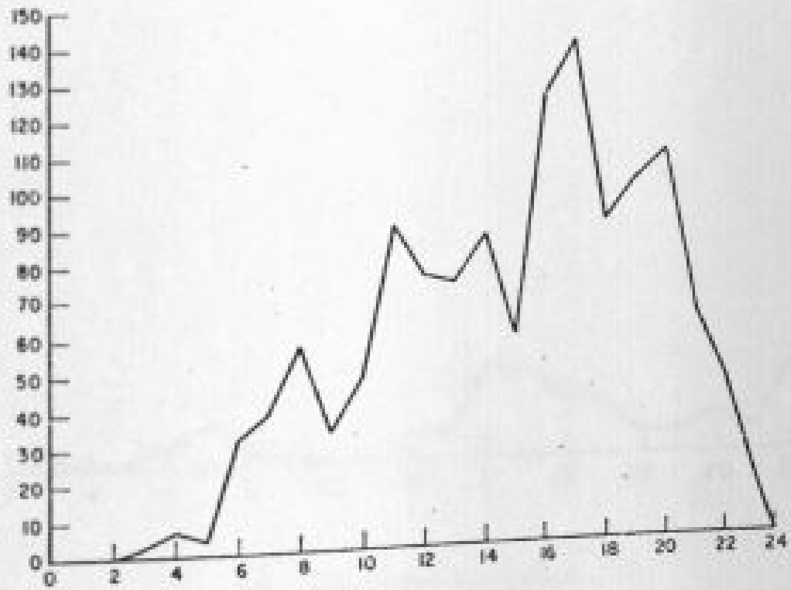
Surtran Demand by Time of Day

From data taken from the Surtran driver's trip sheets for May 16 and 20, 1975 (provided by the Surtran management), and from the ridership survey, certain general characteristics of the ridership demand have been identified. The hourly variation in arrival and departure times of Surtran passengers, disaggregated by employees and non-employees for each of the two survey days, can be seen in Figures 28 through 31. These graphs show that Surtran ridership is oriented toward the afternoon and has strong peaking characteristics. Heavy peaks occur around 8:00 a.m., noon, and 4:00 p.m. The afternoon peak occurs a little later for the from-DFW direction, due to the fact that many one-to-three-day travelers return in the afternoon.

Somewhat surprisingly, employee usage of Surtran tends to be far more homogeneous over the day than employee travel in general and non-employee Surtran travel. In the case of the majority of Surtran users, however, sharp peaking of traffic is clearly evident, creating heavy demands especially in

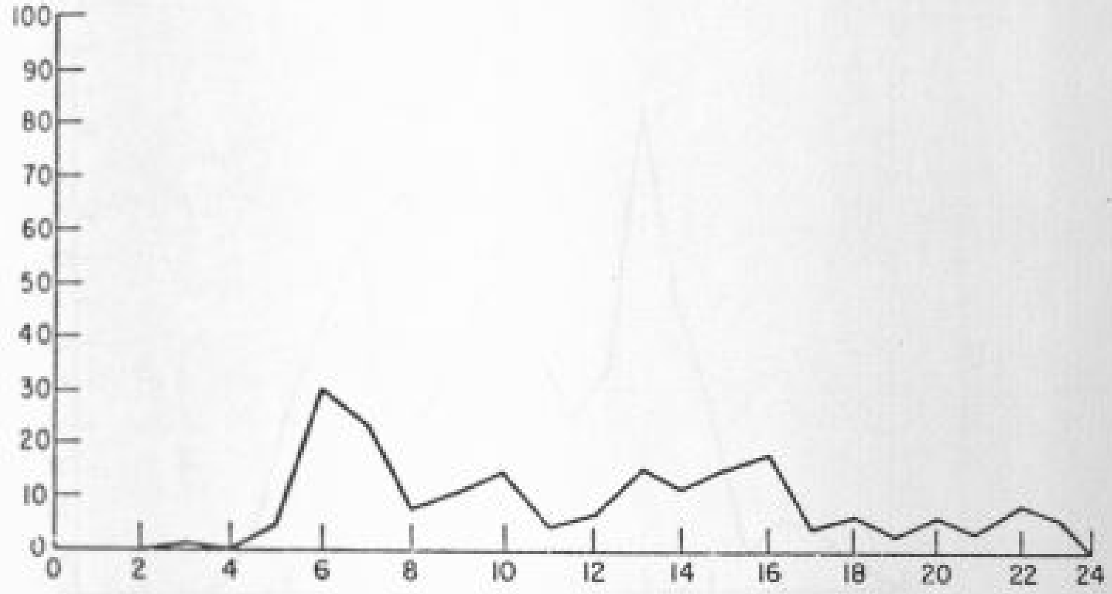


(a) ARRIVING AT DFW

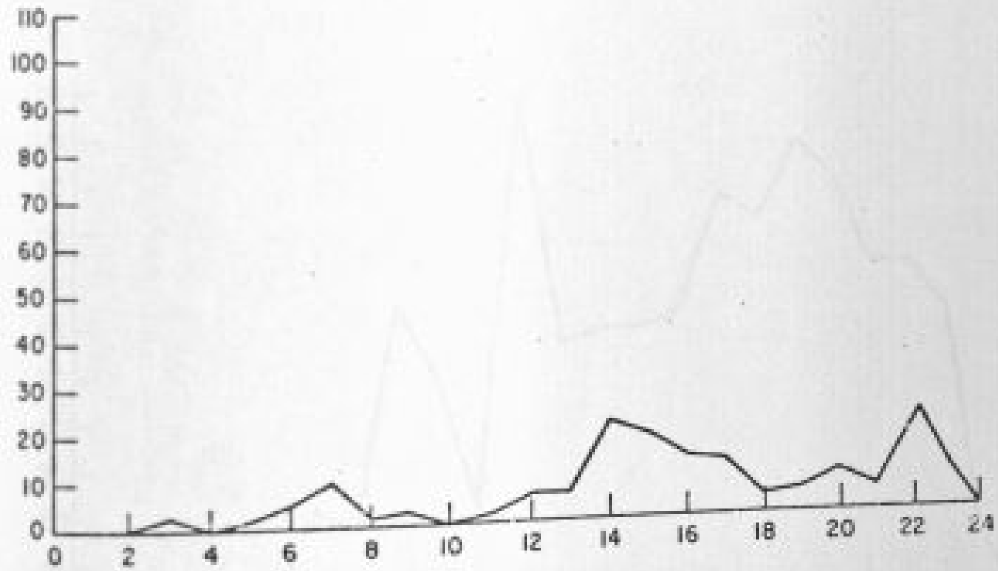


(b) DEPARTING FROM DFW

FIGURE 28. HOURLY DISTRIBUTION OF NON-EMPLOYEE SURTRAN PASSENGERS, FRIDAY

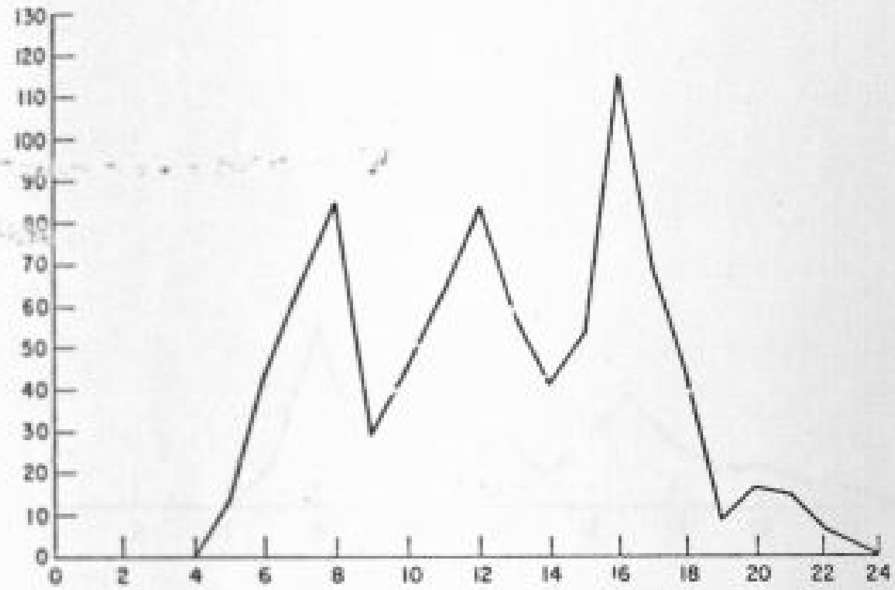


(a) ARRIVING AT DFW

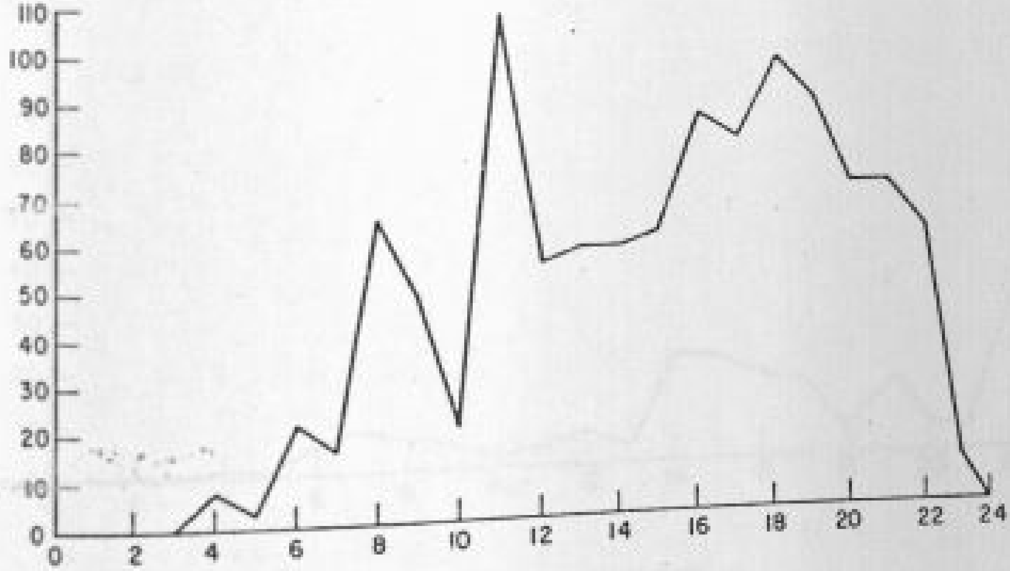


(b) DEPARTING FROM DFW

FIGURE 29. HOURLY DISTRIBUTION OF EMPLOYEE SURTRAN PASSENGERS, FRIDAY

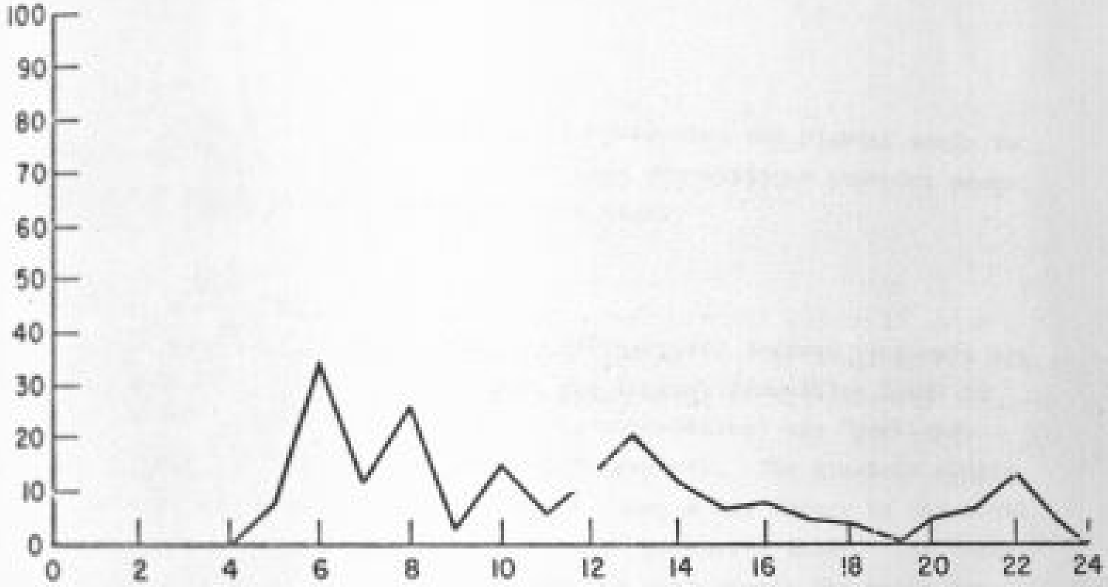


(a) ARRIVING AT DFW

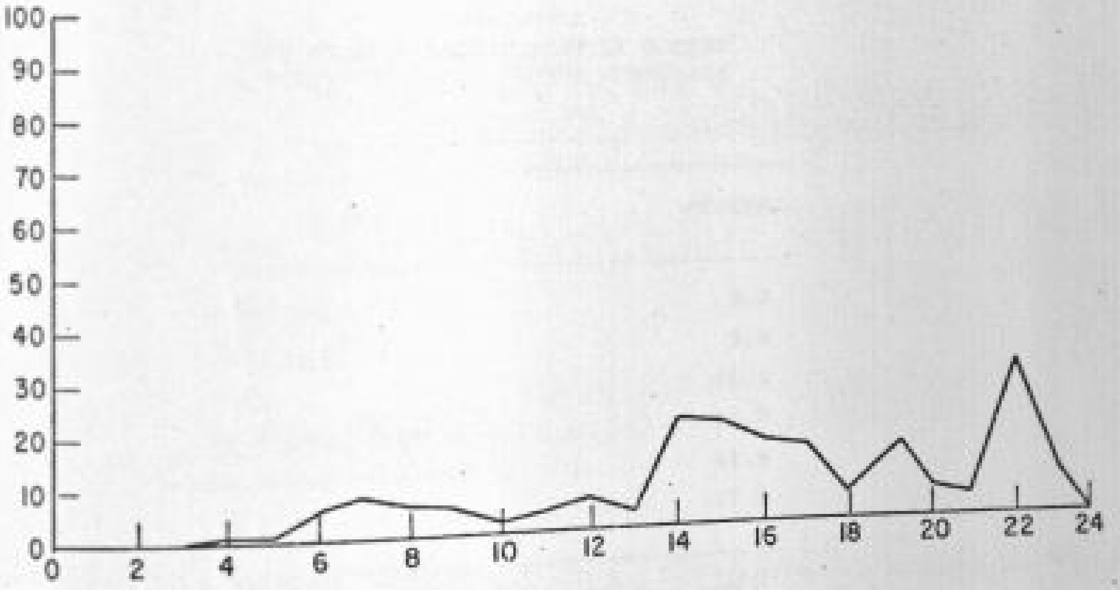


(b) DEPARTING FROM DFW

FIGURE 30. HOURLY DISTRIBUTION OF NON-EMPLOYEE SURTRAN PASSENGERS, TUESDAY



(a) ARRIVING AT DFW



(b) DEPARTING FROM DFW

FIGURE 31. HOURLY DISTRIBUTION OF EMPLOYEE SURTRAN PASSENGERS, TUESDAY

the 16:00 - 17:00 period. It should also be noted that the highest peaks in employee ridership occur at different times than non-employee traveler peaks, so there is not a great superposition of peak loads.

: of Access to Terminal

Modes of access to/from the outlying (off-airport) Surtran terminals are ulated in Table 33. It is evident that the largest proportion (over 58 percent) use personal vehicles (predominantly automobiles) via "park-and-e" (16.7 percent) or "kiss-and-ride" (41.9 percent). The greatest single portion are driven or picked up by someone else, a key factor in the modal ice decisions for using Surtran which will be discussed later. The "Other" egory includes walking to the station (almost exclusively the means for hotel-using riders on the Downtown Dallas route).

TABLE 33

SURTRAN PASSENGERS' MODE OF ACCESS TO/FROM OUTLYING SURTRAN TERMINALS

MODE	PERCENT
City Bus	9.2
Limousine	3.9
Taxi	16.5
Drove Own Vehicle	16.7
Driven by Another	41.9
Other*	11.8
TOTAL	100.0

*Includes walking.

Frequency of Airport Use

Table 34 gives the proportionate distribution of survey respondents annual frequency of travel to/from DFW, while Table 35 gives their frequency of travel to/from Love Field prior to the opening of DFW. It is evident that for the most part there is no significant variation in frequency of primary airport use since the shift to DFW. It is interesting to note, however, that about six percent indicated no previous use of Love Field at all.

The travel survey determined that 31.7 percent of Surtran passengers also were still using Love Field, with a frequency of use distribution as given in Table 36.

Table 37 indicates the breakdown of air mode of these Love Field users. Clearly, the overwhelming proportion use commercial flights.

Ground Trip Purpose

Based on the employee survey, it was determined that employees represented approximately 14 percent of total Surtran passengers on the sample date. Employee ridership was about 25 percent greater in the to-DFW direction, implying that some of these employees may have been picked up or shared a ride after work. As noted in Table 17, the number of employees riding Surtran is about 2.4 percent of the total number of DFW employees making daily trips to the airport.

For the non-employee Surtran passengers, the breakdown of purpose of travel to/from the airport is given in Table 38.

Air Trip Purpose and Duration

Table 39 shows, for airline passengers using Surtran, the distribution of their air trip purpose. The high proportion of businessmen using Surtran is of interest.

The distribution in terms of air trip duration is given in Table 40. Clearly, the substantial majority of trips last four days or less.

TABLE 34

SURTRAN RIDERS' ANNUAL FREQUENCY OF TRAVEL TO/FROM DFW

ANNUAL USE (TIMES PER YEAR)	% OF PASSENGERS
1 - 3	29.7
4 - 8	19.0
9 - 12	12.6
13 - 18	3.8
19 - 24	7.9
25 - 36	8.3
37 - 48	7.4
Over 48	11.3
TOTAL	100.0

TABLE 35

SURTRAN RIDERS' ANNUAL FREQUENCY OF TRAVEL TO/FROM LOVE FIELD BEFORE DFW

ANNUAL USE (TIMES PER YEAR)	% OF PASSENGERS
None	6.3
1 - 3	26.7
4 - 8	20.6
9 - 12	11.4
13 - 18	3.2
19 - 24	8.0
25 - 36	8.5
37 - 48	5.4
Over 48	9.9
TOTAL	100.0

TABLE 36

SURTRAN RIDERS' ANNUAL FREQUENCY OF TRAVEL TO/FROM LOVE FIELD (CURRENT LOVE FIELD USERS)

ANNUAL USE (TIMES PER YEAR)	% OF PASSENGERS
1 - 3	39.9
4 - 8	24.8
9 - 12	13.8
13 - 18	0.9
19 - 24	11.5
25 - 36	4.1
37 - 48	2.3
Over 48	2.7
TOTAL	100.0

TABLE 37

LOVE FIELD AIR MODE CURRENTLY USED BY SURTRAN RIDERS

AIR MODE	% OF PASSENGERS
Commercial	92.2
Private	3.2
Both	4.6
TOTAL	100.0

TABLE 38

SURTRAN PASSENGERS' GROUND TRIP PURPOSE

(NON-EMPLOYEE PERSON-TRIPS)

PURPOSE	PERCENT
Airline Passenger	94.0
Greeting Air Passenger	0.4
Seeing Air Passenger Off	0.6
Pick Up Ticket	0.2
Business at Airport	2.4
Visitor	1.8
Other	0.6
TOTAL	100.0

TABLE 39

SURTRAN-USING AIRLINE PA"SENGERS' AIR TRIP PURPOSE

PURPOSE	PERCENT
Business/Employment	67.4
Vacation	9.2
Convention	4.4
Personal Affairs	6.9
Vis.ting Family, etc.	8.0
Military	1.9
School	1.3
Other	0.9
TOTAL	100.0

Travel Distance and Time

Surtran passengers' perceived versus actual (minimum-path computed) travel distances and times from their origin or destination to DFW are given in Table 41. These data seem to suggest that passengers tend to overestimate both their travel distances and tire to DFW.

Surtran users were also asked to estimate their distance and time to Love Field. These results, together with actual minimum-path computations, are given in Table 42. In this case, there again seems a slight tendency of the respondents to overestimate both their total distance and time to Love Field.

With regard to the impact of relocating the regional air facility from Love Field to DFW, it is particularly interesting to contrast both perceived and actual distance/time statistics for these ground trips. In every case, for the substantial majority of users both perceived and actual values are much larger for their trip to DFW.

While actual distance to DFW is 20 miles or more for a majority of these passengers, actual distance to Love Field is 11 miles or less for most. A majority estimate their distance to DFW to be 25 miles or more, but most passengers estimate the Love Field distance to be 15 miles or less.

Actual travel time for most passengers from their origin/destination is 30 minutes or more to DFW but 24 minutes or less to Love Field. Similarly for perceived time, the results are 40 minutes or more to DFW, 29 minutes or less to Love Field.

Based on these determinations, it can be concluded that the shift from inner-city Love Field to the somewhat more remote (at least vis-a-vis Dallas) DFW has resulted in appreciably longer trip lengths and travel times. These results may have ancillary impacts in terms of travel costs and energy consumption.

Marketing Considerations

In view of recent emphasis on mass transit among transportation planners, the survey data were especially significant in pointing to factors influencing the modal choice of Surtran users. Over one-third (34.5 percent) of the surveyed riders indicated they were using the service for the first time. Passengers were asked to weigh their reasons for using Surtran; the results

TABLE 40

SURTRAN-USING AIR PASSENGERS' AIR TRIP DURATION

TRIP DURATION RANGE	% PASSENGERS IN RANGE
1 Day	22.1
2 - 4 Days	41.3
5 - 7 Days	20.6
1 - 2 Weeks	10.9
3 - 4 Weeks	2.6
Over 1 Month	2.5
TOTAL	100.0

TABLE 41

DISTRIBUTION OF SURTRAN PASSENGERS' PERCEIVED VERSUS ACTUAL TRAVEL DISTANCES AND TIMES BETWEEN ORIGIN/DESTINATION AND DFW

DISTANCE RANGE (MILES)	% PASSENGERS IN RANGE	
	PERCEIVED DISTANCE	ACTUAL DISTANCE
0 - 2	3.0	-
3 - 5	3.2	-
6 - 8	1.8	0.1
9 - 11	2.5	0.1
12 - 15	8.2	1.4
16 - 19	4.6	9.5
20 - 24	24.1	57.3
25 - 29	17.1	17.1
30 - 39	22.6	13.9
40 - 49	6.0	0.6
50 - 75	1.9	-
76 & over	5.0	-
TOTAL	100.0	100.0

TIME RANGE (MINUTES)	% PASSENGERS IN RANGE	
	PERCEIVED TIME	ACTUAL TIME
0 - 5	1.2	-
6 - 10	1.2	-
11 - 15	1.6	0.1
16 - 19	-	0.5
20 - 24	2.5	2.4
25 - 29	2.0	30.9
30 - 39	17.9	53.2
40 - 49	34.7	11.3
50 - 60	28.0	1.6
61 & over	10.9	-
TOTAL	100.0	100.0

TABLE 42

DISTRIBUTION OF SURTRAN PASSENGERS' PERCEIVED
VERSUS
ACTUAL TRAVEL DISTANCES AND TIMES BETWEEN ORIGIN/DESTINATION AND LOVE FIELD

DISTANCE RANGE (MILES)	% PASSENGERS IN RANGE	
	PERCEIVED DISTANCE	ACTUAL DISTANCE
0 - 2	4.0	1.7
3 - 5	18.1	5.5
6 - 8	11.7	36.7
9 - 11	15.8	12.5
12 - 15	14.9	15.2
16 - 19	4.9	7.0
20 - 24	8.0	3.4
25 - 29	1.4	0.9
30 - 39	5.9	11.1
40 - 49	5.8	6.0
50 - 75	5.9	-
76 & over	3.6	-
TOTAL	100.0	100.0

TIME RANGE (MINUTES)	% PASSENGERS IN RANGE	
	PERCEIVED TIME	ACTUAL TIME
0 - 5	3.2	0.9
6 - 10	9.8	2.6
11 - 15	16.9	6.1
16 - 19	0.6	29.7
20 - 24	19.5	24.8
25 - 29	7.8	11.2
30 - 39	17.2	6.6
40 - 49	6.5	7.1
50 - 60	8.6	9.4
61 & over	9.9	1.6
TOTAL	100.0	100.0

are illustrated in Figure 32. It can be seen that "captive" ridership played a significant role in the usage of the Surtran transit service. Included as "other" reasons were such factors as travel cost savings and environmental considerations.

Asked to rate the "convenience" of the station location, over 90.4 percent of the passengers indicated the location as convenient, including 40.6 percent who rated it as "very convenient." Only 9.5 percent indicated the location was inconvenient.

Also important in the market analysis of transit service was the medium through which particular passengers were persuaded to try Surtran. Passenger responses on this item are illustrated in Figure 33.

Demographic Characteristics

The survey determined that 78.0 percent of Surtran users were male and only 22.0 percent female. Their distribution by age, occupation, and income has already been given in Tables 10 through 12. Their industrial affiliation is given in Table 43.

TABLE 43

DISTRIBUTION OF SURTRAN PASSENGERS' INDUSTRIAL AFFILIATIONS

INDUSTRIAL CATEGORY	% PASSENGERS IN CATEGORY
Construction	3.4
Manufacturing	18.6
Transportation	5.9
Wholesale/Retail Trade	11.4
Communications/Utilities	7.5
Public Administration	11.9
Finance/Insurance/Real Estate	12.1
Electronics	0.8
Data Processing	1.4
Oil	3.5
Education	6.5
Military	4.3
Other	12.7
TOTAL	100.0

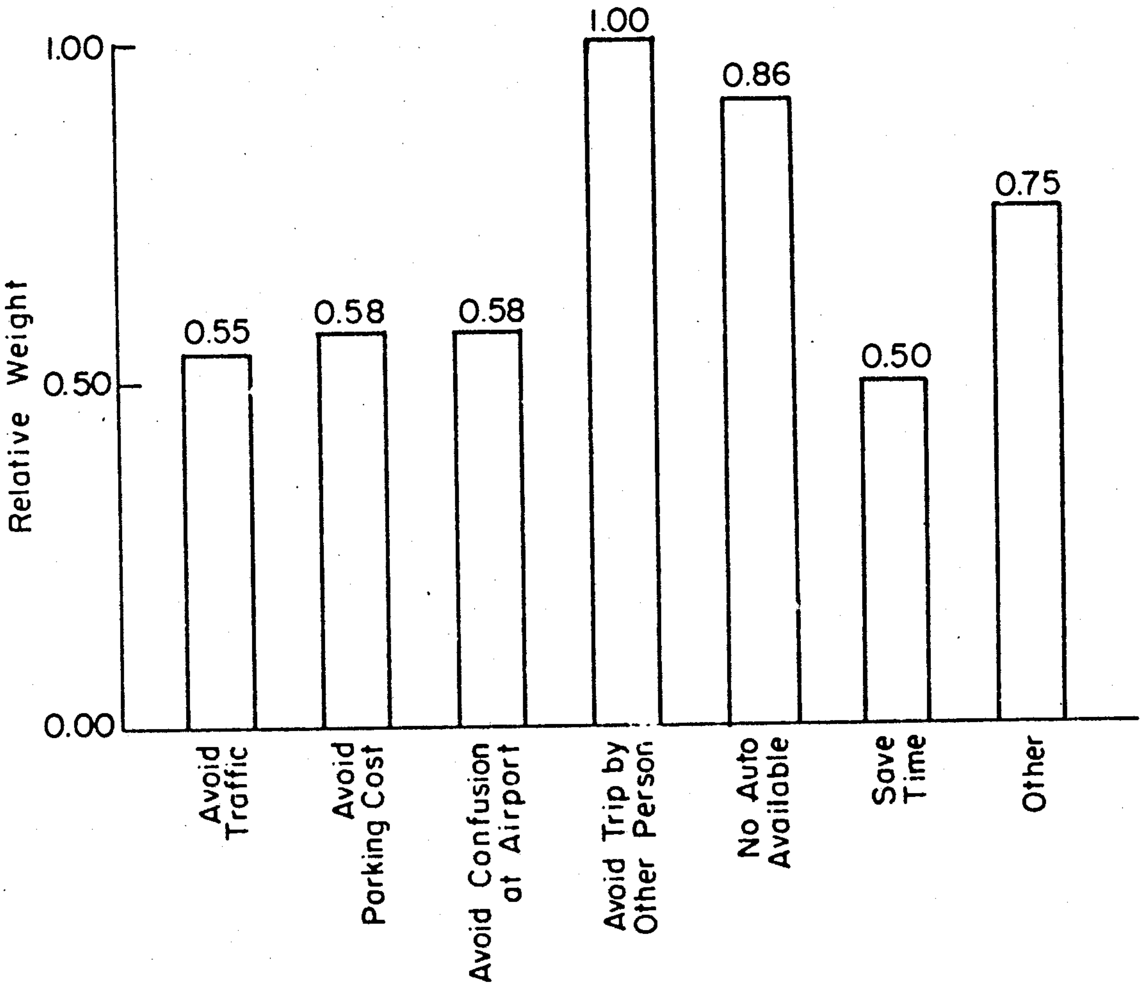


FIGURE 32. SURTRAN PASSENGERS' MODAL CHOICE CONSIDERATIONS

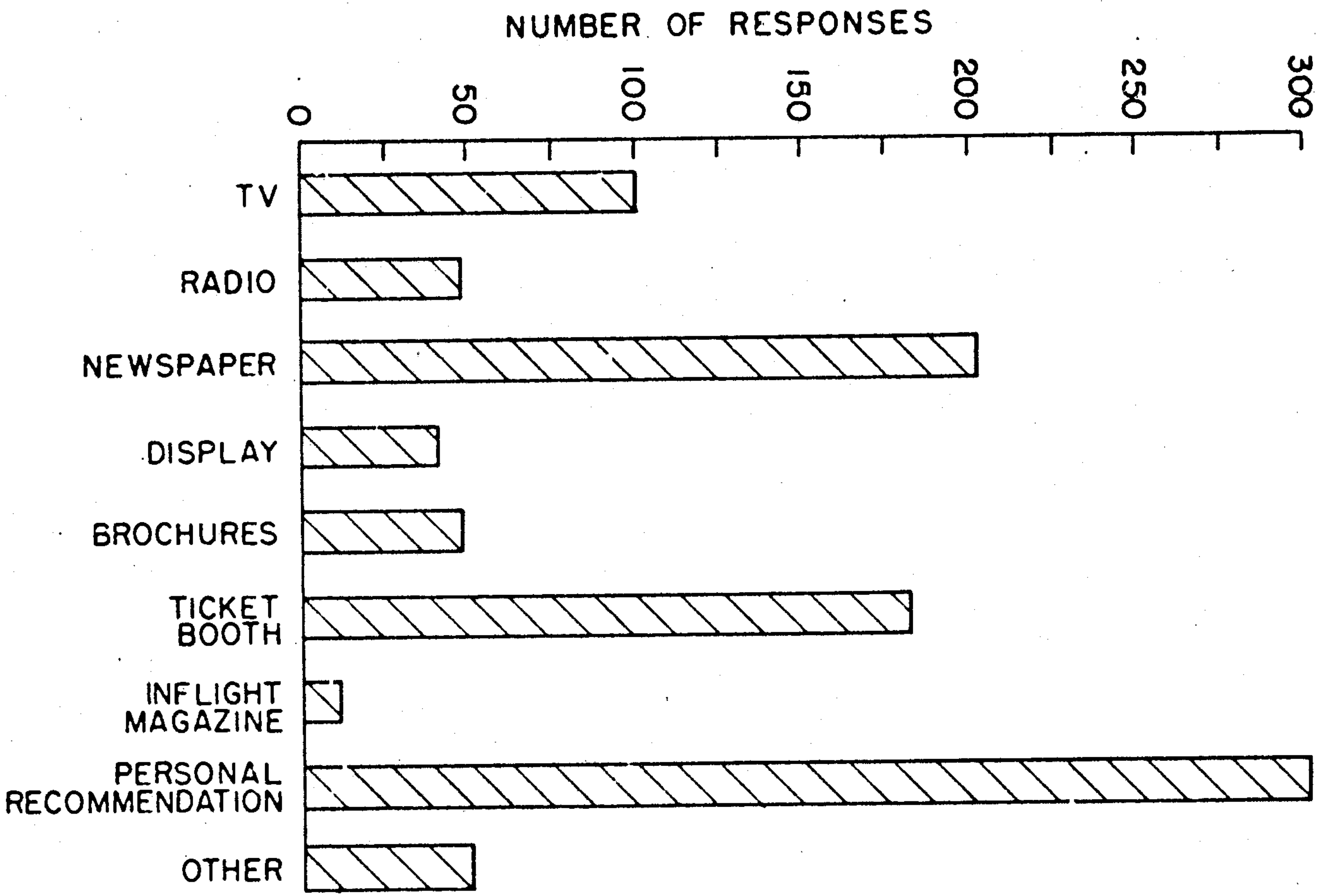


FIGURE 33. SURTRAN PASSENGERS' SOURCE OF INFORMATION ABOUT SURTRAN

As Table 44 indicates, Surtran passengers are virtually equally divided between Dallas/Fort Worth area residents and nonresidents.

TABLE 44

DALLAS/FORT WORTH-AREA RESIDENCY OF SURTRAN PASSENGERS

RESIDENCY	% OF TOTAL PASSENGERS
Residents	49.6
Nonresidents	50.4
TOTAL	100.0

Table 45 gives the five cities accounting for the highest proportion of residents among Surtran passengers who are local residents; Dallas is the city of residence for almost half.

TABLE 45

CITIES WITH GREATEST SHARE OF LOCAL RESIDENT SURTRAN PASSENGERS

CITY OF RESIDENCE	SHARE OF RESIDENTS, %
Dallas	45.5
Fort Worth	18.8
Richardson	13.2
Garland	6.0
Plano	4.9
TOTAL	88.4

AUTOMOBILE USER/TRAFFIC SURVEY

In making a survey of automobile (personally-operated motor vehicle) users of DFW, a total of 886 interviews were conducted, 497 on Friday and 389 on Tuesday. Of this total, 22 were not useable, which reduced the sample size to 864. Even with this reduction and the bad weather experienced on Tuesday, a sample size of 4.94 percent was obtained. Considering the restrictions in the survey technique and the resources available, this sample size is considered adequate for the analysis.

For the traffic survey, automatic machine counters and individual observer personnel making manual counts were used. The deployment of these was discussed in Chapter II.

Daily Traffic Volume

Based both on the automatic machine counter reports and on the manual traffic counts by survey personnel, a total tabulation of 24-hour motor vehicle traffic volumes was developed. From these traffic counts, it has been determined that 67.1 percent of all vehicles using the airport passed through the control plazas (via International Parkway) while the remaining 32.9 percent used the service road and/or the perimeter road, Air Field Drive.

Table 46 gives a tabulation of 24-hour traffic volumes by machine counter stations. (See Figure 11 for key.) Table 47 gives a summary of traffic volumes by roadway location for each of the two survey days (Main Road refers to both International Parkway and the flanking service roads). These counts are slightly higher than the sum of Control Plaza plus service road counts since a small number of vehicles can access the main roadway via Airfield Drive, inner-airport garages, and similar points.)

TABLE 46

24-HOUR VEHICULAR TRAFFIC VOLUMES BY MACHINE COUNTER STATION

STATION	FRIDAY 5/16/75 (VEHICLES)	TUESDAY 5/20/76 (VEHICLES)
1	13,653	11,847
2	13,729	12,372
3	9,278	7,927
4	9,720	8,174
5	7,392	6,363
6	7,225	5,813
7	8,378	6,732
8	8,972	7,613
9	4,269	4,204
10	4,378	4,310
11	2,137	2,247
12	2,341	1,948
13	1,012	812
14	1,649	1,545

Figure 34 illustrates the traffic pattern on the Main Roadway. Figure 35 illustrates the pattern in terms of disaggregated Control Plaza (black arrows) and Service Road (white arrows) volumes.

Traffic Volume by Time of Day

Figures 36(a) and (b) are graphs of hourly inbound and outbound traffic volumes, respectively, on the Friday, 16 May 1975, survey date; Main Roadway, Control Plaza, and Service Road volumes are each shown separately. Figures 37(a) and (b) similarly graph such data for the Tuesday, May 20, date.

An examination of these graphs reveals that the peaks in Service Road volumes frequently occur at times when Control Plaza volumes are at an ebb. High Control Plaza volumes tend to occur in morning and late afternoon hours when airline passenger traffic is heaviest [cf. Figures 12(a) and (b) and Figures 13(a) and (b) for example.]

Figures 38(a) and (b) and 39(a) and (b) compare inbound and outbound air passenger vehicle volumes with total vehicle volumes on the two survey dates. It is evident that employee and air passenger vehicle volumes do not peak at the same time but tend to occur independently, thus mitigating the congestion that would otherwise occur if the two peaking patterns reinforced each other.

Origins/Destinations of Auto Users

As indicated in Tables 7 through 9, trips via personally-operated motor vehicles (referred to as automobiles in this report, although a fraction were pickup trucks, recreational vehicles, motorcycles, etc.) constituted 93.0 percent of all vehicle trips, 65.9 percent of all person trips, and 74.3 percent of air passenger ground trips to or from DFW.

Figure 40 shows the origin/destination distribution of all DFW user O/D's in the Dallas/Fort Worth area. It is interesting to note the substantial differences in distribution of these auto-user trip-ends as compared with those of employees and Surtran users. For example, a slightly heavier concentration of O/D's in the Dallas CBD can be perceived (similar to the Surtran case and in the area north of DFW); however, concentrations as a whole are relatively sparse and dispersed throughout the region, generally resembling the pattern for employees.

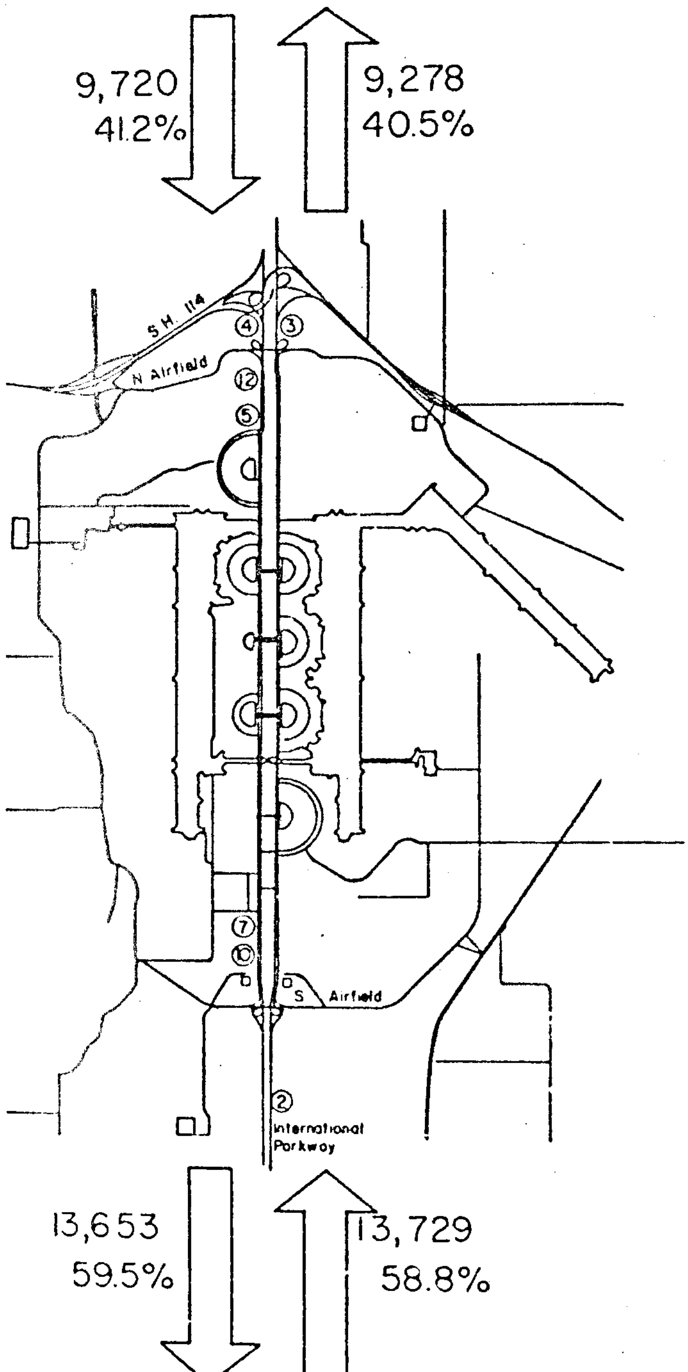


FIGURE 34. MAIN ROADWAY TRAFFIC PATTERN

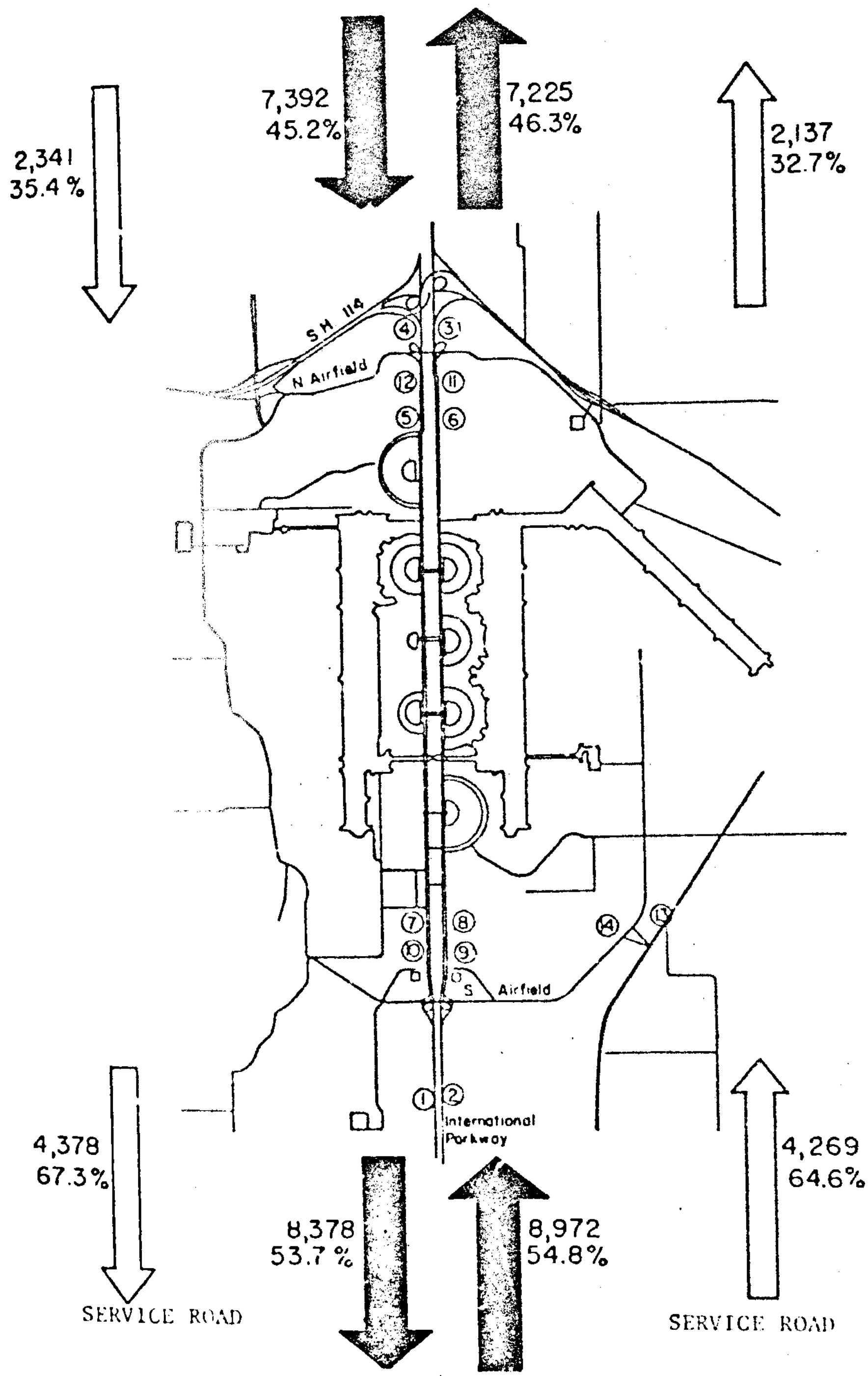
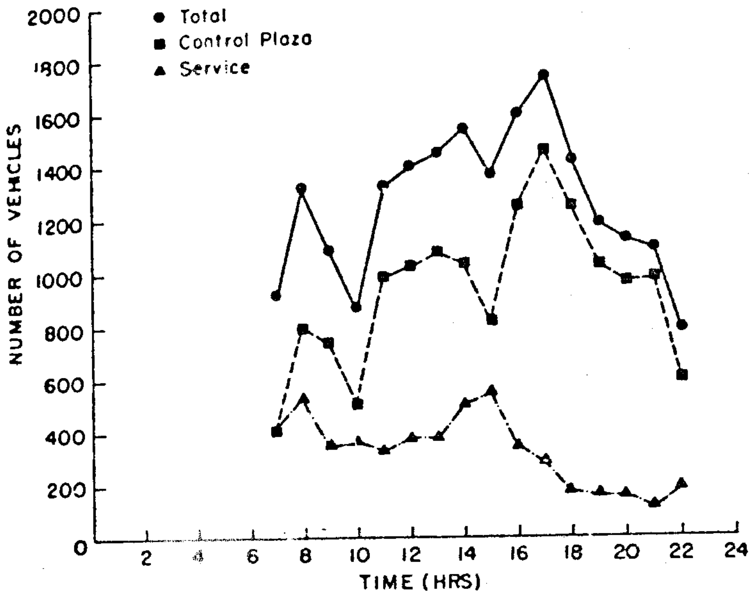
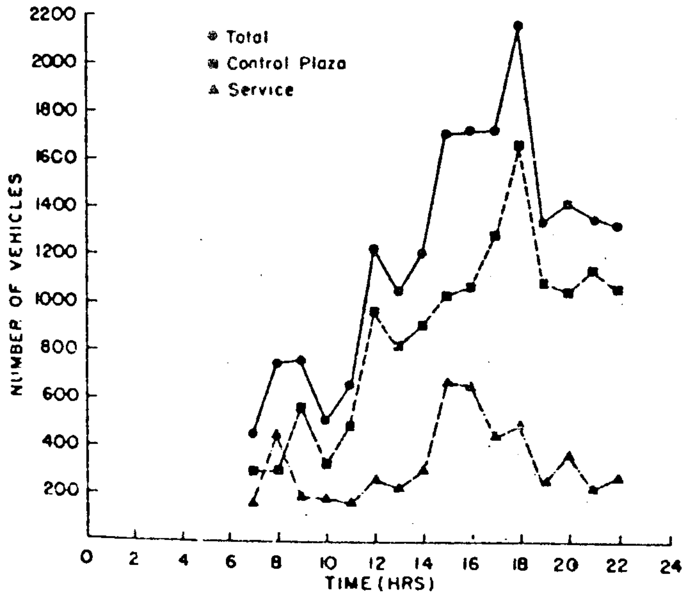


FIGURE 35. MAIN ROADWAY TRAFFIC PATTERNS, BY CONTROL PLAZA AND SERVICE ROAD PATTERNS

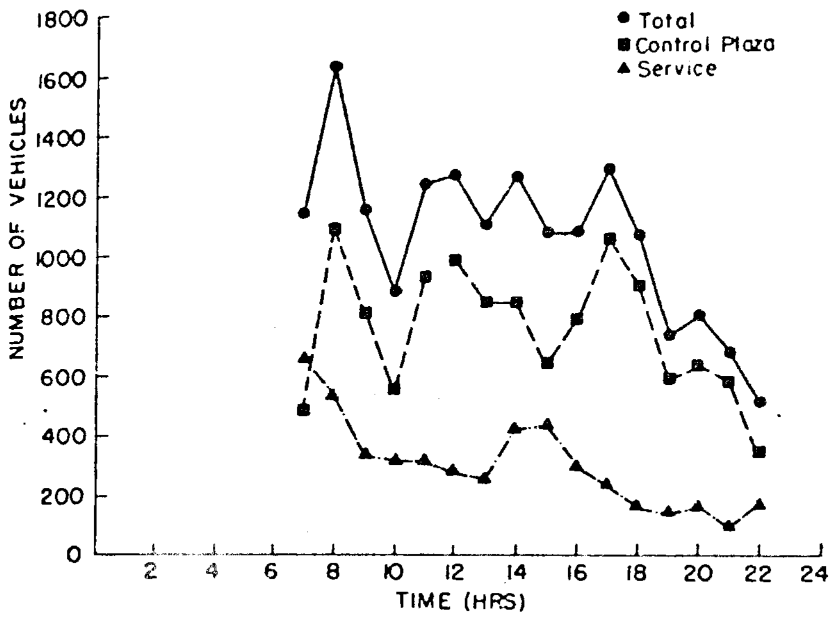


(a) INBOUND

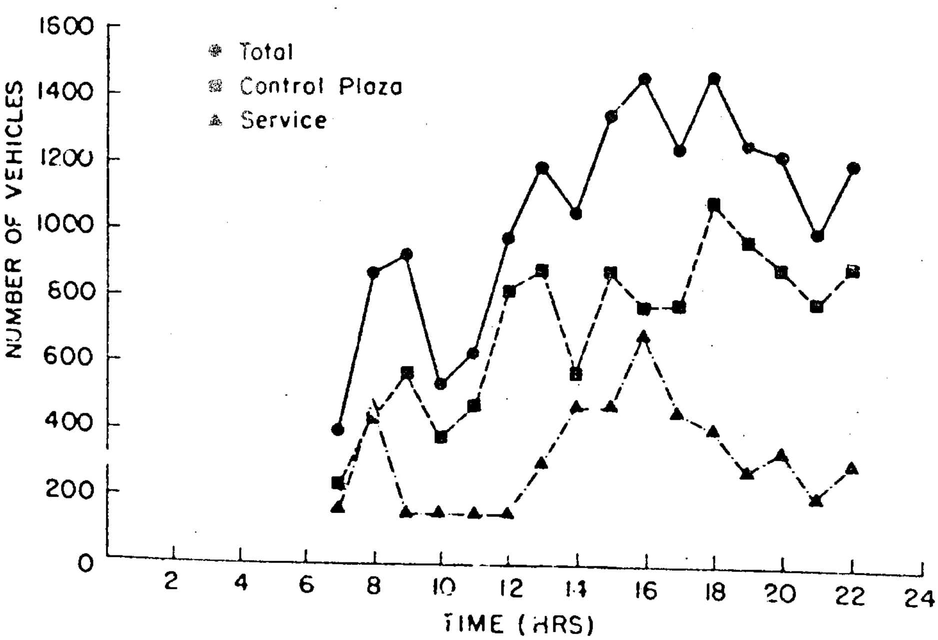


(b) OUTBOUND

FIGURE 36. HOURLY DISTRIBUTIONS OF VEHICLES BY ROADWAY, FRIDAY

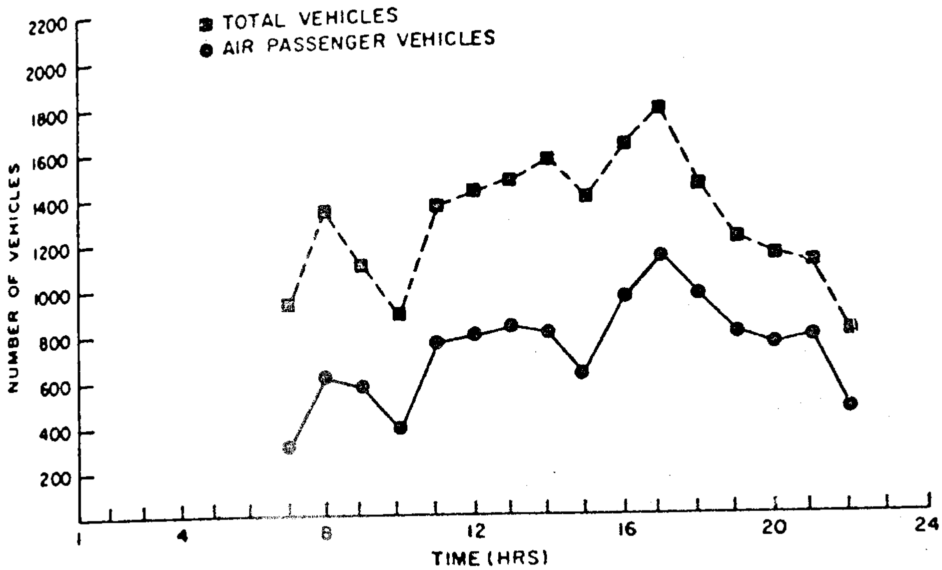


(a). INBOUND

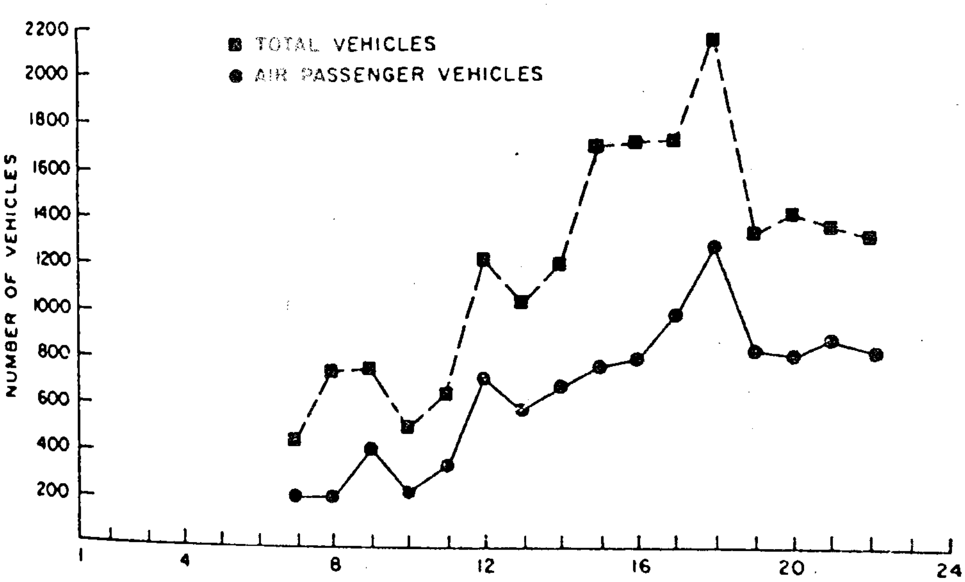


(b). OUTBOUND

FIGURE 37. HOURLY DISTRIBUTIONS OF VEHICLES BY ROADWAY, TUESDAY

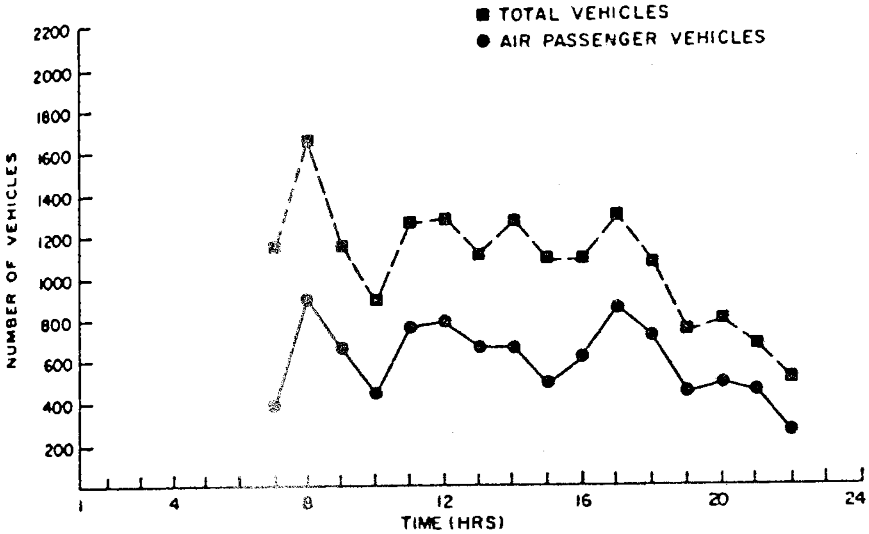


(a). INBOUND

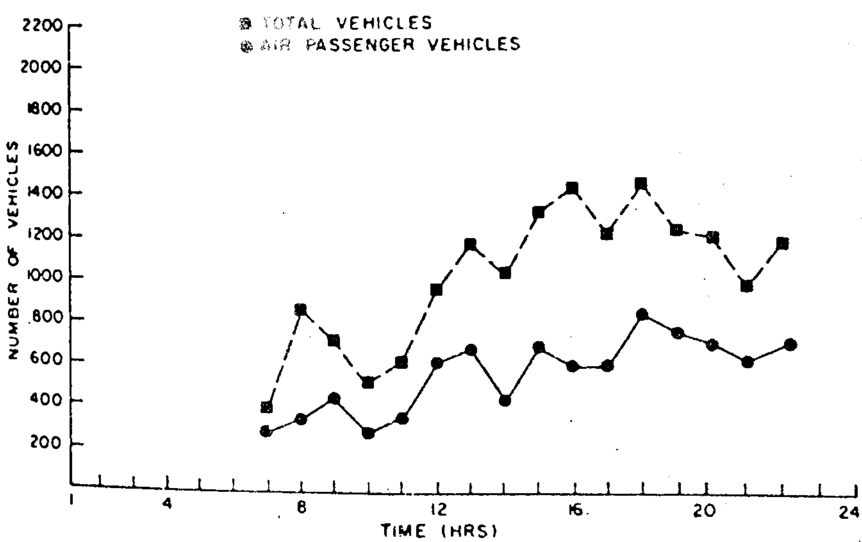


(b). OUTBOUND

FIGURE 38. HOURLY DISTRIBUTIONS OF VEHICLES, TOTAL AND AIR PASSENGER VEHICLES, FRIDAY



(a). INBOUND



(b). OUTBOUND

FIGURE 39. HOURLY DISTRIBUTIONS OF VEHICLES, TOTAL AND AIR PASSENGER VEHICLES, TUESDAY

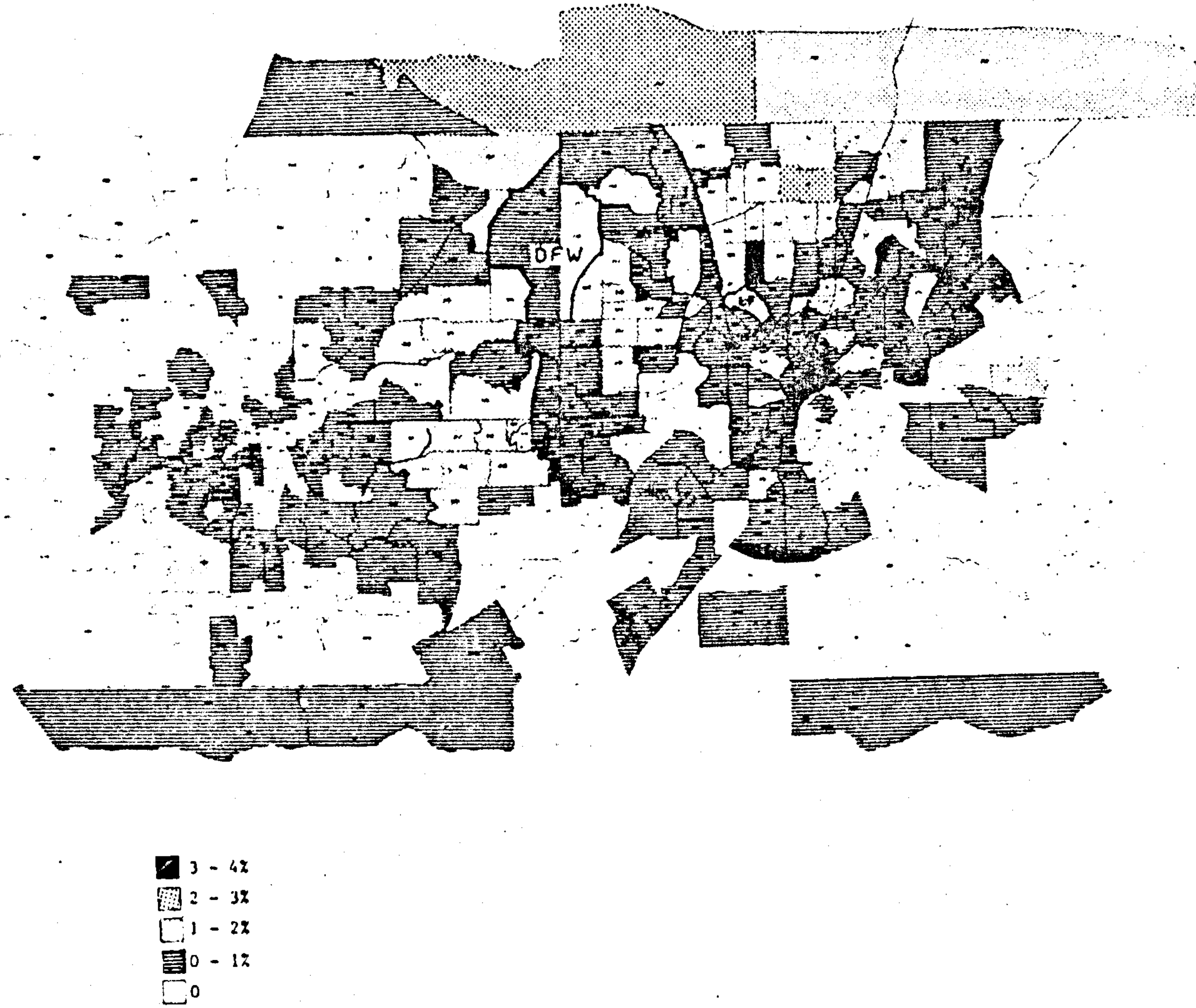


Figure 40. LOCATION OF AUTO-USERS' TRIP-ENDS, BY ZONE

Land Use

As with Surtran passengers, motorists were asked to indicate the type of land use at their ground trip origins and destinations. The proportions of land uses at auto-users' aggregated trip-ends are given in Table 48.

TABLE 48

LAND USE AT AUTO-USERS' ORIGINS/DESTINATIONS

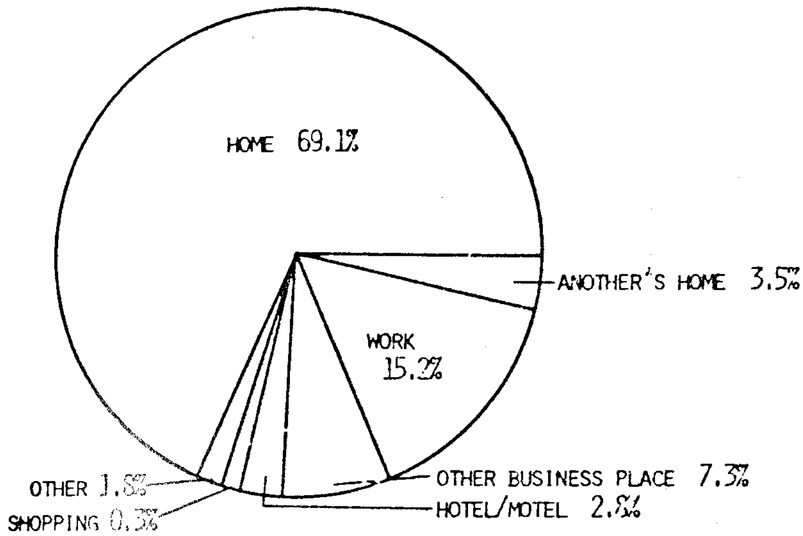
TYPE OF LAND USE	PERCENT
Own Home	67.5
Another's Home	3.7
Work Place	15.1
Other Business Place	7.2
Hotel/Motel	3.0
Shopping	0.5
Other	3.0
TOTAL	100.0

Comparing Table 48 with proportionate land uses at Surtran passengers' O/D's (Table 32), however, reveals significant differences. It is apparent that substantially more motorists begin and end their DFW trips at their own homes or places of work. On the other hand, the percentage of trips beginning or ending at a hotel or motel is about seven times greater for Surtran riders, while trip-ends at "Another's Home" or "Other Business Place" are also more predominant for Surtran users.

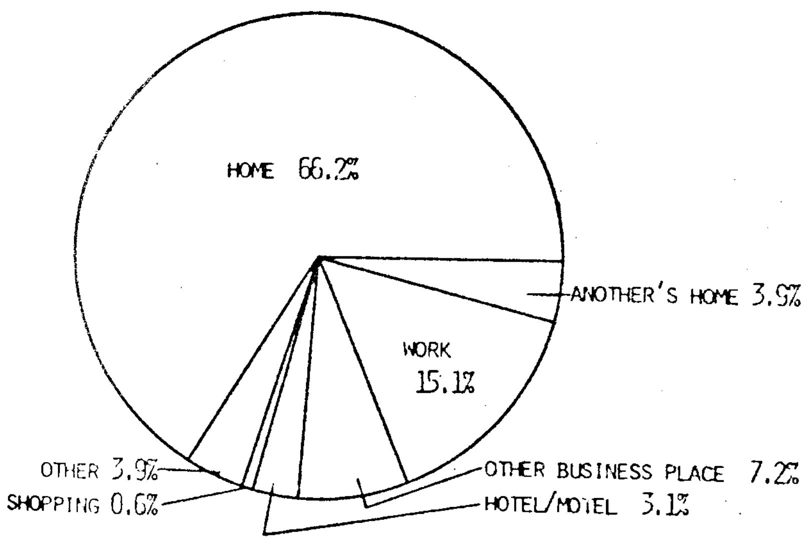
Figures 41(a) and (b) illustrate proportionate types of land use at auto-users' origins and destinations, respectively. There does not appear to be any significant variation in land use distribution between the two trip-end types.

Auto-Users' Modal Characteristics

The survey also determined certain significant characteristics of auto-using air passengers' sub-modal split, i.e., the split between those who drive



(a). AT ORIGINS



(b). AT DESTINATIONS

FIGURE 41. DISTRIBUTIONS OF AUTO-USERS' LAND USE

themselves and those who are driven by someone else. These characteristics would, of course, impact airport access volumes and the demand for long-term parking, curbside space, and auto rental.

The breakdown of auto-users' mode into privately-owned versus rented vehicles is illustrated in Figure 42. The overwhelming bulk of this mode of travel is in privately-owned vehicles.

Survey results indicate that the percentage of vehicles interviewed that carried an air passenger (the first three categories of Table 58) was 81.6 percent on Friday and 86.2 percent on Tuesday. From both days of data, it was determined that 31.7 percent of air passengers using an automobile drove themselves to and from the airport while 68.3 percent were driven by someone else. This statistic is important because a passenger driven to the airport by someone else generates an additional trip from the airport by the person who dropped him off. Similarly, an additional trip to the airport is generated by a passenger who is picked up at the airport. Table 49 summarizes the type of automobile usage for both days of the survey.

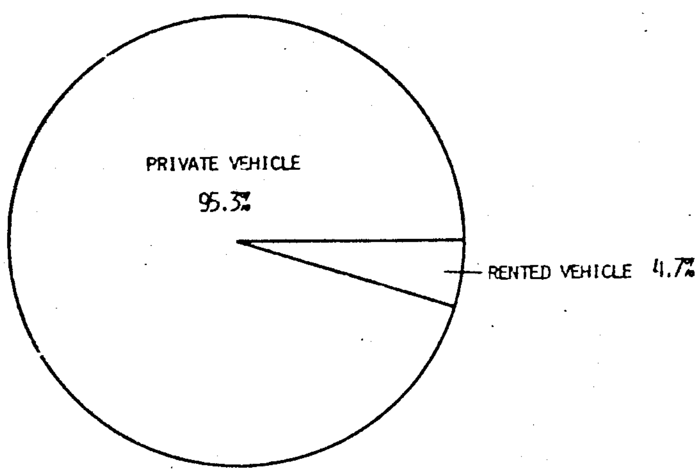


FIGURE 42

PROPORTION OF PRIVATE VERSUS RENTED VEHICLES

TABLE 49

AIR PASSENGERS' TYPE OF AUTOMOBILE SUB-MODE

(PERCENT)

MODE	FRIDAY	TUESDAY	TOTAL
Drive Themselves	27.7	36.7	31.7
Driven by Someone	72.3	63.3	68.3
TOTAL	100.0	100.0	100.0

TABLE 50

AIR PASSENGER AUTO OCCUPANCY

(PERCENT)

AIR PASSENGERS PER VEHICLE	FRIDAY	TUESDAY	TOTAL
1	81.0	85.0	82.8
2	14.2	11.8	13.1
3	2.4	2.6	2.5
4 or more	2.4	.6	1.6
TOTAL	100.0	100.0	100.0

Overall average vehicle occupancy was 1.68 persons per vehicle on Friday and 1.58 on Tuesday for a combined occupancy average of 1.63 persons. These occupancy figures include air passengers, visitors, etc. Average vehicle occupancy in terms of air passengers was 1.26 per vehicle on Friday and 1.19 on Tuesday for a combined average of 1.24. These values measure the number of air passengers in each vehicle which carried at least one air passenger. These statistics are required for converting air passengers to automobiles.

Table 50 shows the distribution of air passengers per vehicle for the two survey dates disaggregated and combined. In Figure 43, air passenger vehicle occupancy is correlated with sub-mode. It can be seen that as air passenger group size increases, the passengers are more likely to be driven to the airport by someone else.

Table 51 lists type of automobile mode for residents and nonresidents, respectively. The table shows the not unexpected result that nonresidents are most often driven to the airport by someone while residents are virtually even in their automobile mode choice, as evidenced by 47.4 percent driving themselves and 52.6 percent being driven by someone.

The type of parking used by all vehicles passing through the control plaza is listed in Table 52, which shows a slight edge for short-term parking over curbside drop-off and pick-up. A similar parking breakdown is shown in Table 53 for passengers who are driven by someone. The indicated reduction in remote parking for this case suggests that vehicles not containing air passengers use the remote parking more than vehicles containing air passengers. Parking characteristics of passengers who drive themselves are also shown in Table 53, which shows that these passengers have a tendency to use short-term parking over remote.

Frequency of Airport Use

As were Surtran passengers, the auto-users were questioned as to their frequency of use both of DFW and, for purposes of comparison, Love Field currently and prior to the opening of DFW. Table 54 tabulates the proportionate distribution of their annual travel frequency to and from DFW. This can then be compared with prior use of Love Field in Table 55.

As was the case with Surtran users (Tables 34 and 35), there appears no

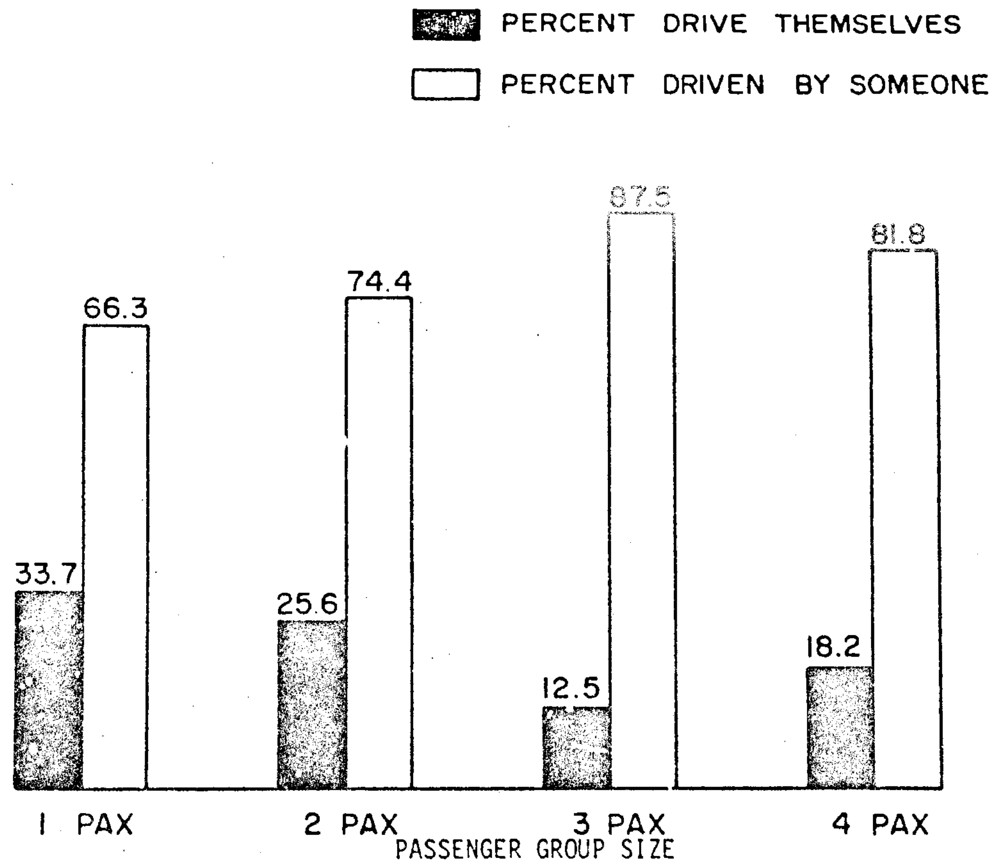


FIGURE 43. AIR PASSENGER VEHICLE OCCUPANCY BY TYPE OF SUB-MODE

TABLE 51

AIR PASSENGERS' AUTOMOBILE SUB-MODE BY RESIDENCY

(PERCENT)

RESIDENTS' SUB-MODE	FRIDAY	TUESDAY	TOTAL
Drive themselves	43.8	51.7	47.4
Driven by Someone	56.2	48.3	52.6
TOTAL	100.0	100.0	100.0

NONRESIDENTS' SUB-MODE	FRIDAY	TUESDAY	TOTAL
Drive themselves	6.6	20.9	12.5
Driven by Someone	93.4	79.1	87.5
TOTAL	100.0	100.0	100.0

TABLE 52

TYPE OF PARKING USED BY ALL VEHICLES

(PERCENT)

TYPE OF PARKING	FRIDAY	TUESDAY	TOTAL
Short Term	54.0	60.2	56.8
Remote	9.1	5.5	7.5
Curb	36.9	34.3	35.7
TOTAL	100.0	100.0	100.0

TABLE 53

TYPE OF PARKING USED BY AIR PASSENGER AUTO-USERS, BY SUB-MODE

Passengers Driven by Others

TYPE OF PARKING	FRIDAY	TUESDAY	TOTAL
Short Term	67.5%	84.1%	76.2%
Remote	32.5	15.9	23.8
TOTAL	100.0%	100.0%	100.0%

Passengers Driving Themselves

TYPE OF PARKING	FRIDAY	TUESDAY	TOTAL
Short Term	51.8%	50.7%	51.4%
Remote	2.2	1.0	1.7
Curb	46.0	48.3	46.9
TOTAL	100.0%	100.0%	100.0%

TABLE 54

AUTO-USERS' ANNUAL FREQUENCY OF TRAVEL TO/FROM DFW

ANNUAL USE (TIMES PER YEAR)	% OF PASSENGERS
1 - 2	12.5
3 - 6	17.3
7 - 11	2.6
12 - 24	26.5
25 - 36	6.2
37 - 48	11.9
> 48	23.0
TOTAL	100.0

significant variation in "before-and-after" airport use by these respondents. Also, as with Surtran users, about 6 percent report no previous use of Love Field at all.

There is some significant difference perceivable between use frequency of the auto-users versus Surtran users, however. Auto-users indicate a substantially higher proportionate airport use -- 23.0 percent using DFW over 48 times per year, for example, versus only 11.3 percent of Surtran riders; 41.1 percent of the auto-users report a use frequency of more than 24 times a year, compared with only 27.0 percent of Surtran users. A similar pattern characterizes previous use of Love Field.

The survey found that 38.4 percent of these respondents continue to use Love Field -- perhaps a lightly higher proportion than of Surtran riders. Table 56 gives their current frequency of use of the older facility, while Table 57 shows the proportionate air mode used.

As with Surtran passengers (cf. Table 37), about 92 percent used commercial flights at Love Field at the time of the survey. Similarity extends to proportionate airport use frequency among this category who, unlike auto-users as a whole, exhibit a usage pattern not different from that of Surtran riders who currently use Love Field (cf. Table 36).

Ground Trip Purpose

Since employees were surveyed separately, they were specifically excluded from the interviews of auto-users. Figure 44 illustrates graphically the percentage distribution of auto-users' purpose of their ground trips to/from DFW. This distribution is then tabulated in Table 58, which also gives the breakdown for each survey date.

The 4.3 percent of respondents "driving through" the airport should be noted. These drivers were, in effect, using the relatively high speed and conveniently located DFW spine road (International Parkway) as a toll road for faster more direct access between the areas north and south of DFW. It is likely that many more vehicles drove through the airport on the service roads without paying a toll. Although the service roads are signed "authorized vehicles only," this is not enforced. This purpose, of course, could not apply to Surtran users.

TABLE 55

AUTO-USERS' ANNUAL FREQUENCY OF TRAVEL TO/FROM LOVE FIELD BEFORE DFW

ANNUAL USE (TIMES PER YEAR)	% OF PASSENGERS
None	6.1
1 - 2	13.6
3 - 6	16.3
7 - 11	3.2
12 - 24	24.5
25 - 36	6.2
37 - 48	10.9
> 48	19.2
TOTAL	100.0

TABLE 56

AUTO-USERS' ANNUAL FREQUENCY OF TRAVEL TO/FROM LOVE FIELD (CURRENT LOVE FIELD USERS)

ANNUAL USE (TIMES PER YEAR)	% OF PASSENGERS
1 - 2	24.9
3 - 6	31.7
7 - 11	1.9
12 - 24	26.8
25 - 36	5.3
37 - 48	2.6
> 48	6.8
TOTAL	100.0

TABLE 57

LOVE FIELD AIR MODE CURRENTLY USED BY AUTO-USERS

AIR MODE	% OF PASSENGERS
Commercial	92.4
Private	6.3
Both	1.3
TOTAL	100.0

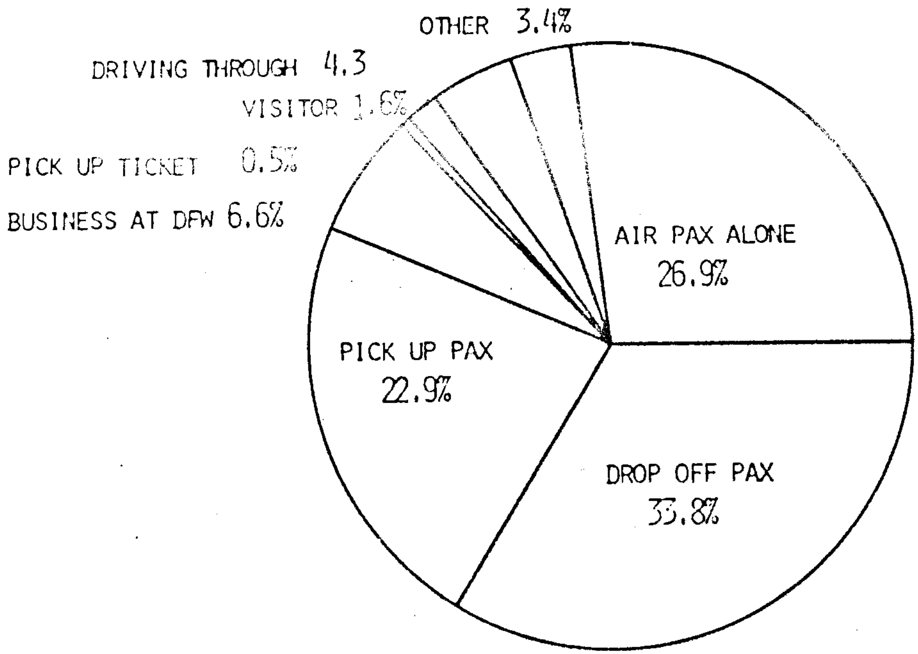


FIGURE 44. AUTO-USERS' VEHICULAR GROUND TRIP PURPOSE

TABLE 58

AUTO-USERS' VEHICULAR GROUND TRIP PURPOSE
(PERCENT)

TRIP PURPOSE	FRIDAY	TUESDAY	TOTAL
Air Passenger Along	22.6	31.6	26.9
Dropping Off Passenger	34.9	32.6	33.8
Picking Up Passenger	24.1	22.0	22.9
Airport Business	8.3	4.5	6.6
Pick-Up Ticket	.4	.5	.5
Visitor	2.3	.8	1.6
Other	3.3	3.4	3.4
Using as Toll Road	4.1	4.5	4.3
TOTALS	100.0	100.0	100.0

The data in Table 58, however, refers to the purpose of vehicular trips, not person-trips as was the case with Surtran. To effect compatibility and thus comparison with the Surtran trip-purpose, tabulations (Table 38), a conversion to person-trips was made including the elimination of "driving through" trips, and the results presented in Table 59.

With this tabulation, substantial differences form the trip-purpose distribution of Surtran riders are obvious. For example, the proportion of auto users that are air passengers is only about two-fifths that of Surtran riders. On the other hand, the proportion of auto users who are greeting or seeing off air passengers is about 50 times that of Surtran users -- probably reflecting economic efficiencies of multiple-riding in personal automobiles not realizable for transit patrons. It may be recalled that the largest proportion of Surtran riders said that their mode choice was based on a desire to "avoid trip by other person." This factor may indicate an untapped or potential selling point for promoting Surtran patronage.

TABLE 59

AUTO-USERS' GROUND TRIP PURPOSE
(Non-Employee Person-Trips)

PURPOSE	PERCENT
Airline Passengers	39.4
Greeting (Picking Up) Air Passengers	20.2
Seeing Off (Dropping Off) Air Passengers	29.7
Pick Up Ticket	0.4
Business at Airport	5.9
Visitor	1.4
Other	3.0
TOTAL	100.0

Air Trip Purpose and Duration

The purpose of air trips (Table 60) of auto users generally follows the corresponding pattern of Surtran riders (Table 39). Aggregating air trip purpose into similar categorical groups and disaggregating by survey date gives results as indicated in Table 61. For both days combined, 69.3 percent of air trips were for business or convention purposes while 27.3 percent were vacation, visiting or personal affairs, and 3.5 percent for military, school and miscellaneous purposes.

Cross-correlation of air trip purpose and duration with other automobile modal characteristics yields some interesting results. A tabulation of air trip purpose by automobile sub-mode is listed in Table 62, which indicates that a higher percentage of passengers on business and convention trips drove themselves than for the other two air-trip purpose categories. This can be attributed to the shorter trip duration and general nature of business trips compared to vacationing and visiting trips. Figure 45 shows this shorter duration of business and convention trips while Figure 46 shows air trip duration by automobile mode. As Figure 46 indicates, the percentage of air passengers who drive themselves is inversely related to the duration of the air trip. This is predictable, because parking costs increase over time.

Type of parking by air trip purpose is tabulated in Table 63. People on business and vacation trips have a tendency to use short-term rather than curbside pick-up and drop-off, while those on military and school trips show a tendency to use only short-term parking. Use of remote parking is highest for business trips primarily due to shorter trip duration and the higher percentage of passengers who drive themselves.

Travel Distance and Time

Auto-users' perceived versus actual travel distances and times, both between O/D and DFW and between O/D and Love Field, have been processed into range distributions in Tables 64 and 65 in the same manner as with employees (Tables 20 and 21) and Surtran riders (Tables 41 and 42). Comparing the results of the three survey components, striking differences are observable.

For example, while 28.5 percent of auto-users travel 15 miles or less from O/D to DFW, only 1.6 percent of Surtran users fall within this range, while 48.6 percent of employees live 15 miles or less from DFW. Auto-users, thus, tend to originate and terminate their trips closer to DFW than Surtran riders -- a somewhat surprising result -- while employees' O/Ds are the closest of all.

TABLE 60

AUTO-USING AIRLINE PASSENGERS' AIR TRIP PURPOSE

PURPOSE	PERCENT
Business/Employment	67.9
Vacation	11.7
Convention	1.3
Personal Affairs	2.4
Visiting Family, etc.	13.2
Military	1.0
School	0.9
Other	1.6
TOTAL	100.0

TABLE 61

AUTO-USING AIRLINE PASSENGERS' PURPOSE OF AIR TRIPS BY CATEGORY GROUPS AND SURVEY DATE

(PERCENT)

PURPOSE	FRIDAY	TUESDAY	TOTAL
Business/ Employment, Convention	63.9	75.7	69.2
Vacation, Visiting, Personal Affairs	31.4	22.4	27.3
Military, School, Other	4.7	1.9	3.5
TOTAL	100.0	100.0	100.0

TABLE 62

TYPE OF SUB-MODE BY AIR TRIP PURPOSE

(PERCENT)

TRIP PURPOSE	TYPE OF SUB-MODE	FRIDAY	TUESDAY	TOTAL
Business/ Employment, Convention	Drive Themselves	39.9	45.6	42.7
	Driven By Someone	60.1	54.4	57.3
TOTAL		100.0	100.0	100.0
Vacation, Visiting, Personal Affairs	Drive Themselves	8.4	8.6	8.5
	Driven By Someone	91.6	91.4	91.5
TOTAL		100.0	100.0	100.0
Military, School, Other	Drive Themselves	00.0	00.0	00.0
	Driven By Someone	100.0	100.0	100.0
TOTAL		100.0	100.0	100.0

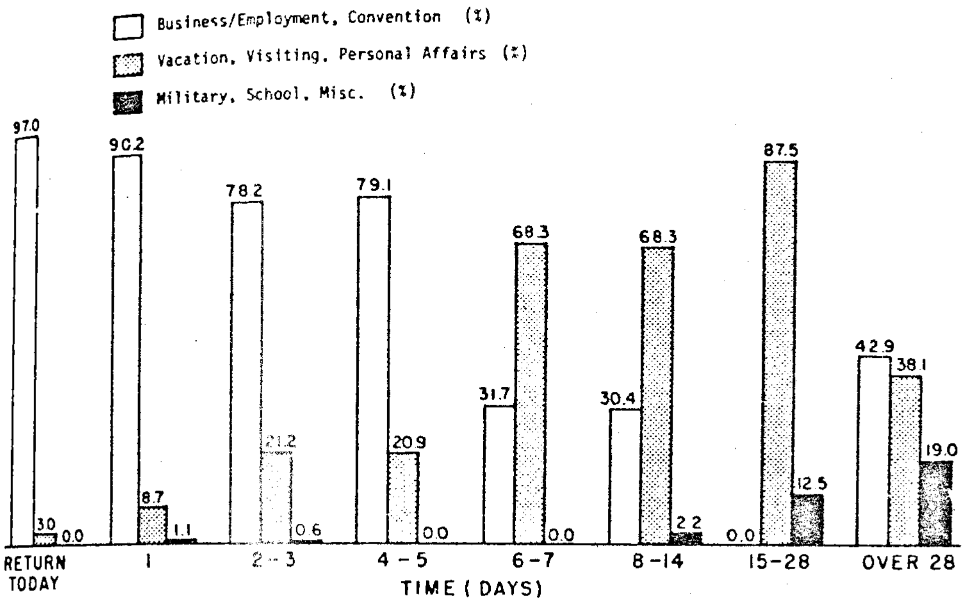


FIGURE 45
TRIP DURATION BY PURPOSE OF AIR TRIP (AUTO USERS)

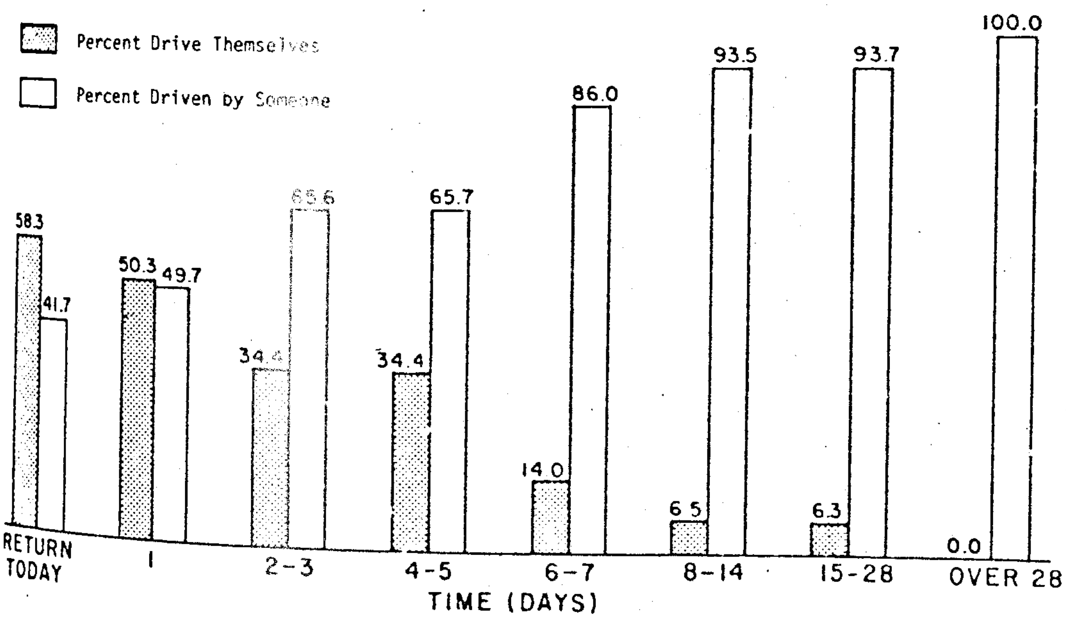


FIGURE 46
TRIP DURATION BY AUTOMOBILE SUB-MODE

TABLE 63. TYPE OF PARKING BY AIR TRIP PURPOSE

(PERCENT)

TRIP PURPOSE	TYPE OF PARKING	FRIDAY	TUESDAY	TOTAL
Business/ Employment, Convention	Short-term	46.9	58.4	52.6
	Remote	12.3	6.7	9.5
	Curb	40.8	34.9	37.9
Vacation, Visiting, Personal Affairs	Short term	60.7	63.2	61.7
	Remote	4.5	4.4	4.4
	Curb	34.8	32.4	33.9
Military, School, Other	Short term	82.2	66.7	82.6
	Remote	5.9	00.0	4.3
	Curb	5.9	33.3	13.1

TABLE 64

DISTRIBUTION OF AUTO-USERS' PERCEIVED VERSUS ACTUAL TRAVEL DISTANCES AND TIMES BETWEEN ORIGIN/DESTINATION AND DFW

DISTANCE RANGE (MILES)	% RESPONDENTS IN RANGE	
	PERCEIVED DISTANCE	ACTUAL DISTANCE
0 - 5	5.1	0.6
6 - 10	13.6	9.2
11 - 15	19.8	18.7
16 - 20	23.5	23.1
21 - 25	12.5	23.8
26 - 30	11.3	10.5
31 - 35	3.7	7.7
36 - 40	3.7	5.0
41 - 60	2.3	1.4
Over 60	4.5	-
TOTAL	100.0	100.0

TIME RANGE (MINUTES)	% RESPONDENTS IN RANGE	
	PERCEIVED TIME	ACTUAL TIME
0 - 10	9.1	0.6
11 - 20	27.2	18.0
21 - 30	32.1	37.5
31 - 40	13.6	31.3
41 - 50	10.8	11.1
51 - 60	3.4	1.4
Over 60	3.8	0.1
TOTAL	100.0	100.0

TABLE 65

DISTRIBUTION OF AUTO-USERS' PERCEIVED VERSUS ACTUAL TRAVEL DISTANCES AND TIMES BETWEEN ORIGIN/DESTINATION AND LOVE FIELD

DISTANCE RANGE (MILES)	% RESPONDENTS IN RANGE	
	PERCEIVED DISTANCE	ACTUAL DISTANCE
0 - 5	19.9	13.2
6 - 10	26.8	32.8
11 - 15	13.6	15.4
16 - 20	12.0	14.7
21 - 25	6.9	8.5
26 - 30	4.3	4.3
31 - 35	3.4	2.7
36 - 40	3.3	2.9
41 - 60	6.9	5.5
Over 60	2.9	-
	100.0	100.0

TIME RANGE (MINUTES)	% RESPONDENTS IN RANGE	
	PERCEIVED TIME	ACTUAL TIME
0 - 10	21.5	5.3
11 - 20	31.2	36.8
21 - 30	19.5	30.3
31 - 40	8.2	13.5
41 - 50	7.2	5.5
51 - 60	6.8	6.7
Over 60	5.6	1.9
	100.0	100.0

Auto users apparently estimate their travel distance and time somewhat more accurately than Surtran riders. In all three survey component populations, there may be a slight tendency to underestimate distance and time -- well exhibited by the fact that 9.1 percent of auto users estimated their travel time as 5 minutes or less, although only 0.6 percent actually fell in this range.

As with the Surtran case, auto-users' trip lengths and times to Love Field would be substantially less as a whole. For example, over 60 percent would travel 15 miles or less between Love Field and their O/D; over 60 percent travel 16 miles or more between DFW and their O/D. For air facility users as a whole, this implies somewhat increased travel costs, energy consumption, and travel time due to the shift of major air operations to DFW.

Demographic Characteristics

Figure 47 shows the proportion of male versus female auto users. Compared with Surtran riders (page 101), it is apparent that females constitute a somewhat larger proportion of the auto users. Further broken down into auto drivers versus passengers, Figure 48 indicates that proportionately fewer women are drivers than passengers. Approximately one-fourth of auto-using air passengers are women, as illustrated in Figure 49.

Some interesting contrasts are revealed over the question of residency. The survey determined that an overwhelming 94.2 percent of automobile drivers were DFW-area residents, and only 5.8 percent nonresidents. This contrasts sharply with the residency of Surtran riders (Table 44), only 49.6 percent of whom are residents.

However, 94.0 percent of the Surtran users were found to be air passengers. If only air passenger auto users are considered, the survey has found that 58.4 percent are residents, 41.6 percent are nonresidents (Table 6). This distribution is closer to the Surtran results, although, still indicating a slight preponderance of residents among the auto users.

The distributions of auto-users' ages, occupations, and incomes have already been tabulated in Tables 10 through 12. Industrial affiliations are tabulated in Table 66, disaggregated for drivers versus air passengers.

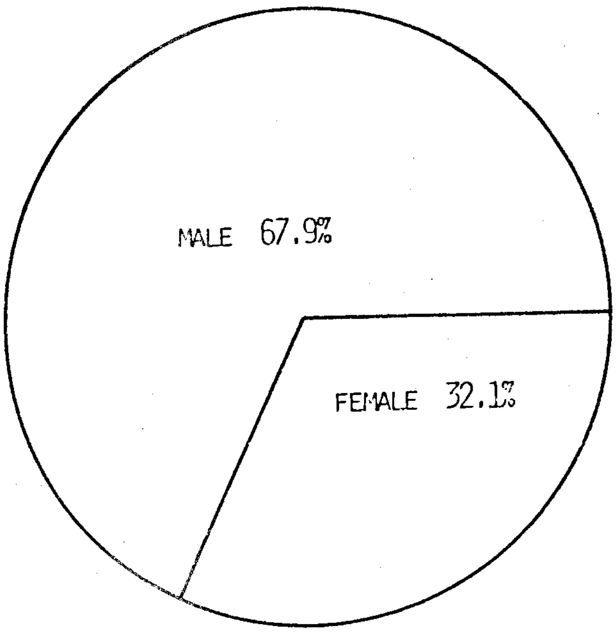


FIGURE 47. SEX OF AUTO-USERS

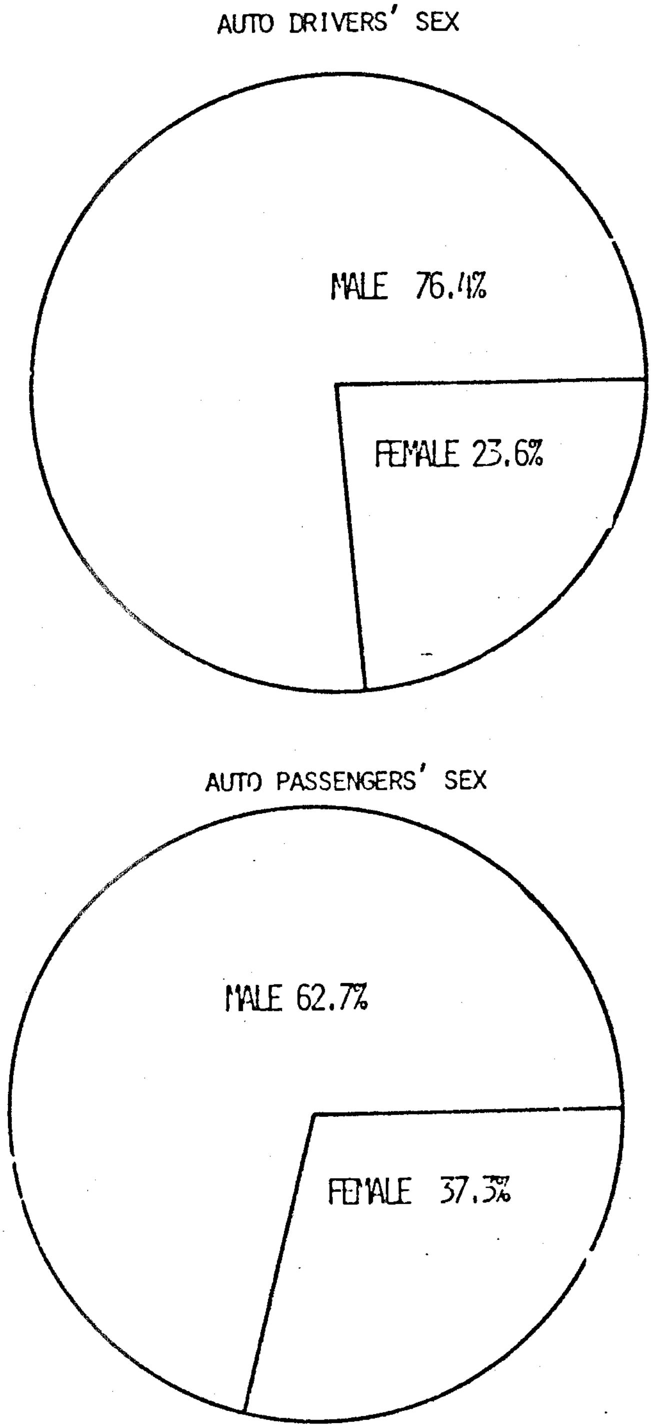


FIGURE 48. SEX OF AUTO-USERS, BY DRIVERS AND PASSENGERS

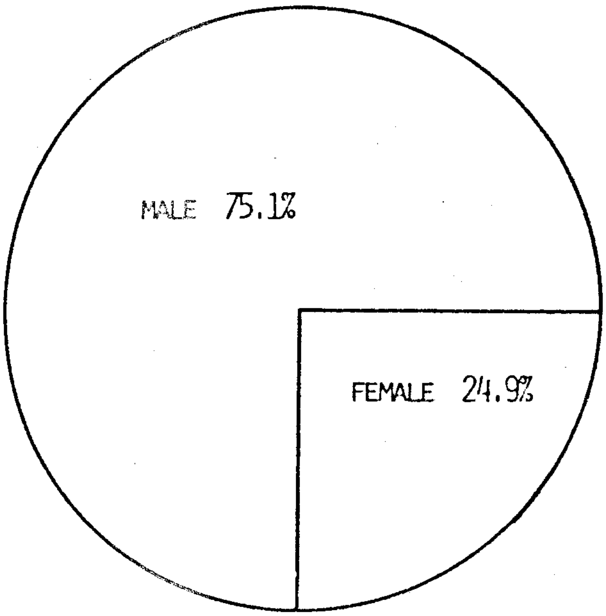


FIGURE 49. SEX OF AUTO-USING AIR PASSENGERS

TABLE 66

DISTRIBUTION OF AUTO-USERS' INDUSTRIAL AFFILIATIONS

INDUSTRIAL CATEGORY	% RESPONDENTS IN CATEGORY	
	Drivers	Air Pax
Construction	3.4	3.5
Manufacturing	8.5	11.7
Transportation	9.5	8.2
Wholesale/Retail Trade	14.1	15.2
Communications/Utilities	7.8	4.5
Public Administration	5.6	7.4
Finance/Insurance/Real Estate	14.3	12.1
Electronics	1.2	1.8
Data Processing	1.7	1.9
Oil	0.7	1.4
Education	3.6	5.7
Military	1.5	4.7
Other	28.1	21.9
TOTAL	100.0	100.0

It is of interest to correlate automobile sub-mode with certain demographic characteristics. It is seen from Figure 50, that young and old passengers are more likely to be driven to the airport by someone else, while a higher percentage of middle-aged passengers drive themselves. This is probably related to higher incomes of the middle aged passengers. The proportion of passengers driving themselves to the airport increases with income (Figure 51), which is probably due to their ability to pay parking fees.

SUMMARY

Through the investigation of responses to the DFW survey questions, the following air passenger characteristics of auto-users were determined:

(1) 54.7 percent of vehicles interviewed at the airport contained at least one air passenger.

(2) 31.7 percent of air passengers drove themselves and 68.3 percent were driven by someone.

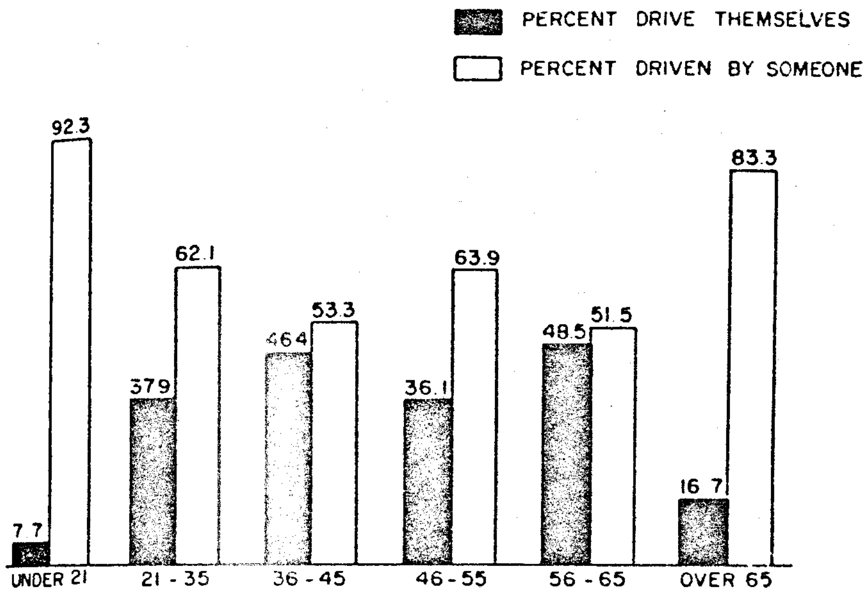


FIGURE 50. CORRELATION OF AUTO-USERS' AGE AND SUB-MODE

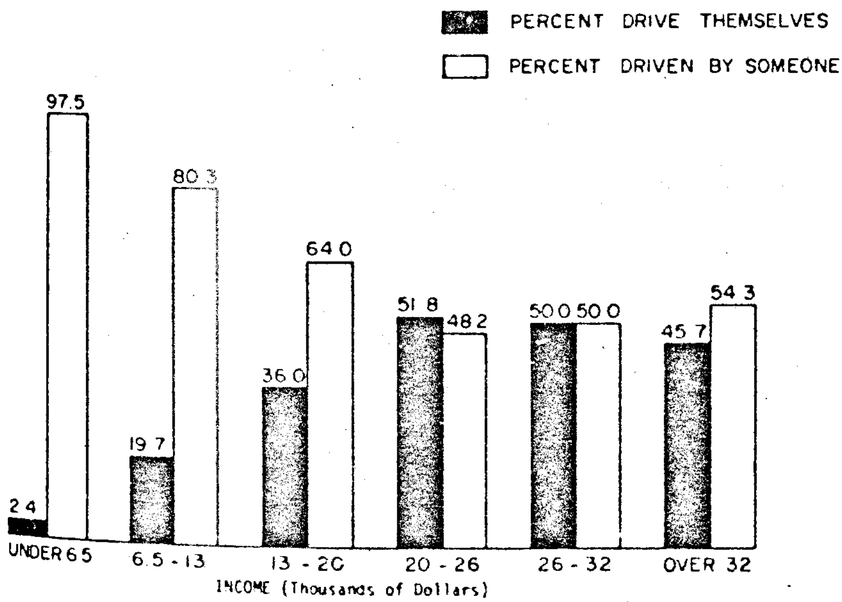


FIGURE 51. CORRELATION OF AUTO-USERS' INCOME AND SUB-MODE

(3) Overall vehicle occupancy was 1.63 persons per vehicle while air passenger vehicle occupancy was 1.24.

(4) 87.5 percent of nonresidents who use auto were driven to the airport by someone else while 52.6 percent of residents were driven by someone else.

(5) A greater percentage of passengers with higher incomes tended to drive themselves to the airport.

(6) Short-term parking was the major type of parking used at DFW.

(7) 69.3 percent of all air trips were for business/employment, convention purposes.

IV. AIR PASSENGER ACCESS VOLUMES

INTRODUCTION

The major objective of this chapter is to describe a model of airport trip generation which expresses access volumes as a function of an airline schedule. The Dallas/Fort Worth Regional Airport (DFW) is used as a test case. Only volumes of automobiles carrying airline passengers and visitors are modeled. This is feasible at DFW because passenger and visitor vehicle traffic is largely segregated from employee vehicle traffic,which uses a separate service roadway system (see Chapter II). Employee access volumes are treated in the next chapter of this report.[19]

There have been a number of studies aimed at estimating the demand on airport access facilities as a function of the socio-economic characteristics of the airport users.[20] In this chapter, it is assumed that demand forecasts have already been obtained, probably from the airlines, in the form of future flight schedules along with an approximate load factor for each flight; this informaton serves as input to the method. That is to say, the model is not a demand model, but rather it transforms a forecast of passenger demand into a forecast of corresponding airport access volumes in short time intervals throughout the entire day or in selected peak periods.

Results of research described in this chapter will enable airport operators and planners to estimate the effect of anticipated changes in airline schedules on ground traffic volumes. The model has its greatest advantage over existing methods in estimating the peaking characteristics of airport access traffic.

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[19] See also: Zambrano, W. A., "Employee Travel at the Dallas/Fort Worth Regional Airport," Unpublished M.S. Thesis in Civil Engineering, The University of Texas at Austin, May 1976.

[20] deNeufville, R. D., "The Demand for Airport Access Service," Traffic Quarterly, VXXVII, No. 4, October 1973, pp. 583-600; and Navin, R. P. D., and R. P. Wolsfeld, "Analysis of Air Passenger Travel in the Twin Cities Metropolitan Area," Highway Research Board, HRR 369, 1971.

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MODEL DEVELOPMENT

Previous Models

From a review of previous studies of airport trip generation, only one analytical method for relating access volumes directly to measures of air-side activity could be found, namely, the Koussios-Homburger model.[21] This model was designed to predict vehicular volumes at San Francisco International Airport and consists of equations which predict the hourly volumes of vehicles inbound and outbound on the main access highway. The equations were developed by step-wise multiple regression techniques which tested the following variables:

Dependent Variables:

Z_1 = number of vehicles inbound on main access highway per hour.

Z_2 = number of vehicles outbound on main access highway per hour.

Independent Variables:

X_1 = number of air passenger deplanements per hour.

X_2 = number of air passenger enplanements per hour.

X_3 = sum of air passenger enplanements and deplanements per hour.

Time Shift Notation:

(t) = any time "t"

(t + 1) = one hour after time "t"

(t - 1) = one hour before time "t"

The dependent variables were tested against independent variables for the same hour, for the following hour, and for the preceding hour. These shifts in time were intended to account for the fact that passengers at San Francisco International Airport reach the airport access/egress points about 45 minutes before or after their flight departure or arrival times, respectively.

From the above analysis, multiple regression equations were obtained relating traffic on the main access highway to air passenger activity. Sample results are shown in Table 67.

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[21] Koussios, D. and W. S. Homburger, Vehicular Traffic Patterns at an Airport in Relation to Airline Passenger Volumes, University of California, Berkeley, May 1967.

TABLE 67. RESULTS OF KOUSSIOS-HOMBURGER MODEL

Direction	Regression Equation	R^2	Standard Error
Entering	$Z_1(t) = 280.8 + .528X_1(t - 1) + .857X_2(t + 1)$	0.823	346.7
Leaving	$Z_1(t) = 239.2 + 1.000X_1(t - 1) + .473X_2(t + 1)$	0.876	294.1

TABLE 68. INDEX OF TIME INTERVALS

TIME INTERVALS	DESCRIPTION
1	Time prior to his scheduled departure time that an originating passenger arrived at the airport
2	Time that it took a vehicle which dropped of an originating passenger to leave the airport relative to the scheduled departure time.
3	Time it took terminating passengers to exit the control plaza after deplaning.
4	Time that a vehicle picking up a terminating passenger arrived at the airport relative to the scheduled arrival time.

For vehicles entering the airport, the $X_1(t - 1)$ factor corresponds to vehicles arriving to pick up passengers who deplaned the preceding hour, while the $X_2(t + 1)$ factor corresponds to vehicles bringing in passengers who will be enplaning in the next hour. For vehicles leaving the airport the $X_1(t -1)$ factor corresponds to vehicles taking away passengers who deplaned the preceding hour, while the $X_2(t + 1)$ factor corresponds to vehicles that dropped off passengers who will enplane in the next hour.

There are several drawbacks to the Koussios-Homburger model, including:

1. The model uses enplaning and deplaning passengers, which include transfer passengers who do not use ground access facilities. These may not be significant at San Francisco International Airport but would be at an airport with high transfer-passenger percentages, such as DFW.

2. Not all of the vehicle volumes on the roadway are directly related to air passengers. Other trip purposes include going to work (employees), conducting business at the airport, picking up tickets, and visiting. These trips should be factored out of the vehicle volumes so that only vehicle volumes relating to air passengers are considered in the regression equations.

3. Time blocks of less than one hour are not considered.

The Koussios-Homburger model represents a useful methodology for predicting vehicular volumes in relation to air passenger volumes. One important feature of the model is that it uses aggregate data for air passenger volumes and vehicle volumes. The model developed in this research, on the other hand, disaggregates passenger data by flight.

Model Description

The model is based on the distributions of the times before or after flights that passenger-related vehicles cross the airport boundary. Total traffic volume estimates are obtained for a particular time interval by superimposing all of the distributions that overlap in that time interval. In this way an estimate of total expected number of vehicles crossing the airport boundary during the time interval is obtained. Inputs to the model include: (1) the times of flight arrivals and departures, (2) the expected number of originating or terminating passengers on each flight, and (3) the above distributions of times relative to the flight that vehicles enter or leave the airport. Outputs are estimates of vehicular traffic volumes by 15-minute time interval and by direction.

Analysis of Passenger Arrival and Departure Times

From the data, four time-interval distributions which explain the vehicle arrival and departure times of auto-users were defined. These time intervals were:

(1) the time prior to his scheduled departure time that an originating passenger entered the airport,

(2) the time that it took a vehicle which dropped off an originating passenger to leave the airport relative to the scheduled departure time,

(3) the time it took terminating passengers to exit the control plaza after deplaning, and

(4) the time that a vehicle picking up a terminating passenger entered the airport relative to the scheduled flight arrival time.

To test the influence that various factors might have on the above time interval distributions, contingency tables were constructed to test the null hypothesis, H_o, that the distributions of the time at which air passengers enter and leave the airport are statistically independent of certain factors, including: (1) type of auto usage, (2) purpose of air trip, and (3) length of airline flight. From these contingency tables, Chi-square values were calculated which led to the estimation of significance probabilities. Significance probability, usually denoted by P_I, is the probability of obtaining a Chi-square value as large or larger than the one calculated in the test, given that the hypothesis tested is true. A significance level of 0.05 was chosen.

From these tests, very few categories of the various factors were found to have a P_I value as small as 0.05.[22] Therefore, it was concluded that the above factors did not play a significant role in explaining the group arrival and departure times of air passenger vehicles.

Goodness-of-Fit Tests

The first step in developing the model was to perform goodness-of-fit tests of various theoretical probability distributions against the observed distributions for the above time intervals. This was accomplished by employing

[22] Dunlay, et al., op. cit.

the Kolmogorov-Smirnov (K-S) one-sample, goodness-of-fit test. Briefly, the K-S test involves specifying the cumulative probability values which would occur under the hypothesis H_o, that the observed data follow a selected theoretical distribution, and comparing those values with the observed cumulative probability distribution. The point at which these two distributions show the greatest deviation is determined, and the sampling distribution of this test statistic is used to estimate the probability that a divergence as large as the one observed would occur if the observations were a random sample from the theoretical distribution.

The K-S test was chosen over the Chi-square test because it requires only the assumptions that sampling is random and that the sampled population is continuous. Another reason is that the K-S test treats individual observations and thus, unlike the Chi-square test, does not lose information through the combining of data into discrete categories.

The data for the Tuesday and Friday DFW travel survey dates were combined into one sample and then divided randomly into two smaller subsamples. This was done to approximate the requirement of the K-S test that the hypothesized (theoretical) distribution be specified completely and without regard to any information contained in the sample. Toward this end, the sample means and variances were calculated from one subsample. These statistics were used to estimate the parameters of several standard distributions, including the log normal, gamma, Pearson Type III, normal, and the Erlang-rounded-down and up. The resulting theoretical cumulative distributions were then compared to the observed cumulative distribution defined from the other subsample to determine the maximum deviations between the two. Table 68 presents an index of the time intervals considered. Table 69 summarizes the results of the K-S test statistics along with the critical values for rejection of H_o for the 5 and 10 percent significance levels. From Table 69, it is seen that all but the second time interval, whose best fit was the rounded-down Erlang, can be fit at the 10 percent significance level, and, even in that case, the maximum deviation is very close to the 10 percent value. Table 70 shows the theoretical distributions found to best approximate the sample values for the four time intervals. Graphic comparisons of these theoretical probability density functions together with observed frequencies are shown in Figure 52.

TABLE 69. KOLMOGOROV-SMIRNOV TEST-COMPUTED MAXIMUM DEVIATIONS

THEORETICAL DISTRIBUTION		TIME INTERVAL			
		1	2	3	4
log-normal		0.096	0.150	0.047	0.163
gamma		0.074	0.128	0.069	0.156
Erlang Rounded Down		------	0.115	------	0.273
Erlang Rounded Up		0.142	0.202	0.065	0.153
Pearson Type III		0.062	--------	0.056	-----
normal		------	0.188	------	0.129
MAX ALLOWABLE DEVIATION	10%	0.1132	0.1132	0.0917	0.1438
	5%	0.1263	0.1263	0.102	0.1263

TABLE 70. RESULTS OF K-S GOODNESS-OF-FIT TESTS

TIME INTERVAL	BEST FIT THEORETICAL DISTRIBUTION
1	gamma
2	Erlang-Rounded-Down
3	log-normal
4	normal

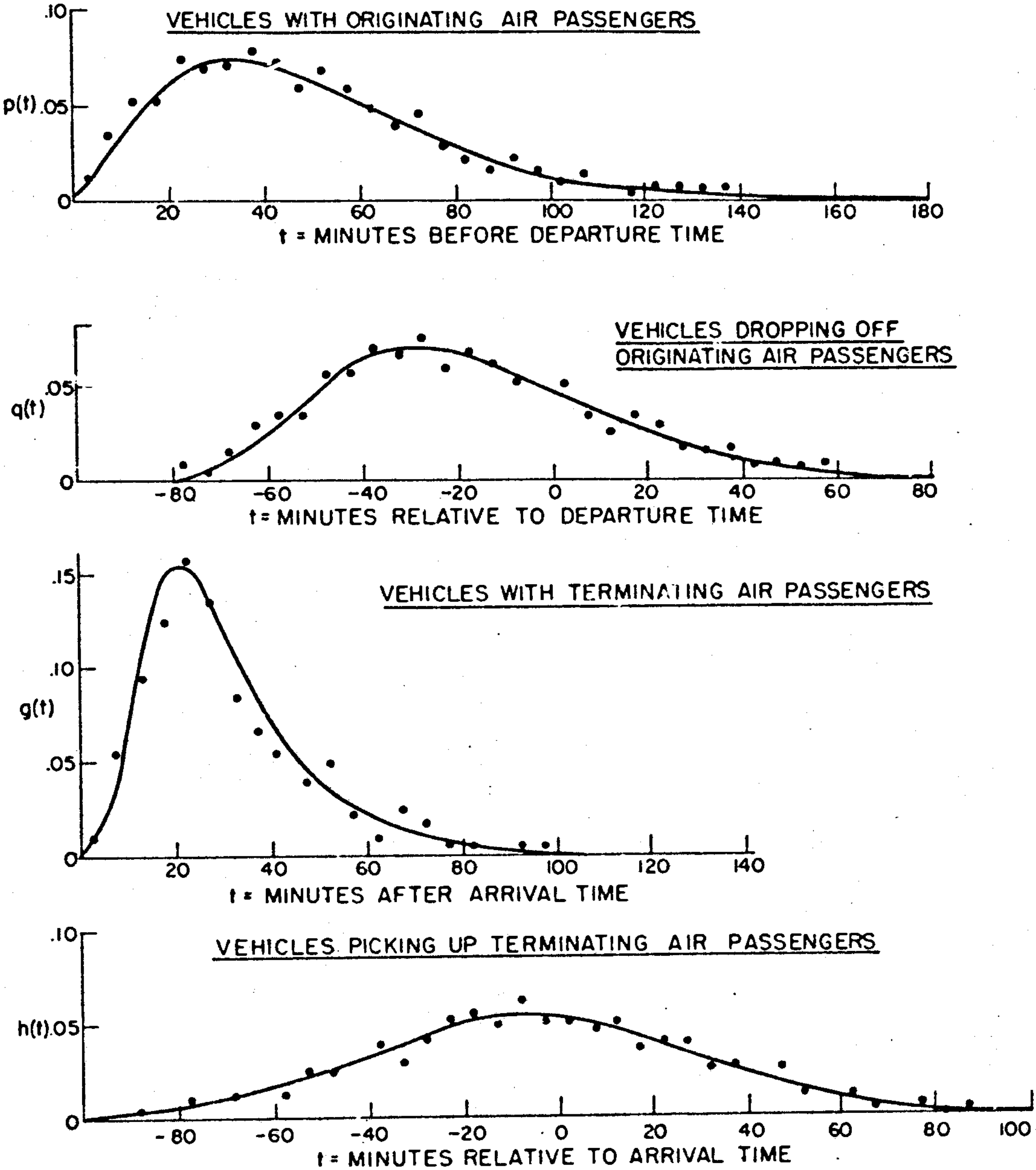

FIGURE 52
GRAPHIC COMPARISONS OF THEORETICAL PROBABILITY DENSITY FUNCTIONS, WITH SAMPLE FREQUENCIES

Derivation of Model

The theoretical concepts of the model are best introduced by examining Figure 53, where four probability density functions (pdf's) associated with the scheduled departure and arrival times of flights k and m are shown. Note that each arriving flight has two pdf's associated with it, one for vehicles which carry passengers away from the airport and one for vehicles of people who come to the airport to pick up terminating passengers. Similarly, a departing flight generates vehicles bringing originating passengers to the airport and vehicles leaving the airport after dropping off passengers.

The following notation will be used in developing the model.

K = set of departing flights whose pdf's overlap in $(t, t + \Delta t)$;

M = set of arriving flights whose pdf's overlap in $(t, t + \Delta t)$;

$p_k(t, t + \Delta t)$ = area under flight k's probability density function (pdf) (solid curve) in $(t, t + \Delta t)$;

$q_k(t, t + \Delta t)$ = area under flight k's pdf (dashed curve) in $(t, t + \Delta t)$;

$g_m(t, t + \Delta t)$ = area under flight m's pdf (solid curve) in $(t, t + \Delta t)$;

$h_m(t, t + \Delta t)$ = area under flight m's pdf (dashed curve) in $(t, t + \Delta t)$;

O_k = number of originating passenger vehicles associated with departing flight k;

D_k = number of vehicles which dropped off originating passengers for departing flight k;

T_m = number of terminating passenger vehicles associated with arriving flight m;

U_m = number of vehicles which picked up terminating passengers from arriving flight m.

The expected number of vehicles arriving at the airport with flight-k passengers in $(t, t + \Delta t)$, $O_k(t, t + \Delta t)$, is

$$E\{O_k(t, t + \Delta t)\} = O_k p_k(t, t + \Delta t)$$

while the expected value of number of flight m passenger vehicles arriving at the airport in $(t, t + \Delta t)$, $U_m(t, t + \Delta t)$, is

$$E\{U_m(t, t + \Delta t)\} = U_m h_m(t, t + \Delta t)$$

Therefore, the total expected number of passenger-related vehicles arriving at the airport in $(t, t + \Delta t)$, $N_A(t, t + \Delta t)$, is

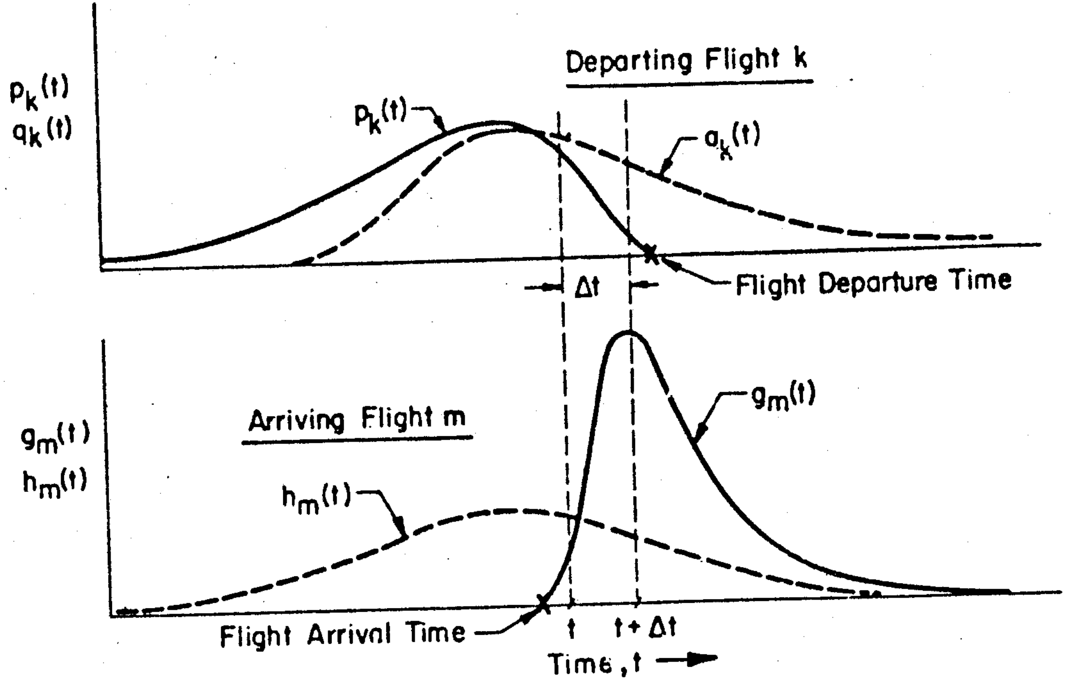

FIGURE 53. FOUR PROBABILITY DENSITY FUNCTIONS ASSOCIATED WITH FLIGHT DEPARTURE/ARRIVAL TIMES

$$E\{N_A(t, t + \Delta t)\} = \sum_{k \in K} O_k p_k(t, t + \Delta t) + \sum_{m \in M} U_h h_m(t, t + \Delta t) \quad (1)$$

Similarly, the total expected number of passenger vehicles leaving the airport in (t, t + Δt) is

$$E\{N_A(t, t + \Delta t)\} = \sum_{m \in M} T_m g_m(t, t + \Delta t) + \sum_{k \in K} D_k q_k(t, t + \Delta t) \quad (2)$$

The data collected were not sufficient to calculate the sample variances of $N_A(t, t + \Delta t)$ and $N_L(t, t + \Delta t)$, i.e., the variation over different days in the number of vehicles in a particular time interval. However, a rough approximation of these variances can be obtained by making the following assumptions:

(1) the probabilities p_k, h_m, q_k, and g_m apply independently and identically to all passengers on a flight who use automobiles to or from the airport,

(2) each of the $O_k(U_m, T_m, D_k)$ passenger vheicles has the same probability $p_k(h_m, g_m, q_k)$ of falling in interval $(t, t + \Delta t)$, independently of any other passenger vehicle. That is to say, each passenger on a flight constitutes a Bernoulli trial with the same probability of success, i.e., of falling in a particular interval.

The significance of the two above assumptions is that the random variables $O_k(t, t + \Delta t)$, the number of originating passenger vehicles arriving for flight k at the airport in time interval $(t, t + \Delta t)$, has a binomial distribution with mean $O_k p_k(t, t + \Delta t)$ and variance $O_k p_k(t, t + \Delta t)\ [1 - p_k(t, t + \Delta t)]$.

Similarly,

$U_m(t, t + \Delta t) \sim \text{binomial}\{U_m h_m(t, t + \Delta t);\ U_m h_m(t, t + \Delta t)[1-h_m(t, t + \Delta t)]\}$

$T_m(t, t + \Delta t) \sim \text{binomial}\{T_m g_m(t, t + \Delta t);\ T_m g_m(t, t + \Delta t)[1-g_m(t, t + \Delta t)]\}$

$D_k(t, t + \Delta t) \sim \text{binomial}\{D_k q_k(t, t + \Delta t);\ D_k q_k(t, t + \Delta t)[1-q_k(t, t + \Delta t)]\}$

Note that $E\{N_A(t, t + \Delta t)\}$, given by Eq. (1), does not depend on the mutual independence of the means. If it were true that O_k and U_m were an independent set of random variables then the variance of $N_A(t, t + \Delta t)$ would be*

$$\mathrm{Var}\{N_A(t, t + \Delta t)\} = \sum_{k \in K} O_k p_k(t, t + \Delta t)[1 - p_k(t, t + \Delta t)] + \sum_{m \in M} U_m h_m(t, t + \Delta t)[1 - h_m(t, t + \Delta t)] \quad (3)$$

The assumptions of independence are probably valid:

(1) the O_k, $k \in K$, probably form a pairwise independent set, since they apply to different flights. A similar argument applies for U_m, $m \in M$.

(2) For any choice of k and m, O_k and U_m are also probably independent. The O_k refers to passengers due to leave, while U_m is related to passengers due to arrive; there is no apparent reason why the two would vary simultaneously under normal conditions. However, severe weather, which prevents arrivals and departures from the airport, might cause both quantities to decrease simultaneously.

Similarly, $E\{N_L(t, t + \Delta t)\}$ is given by Eq. (2) and

$$\mathrm{Var}\{N_L(t, t + \Delta t)\} = \sum_{k \in K} D_k q_k(t, t + \Delta t)[1 - q_k(t, t + \Delta t)] + \sum_{m \in M} T_m g_m(t, t + \Delta t)[1 - g_m(t, t + \Delta t)] \quad (4)$$

Hence, the mean and variance of the total number of vehicles arriving and leaving the airport in any interval $(t, t + \Delta t)$ can be estimated using Eqs. (1) through (4).

It can be argued that distribution of the total number of vehicles entering or leaving the airport in any moderate size time interval is approximately normal for large sets K and M by the Central Limit Theorem and the above assumption that $N_A(t, t + \Delta t)$ is the sum of independent random variables

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*For the variance of a sum of random variables to be equal to the sum of the individual variances requires only that the variables be pair-wise uncorrelated. However, the stronger assumption of independence has been made to support a subsequent argument for normality.

$O_k(t, t + \Delta t)$, $k \varepsilon K$ and $U_m(t, t + \Delta t)$, $m \varepsilon M$ and that $N_L(t, t + \Delta t)$ is the sum of the independent random variables $D_K(t, t + \Delta t)$, $k \varepsilon K$ and $T_m(t, t + \Delta t)$, $m \varepsilon M$.* This argument could not be tested in this research.

APPLICATION OF MODELS

A computer program for executing the model was developed to facilitate the task of superimposing the distributions of the various flights. The program first reads the input data and converts air passenger volumes to vehicle volumes by applying air passenger vehicle occupancy rates. Then the parameters of each of the four above probability distributions are estimated. These parameters are used for calculating required probabilities in four separate subroutines; each subroutine calculates expected vehicle volumes in 15-minute time intervals. This process is repeated for each flight and the vehicle volumes from each of the four subroutines are combined in each time interval. Hence, the total expected number of outbound vehicles for each time interval is obtained by adding the volumes of terminating-passenger vehicles to the volumes of vehicles which dropped off originating passengers. Similarly, the total expected number of inbound vehicles for each time interval is obtained by adding the volumes of originating-passenger vehicles to the volumes of vehicles arriving to pick up terminating passengers.

Approximate variances for each time interval are computed in a similar process. Finally, the accumulated variances are converted to standard deviations and one standard deviation is added to and subtracted from the expected volumes of inbound and outbound vehicles in each time slice. The resulting ranges of volume are plotted as a function of time of day and compared to observed volumes in Figures 54 through 57.

Figure 54 shows estimated vs. observed volumes of inbound vehicles for 1-hour intervals over 16 hours of the day for Friday, 16 May 1975. Figure 55 shows estimated vs. observed volumes of outbound vehicles for the same day.

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*Even for small sets K and M, one can argue that the normal approximation is satisfactory for the above binomial distributions for large values of O_k, U_m, D_k, and T_m and for moderate size time intervals where the probability values are neither close to zero nor unity. For very short time intervals, the Poisson approximation would apply.

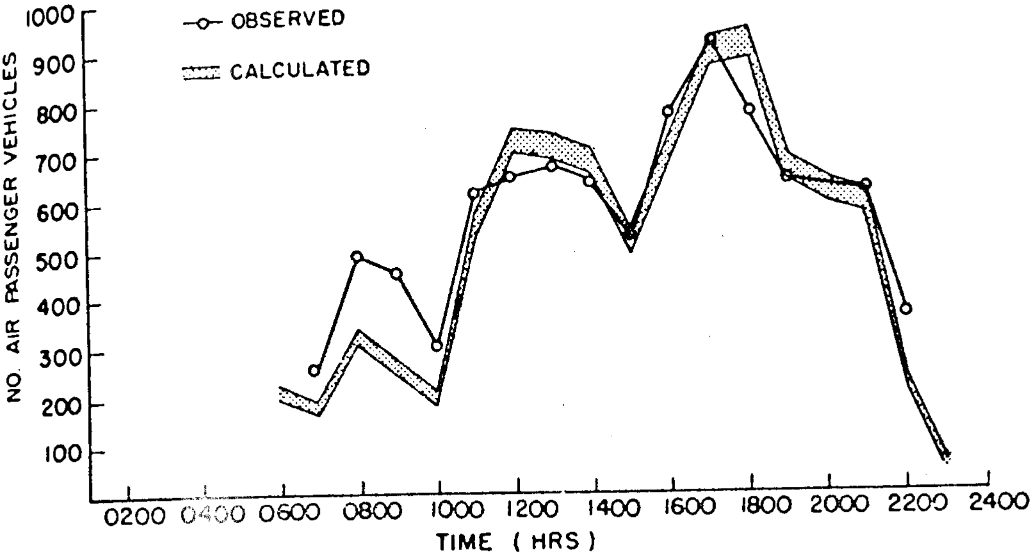

FIGURE 54
HOURLY ESTIMATED VERSUS SAMPLE VOLUMES OF INBOUND VEHICLES, FRIDAY

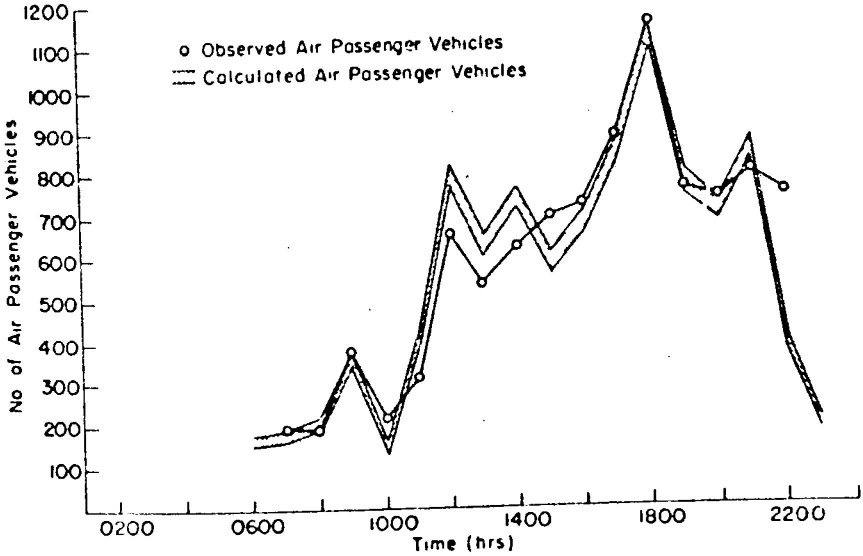

FIGURE 55
HOURLY ESTIMATED VERSUS SAMPLE VOLUMES OF OUTBOUND VEHICLES, FRIDAY

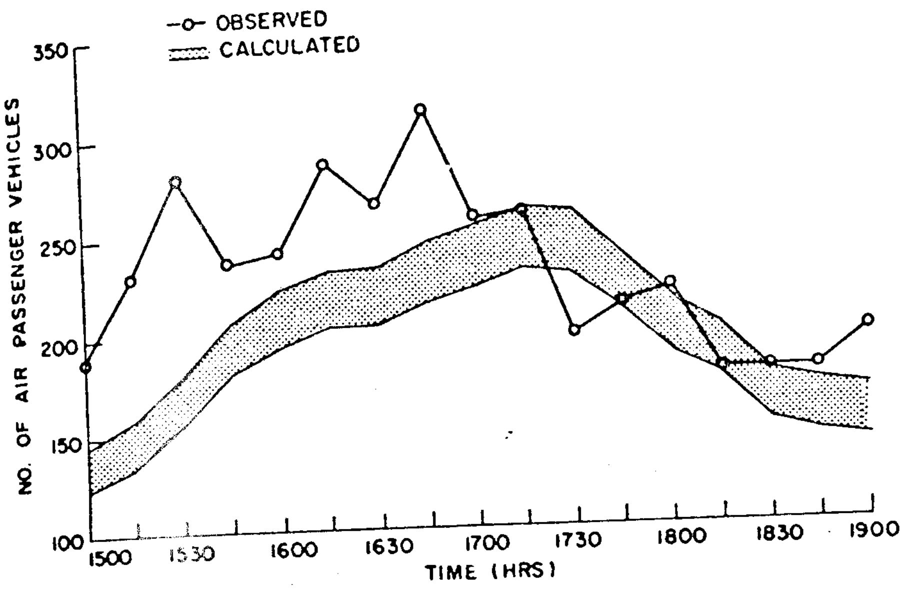

FIGURE 56
15-MINUTE ESTIMATED VERSUS SAMPLE VOLUMES OF INBOUND VEHICLES. FRIDAY

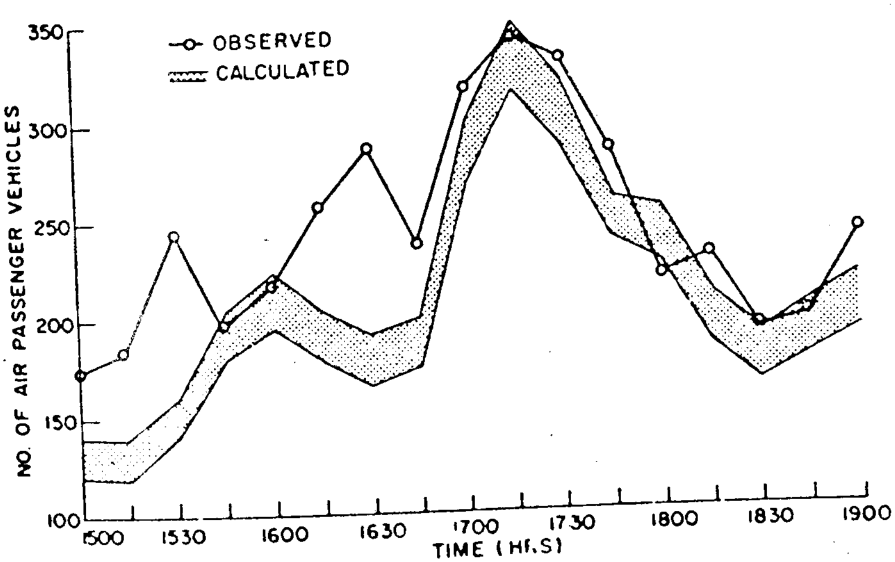

FIGURE 57
15-MINUTE ESTIMATED VERSUS SAMPLE VOLUMES OF OUTBOUND VEHICLES, FRIDAY

Note that there is reasonably close agreement in both figures between model estimates and hourly traffic counts.

Comparisons by 15-minute interval between model estimates and actual traffic counts are shown in Figures 56 and 57. Here again, there is close agreement except for the period 1500 to 1700 hours. During that period there were substantial volumes of airport employee-related vehicles using the main public roadway in addition to the service roads. This was not accounted for in the model estimates of public-roadway traffic volumes; those estimates considered only air passenger-related vehicles. Prior to the DFW survey it was thought that employee vehicles used only the service roadway system. Future research should be aimed at factoring out these employee vehicles to obtain better estimates of DFW air passenger vehicular volumes. Volumes of employee vehicles are explicitly modeled as a function of work-shift schedules in the next chapter of this report.

CONCLUSIONS AND RECOMMENDATIONS

This chapter has presented a method for transforming an existing or forecasted airline schedule into estimates of volumes of ground vehicles entering and leaving an airport in any time period. The method accounts for both air passengers who drive themselves to the airport and air passengers who are dropped off and picked up by others. In addition, it is easy to apply in that it requires only (1) the airline schedule and approximate load factors and (2) the distributions of times at which passenger-related vehicles enter and leave the airport relative to scheduled flight times. Model estimates have been found to compare favorably with actual traffic counts at DFW. The model has application in providing information for the design of airport access highways, traffic control systems, and airport parking facilities.

Future research is needed to test the method at other airports. The method should be combined with similar procedures for estimating employee access volumes, volumes of commercial and service vehicles, and volumes of public transportation vehicles. At DFW, the above classes of airport users were largely distinguishable (because of the service road system) and could be treated separately. This is not the case at most other airports.

Research is also needed to further explore the factors which might affect the times at which passengers enter and leave the airport relative to scheduled times. In particular, the possibility of disaggregating these distributions by (1) type of flight, (2) purpose of air trip, (3) time of day, (4) trip length, and (5) type of automobile usage, i.e., whether the passenger drove himself or was driven by someone else, should be explored. These factors were found not to be significant in this research for DFW.

Finally, and most importantly, research is needed to account for the effect of "lateness;" in this research actual flight times rather than scheduled flight times were used. This is probably not too inaccurate for vehicles associated with departing flights. However, vehicles associated with arriving flights are directly affected by lateness.

V. EMPLOYEE ACCESS VOLUMES

INTRODUCTION

Volumes of employee vehicles entering and leaving an airport are generated almost exclusively by the schedule of airport employee work shifts. This chapter presents an easy-to-apply analytical model for transforming an existing or future employee work shift schedule into estimates of incoming and outgoing volumes of employee vehicles in any time interval. These estimates have application to the planning and design of airport access facilities and employee parking areas.

An analysis is presented of data obtained from the employee survey component of the Dallas/Fort Worth Regional Airport travel survey of May 1975, described in Chapters II and III of this report and in a previous report.[23] The analysis focuses on estimating theoretical probability distributions for the differences between work shift times and actual entering and leaving times of airport employees. The model requires these distributions as input along with (1) periods of the day and lengths of time intervals to be considered, (2) estimates of parameters for the above theoretical distributions for each period, (3) starting or ending time of each work shift, and (4) number of employees per shift. The output is the expected value and variance of the number of employee vehicles entering and leaving the airport in each 15-minute time interval throughout the day.

DISTRIBUTIONS OF ARRIVAL AND DEPARTURE TIMES OF DFW EMPLOYEES

The DFW Airport taken as a whole is one of the largest employers in the Dallas/Fort Worth area and as such is a major traffic generator from the standpoint of employee vehicles alone. The arrivals and departures of employees' vehicles are in addition to the traffic volumes generated by the airline passenger and visitor activity and must be considered both in modeling airport access volumes and in the subsequent design of airport access and parking facilities. Therefore, the distribution of employees' arrival and

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[23] Dunlay, et al., op. cit.

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departure times at the airport relative to their work shift times is of critical interest in this research.

The purpose of this section is to describe the distributions of DFW employees' arrival and departure times at the airport relative to work shift starting and ending times. The term "time difference distribution" refers to the observed frequency distribution of the above time differences as obtained from the DFW data.

DETERMINATION OF THE PERIODS OF THE DAY FOR ANALYSIS

Figures 21(a) and (b) in Chapter III are histograms of the percentages of DFW employees by starting work shift times and ending work shift times, respectively, during a normal work day. Figure 21(b) is roughly the same as Figure 21(a) but shifted to the right by eight hours. It was noted from Figure 21(a) that for starting work shift times, there were approximately five distinct periods of the day and their limits were tentatively 0 to 4, 4 to 10, 10 to 13, 13 to 20, and 20 to 24 hours. Ranges of alternative limits around the above tentative periods were tested and fixed for each period when the percent of DFW employees distributed by five-minute interval tended to change most significantly.[24] A similar procedure was followed for the ending work shift periods. The definitive limits of the periods based on this process are shown in Table 71. The objective here was to distinguish time periods during which the arrival or departure patterns of employees remained approximately stationary. The next step was to determine which theoretical probability distribution best explained the observed time difference distribution within each of the above periods.

TABLE 71. LIMITS OF PERIODS OF STARTING AND ENDING WORK SHIFTS

PERIOD	TIME OF: STARTING WORKSHIFT	TIME OF: ENDING WORKSHIFT
First	0 to 0500	0 to 0600
Second	0500 to 0900	0600 to 1000
Third	0900 to 1300	1000 to 1400
Fourth	1300 to 2100	1400 to 1900
Fifth	2100 to 2400	1900 to 2400

[24] Nie, Norman, et al., Statistical Package for the Social Sciences (New York, McGraw-Hill, 1975).

ESTIMATION AND TESTING OF THEORETICAL PROBABILITY DISTRIBUTIONS

Figures 58 and 59 show typical observed time-difference distributions. From a visual inspection of these data for each period, the following observations were made:

(1) Theoretical distributions considered as candidates to fit the observed time difference distributions were

   (a) normal distribution,

   (b) lognormal distribution,

   (c) exponential distribution,

   (d) gamma distribution, and

   (e) Erland distribution.

(2) When DFW employees were asked what time they entered or left the airport, there was an apparent tendency to answer to the nearest five minutes. Therefore, the intervals selected were five minutes in length centered around even five-minute epochs, i.e., the actual boundaries were defined according to the formulas 5(N + 0.5), where N is a positive integer (the first interval had the lower bound of zero).

The Kolmogorov Smirnov (K-S) Test was selected for use in testing the goodness-of-fit of the candidate theoretical probability distributions.[25] The K-S test is based on the measurement of the maximum vertical difference between an observed cumulative probability distribution and a selected theoretical cumulative distribution function (cdf). This measured difference is then compared with tabled values of the K-S statistic for the appropriate sample size and level of significance.[26]

Figure 60 is a flow chart of the sequence of steps followed in finding the theoretical distribution that best fits the observed time difference distribution. First of all, the data were divided randomly into two approximately equal parts. This division was made to approximate the K-S test requirement that the parameters of the theoretical distribution should not be obtained

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[25] Gerlough, Daniel L. and Frank C. Barnes, Poisson and Other Distributions In Traffic, (Saugatuck, Conn.: Eno Foundation for Transportation, 1971) pp. 35-44.

[26] Ibid., pp. 120-121.

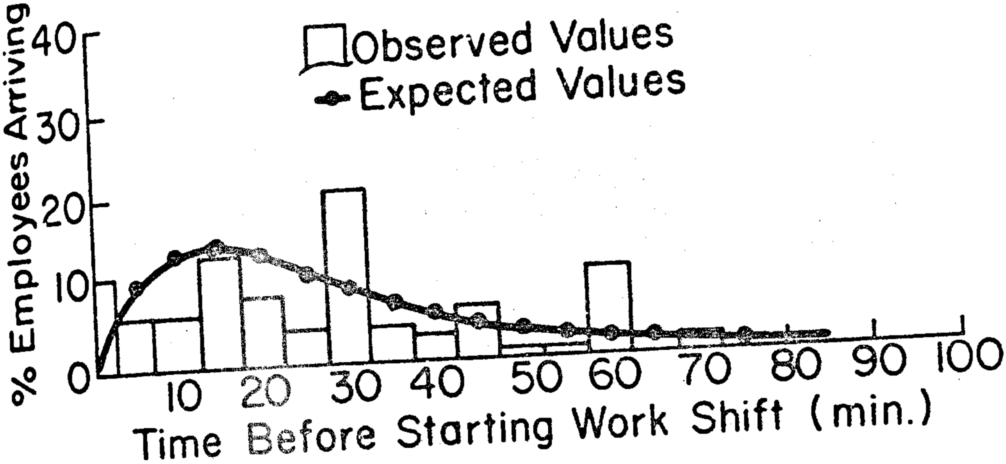

FIGURE 58.
TYPICAL OBSERVED AND EXPECTED TIME-DIFFERENCE DISTRIBUTIONS
(STARTING WORK SHIFT)

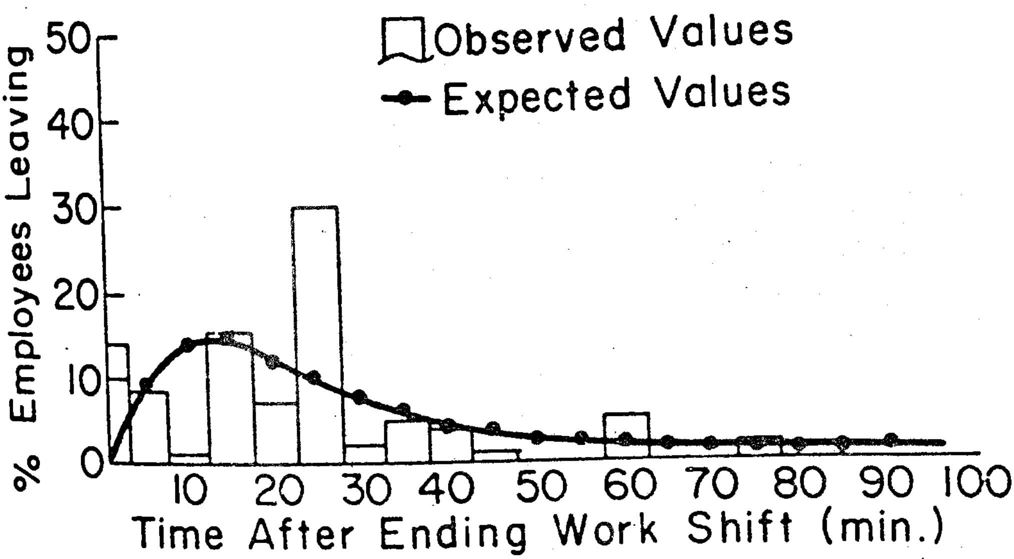

FIGURE 59.
TYPICAL OBSERVED AND EXPECTED TIME-DIFFERENCE DISTRIBUTIONS
(ENDING WORK SHIFT)

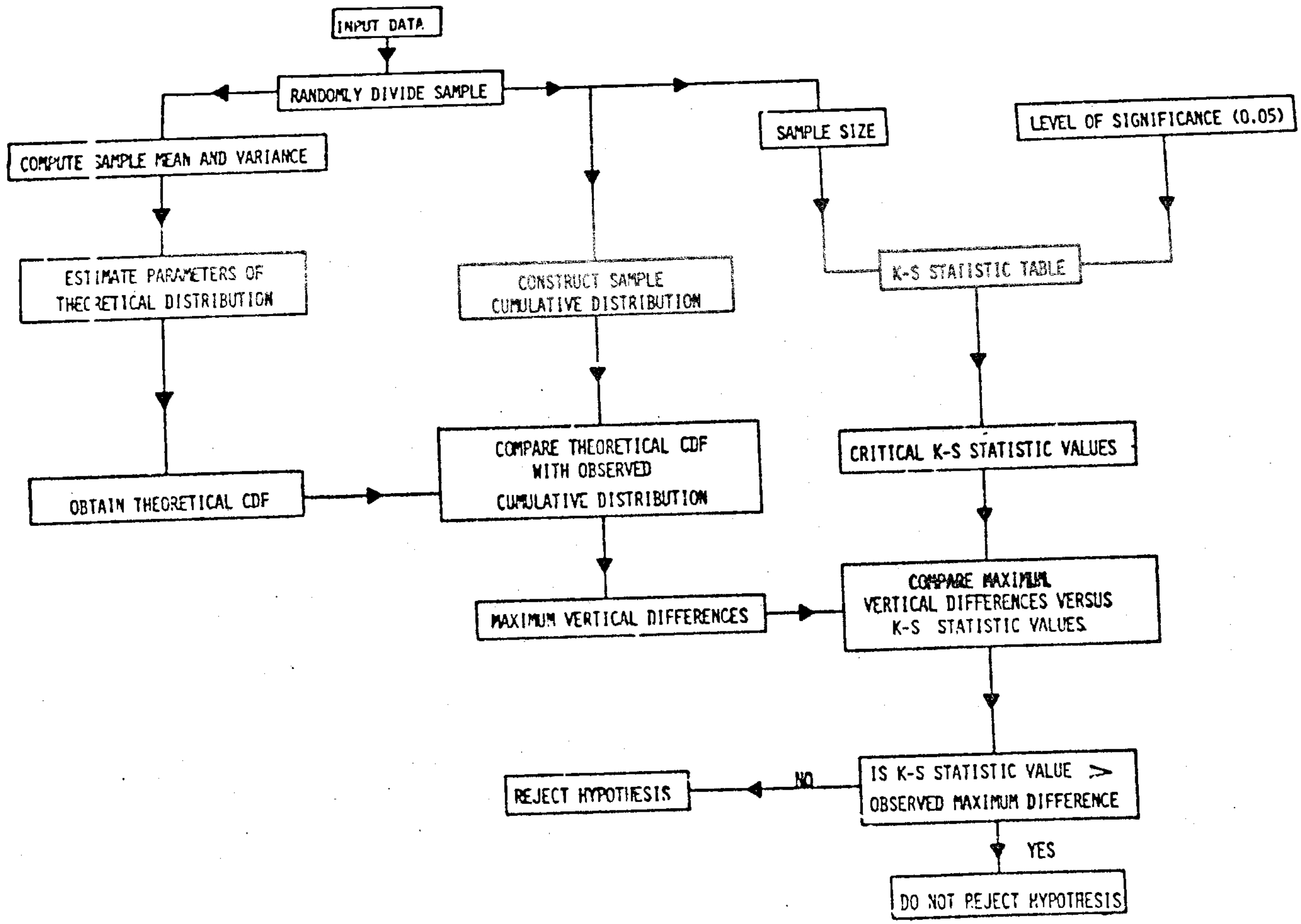

FIGURE 60. FLOW CHART OF SEQUENTIAL STEPS TO FIND THEORETICAL DISTRIBUTION OF BEST FIT

from the same sample that is tested. From one subset of the data the sample mean and variance were computed and used to estimate the parameters of each candidate theoretical distribution. From the other subset the observed cumulative probability distribution function was constructed. Then each theoretical cdf was compared to the observed cumulative distribution function, and the maximum vertical differences were obtained. The minimum of the maximum vertical differences was then compared with the tabled K-S test statistics. If the computed value was less than 0.05 K-S statistic, it was concluded that there was no reason to reject the hypothesis that the corresponding theoretical distribution fits the observed time difference distribution at the 0.05 significance level.

In Tables 72 and 73 are shown the different periods of day for the particular theoretical distributions along with the corresponding probability density functions and estimated parameters. The theoretical distribution that fits most frequently is the gamma distribution. Figures 58 and 59 show sample comparisons of the observed distributions in the form of histrograms with the best fit theoretical pdf's for DFW employees entering and leaving the airport, respectively.

MODEL DEVELOPMENT

The purpose of this section is to derive the model for estimating employee vehicular volumes entering and leaving the airport. Figures 61 and 62 show examples of how DFW employees arrive at and leave the airport, respectively, in terms of the theoretical probability density function (pdf) found to best fit the data for a particular time period. Note that for the ith work shift the area under the pdf corresponding to a time interval $(t, t + \Delta t)$ represents the probability that a given employee working on that shift will arrive between time t and time $t + \Delta t$.

EMPLOYEE VEHICLE TRAFFIC ENTERING THE AIRPORT

Figure 61 shows pdf's for a number of starting work shifts plotted with the horizontal scale reversed from that of Figure 58 so that time increased to the right. Let I denote the set of starting work shifts whose pdf's overlap significantly in interval $(t, t + \Delta t)$. From each pdf one can estimate the probability that an employee selected at random from any shift (say shift i)

TABLE 72. GOODNESS-OF-FIT TESTS FOR DFW EMPLOYEES STARTING THEIR WORK SHIFTS

PERIOD OF DAY (HRS)	SAMPLE SIZE	THEORETICAL DISTRIBUTIONS			K-S VALUE	LEVEL OF SIGNIFICANCE
		NAME	DENSITY FUNCTION	PARAMETERS		
0 to 5	41	gamma	$f(x)= \frac{\alpha^k}{(k-1)!} x^{k-1} e^{-\alpha x}$	$\alpha = 0.52$ $k = 1.15$	.189	0.1
5 to 9	716	gamma	Same	$\alpha = 0.065$ $k = 1.13$	.049	0.05
9 to 13	166	gamma	Same	$\alpha = 0.053$ $k = 1.44$	.105	0.05
13 to 21	379	gamma	Same	$\alpha = 0.067$ $k = 1.67$	.069	0.05
21 to 24	144	negative exponential	$f(x) = \alpha e^{-\alpha x}$	$\alpha = 0.042$	.0105	0.05

TABLE 73. GOODNESS OF FIT FOR DFW EMPLOYEES ENDING THEIR WORK SHIFTS

PERIOD OF DAY (HRS.)	SAMPLE SIZE	THEORETICAL DISTRIBUTIONS			K-S VALUES	LEVEL OF SIGNIFICANCE
		NAME	DENSITY FUNCTIONS	PARAMETERS		
0 to 6	107	Erlang (rounded up)	$f(x) = \frac{\alpha^k}{(k-1)!} x^{k-1} e^{-\alpha k}$ (k = positive integer)	$\alpha = 0.078$ $k = 2.0$	.131	0.05
6 to 10	131	gamma	$f(x) = \frac{\alpha^k}{(k-1)!} x^{k-1} e^{-\alpha k}$	$\alpha = 0.081$ $k = 1.79$	.106	0.10
10 to 14	78	gamma	Same	$\alpha = 0.056$ $k = 1.46$	.138	0.10
14 to 19	686	negative exponential	$f(x) = \alpha e^{-\alpha x}$	$\alpha = 0.065$	.052	0.05
19 to 24	341	gamma	Same	$\alpha = 0.065$ $k = 1.64$	.074	0.05

leaves the airport in a specified time interval $(t, t + \Delta t)$; this probability is denoted by $P_i(t, t + \Delta t)$.

By denoting the total number of employee vehicles for shift i as N_i, the expected number of shift i vehicles entering the 'rport in time interval $(t, t + \Delta t)$ is

$$E\{N_i(t, t + \Delta t)\} = N_i P_i(t, t + \Delta t) \tag{1}$$

where $N_i(t, t + \Delta t)$ is a random variable representing the number of shift i employee vehicles which enter the airport in the time interval $(t, t + \Delta t)$. Therefore, the total expected value of the number of employee vehicles arriving in $(t, t + \Delta t)$ for all work shifts, $N(t, t + \Delta t)$, is

$$E\{N(t, t + \Delta t)\} = \sum_{i \in I} N_i P_i(t, t + \Delta t) \tag{2}$$

An approximate variance can be obtained for $N(t, t + \Delta t)$ by making the assumptions:

(1) $P_i(t, t + \Delta t)$ applies independently and identically for each of the N_i passenger vehicles arriving for shift i, $\forall\, i \in I$.

(2) the $N_i(t, t + \Delta t)$'s are stochastically independent, $\forall\, i \in I$.

Assumption (1) implies that

$$N_i \sim \text{binomial}\,\{N_i P_i(t, t + \Delta t),\ N_i P_i(t, t + \Delta t)\,[1 - P_i(t, t + \Delta t)]\},\ \forall i.$$

Assumption (2) implies that the variance of $N(t, t + \Delta t)$ can be expressed as the sum of individual variances, i.e., (Ref.)

$$\text{Var}\{N(t, t + \Delta t)\} = \sum_{i \in I} N_i P_i(t, t + \Delta t)\,[1 - P_i(t, t + \Delta t)] \tag{3}$$

Equations (2) and (3) enable one to estimate the mean and variance, respectively, of the total number of employees' vehicles entering the airport for all shifts in any arbitrary time interval $(t, t + \Delta t)$.

For large set I and moderate size time intervals, where the $P_i(t, t + \Delta t)$'s are neither close to zero nor to unity, the random variable $N(t, t + \Delta t)$ is approximately normally distributed by the well-known normal approximation of the binomial. For very short time intervals, i.e., small values of Δt, and large I, the Poisson approximation applies.

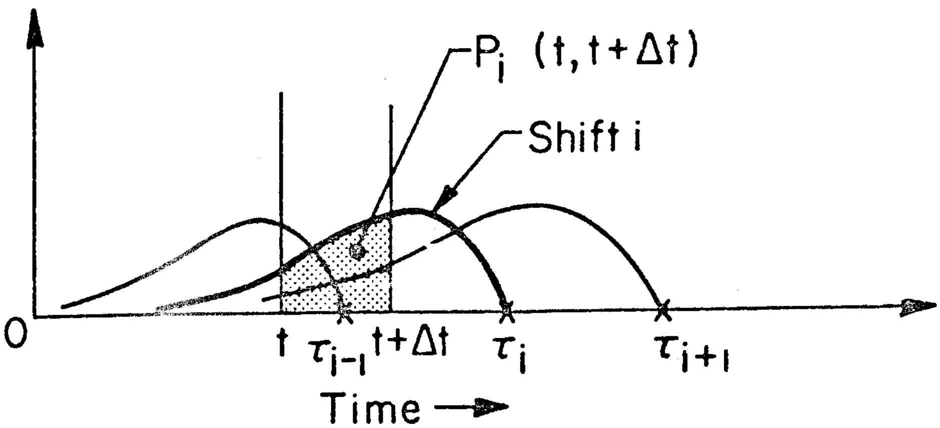

FIGURE 61
GRAPH OF TYPICAL PROBABILITY DENSITY FUNCTION FOR ARRIVING EMPLOYEES

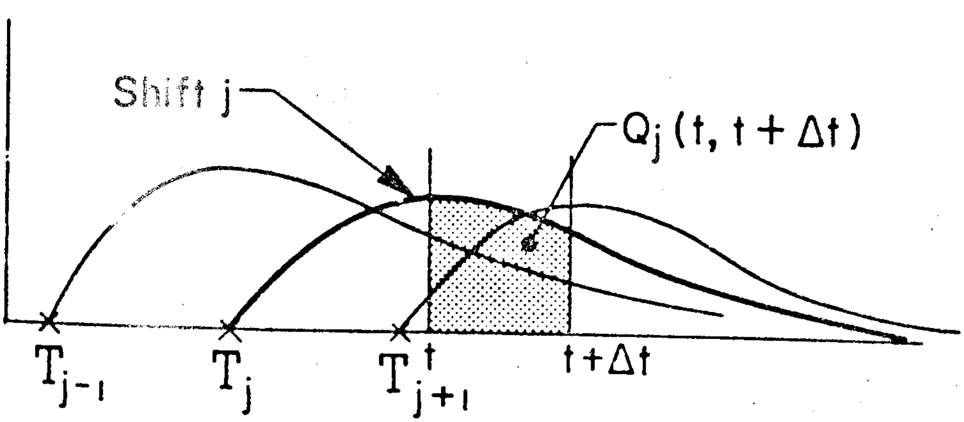

FIGURE 62
GRAPH OF TYPICAL PROBABILITY DENSITY FUNCTION FOR TERMINATING EMPLOYEES

EMPLOYEE VEHICLE TRAFFIC LEAVING THE AIRPORT

In Figure 60, several pdf's for ending work shifts are shown in close proximity to each other, superimposed on the same time axis. By an argument and set of assumptions analogous to the one above for arriving employee vehicles, one can derive the following equations for the mean and variance of the total number of employee vehicles leaving the airport in time interval $(t, t + \Delta t)$, $M(t, t + \Delta t)$:

$$E\{M(t, t + \Delta t)\} = \sum_{j \in J} M_j Q_j(t, t + \Delta t) \tag{4}$$

$$\mathrm{Var}\{M(t, t + \Delta t)\} = \sum_{j \in J} M_j Q_j(t, t + \Delta t)[1 - Q_j(t, t + \Delta t)] \tag{5}$$

where $Q_j(t, t + \Delta t)$ = area under ending work shift j's pdf in $(t, t + \Delta t)$ -- see Figure 7,

J = set of ending work shifts whose leaving pdf's overlap in $(t, t + \Delta t)$, and

M_j = total number of employee vehicles leaving the airport after shift j.

Thus, equations (4) and (5) yield the mean and variance, respectively, of the total number of employee vehicles leaving the airport from all shifts in set J in a specified time interval $(t, t + \Delta t)$.

As before, $M(t, t + \Delta t)$ is approximately normally distributed for a reasonably large set J and moderate size time intervals.

APPLICATION OF THE MODEL

Figure 63 is a flow chart of the steps involved in estimating the volumes of DFW employee vehicle entering or leaving the airport from employee work shift information.

PRELIMINARY VALIDATION OF MODEL

The Dallas/Fort Worth Regional Airport presented a unique opportunity to test the proposed employee traffic model; the configuration of DFW makes it possible to observe, separately, the employee vehicles on the airport service roads. Distinguishing employee traffic from air passenger and visitor traffic at most other airports is difficult, if not impossible. This does not invalidate the

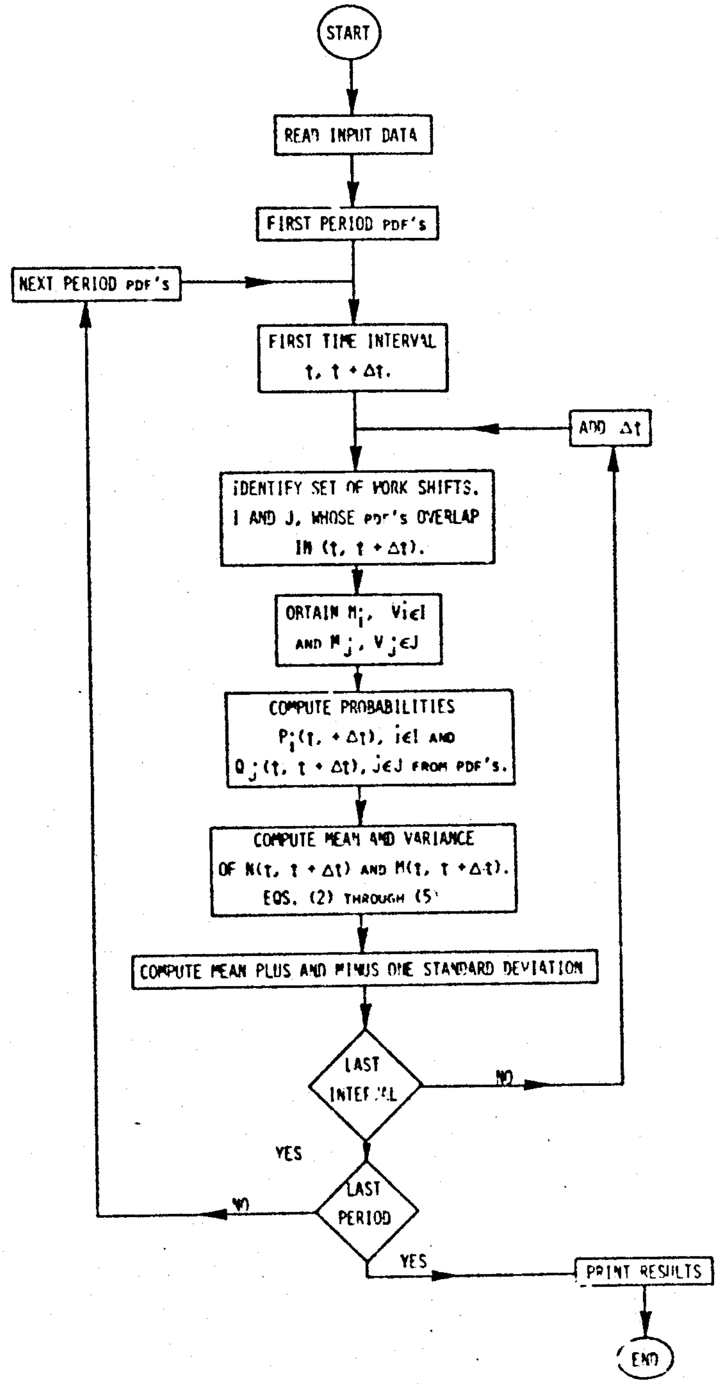

FIGURE (3
FLOW CHART OF SEQUENTIAL STEPS TO
ESTIMATE VOLUMES OF DFW EMPLOYEE VEHICLES

model for application at other airports. It does imply, however, that to validate the model at other airports, the combined estimates from the proposed employee model and a model of air passenger and visitor traffic as in Chapter IV would have to be compared with counts of mixed access traffic.

Not all airport employees use the DFW service roads on which the traffic counts were made; however, those who do not (approximately 27 percent) could be deterministically factored out for the model test. Fortunately, it was safe to assume that air passengers and visitors do not use the service roads. Therefore, data on the subset of employees who do use the service roads could be used in the model along with data on employee vehicle occupancy to obtain estimates of the expected traffic volumes on the service roads to compare with observed ones. Traffic volume estimates were obtained by half-hour time intervals during inbound and outbound peak periods. Only the peak period performance of the model was tested due to limits on data-collection resources. Besides, it is for these periods that the accuracy of the model is of greatest concern.

Figure 64 shows model estimates versus service road counts for the 6:00 a.m. through 9:00 a.m. inbound peak. Data points in the figure were plotted at the mid-points of half-hour time intervals. Note that, except for the interval (7:30-8:00 a.m.), model estimates compare favorably with the observed traffic volumes. In the 7:30-8:00 a.m. interval, the model estimate exceeds the observed traffic volume by about 30 percent. No causal explanation for this discrepancy could be found.

Figure 65 compares model estimates and traffic counts for the 2:30 p.m.-6:00 p.m. outbound employee peak. Here, the model performance over the entire period appears reasonably accurate. There are, however, a few intervals within the peak for which the estimates differ significantly from the counts, e.g., the 3:30-4:00 p.m. interval.

Although no causal explanation for the above discrepancies could be found, one hypothesis is offered below.

The main inputs to the model are the distributions of the times at which employees enter and leave the airport relative to shift times. Although the available data were not sufficient for a formal sensitivity analysis, it is obvious from the model formulation that estimates produced by the model are sensitive to the input distributions. At DFW, these distributions were

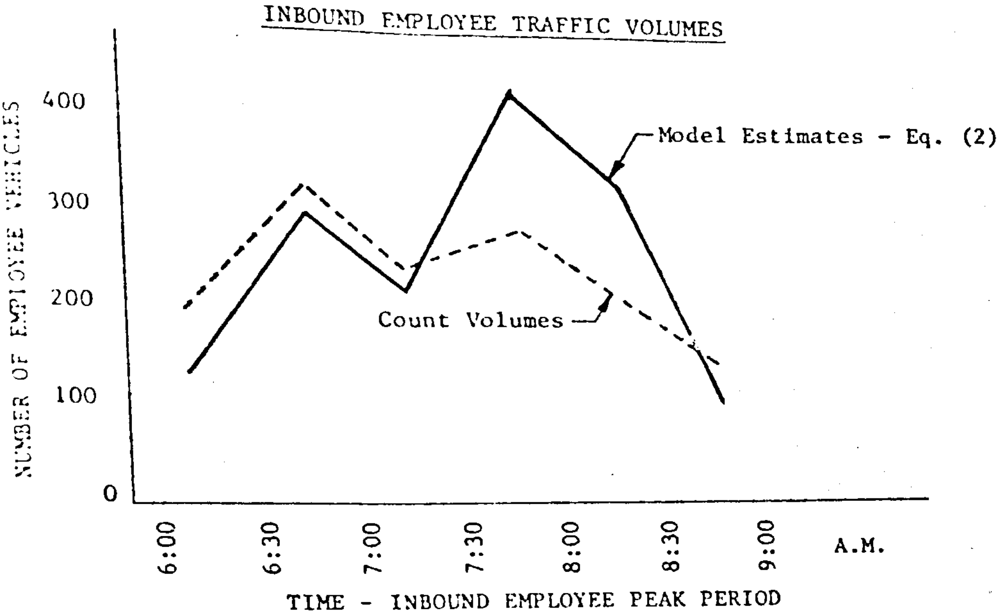

FIGURE 64. MODEL ESTIMATES VERSUS TRAFFIC COUNTS - INBOUND EMPLOYEES

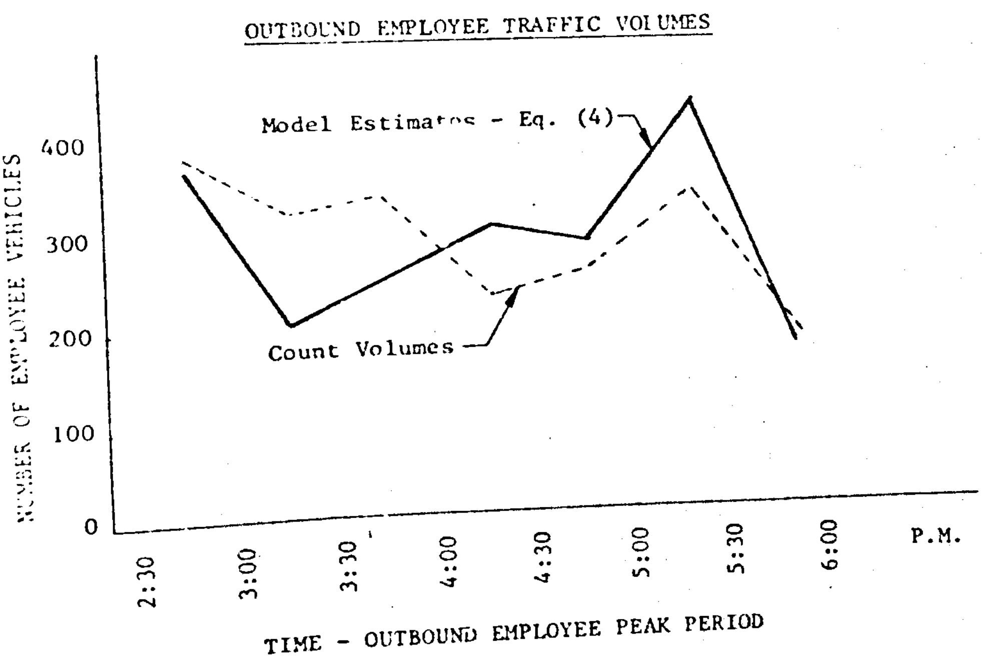

FIGURE 65. MODEL ESTIMATES VERSUS TRAFFIC COUNTS - OUTBOUND EMPLOYEES

constructed based on actual entering and leaving times taken from answers to the questionnaire. The question was phrased, "What time did you arrive at (leave) the airport TODAY?" (See Figure 64.) Feedback from employees indicated that some of them interpreted this to mean their office or work area rather than the intended interpretation, namely their times at the airport gates. The resulting differences could be substantial (as large as a half hour) because most employees park in remote parking areas and ride an intra-airport transit system called Airtrans to their final destination. It is suspected that these misinterpretations distorted the distributions of employee arrival and departure times, and, hence, the model estimates.

CONCLUSIONS AND RECOMMENDATIONS

The following are the major conclusions and recommendations of this chapter:

(1) Very little information exists on the application of data from airport employee travel surveys to estimating employee access volumes.

(2) The type of vehicle most commonly used for work trips is the employee's own vehicle.

(3) DFW employees who use public transportation are mostly of relatively low income, female, between the ages of 21 and 44 years, and residents of the two major cities of the region.

(4) A misinterpretation of the survey question on actual arrival and departure times of employees probably contributed to the discrepancies between model estimates and traffic counts of employee vehicles.

(5) For application and testing at other airports, the proposed model should be coupled with a model for estimating volumes of air passenger and visitor vehicles.

(6) The model developed in this research should enable the airport planner to gain insight into the probable effects of proposed or forecasted changes in the employee work schedule on airport access traffic volumes.

VI. PUBLIC TRANSPORTATION VOLUMES

INTRODUCTION

This chapter describes preliminary efforts toward the development of a model to estimate public transportation passenger volumes for a scheduled bus service based on scheduled airline passenger volumes, with the specific objective of estimating the expected numbers of bus passengers boarding or debarking from buses at airline terminals. By interrelating transit bus and airline schedules, it should be possible to use such a model to estimate volumes from airline passenger volumes for each individual scheduled bus as a function of bus service levels (headways, travel time, cost, etc.).

The model sought in this research could be applied after the modal split is initially estimated (e.g., via a marginal disability modal split model). Having projected the modal split, the planner could utilize the hypothetical passenger volume model to convert airline passenger activity to transit bus passenger volumes of a scheduled transit service -- the last step, in effect, of a planning process beginning with the estimation of modal split. The transit operator would be able to relate the frequency of bus service to variations in airline schedules. Output from the model would be the expected number of passengers on each bus -- a level of detail not currently available, at least for an air/ground interface type of service.

An obvious first step in the development of such a model is an investigative analysis of the relationship existing between airline and bus schedules. The project's DFW travel survey has provided appropriate data for such an analysis, towards which the work described in this chapter can be considered a first step.

INITIAL RESEARCH PROCEDURE

The data gathered in the Surtran passenger survey were investigated in stages. First, frequency distributions and histograms were constructed for the results of each of the questions in the Surtran survey. Characteristics of Surtran riders and their ground and air trips were tabulated and compared with corresponding information gathered in the automobile user survey to see

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where significant differences existed. Characteristics of the Surtran bus service and automobile travel were then compared. Next, observable characteristics of Surtran ridership demand by route and time of day were compiled. Finally, various characteristics of trips, trip makers, modes, and airline flights were cross-tabulated to examine what discernable dependencies exist among these quantities. Important results of the above analysis have been presented in Chapter III.

Analysis

From the investigation of trip maker, ground trip, and air trip characteristics, no useful relationships could be developed. In those characteristics where variation between modes might be expected, no significant differences existed. For air passengers, no variation was found in those variables that were expected to be explanatory, such as air passenger's income, purpose of air trip, and duration of air trip (the exception is residency in the Dallas/Fort Worth area, where some difference between the two modes does exist). Where variation between the two modes did exist, it was in characteristics where no clear causal relationships could be deduced.

PRELIMINARY MODEL DEVELOPMENT

Eventually, research attention focused on certain specific characteristics of the DFW public transportation mode (Surtran) which appeared significant in terms of determining interrelationships between transit service, air passenger modal choice, and airline flight schedules.

In-Vehicle Travel Time

The Surtran travel time between DFW and the off-airport terminal varies from route to route but generally averages about 40 minutes. The Downtown Dallas route has a travel time of 35 to 45 minutes, depending on what airline terminal is being used. For downtown Dallas hotels, an average of an additional 10 minutes is required. The same travel time of 35 to 45 minutes applies to the Fort Worth and North Central Dallas routes, while the Love Field route takes 30 to 40 minutes.

Frequency of Service

The scheduled frequency of service (headways) is constant during the daylight hours for most of the routes. The exception is the North Central route, which has 20-minute headways during ridership peaks, from 6:40 a.m. to 8:00 a.m. and 6:00 p.m. to 7:00 p.m. Otherwise, the North Central route operates on 30-minute headways from 8:00 a.m. to 10:30 p.m. The Downtown Dallas and Fort Worth routes also have 30-minute headways, from 5:00 a.m. to 10:00 p.m. and from 6:00 a.m. to 8:00 p.m., respectively. The Love Field route has 35-minute headways from 5:00 a.m. to 7:00 p.m. The Arlington route operates on one-hour headways from 6:00 a.m. to 11:00 p.m. All routes except the Arlington route have only marginal service during the late night/early morning hours, less than one bus per hour. There is a total of approximately 192 scheduled buses run to and from DFW per day.

Total travel time on public transportaton is a function of in-vehicle time, scheduled frequency of service (headways), reliability, and travel time to/from the station on the interface mode. The relationship of headways to the total travel time is not as obvious as the others. The "average" passenger's wait time at the station depends on his familiarity with the Surtran schedule. Based on observations during the Srutran survey, the majority of Surtran passengers wait between 5 and 10 minutes for a bus at off-airport stations. This is true only for the to-DFW direction of travel because those air passengers deplaning at DFW have no control over when they reach the curb to begin their wait for a Surtran bus. For the from-DFW direction, the average waiting time for Surtran passengers is probably very close to half a headway, or about 15 minutes.

From the distribution of Surtran passengers' trip ends around the stations and data on travel times in the Dallas/Fort Worth area, one can estimate the average travel time between the Surtran station and the ultimate ground trip end. This average travel time is approximately 15 minutes. Therefore, the average total travel time for Surtran passengers is approximately 60-65 minutes for passengers traveling to DFW and 70 minutes for those leaving DFW.

Fare System

At the time of the survey in May 1975, the fare between DFW and any off-airport terminal was $2.50. For service at the door of the hotels on the Downtown Dallas route, passengers were charged $4.00.

Service Area

The primary service area of each route can be defined by looking at the maps of origin and destination trip ends (Figures 24(a) and (b) through 27(a) and (b)). Based on these, boundaries of the general service area of each route were perceived. Considerable overlap of service areas was noticed in the Central Dallas area.

Surtran Passengers' Boarding Time Relative to the Airline Flight Time

As discussed in Chapter II, a short follow-up survey was conducted on Surtran in November 1975 to obtain data on when air passengers board/deboard Surtran relative to their flight arrival or departure time. The distribution of passengers over time was needed for Surtran travel both to and from the airport.

The exact data collected in the minisurvey proved in the analysis stage to be somewhat awkward. The survey asked, "What time did you board Surtran?," rather than, "What time did you reach the curb, to wait for the bus?" It is this latter time that governs when a passenger is available to board a bus and, therefore, the volume of passengers from a particular flight boarding a particular bus. That is to say, it is the difference in time between when a Surtran passenger's flight arrives and when that passenger reaches the curb (becomes available to board a bus) that is really of interest in this research.

Some additional manipulations were necessary to derive the desired information. First, the data were sorted so that only those passengers who had ridden when the same scheduled headways (20 minutes, 30, 35, etc.) were in effect were considered at one time. Then, the difference in time between the scheduled airline flight arrival time and the time when the passenger boarded the bus was calculated. These time differences were grouped by five-minute intervals, to facilitate calculations. Fortunately, most of the survey forms returned fell into one headway category, namely, passengers serviced by

30-minute headway schedules. The main routes, i.e., Downtown Dallas, North Central, and Fort Worth, also all have similar travel times between DFW and the off-airport terminal, which further aided the data reduction.

For terminating air passengers (riding Surtran from DFW), the difference in time between when the air passenger boarded a Surtran bus and when that passenger's flight had arrived (or had been scheduled to arrive) was calculated. These values were then grouped into five-minute intervals. Next, the frequency of responses in each five-minute "cell" was distributed uniformly over the six five-minute cells within the previous 30 minutes, inclusive of the cell during which they boarded. This involved the assumption that the passengers on a bus arrived at the curb uniformly over the previous 30 minutes to wait for the bus. The reason that 30 minutes was chosen was that, given a schedule with 30-minute headways, if a passenger had arrived at the curb any sooner than 30 minutes before the bus in question, he would have boarded the previous bus one headway earlier. After this procedure was repeated for each five-minute cell, the distributed frequencies were summed for each cell, to yield an estimated frequency of passengers who had arrived at the curb at any time after their flight had landed (as opposed to the time they boarded the bus). This is the distribution that is needed to predict the volume of passengers on each bus of the schedule.

Again, the assumption was made that the passengers on each bus had arrived at the curb uniformly over the previous 30 minutes. Although this assumption is not precise, in the absence of knowing the true distribution of arrivals at the curb, the assumption of uniformity is necessary.

The resultant frequency histogram was used to calculate the mean and variance of the sample distribution. The mean and variance were used to define the parameters of a number of standard distributions, to see which theoretical distribution was most closely approximated by the sample distribution. The theoretical distributions tried were the uniform, normal, log normal, negative exponential, shifted negative exponential, gamma, Erlang rounded up, Erlang rounded down, and Pearson type III distributions. The fit of the sample distribution to these distributions was tested using the Chi-Square test and the Kolmogorov-Smirnov test.

For deplaning airline passengers (Surtran from DFW), the sample distribution fit the gamma distribution best with mean = 26.8 minutes and variance =

375.8 minutes[2] (standard deviation = 1914 minutes), as derived from the sample distribution. The distribution is illustrated in Figure 66. The sample distribution fit the gamma distribution with a Chi-Square level of significance of x = 0.27 with 3 degrees of freedom. The sample size for which the sample distribution was developed was 71. The accompanying cumulative distribution is shown in Figure 67. This indicates that, by 20 minutes after their flight arrived, 45 percent of Surtran-riding air passengers had reached the curb, and at 40 minutes, 80 percent had reached the curb.

An analogous method, with some modifications, was used to determine the distribution in time of airline passengers arriving at the Surtran station, relative to when their flight was scheduled to depart form DFW. The difference is that, for the Surtran trip to DFW, an air passenger can control the time that he arrives at the off-airport terminal to wait for the next bus. How well a passenger controls his arrival time depends on the reliability of his access mode, and his familiarity with the schedule. Given ideal conditions, an air passenger would examine the Surtran time closest to his actual desired leaving time. He would then time his arrival at the Surtran station to a few minutes before the bus left. To a certain extent, this is the assumption that was made.

In the same way as before, the survey responses were separated into groups within which all respondents were subject to the same headway (30 minutes, 35 minutes, etc.). Then, the difference in time between when they boarded Surtran and the time that their flight was scheduled to leave was calculated and grouped into five-minute intervals for convenience. Then this difference was implemented: rather than being distributed uniformly over the previous 30 minutes, the cell frequency was distributed uniformly over the 30-minute interval centered at the time at which the passengers boarded the bus. In practice, to allow for those Surtran passengers who are unfamiliar with the schedule, and for convenience, each five-minute cell frequency was distributed uniformly over six cells, three cells earlier and two cells later than the cell in question. As before, the reason the frequencies were distributed over 30 minutes is that, if a passenger had fallen outside of this range for one bus, another bus in the same schedule would have become more attractive.

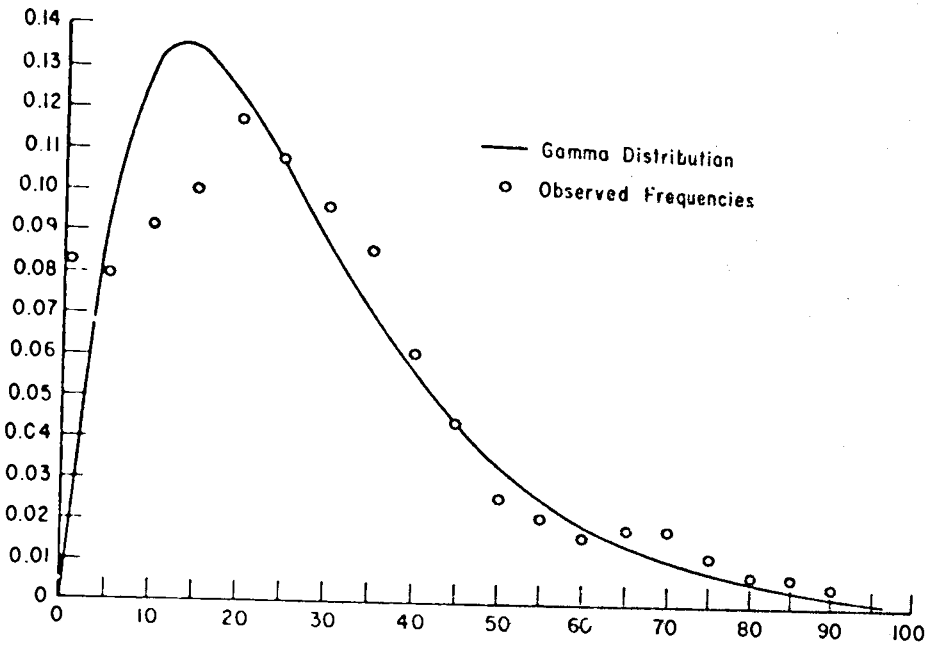

FIGURE 66
SAMPLE DISTRIBUTION AND GAMMA DISTRIBUTION OF DEPLANING PASSENGERS DEPARTING DFW VIA SURTRAN

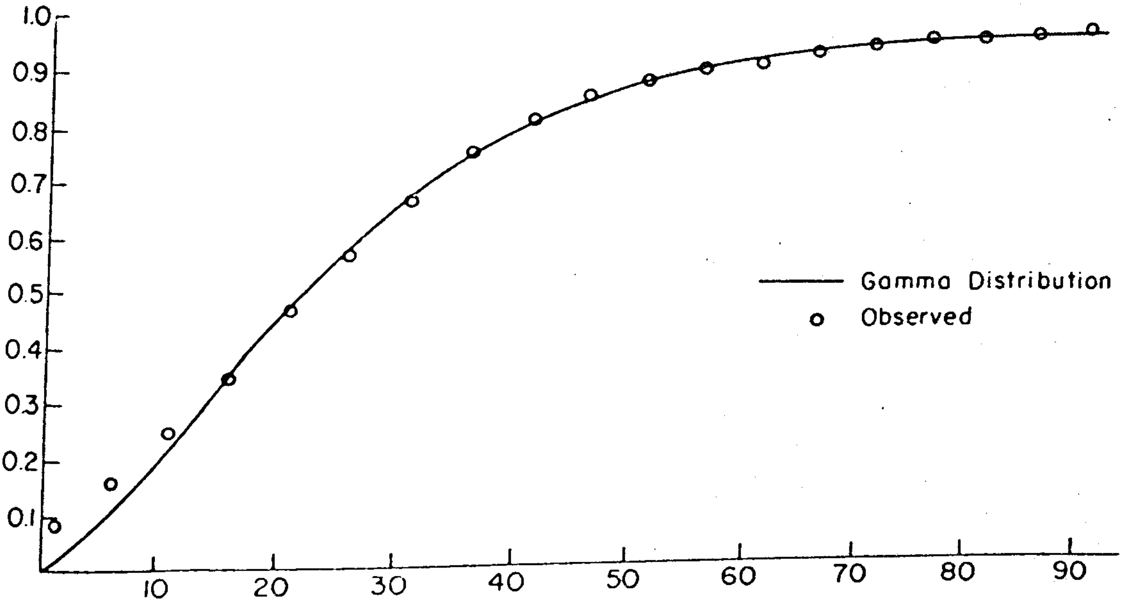

FIGURE 67
CUMULATIVE DISTRIBUTION OF DEPLANING PASSENGERS DEPARTING DFW VIA SURTRAN

After the passengers in each five-minute cell had been distributed over the adjacent cells, the distributed frequencies were summed for each cell. This yielded the distribution for the passengers on Surtran who desired to catch a bus to the airport, relative to their flight departure time. It is this distribution that governs the demand that will be placed on buses as they arrive. This analysis was based on the assumption that trip-makers' behavior reflects their true, desired behavior, in that passengers boarding a bus actually desired to catch a bus somewhere in the 30-minute interval centered at the time they did board. The assumption is deemed adequate since reliability of the Surtran schedule is judged to be good, and the reliability of the Surtran access mode was good in the majority of cases. Also, the Surtran schedule pamphlet is generally available, and most Surtran riders are repeat riders; for these reasons, riders would probably be familiar with the schedule. Again, the assumption that the riders' desired time to leave the Surtran terminal is uniformly distributed over the 30-minute interval is not precise, but the true distribution was not yet known, so uniformity was a logical default assumption.

After summing the distributed cell frequencies to obtain the resultant frequency distribution, the mean and variance of the sample distribution were calculated. The mean and variance were used to define the parameters of the same standard theoretical distributions, and the sample distribution was compared to these.

For enplaning airline passengers (taking Surtran to DFW), the sample distribution fit the log-normal distribution best. For a travel time on Surtran to DFW of 40 minutes, the distribution of the difference in time between when the air passenger arrived at the Surtran station and the time when his flight left DFW had a mean of 103.5 minutes and variance of 1190 minutes^2 (standard deviation = 34.5 minutes), as derived from the sample distribution. The distribution is illustrated in Figure 68. The sample distribution fit the log-normal distribution with a Chi-Square level of significance of x = 0.xx with 4 degrees of freedom. The sample size for which the sample distribution was developed was 142. The cumulative distribution is shown in Figure 69, where it can be seen that, by 120 minutes before a flight is scheduled to leave, 27 percent of the passengers riding Surtran have arrived at the off-airport terminal to wait for a bus, and, by 90 minutes before, 61 percent were wanting

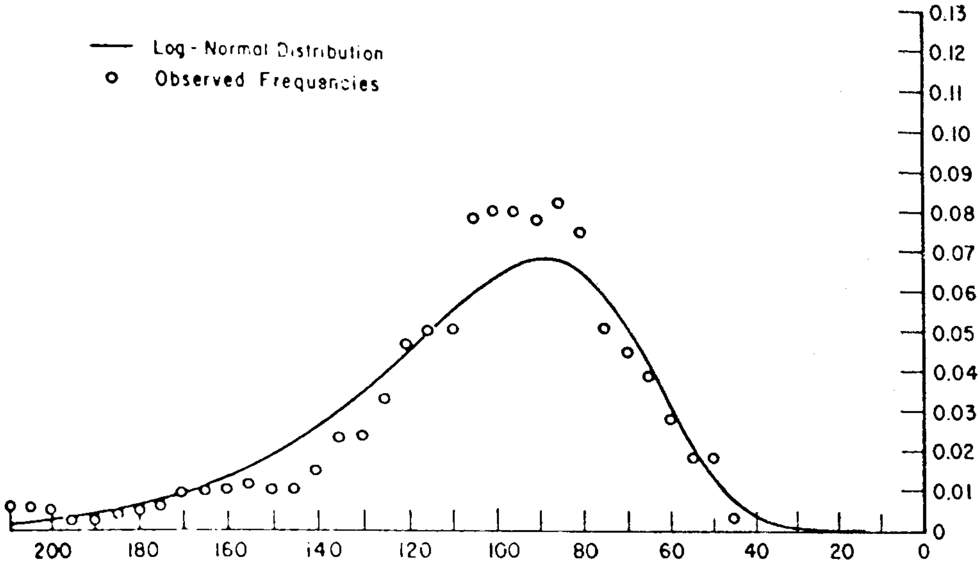

FIGURE 68
SAMPLE DISTRIBUTION AND LOG-NORMAL DISTRIBUTION OF ENPLANING DFW-BOUND PASSENGERS ARRIVING AT OUTLYING SURTRAN STATION

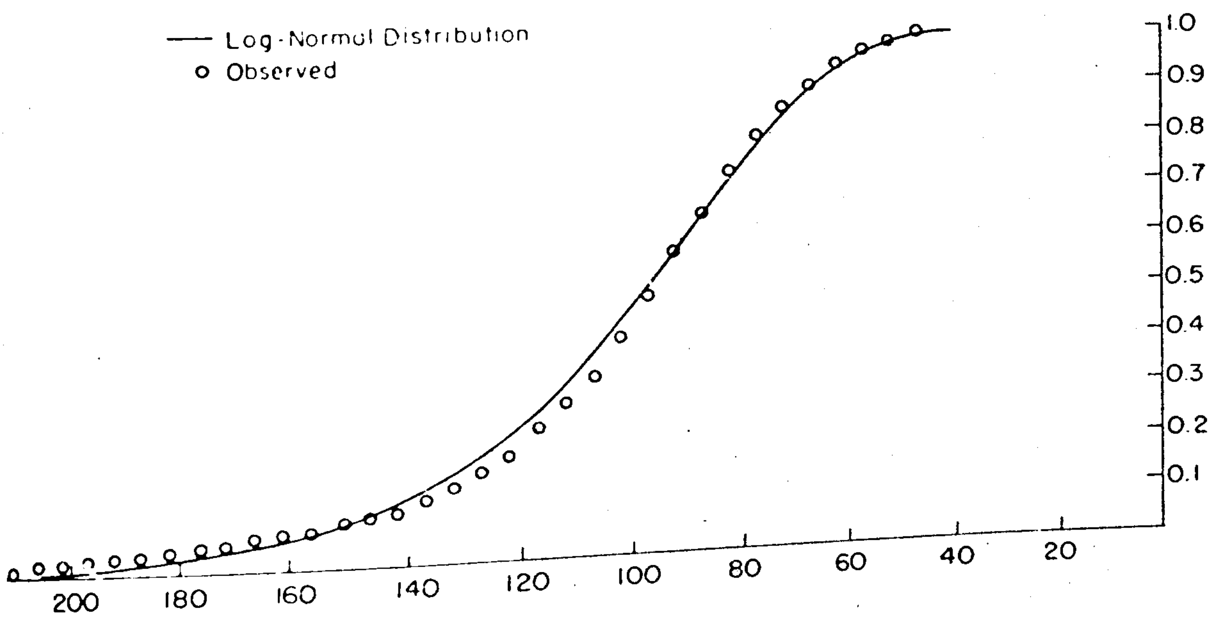

FIGURE 69
CUMULATIVE DISTRIBUTION OF ENPLANING DFW-BOUND PASSENGERS ARRIVING AT OUTLYING SURTRAN STATION

to board a bus. It should be noted that these curves relate the passengers' desired behavior and not their actual behavior, which is affected by the existing Surtran schedule. This distribution and the distribution for airline passengers leaving DFW by Surtran were considered essential links in the development of a model of Surtran demand.

Preliminary Model Evaluation

A preliminary model developed during project research has not given satisfactory results -- on the average, only 56 percent of actual bus volumes (based on buses leaving DFW) were within two standard deviations of the predicted volumes. In order to pass a hypothesis test, 95 percent should fall within two standard deviations. This indicates that the preliminary model does not realistically reflect the passenger loadings on buses at DFW.

There are a number of possible explanations for the model's failure to date. Perhaps the most likely is that the current model's assumptions are unrealistic, that is, that the underlying assumptions in its structure are too simple to accurately represent the complex behavior of flights and passengers and buses at DFW.

One of the assumptions of the model is that the proportion of air passengers either enplaning or deplaning who will take Surtran is the same for all flights at DFW. Also, the distribution of these passengers among the Surtran routes is the same for all flights. Although this does not seem obvious, no relationships could be found to indicate otherwise.

Another assumption is that every bus visits every airline terminal at the airport, serving passengers from all flights that could contribute to the volume on a particular bus. This was not valid: on some routes, a particular bus serves only two of the four terminals during certain hours of its schedule. Such additional data would make the preliminary model much more complicated. Also, because of the 20 minutes it takes a bus to visit all the terminals at DFW, there is a built-in time error, as one bus has only one arrival and departure time associated with it.

One assumption which might be corrected has been that the mode split for passengers on all flights was the same regardless of the time of day. The breakdown of such data would not complicate the model significantly and the results could possibly be thereby improved. This relationship needs more thorough exploration.

In conclusion, the project staff determined that the predictive power of the preliminary model does not warrant the unwieldly data preparation and reduction operations required for its use at DFW. The only application in which the model might prove reasonably accurate is on a more aggregate basis, possibly at an hourly volume level. The model could be considerably simplified to provide this output. However, at a smaller airport with more compact terminal layout and simpler airline and bus transit schedules, the model might be useful and reasonably accurate.

VII. CONCLUSIONS AND RECOMMENDATIONS

The research of this project has been intended to produce a relevant contribution to transportation impacts analysis, particularly of airports, and to provide greater quantitative insight and knowledge of changes in ground transportation patterns that can be expected to accompany the implementation of major new airports or airport improvements. A methodology has been devised through which disaggregate models of airport trip generation can be developed, with a view towards both augmenting impacts analysis research and enhancing the long-range planning of airport ground-side facilities.

The DFW Travel Survey was successfully completed within the research objectives, procedures, and experiences as described in the report. A preliminary analysis of results is also provided in this report. The data generated by the DFW Travel Survey was the basis for estimating and modeling airport trip generation. It also allowed a preliminary examination of the spatial distribution of off-airport trip-ends.

While the bulk of other studies in this field have concentrated on airport access problems from the standpoint of ground traffic demand projections, our own efforts have been directed, in part, towards augmenting the relatively little research into the other side of this coin, viz., assessing the impact of new or expanded airport facilities, once installed, on ground transportation patterns. In addition, previous studies of airport access have been mainly directed toward determining ground access requirements for a specific airport. This research has sought to develop models for estimating ground transportation volumes as a function of aircraft and/or airline passenger, visitor, and employee activity in general.

Models have been developed and are now available for transforming existing or proposed airline schedules and employee work-shift schedules at an airport into estimates of the volumes of automobile access traffic in any time period. The general concepts underlying the methods have been presented in this report. The models can be used to obtain more accurate estimates of short-term peaks in airport access traffic than it has been possible to obtain using previous methods. They can also be used to evaluate the effects that alternative changes in airline schedules or airport employees work hours may have on access traffic and parking congestion.

The models have been applied to only one major airport, DFW. It is hoped that further applications of the methods will be performed and reported for other major airports so that a better understanding of their accuracy and ultility can be obtained.

THE AUTHORS

William J. Dunlay was an Assistant Professor of Civil Engineering at The University of Texas at Austin during the time of this project. He completed his BSCE and MS degrees at the Pennsylvania State University in 1965 and 1970, respectively, and his Ph.D. degree at The University of California, Berkeley in 1973. His experience includes work as a Highway Engineer with the Federal Highway Administration; a Research Engineer for The Federal Aviation Administration; an Instructor at The Pennsylvania State University; a Consultant with DeLeuw, Cather & Co., and Peat, Marwick, Mitchell & Co.; and a Research Assistant at the University of California, Berkeley. Dr. Dunlay is now an Assistant Professor of Civil and Urban Engineering at the University of Pennsylvania.

Lyndon Henry was a Research Associate with the Council for Advanced Transportation Studies at the time of the project. He has completed all course work toward an MS degree in Community and Regional Planning. He received a BA degree from The University of Texas at Austin in 1964. His experience includes a position as Executive Director of the Texas Association for Public Transportation, a non-profit research agency.

Thomas G. Caffery was a graduate student working toward an MS degree in Civil Engineering and a Research Assistant with the Council for Advanced Transportation Studies at the time of the project. He received his BSCE degree from Louisiana State University in 1974. He is now employed as an Engineer with the Federal Highway Administration.

Douglas . Wiersig was a graduate student working toward an MS degree in Civil Engineering and a Research Assistant with the Council for Advanced Transportation Sutdies at the time of the project. He received his BSCE degree from the University of Nevada at Reno in 1974. He is now a graduate student in Civil Engineering at The University of Tennessee.

Waldo A. Zambrano was a graduate student working toward an MS degree in Civil Engineering at the time of the project. He received a BS degree from The University of Zulia, Venezuela,in 1972. During the following year he was employed as an Assistant Professor at the same university.

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