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16. Abstract

A contraflow lane is in operation on I-45N in Houston during both the morning and afternoon peaks. Operation of that lane requires taking a lane away from the off-peak direction mixed-flow traffic to serve as the contraflow lane. It was recognized at the outset that, at some time, off-peak direction traffic would become sufficiently large to cause continued operation of the contraflow lane to be undesirable; contraflow was never intended as the long-range improvement for the corridor. This report evaluates demand/capacity relationships in the off-peak direction of flow and estimates the year in which it would be desirable to terminate contraflow operation. Alternative actions that could be taken at that time are also evaluated.

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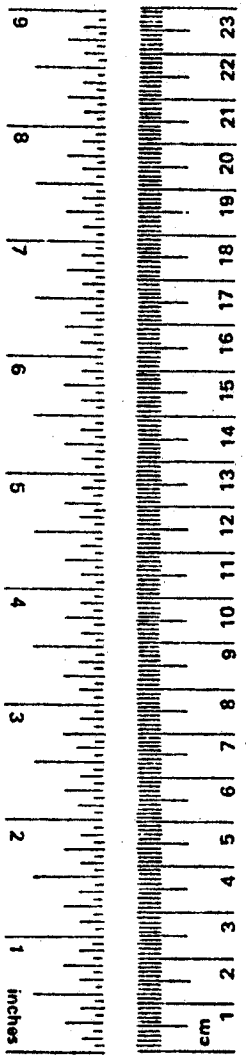
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

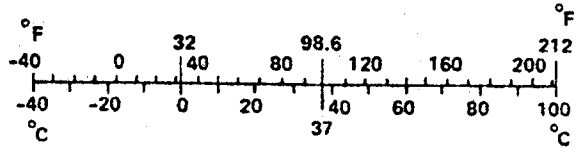
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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



THE I-45N CONTRAFLOW LANE

HOUSTON, TEXAS

AN ASSESSMENT OF THE OPERATIONAL LIFE

by

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Research Report 205-16

Priority Use of Transportation Facilities
Research Study Number 2-10-74-205

Sponsored by

State Department of Highways and Public Transportation
In Cooperation with
U.S. Department of Transportation
Federal Highway Administration

Texas Transportation Institute
The Texas A&M University System
College Station, Texas

December 1981

ABSTRACT

A contraflow lane is in operation on I-45N in Houston during both the morning and afternoon peaks. Operation of that lane requires taking a lane away from the off-peak direction mixed-flow traffic to serve as the contraflow lane. It was recognized at the outset that, at some time, off-peak direction traffic would become sufficiently large to cause continued operation of the contraflow lane to be undesirable; contraflow was never intended as the long-range improvement for the corridor. This report evaluates demand/capacity relationships in the off-peak direction of flow and estimates the year in which it would be desirable to terminate contraflow operation. Alternative actions that could be taken at that time are also evaluated.

Key Words: Priority Treatment, Contraflow Lane, High-occupancy Vehicles.

SUMMARY

During the 1970's, Houston was the fastest growing major city in the United States. The I-45N corridor (Figure S-1) was one of the high growth regions within the Houston metropolitan area. Over the past 10 years, that corridor experienced annual increases in population, housing, and employment in the range of 6% to 9%, rates about twice as great as the growth rates for Harris County as a whole. Projections call for a continuation of intense development in this corridor. The I-45N corridor serves major residential growth areas plus other significant developments such as the expanding Intercontinental Airport; daily auto traffic to the airport is projected to continue increasing at annual rates of 6% to 10% for the remainder of this century. Significant new office development is also taking place in the corridor; an additional 4,000,000 square feet of office space is planned to be constructed along North Belt alone by the end of 1983.

As a result of this substantial growth, corridor traffic volumes have increased; these volumes typically grew by 3% to 10% per year during the 1970's. As the 1980's began, I-45N had become one of the most congested freeways in the state.

In response to the mobility problems developing in the I-45N corridor, in the mid 1970's the State Department of Highways and Public Transportation began planning short-range highway-related improvements. Jointly with the City of Houston's Office of Public Transportation (now the Harris County Metropolitan Transit Authority) and using an Urban Mass Transportation Administration Service and Methods Demonstration grant, it was decided that a contraflow lane would be provided on I-45, and that authorized buses and vanpools would be allowed to use the lane. This represented the first significant action taken in Texas to provide priority treatment for high-occupancy vehicles. The I-45N contraflow lane is the longest such lane in the nation, and the only contraflow facility to operate during both morning and afternoon peak periods.

The Concept of Operational Life

The contraflow concept involves taking a lane away from off-peak direction traffic and reserving that lane for use by authorized high-occupancy vehicles travelling in the peak direction. Thus, for this concept to be viable, a significant directional imbalance must exist during peak periods; that is, traffic volumes in the peak direction must be considerably greater than volumes in the off-peak direction.

When planning first began for contraflow, the ratio of peak direction volume to off-peak direction volume during rush hours was about 60/40. It was recognized that, with the large growth to the north in the I-45N corridor, this directional imbalance would be reduced over time. At some point, the off-peak direction volumes would increase by a sufficient amount that, by continuing to take a lane away from that traffic for contraflow,

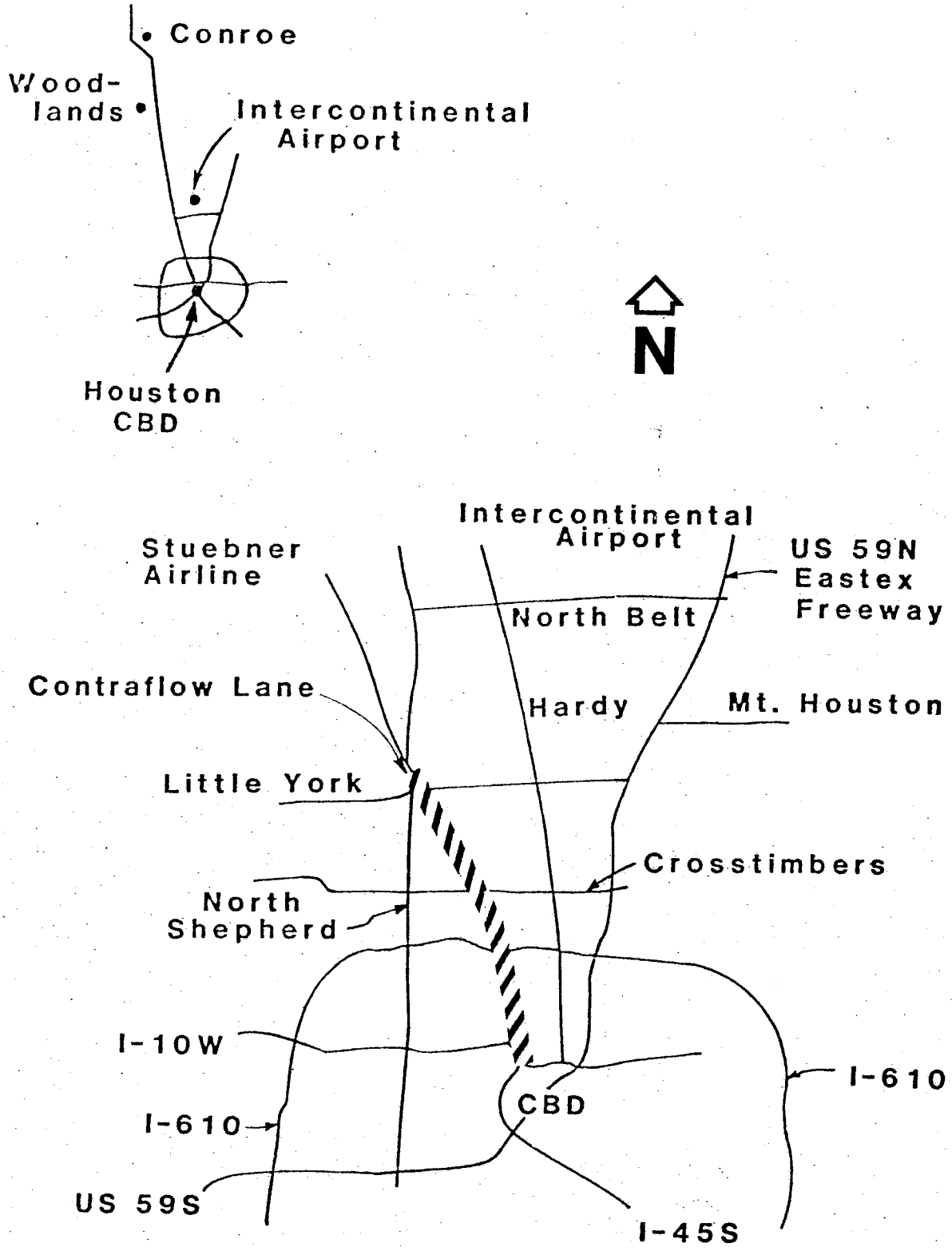


Figure S-1: Location of I-45N Corridor and Contraflow Lane

traffic would be unacceptably impacted and delay costs would become prohibitive.

For this reason, the contraflow lane was never intended to be a permanent improvement. It was established as a short-range improvement designed to enhance corridor mobility until such time as a more permanent improvement (i.e., physically separated median lane for authorized high-occupancy vehicles) could be made operational. It also provided an opportunity to monitor public acceptance of that improvement prior to committing more monies to such projects.

Since contraflow opened in 1979, traffic volumes in the off-peak direction have increased. It is becoming apparent that, in the not-too-distant future, traffic demands in the off-peak direction will require all capacity available. At that time, it would be desirable to no longer use an off-peak direction freeway lane for contraflow. The desirable operational life of contraflow has then ended.

Time Frame for Discontinuing Contraflow

Figure S-2 shows selected traffic demand versus traffic capacity relationships for off-peak direction traffic in the I-45N Corridor. At the point where demand equals capacity, it would be desirable to terminate the contraflow lane operation. Based on the data in Figure S-2, it appears that such a condition will effectively exist by 1985, if not sooner.

Alternative Futures for the Contraflow Lane

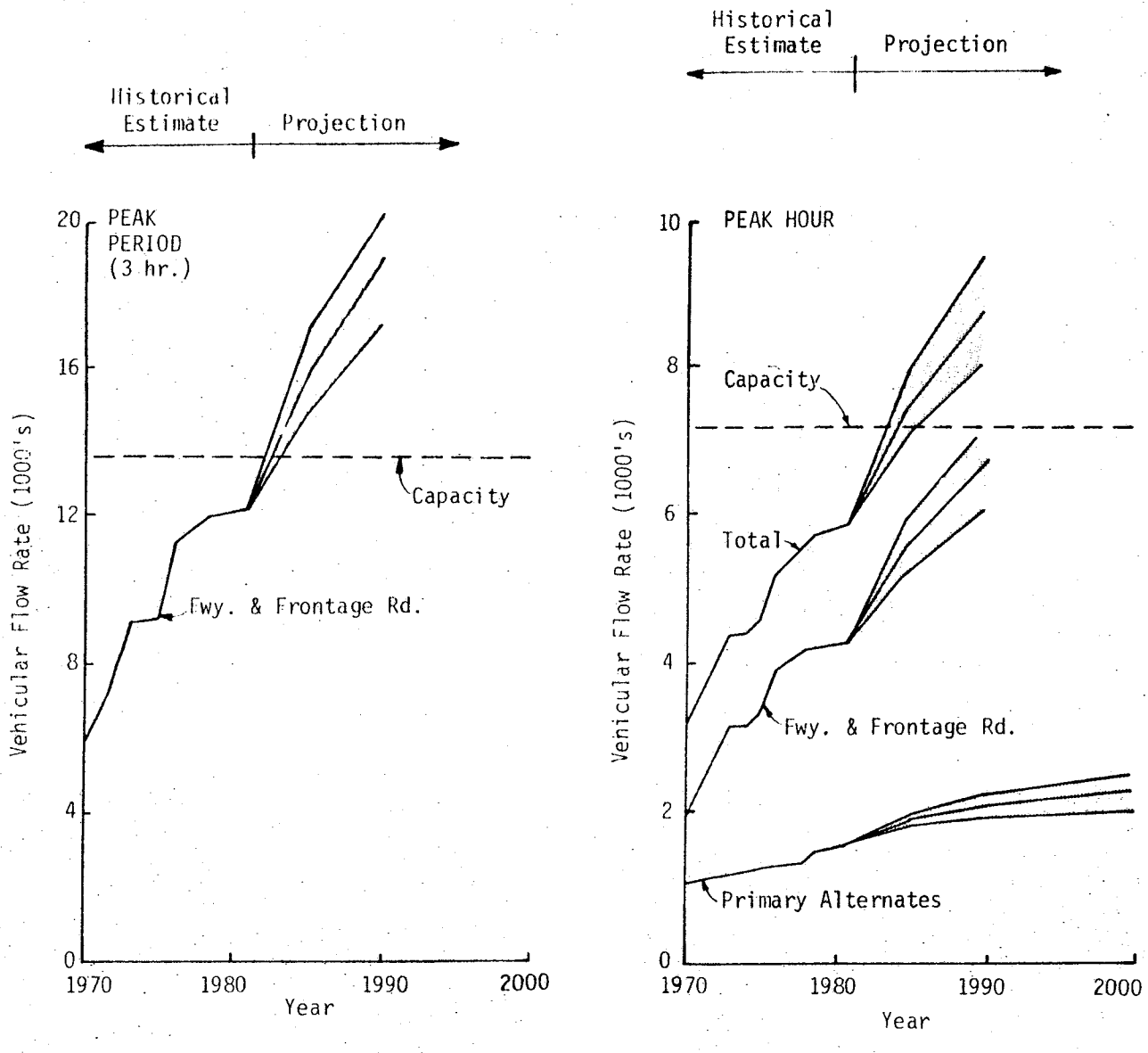
At the time (by 1985) that the desirable contraflow life has ended, any of three actions could be pursued. A summary of the impacts of these alternative actions is shown in Figure S-3, Table S-1, and Table S-2.

Continue Contraflow Indefinitely

Due to the large volume of persons using contraflow, it would be difficult to discontinue the operation. However, continuing to use contraflow will create considerable congestion and delay costs for off-peak direction traffic. Congestion in the off-peak direction would become nearly as intense as peak-direction congestion. It appears that, by 1983, it would be more economical to replace contraflow with a new median facility than it would be to continue contraflow operations (Figure S-3).

Eliminate Contraflow Without Replacement

This alternative would "dump" all of the contraflow traffic back into the peak direction mixed-flow lanes. The result would be a massive increase



Demand/Capacity
Freeway and Frontage Road
Peak Period (3 hr.)

Demand/Capacity
Freeway, Frontage Road, and Primary
Alternate Routes
Peak Hour

Figure S-2: Selected Demand/Capacity Relationships for Off-Peak Direction Traffic, I-45N Corridor

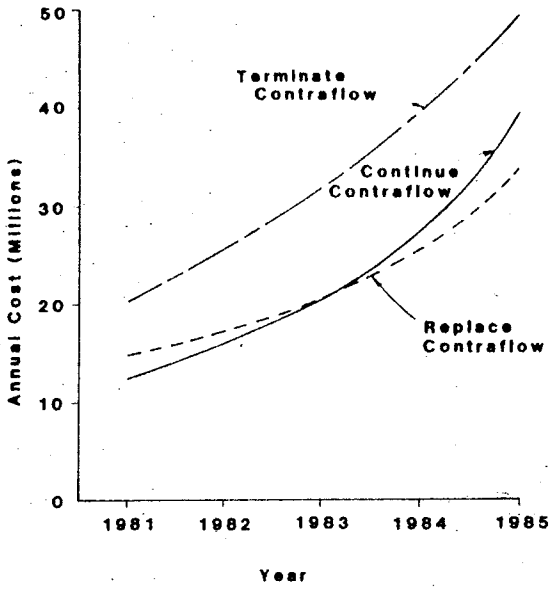


Figure S-3: Estimated Annual Costs of Various Alternatives Involving the Contraflow Lane

Table S-1: Estimated Benefit/Cost Ratio Associated With Alternative Contraflow Actions, 1981-2000 Analysis Period

Alternative Action	Benefit/Cost Ratio
Terminate Contraflow With No Replacement	-28.8*
Replace Contraflow With a Separate HOV Lane	7.7

*The b/c ratio is negative since the change in benefits associated with this alternative is negative.

in total congestion and delay cost, since the increased delay to peak-direction traffic would be much greater than the delay savings to off-peak direction flow. Such an action would have negative impacts on the public transportation system, and this alternative is the most uneconomical action that could be taken (Figure S-3). The length of the freeway over which traffic is heavily congested during peak periods would extend an additional 3 to 5 miles due to dumping contraflow traffic back into the main lanes. All traffic travelling that section would experience a 12 to 20 minute increase in travel time. As shown in Table S-1, negative benefits are associated with such an action.

Table S-2: Major Advantages and Disadvantages to I-45N Corridor Traffic Associated with Alternative Contraflow Actions

Alternative Action	Major Advantages	Major Disadvantages
1. Continue Contraflow	• Priority treatment maintained	• High operating costs remain • Off-peak direction traffic severely impacted
2. Terminate Contraflow	• No capital or operating costs incurred for priority treatment • Improves off-peak direction traffic flow	• Massive impacts on peak direction traffic • Decreased bus productivity • Negative impact on public transportation system • Highly unfavorable net cost
3. Replace contraflow with median priority lane	• Maintains priority treatment • Improves off-peak direction flow w/o negatively affecting peak direction • Favorable benefit/cost ratio	• Initial capital cost ($50,000,000)

Replace Contraflow With a Median Authorized Vehicle Lane

This alternative continues provision of priority treatment. That treatment is provided in a safer, more permanent manner.

This approach benefits both directions of traffic flow. The lane presently used by contraflow is returned to serve mixed flow in the off-peak direction. The traffic presently using contraflow uses the median priority lane and, therefore, is not added to the peak-direction traffic stream. A positive public transportation improvement remains in place. This also appears to represent the optimum action from an economic standpoint (Figure S-3). The analyses suggest the lane should be replaced in 1983; a positive benefit/cost ratio (7.7) would accompany such an action.

Recommendation

The present contraflow operation should be discontinued within 2 to 4 years. A median, physically separated authorized vehicle lane should be provided to take the place of contraflow within that time frame.

IMPLEMENTATION STATEMENT

This project is oriented to assist the Department in planning and implementing priority treatment techniques for high-occupancy vehicles. District 12 (Houston) of the State Department of Highways and Public Transportation is in the process of planning future improvements in the I-45N corridor; one possible improvement will be replacing contraflow, which was always intended as a short-range improvement, with a more permanent high-occupancy vehicle improvement.

An issue facing the District in this planning process involves assessing the operational life of contraflow. That is, how long can a freeway lane be taken away from off-peak direction traffic without unduly hindering that traffic. This report was specifically oriented toward assisting the District in that effort.

DISCLAIMER

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INTRODUCTION

The contraflow lane[1], located on I-45N (Figure 1), represents the first major action taken in Texas to provide priority treatment for high-occupancy vehicles. This priority lane serves a major growth area, including the Woodlands, Conroe, Northern Harris County, and the Houston Intercontinental Airport. The contraflow lane has been successful and has experienced rapid increases in utilization. Trends in lane utilization are shown in Figures 2 and 3. At present, during the peak hour, the contraflow lane moves as many persons as do two mixed-flow freeway lanes.

The Issue of Operational Life

The contraflow concept takes a lane away from the off-peak direction flow and reserves that lane for use by authorized high-occupancy vehicles traveling in the peak direction. As a result, for contraflow to be an applicable priority treatment, a significant directional imbalance in traffic flow must exist during peak operating periods[2].

Intensive planning for the I-45N contraflow lane began in the mid-1970's. At that time, the peak-period directional split was in the range of 60/40. It was recognized, however, that the tremendous growth to the north would reduce this directional imbalance over time. At some point, the directional imbalance will become sufficiently non-existant that, by continuing to take a lane

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[1] A thorough description of the contraflow lane and an evaluation of the first year of operation are contained in Research Report 205-9 entitled "Evaluation of the First Year of Operation, I-45 Contraflow Lane, Houston."

[2] Additional discussion of this requirement is included in Research Report 205-8 entitled "Preliminary Evaluation of Applicable Priority Treatment Techniques on Existing Urban Freeways in Texas."

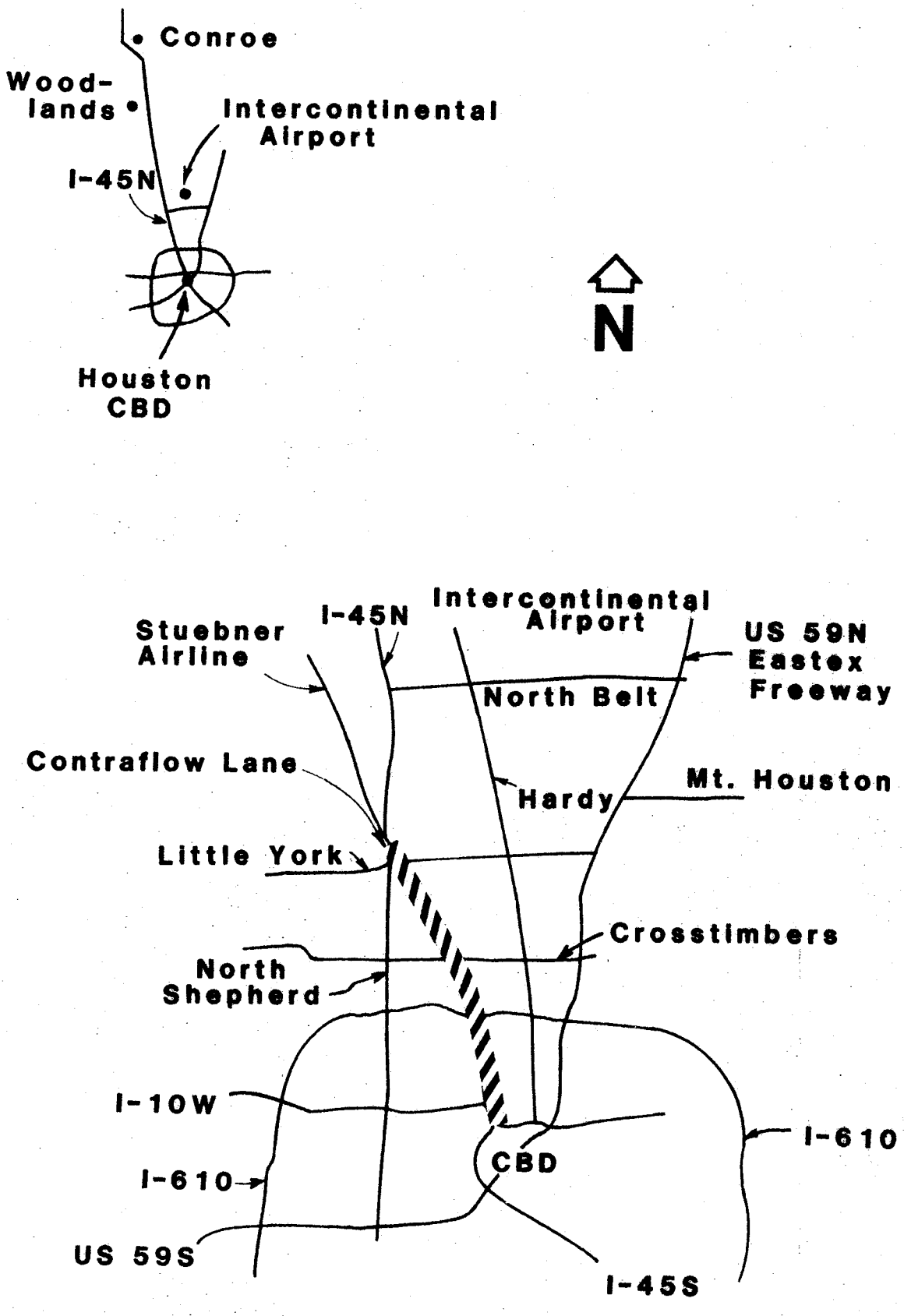


Figure 1: Location of North Freeway Contraflow Lane

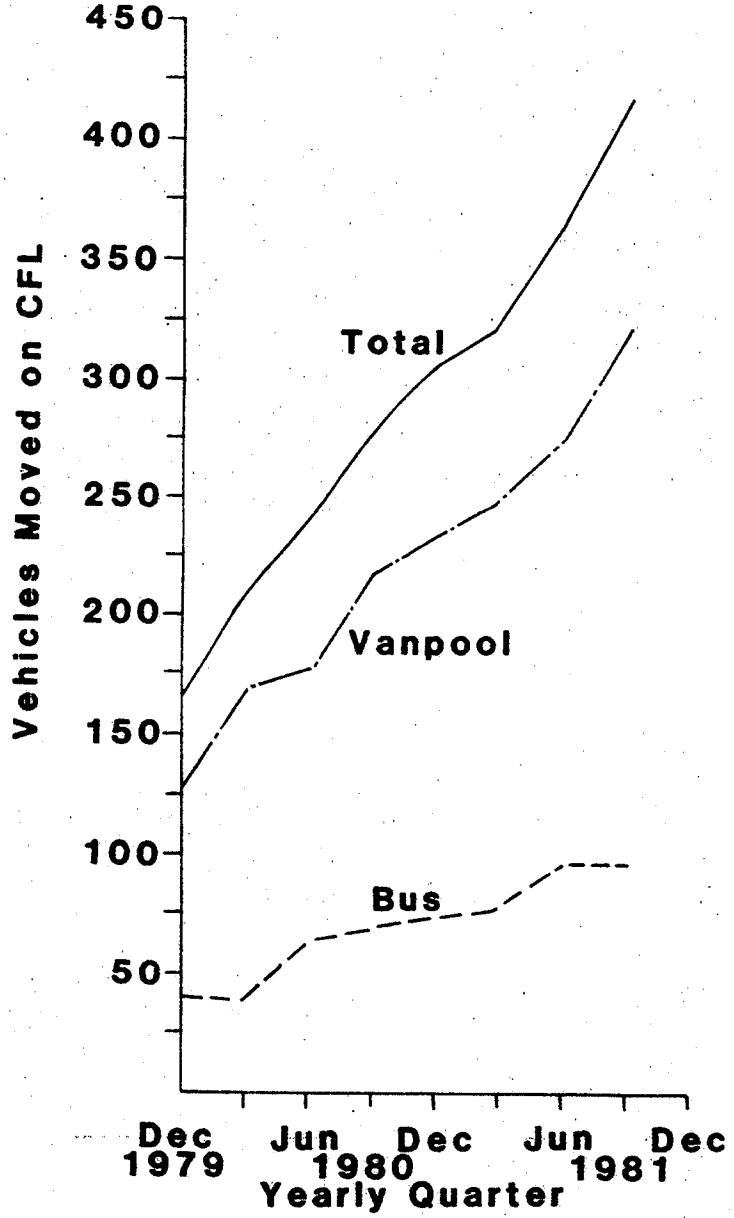


Figure 2: Trends in Contraflow Vehicle Movement to Sept. 1981, Daily Totals (One Direction)

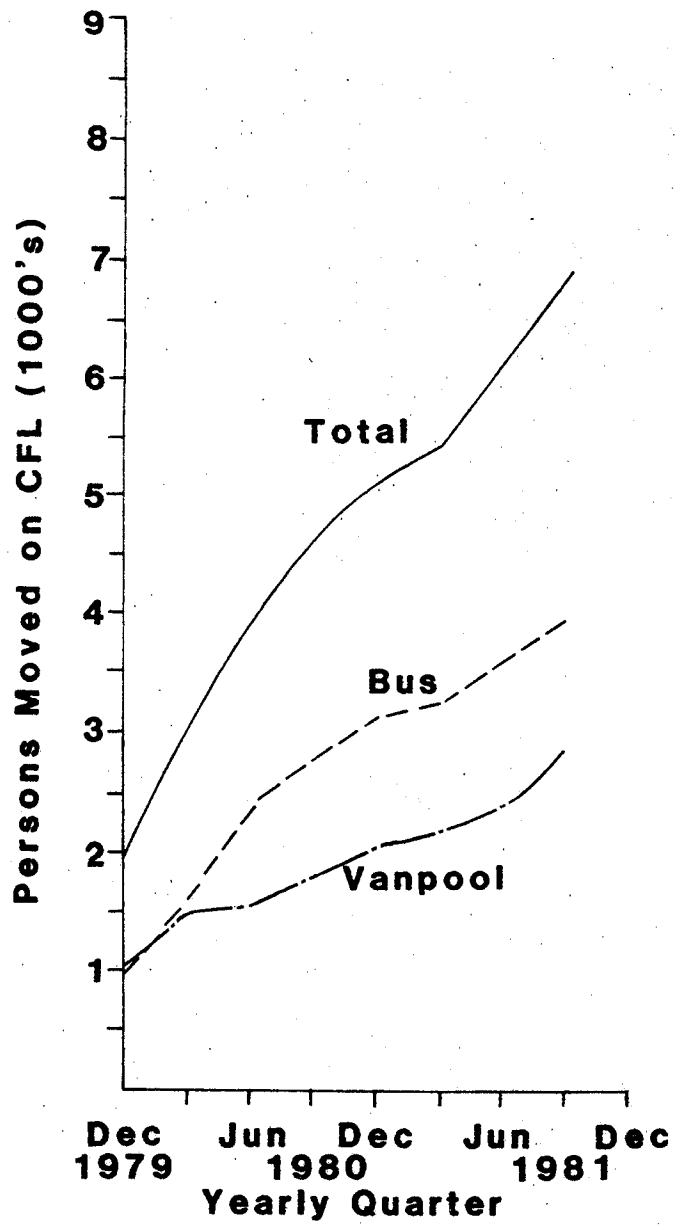


Figure 3: Trends in Contraflow Person Movement to Sept. 1981, Daily Totals (One Direction)

from off-peak direction traffic for contraflow, traffic would be unacceptably impacted by the imposed constraint on available capacity.

For this reason, the contraflow lane was never intended to be a permanent improvement. It was established as a short-range improvement that would enhance mobility in the corridor until such time as a more permanent improvement (e.g., physically separated median authorized vehicle lane) could be made operational. The contraflow lane would also provide an opportunity to test public acceptance of priority lanes prior to committing further monies to such improvements.

Since the contraflow lane opened in August 1979, not only has contraflow traffic increased but so have traffic volumes in the off-peak direction. It is becoming apparent that, at some time in the not-to-distant future, traffic demands in the off-peak direction will exceed available capacity to serve that traffic. At that time, it would be desirable to no longer use an off-peak direction freeway lane for contraflow; in effect, the desirable operational life of a contraflow lane has ended when this situation exists. At that time one of three actions can be taken. The contraflow lane can continue to be operated with severe impacts on off-peak direction traffic. The contraflow lane can be discontinued with severe impacts on peak-direction traffic. The third alternative is to replace contraflow with a permanent, median high-occupancy vehicle lane; that alternative allows all off-peak direction mixed-flow lanes to serve mixed-flow traffic and also continues to provide a priority treatment lane in the peak direction.

Planning has already been initiated to replace the contraflow lane with an exclusive, physically separated median authorized vehicle lane. The urgency of this planning process is directly related to the operational life of the contraflow lane. Once that improvement is provided, all of

the mixed-flow lanes will be available to serve mixed-flow traffic during peak periods.

In order to assist in this planning process, District 12 of the State Department of Highways and Public Transportation requested the Texas Transportation Institute to evaluate the operational life of the contraflow lane. That evaluation, which is largely a demand-capacity analysis of off-peak direction traffic, is presented in this report. It is intended to identify the approximate time frame in which it would be desirable to cease the operation of the contraflow lane. The results of this study suggest that, at that time, the only realistic action to pursue will be to replace contraflow with a physically separated median lane, thereby continuing priority treatment while also letting off-peak direction traffic lanes serve only mixed-flow traffic.

The Study Corridor

While the contraflow lane is physically located on the I-45N facility, this is not the only roadway in the corridor available to serve off-peak direction traffic. Accordingly, the demand-capacity of alternative routes in the off-peak direction was also evaluated in identifying the operational life of contraflow.

Some alternative routes are more attractive as diversionary routes than others. As a result, demand capacity analyses are performed for each of the roadway classifications shown below:

- I-45 Mainlanes and Frontage Roads
- Primary Corridor Routes. These are the routes to which diversion of I-45 traffic is most likely to occur, and include N. Shepherd and Airline.

- Secondary Corridor Routes. These routes, due to their location, are not highly attractive as diversionary facilities but, as the capacity of I-45N and the primary routes becomes fully utilized, are likely to serve some traffic diversion. Included in these facilities are West Hardy, Irvington, Fulton and Yale.

The location of all these facilities is shown in Figure 4. For purposes of analysis the critical section was considered to exist between N. Shepherd and Crosstimbers. This is presently the most congested section during p.m. contraflow operation.

Study Objectives

The time at which contraflow should desirably be replaced by a median authorized vehicle lane is a function of two major concerns. The two primary study objectives are intended to quantify these concerns.

Objective 1. Assessment of Operational Life

The operational life has been defined as the future time at which vehicular travel demand during peak periods in the off-peak direction would equal available capacity. The evaluations presented in this report are performed for a variety of time periods (peak hour, two hours, three hours). All of the roadway facilities identified in "The Study Corridor" section are addressed in the evaluation. The analyses address the off-peak direction traffic flow during the p.m. peak period (southbound traffic).

Objective 2. Impact of Contraflow Closure

An alternative would be, once the operational life of contraflow has ended, to discontinue contraflow without providing a replacement priority treatment for the high-occupancy vehicles presently using contraflow. This would, among other things, require "dumping" all the contraflow traffic back

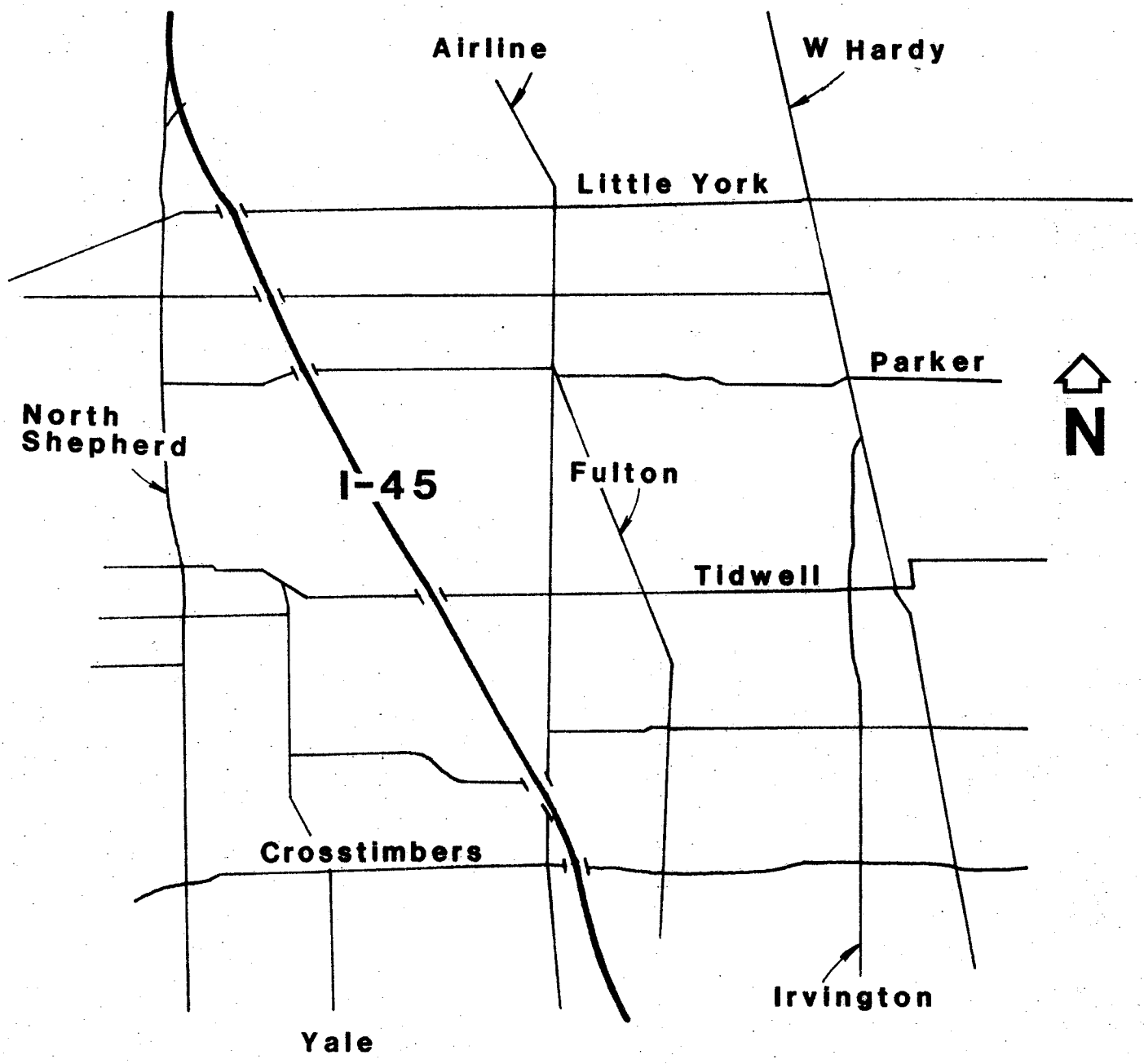


Figure 4: The North Freeway Contraflow Lane Corridor

into the peak-direction mixed-flow lanes. Impacts of such an action are identified in this report.

Study Design

The evaluations presented in this report consist of the four phases shown below.

Phase I. Data Collection

A. A review of existing data and an assessment of current conditions in the study corridor in terms of the following.

1) Current travel demand within the corridor.
2) Current roadway capacities within the corridor.
3) Current travel times within the corridor.
4) Critical intersections/interchanges in the corridor.
5) Available traffic forecasts.
6) Current and potential development within the corridor.
7) Current and projected socio-economic characteristics of the corridor (i.e., population, households, and employment).

Phase II. Data Analyses

A. Preliminary identification of trends and data inconsistencies.

Phase III. Development of Forecasts

A. Identification and evaluation of possible trends.

B. Identification and selection of probable trends.

C. Preparation of forecasts.

Phase IV. Implications of the Traffic Forecasts on Contraflow Lane Operations

This evaluation was performed to determine the following:

A. The operational life of the contraflow lane under a range of possible traffic growth rates.

B. The implications of closing the contraflow lane at the end of its operational life.

C. Possibilities for, and implications of, extending the operational life of the contraflow lane.

HISTORICAL AND CURRENT CORRIDOR TRAFFIC CONDITIONS

Historical trends in traffic as well as existing conditions are critical factors in evaluating the operational life of the contraflow lane. This section of the report documents traffic trend data for all classifications of roadways considered in this study. The locations of all traffic counts referred to in this section are shown in Figure 5.

I-45N Mainlanes

Two permanent count stations, one just south of the North Loop and one at Cypress Creek, are located along I-45N (Figure 5). Neither of these counts is located in the critical section (N. Shepherd to Crosstimbers). Historical trends at these locations are depicted in Figure 6.

In addition, the Department has taken average daily traffic counts at several other locations in the corridor. Two of these counts, at Airline and Little York, are in the critical analysis section. Historical counts at these locations are shown in Figure 7, and the data are provided in Table 1.

In reviewing the average daily traffic figures, it might be noted that maximum daily traffic is typically 20% to 25% higher than average daily traffic. In determining capacity, freeway lanes were assumed to have a capacity of 1800 vehicles per hour. The frontage roads were assumed to have a per lane capacity of 1800 vehicles per hour of green time.

Primary and Secondary Alternates

The City of Houston has conducted traffic counts on those routes designated as primary and secondary alternates. Historical data are shown in Figures 8

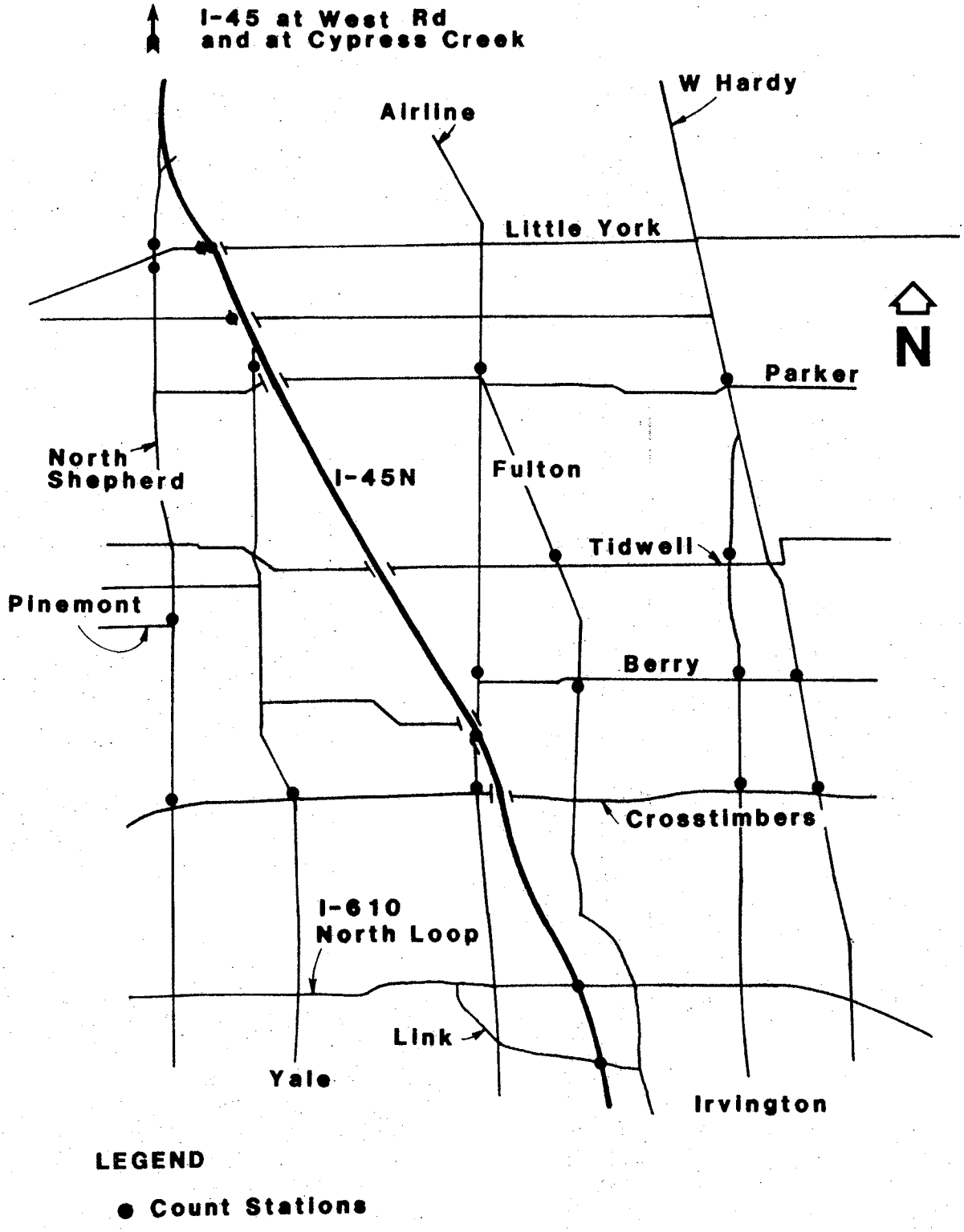
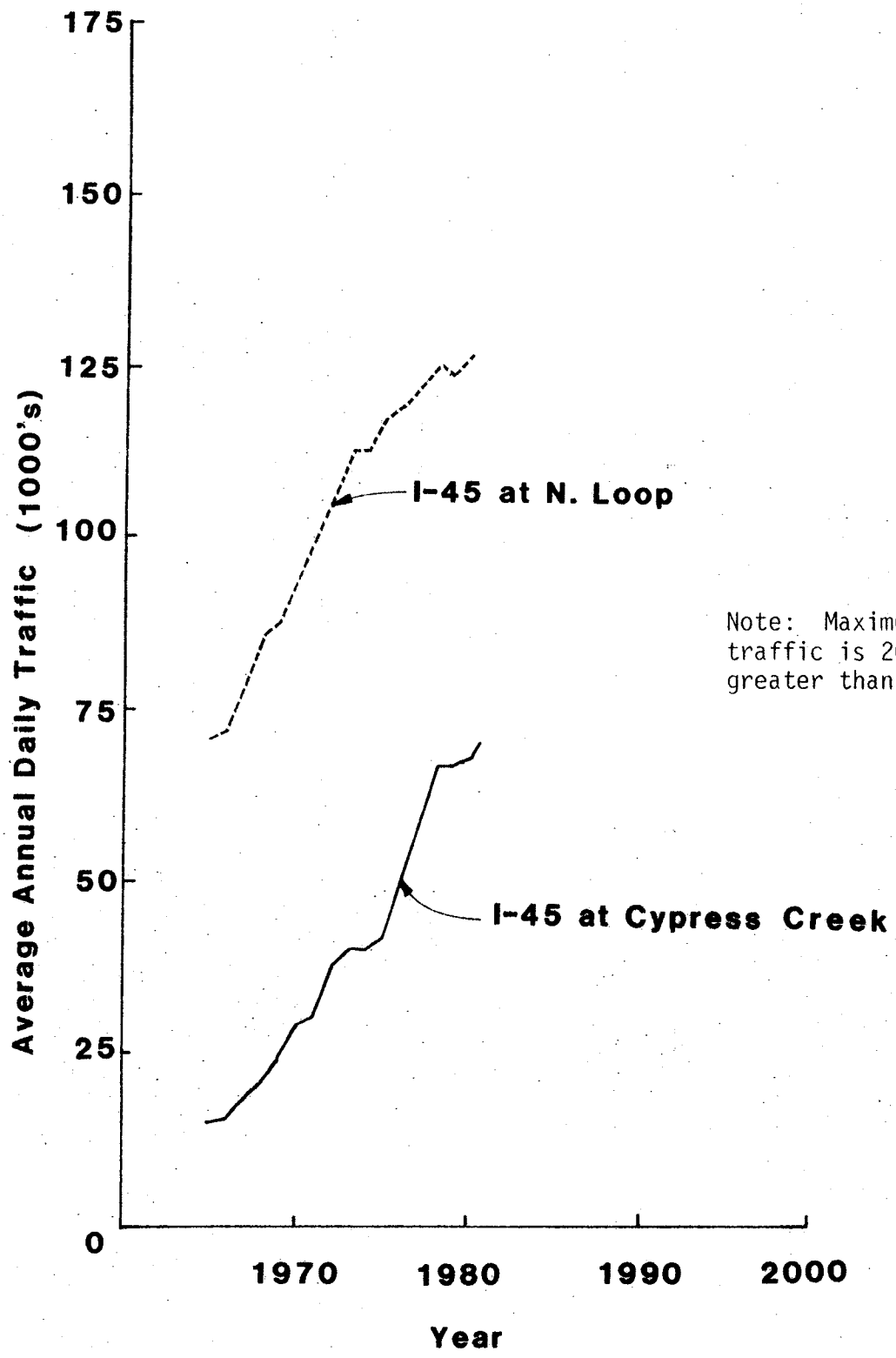


Figure 5: Locations of Traffic Count Stations Referenced in this Study



Source: SDHPT

Figure 6: Trends in Average Annual Daily Traffic at the Two Permanent Count Stations in the Study Corridor

Table 1. Historical Trends in Traffic Data, I-45

Year	Average Daily Traffic (1000's), Location Along I-45			
	N. Loop	Cypress Creek	Airline	N. Little York
1965	71	15	44	31
1966	74	17	44	-
1967	77	19	51	45
1968	86	21	54	-
1969	88	25	-	-
1970	94	28	81	69
1971	99	32	87	75
1972	107	37	99	91
1973	112	40	101	103
1974	112	40	103	106
1975	117	44	106	112
1976	119	51	114	131
1977	123	57	114	131
1978	125	64	122	142
1979	124	64	-	-
1980	126	65	-	-

Source: State Department of Highways and Public Transportation

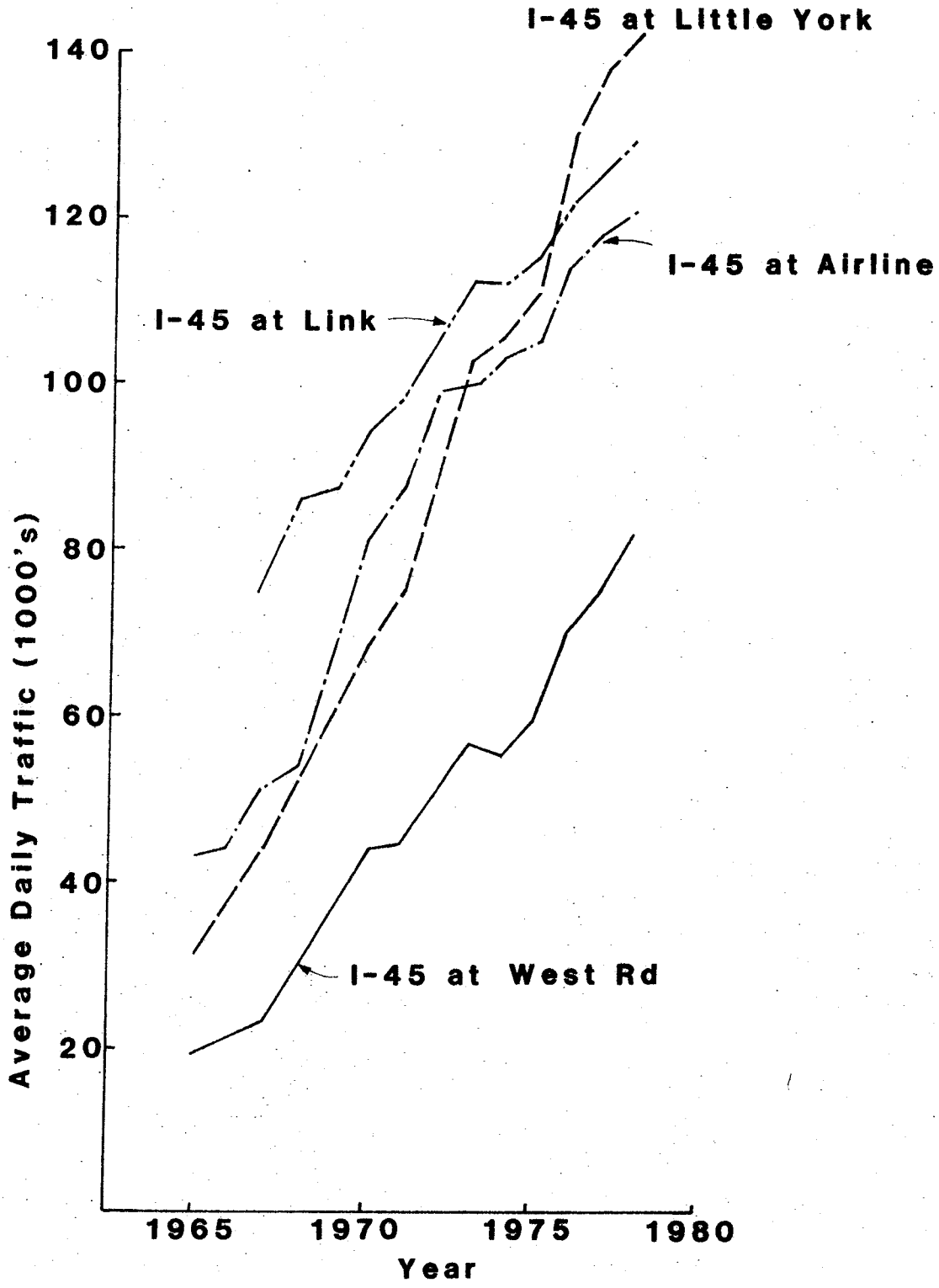
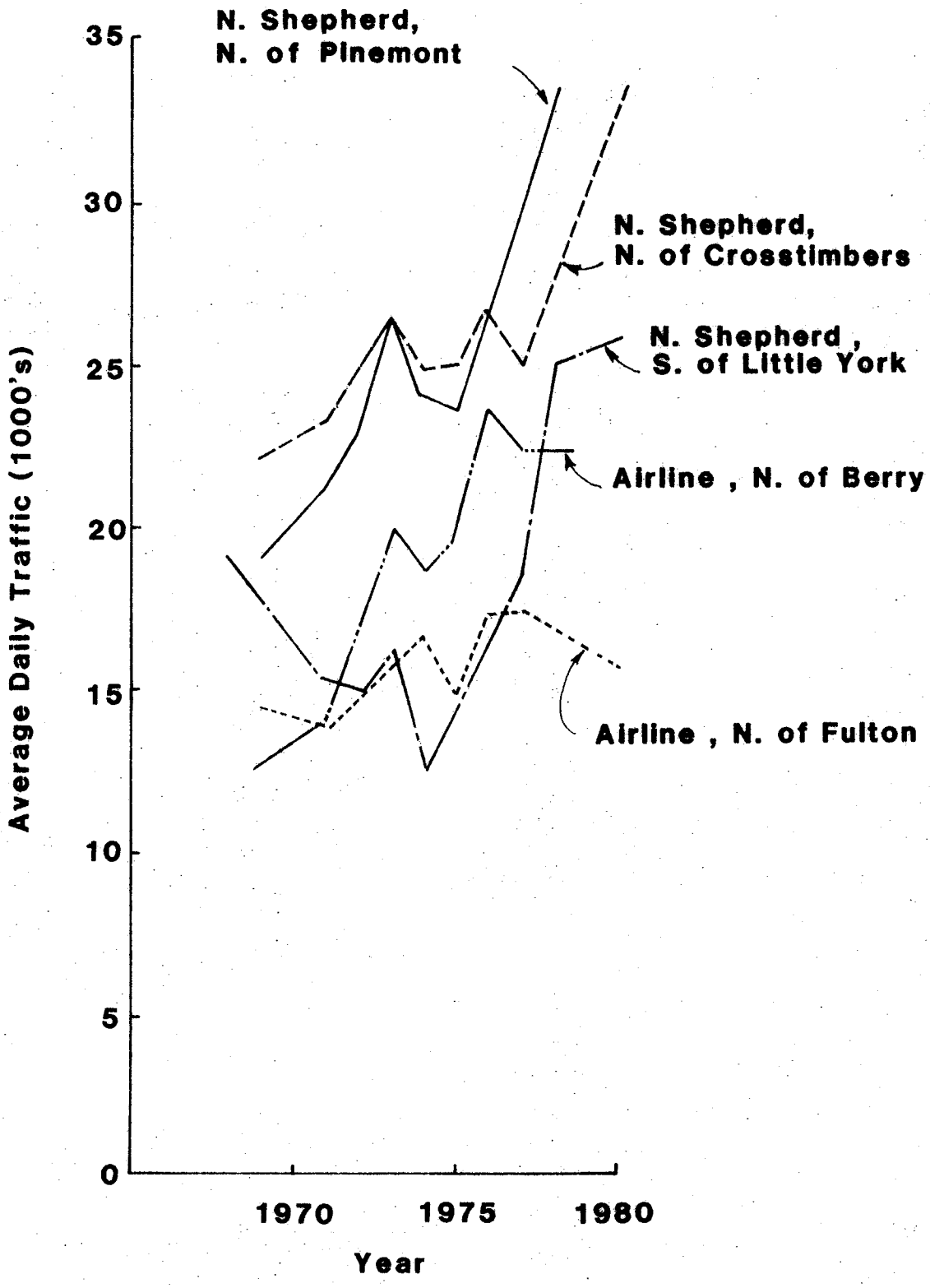
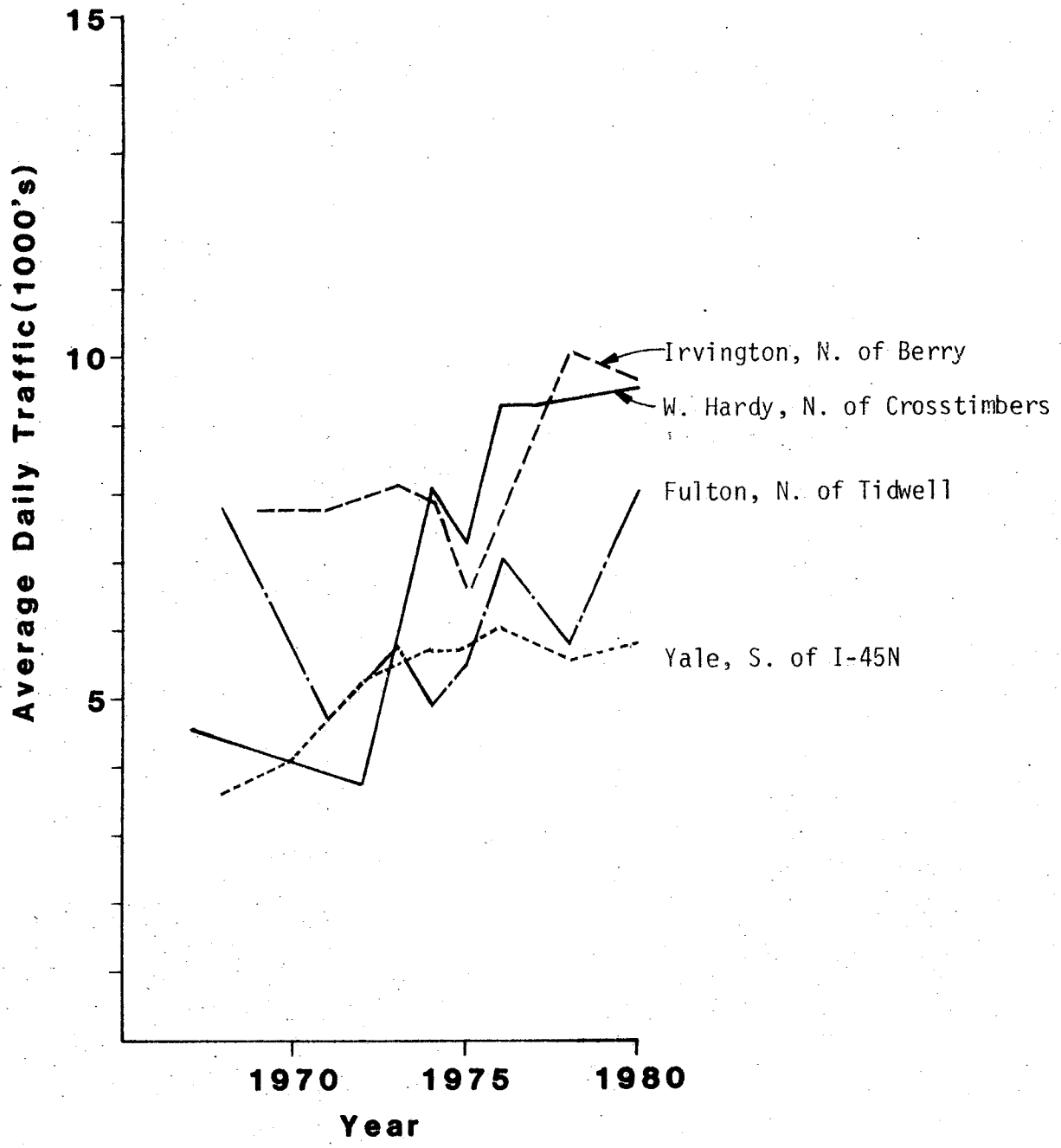


Figure 7: Historical Trends in Average Daily Traffic at Selected Count Locations in the I-45 Corridor



Source: City of Houston

Figure 8: Historical Traffic Counts on Primary Alternate Routes



Source: City of Houston

Figure 9: Historical Traffic Counts on Secondary Alternate Routes

and 9. Capacity for these roadways was assumed to be 1800 vehicles per hour of green time per lane.

Critical Intersections

Intersections will control capacity on all corridor routes except the freeway main lanes. Table 2 lists the critical (i.e. major) intersections within the I-45N corridor. Also included in Table 2 are signal cycle lengths and effective green times from which roadway capacities were calculated. These critical intersections are shown graphically in Figure 10.

I-45N Corridor Roadway Facilities, Current Status

In September 1981, Texas Transportation Institute staff conducted traffic counts on all corridor roadways. The current status of roadways, relating demand to capacity, is summarized in Tables 3, 4 and 5. At present, with the possible exception of the frontage roads during peak-hour operation, some unused capacity exists on all roadways in the off-peak direction of travel. As a result, it is assumed that no significant latent travel demand has developed in the off-peak travel direction.

Table 2. Critical Intersection Analysis

Corridor Route and Directional Approach Lane	Cross Street	Thru Green Time (Sec)*	Cycle Length (Sec)
N. Shepherd	Crosstimbers	35	70
Two Lanes	Pinemont	35	90
	Donovan	35	90
	Tidwell	65	85
	Parker	40	70
	Little York	25	60
W. Hardy	Little York	30	65
One Lane	Irvington	20	50
	Parker	25	55
	Tidwell	25	55
	Berry	20	45
	Crosstimbers		
Irvington	W. Hardy		
One Lane	Tidwell	20	45
	Berry	15	60
	Crosstimbers	25	60
Fulton	Crosstimbers	15	60
One Lane	Berry	-	-
	Tidwell	15	45
	Airline	-	-
Airline	Little York	15	45
Two Lanes	Rittenhouse	20	45
	Tidwell	30	70
	Berry	35	60
	East Frontage Rd.	15	40
	Crosstimbers	20	60
Yale	Crosstimbers	15	60
One Lane	Victoria	30	50
	Tidwell	15	70
Frontage Road	Little York	20	80
Two Lanes	Parker	15	60
	Tidwell	20	70
	Airline	20	80
	Crosstimbers	20	80

* Green and Yellow

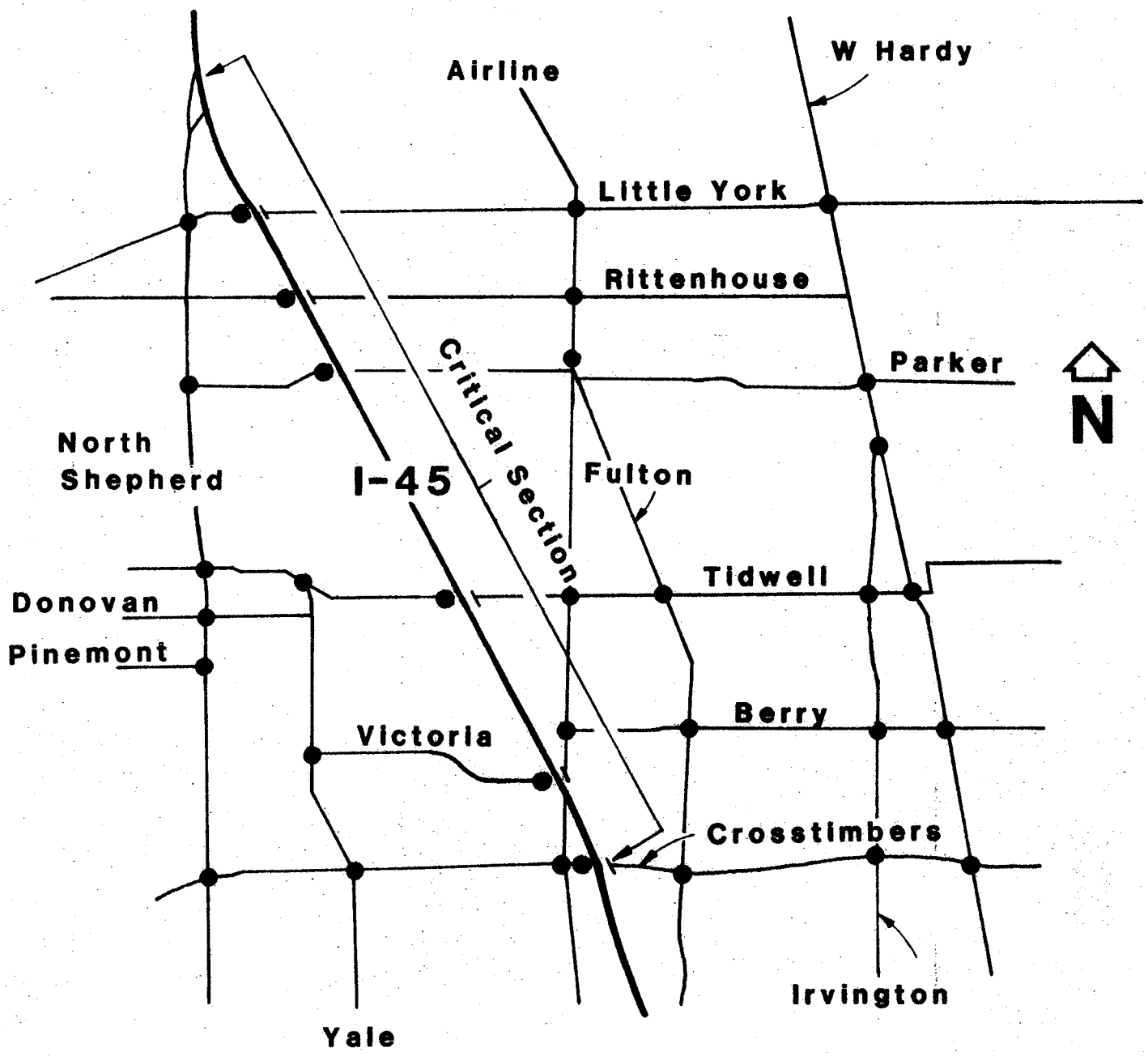


Figure 10: Location of Critical Intersections in I-45N Corridor

Table 3. 1981 Peak Hour Data Used in Corridor Demand Analysis

Alternate Routes	North Corridor (I-45) - PM Period - Inbound Direction					
	Highest Peak Hour Demand (vehicles)	# of Lanes	% Thru Green Time	Total Capacity (veh/hr)	Volume/ Capacity	Unused Capacity (veh/hr)
I-45 Mainlanes	3384	2*	-	3600	0.94	216
I-45 Frontage Rd.	942	2	25	900	1.04	-42
I-45 Mainlanes and Frontage Rd.	4326	4*	-	4500	0.96	174
Primary Alternates						
Airline	479	2	35	1260	0.38	781
N. Shepherd	1150	2	40	1440	0.80	290
Total, Primary	1629			2700	0.60	1071
Secondary Alternates						
W. Hardy	256	1	40	720	0.36	464
Irvington	502	1	40	720	0.70	216
Fulton	480	1	25	450	1.07	-30
Yale	405	1	25	450	0.90	45
Total, Secondary	1643			2340	0.70	697
TOTAL CORRIDOR	7598			9540	0.80	1942

* Two main lanes serve off-peak direction traffic, the third serves the contraflow lane.

Table 4. 1981 Peak Two Hour Data Used in Demand Analysis

Alternate Routes	North Corridor (I-45) - PM Period - Inbound Direction					
	Highest Two Hour Period Demand (veh)	# of Lanes	% Thru Green Time	Total Capacity (veh/2hr)	Volume/ Capacity	Unused Capacity (veh/2hr)
I-45 Mainlanes	6600	2*	-	7200	0.92	600
I-45 Frontage Rd.	1755	2	25	1800	0.98	45
I-45 Mainlanes and Frontage Rd.	8355	4*	-	9000	0.93	645
Primary Alternates						
Airline	931	2	35	2520	0.37	1589
N. Shepherd	2190	2	40	2880	0.76	690
Total, Primary	3121			5400	0.58	2279
Secondary Alternates						
W. Hardy	505	1	40	1440	0.35	935
Irvington	951	1	40	1440	0.66	489
Fulton	905	1	25	900	1.01	-5
Yale	810	1	25	900	0.90	90
Total, Secondary	3171			4680	0.68	1509
TOTAL CORRIDOR	14647			19080	0.77	4433

* Two main lanes serve off-peak direction traffic, the third serves the contraflow lane.

Table 5. 1981 Peak Period (3 hour) Data Used in Demand Analysis

Alternate Routes	North Corridor (I-45) - PM Period - Inbound Direction					
	Highest Three Hour Period Demand (veh)	# of Lanes	% Thru Green Time	Total Capacity (veh/3hr)	Volume/ Capacity	Unused Capacity (veh/3hr)
I-45 Mainlanes	9711	2*	-	10800	0.90	1089
I-45 Frontage Rd.	2480	2	25	2700	0.92	220
I-45 Mainlanes and Frontage Rd.	12191	4*	-	13500	0.90	1309
Primary Alternates						
Airline	1380	2	35	3780	0.37	2400
N. Shepherd	3195	2	40	4320	0.74	1125
Total, Primary	4575			8100	0.56	3525
Secondary Alternates						
W. Hardy	726	1	40	2160	0.34	1434
Irvington	1324	1	40	2160	0.61	836
Fulton	1350	1	25	1350	1.00	0
Yale	1130	1	25	1350	0.84	220
Total, Secondary	4530			7020	0.65	2490
TOTAL CORRIDOR	21296			28620	0.74	7324

* Two main lanes serve-off-peak direction traffic, the third serves the contraflow lane.

OPERATIONAL LIFE OF CONTRAFLOW

As indicated previously, it would be desirable to terminate the contraflow operation before the time at which all capacity in the off-peak direction is being utilized. Continuing to operate contraflow after that time would noticeably impact off-peak direction traffic. Projections of travel demand are an essential element of the demand/capacity analysis.

Basis for Projecting Traffic Data

Historical traffic data, which are presented in more detail in previous parts of this report, are generally available for the study corridor. A key element to assessing future demand-capacity ratios involves projecting the historical traffic data.

Extrapolation of historical traffic data represents one approach for forecasting demand. However, recognizing that traffic generation correlates with land use, changes in development also will influence traffic growth rates. A combination of traffic and development trend data are used to estimate future traffic growth rates in the I-45N corridor. It might be noted that projected growth rates in the I-45N corridor in factors such as population, households, and employment are approximately twice the corresponding rates for Harris County as a whole.

Table 6 summarizes the relevant growth data. The projected rates of increase in corridor population, households, and employment (Table 7) were used as the basis for determining future growth in corridor traffic. For example, during the 1970's, population, households, and employment increased at an average annual rate of 7.33% (average of 5.9%, 7.5% and 8.6%). From

Table 6. Trends in Demographic Data, I-45N Corridor

Year	Population (1000's)	Households (1000's)	Employment (1000's)	Daily Traffic In and Out of Airport (1000's)
1970	478	133	91	-
1980	849	275	207	50
1985	1072	420	287	80
1990	1365	502	323	110
2000	1603	592	389	210

Sources:
Population, households, employment: Rice Center
Daily Traffic at airport: Turner, Collie, and Braden, Inc.

Table 7. Measures of Historical and Future Growth in I-45N Corridor, 1970 to 2000, Average Annual Percentage Increase

Measure of Growth	Time Frame			
	1970 - 1980 (historical)	1980 - 1985	1985 - 1990	1990 - 2000
I-45N Traffic Counts				
I-45 @ N. Loop	3.0%	2.8%	1.5%	0.7%
I-45 @ Cypress Creek	8.7%	8.1%	4.4%	2.0%
I-45 @ Airline	5.2% (1970-78)	4.8%	2.6%	1.2%
I-45 @ N. Little York	9.5% (1970-78)	8.8%	4.8%	2.2%
Primary Alternate Routes				
Airline, N. of Fulton	0.9%	0.8%	0.5%	0.2%
N. of Berry	5.1%	4.7%	2.6%	1.2%
Shepherd, N. of I-45	4.1%	3.8%	2.1%	0.9%
N. of Pinemont	5.5%	5.1%	2.8%	1.3%
S. of Little York	5.2%	4.8%	2.6%	1.2%
Secondary Alternate Routes				
Yale, N. of Crosstimbers	2.9%	2.7%	1.5%	0.7%
S. of I-45	3.2%	3.0%	1.6%	0.7%
Fulton, N. of Tidwell	3.4%	3.2%	1.7%	0.8%
West Hardy, N. of Parker	2.2%	2.0%	1.1%	0.5%
E. of Crosstimbers	8.7%	8.1%	4.4%	2.0%
N. of Berry	3.6%	3.3%	1.8%	0.8%
Irvington, N. of Berry	2.3%	2.1%	1.2%	0.5%
Population	5.9%	4.8%	4.9%	1.6%
Households	7.5%	8.8%	3.7%	1.6%
Employment	8.6%	6.8%	2.4%	1.9%
Daily Traffic at Airport	-	9.8%	6.6%	6.7%

Note: The change in the rate of growth in corridor population, households, and employment were used to estimate the future change in growth in the traffic volumes.

Sources: Traffic Counts: State Department of Highways and Public Transportation and City of Houston
Population, Households, and Employment: Rice Center
Daily Traffic at Airport: Turner, Collie and Braden, Inc.

1980 to 1985, it is projected by Rice Center that these development indicators will grow at an annual rate of 6.8%, or about 93% of the rate experienced from 1970 to 1980. Thus, it was assumed that the traffic volumes would increase from 1980 to 1985 at 93% of the annual rate of increase from 1970 to 1980. Similiar analyses were made for the 1985 to 2000 time period.

As a result of this analysis, the traffic growth rates shown in Table 8 were used in the demand/capacity analysis. The intermediate growth rates were determined using the procedure described in this section. Recognizing the uncertainty that exists in projecting traffic, high and low estimates were developed; these estimates are ± 25% of the intermediate estimate. Based on available data, the intermediate appears to be the best estimate to use for planning purposes.

Assumptions Used in Analysis

Traffic growth rates shown in Table 8 were used to obtain a range of estimates for future travel in the I-45 corridor. Those growth rates were applied to traffic counts on the various facilities conducted on a clear day in September 1981 (Tables 3, 4 and 5).

The following information and assumptions were also used in estimating the operational life of the contraflow lane.

- The critical corridor section to be evaluated is located between N. Shepherd and Crosstimbers.
- The critical direction of travel is the p.m. off-peak inbound (southbound).
- The evaluation was performed for three time periods.
  - Peak Hour (4:30 to 5:30 p.m.)
  - Peak Two Hours (4:00 to 6:00 p.m.)
  - Peak Period (3:30 to 6:30 p.m.)

Table 8. Traffic Growth Rates Used to Project Demand, I-45N Corridor, N. Shepherd to Crosstimbers Section

Roadway	Annual Percent Growth Rate								
	Low Estimate			Intermediate Estimate			High Estimate		
	1980-85	85-90	90-2000	1980-85	85-90	90-2000	1980-85	85-90	90-2000
I-45 Mainlanes[1]	5.1%	2.8%	1.3%	6.8%	3.7%	1.7%	8.5%	4.6%	2.1%
Frontage Roads[2]	5.1%	2.8%	1.3%	6.8%	3.7%	1.7%	8.5%	4.6%	2.1%
Primary Alternate Routes[3]	2.9%	1.6%	0.8%	3.9%	2.1%	1.0%	4.9%	2.6%	1.2%
Secondary Alternate Routes[4]	2.6%	1.4%	0.7%	3.5%	1.9%	0.9%	4.4%	2.4%	1.1%

[1]Obtained by averaging the Airline and Little York values (values in the critical section) from Table 7

[2]Assumed to grow at same rate as mainlanes

[3]Obtained by averaging values for N. Shepherd and Airline from Table 7

[4]Obtained by averaging values for Irvington, West Hardy, Fulton, and Yale from Table 7.

- The following were considered to represent corridor routes and directional lanes.

  - I-45N mainlanes (2) and frontage roads (2)
  - Primary alternate routes -- N. Shepherd (2) and Airline (2)
  - Secondary alternate routes -- Irvington(1), West Hardy (1), Fulton (1), and Yale (1)

- Current traffic volumes (September 1981) were counted by TTI during the p.m. peak period, mid-week, with clear weather.

Operational Life

Once all capacity is utilized, the desirable operational life of contraflow has ceased. Figures 11, 12 and 13 present the demand/capacity analysis for both the peak hour and peak period for all roadways considered in the study. Table 9 summarizes the results of those analyses.

From a decision-making standpoint, perhaps two of the values shown in Table 9 could be considered most critical. Using the intermediate estimate, the following dates are significant.

- 1983. Year in which all the off-peak capacity on the frontage roads and freeway mainlanes will be used for the entire peak period (3 hours) if contraflow continues to occupy an off-peak direction lane.

- 1985. Year in which all the off-peak direction capacity on the frontage roads, mainlanes, primary and secondary alternate routes will be used during the peak hour if the contraflow lane continues to occupy an off-peak direction lane.

It appears that the desirable operational life of contraflow will cease by the end of 1985, if not sooner.

Impact of Short-Range Improvements

It is possible that, in the next 2 to 4 years, certain improvements could be implemented in the I-45N corridor that would increase capacity. Specifically, the following improvements might be undertaken.

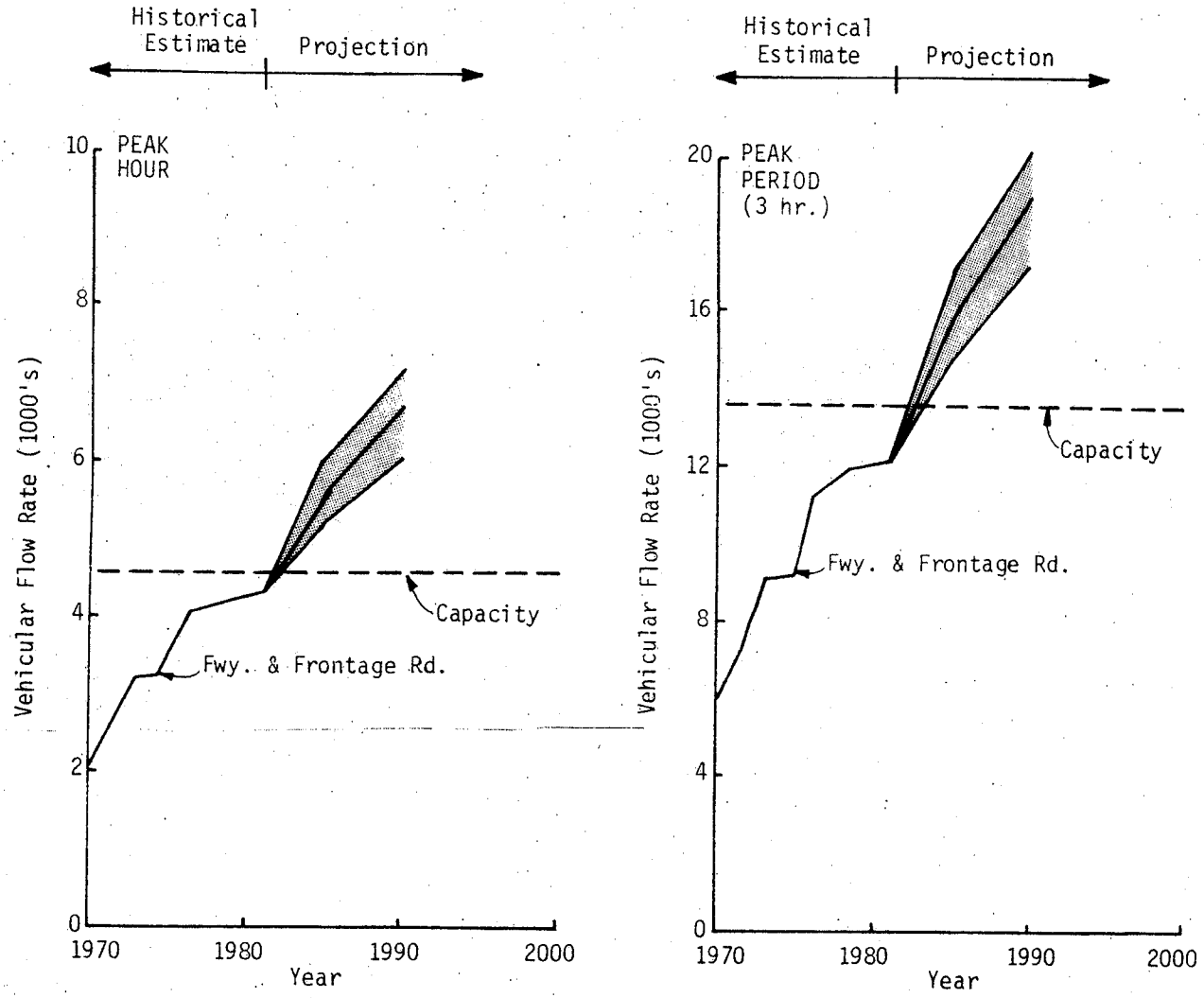


Figure 11: Freeway Mainlanes and Frontage Road, Demand/Capacity Relationships, Peak Hour and Peak Period

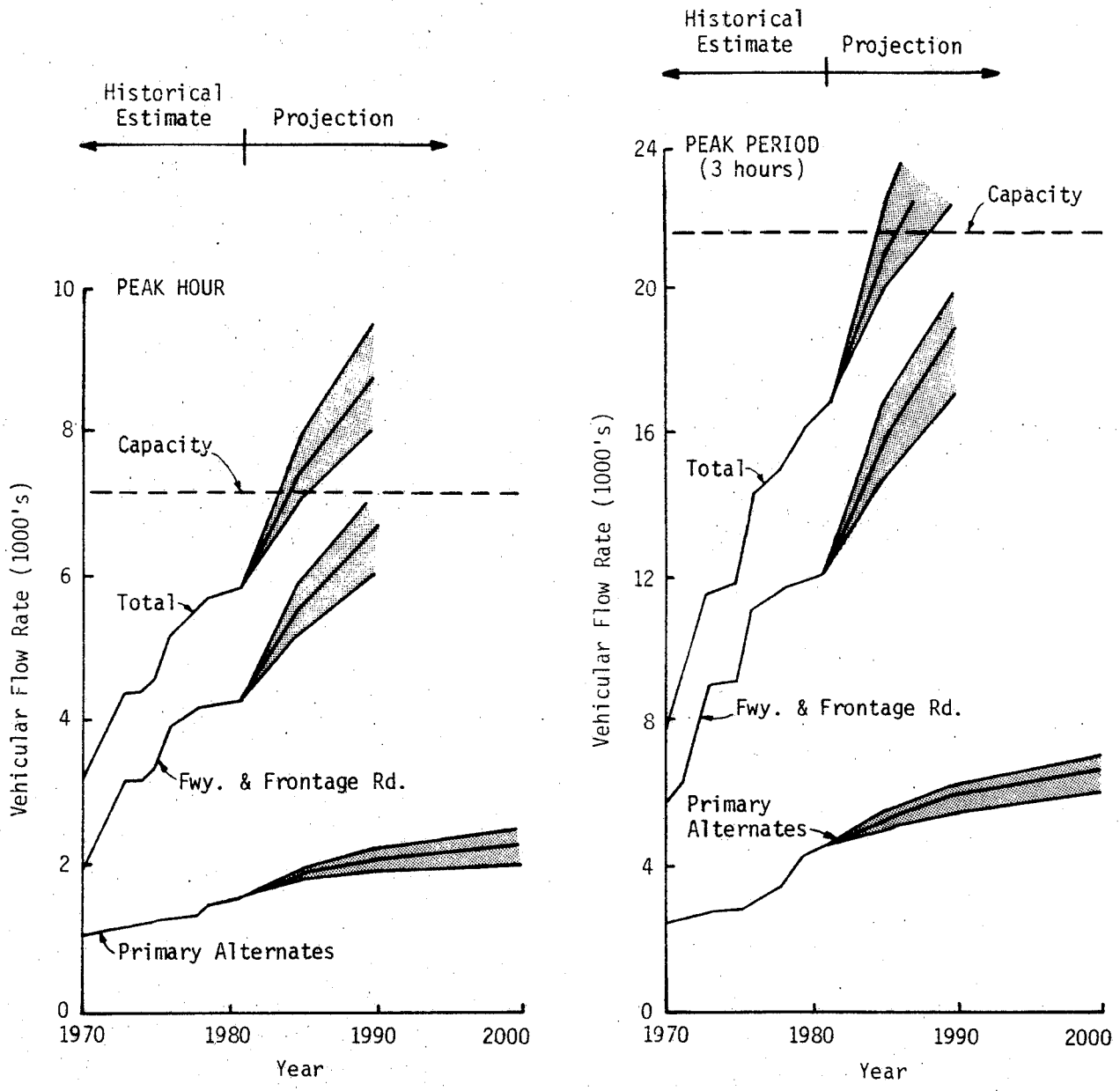


Figure 12: Freeway Mainlanes, Frontage Road and Primary Alternates, Demand/Capacity Relationships, Peak Hour and Peak Period

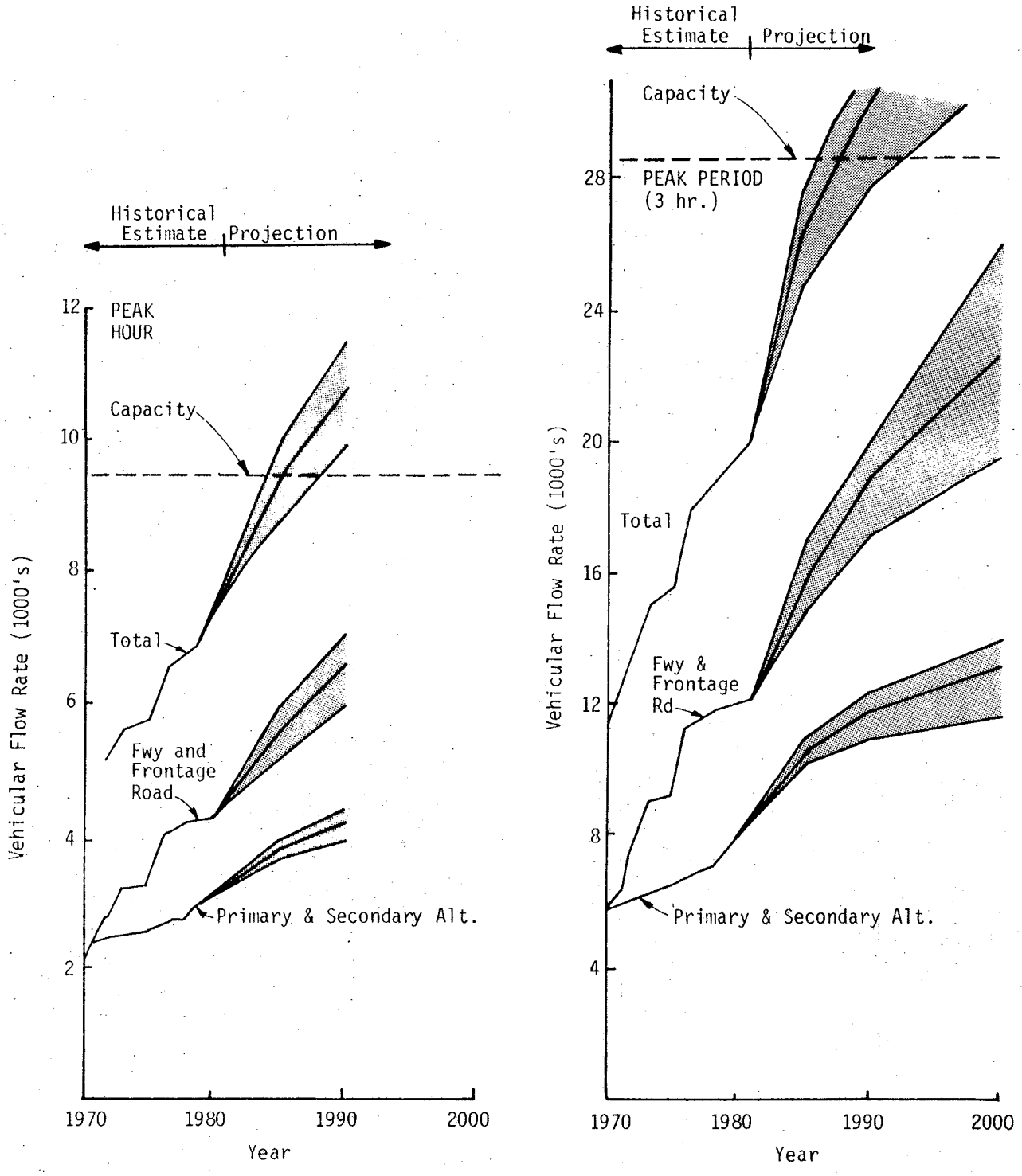


Figure 13: Freeway Mainlanes, Frontage Road, Primary Alternates and Secondary Alternates, Demand/Capacity Relationships, Peak Hour and Peak Period

Table 9. Approximate Year in which Termination of Contraflow is Desirable Based on Demand/Capacity Relationship

Roadway System	Year in which Demand will Exceed Capacity					
	Low Growth Estimate		Intermediate Growth Estimate[1]		High Growth Estimate	
	Peak Hour	Peak Period (3 hrs)	Peak Hour	Peak Period (3 hrs)	Peak Hour	Peak Period (3 hrs)
I-45 Mainlanes and Frontage Roads	1982/83	1983	1982/83	1983	1982/83	1982/83
I-45 Mainlanes, Frontage Roads, and Primary Alternate Routes[2]	1985	1988	1984	1986	1983	1984
I-45 Mainlanes, Frontage Roads, Primary and Secondary Routes[3]	1988	1992	1985	1988	1984	1986

[1]Based on available data, this appears to represent the best estimate of future conditions.

[2]Primary alternate routes include N. Shepherd and Airline

[3]Secondary alternate routes include Irvington, West Hardy, Fulton, and Yale

- Frontage Road - Increase inbound, thru traffic green time from 25% to 35%.
- West Hardy - Increase cross-section from 2 to 4 lanes or designation of one-way pairs between East and West Hardy.
- Fulton, Yale - Increase cross-section from 2 to 4 lanes or adjust green time of inbound, thru traffic from 25% to 40%.

The impacts of these actions on peak-hour capacity is shown in Table 10.

The actions shown in Table 10 would increase capacity by 1980 vehicles per hour. This would represent a 21% increase in total corridor capacity.

Table 10: Impact of Selected Short-Range Improvements on Capacity, I-45N Corridor, Peak Hour, Off-Peak Direction

Roadway and Improvement	Capacity (vph)		Percent Increase
	Current[1]	After Improvement	
Frontage Road; increase green time 25% to 35%	900	1260	40%
West Hardy; increase cross section to 4 lanes (2 each direction)	720	1440	100%
Fulton, Yale; increase cross section to 4 lanes (2 each direction)	900	1800	100%
Total Increase = 1980 vph = 21%			

[1]Refer to Table 3

As can be seen from Figures 11, 12, and 13 this increase in corridor capacity, based on primary alternates, freeway mainlanes, and frontage roads (Figure 12), could extend the operational life of contraflow by as much as 3 to 4 years. However, for that to happen, the improvements shown in Table 10 would need to become effective in the next 2 to 4 years. The feasibility of that occurring is not known. In addition, with the exception of the possible improvements to the frontage road, all these possible improvements are on secondary alternate routes. Those are the last routes to which traffic will choose to divert.

IMPACT ON TRAVEL TIME AND DELAY

The various alternatives (i.e., continue contraflow, eliminate contraflow, or replace contraflow) will have varying impacts on travel time and delay along I-45N. Three different groups of traffic, listed below, will be affected by the treatment of contraflow.

- Off-peak direction traffic. Whether or not contraflow is continued will determine the number of freeway lanes available to serve off-peak direction traffic.
- Contraflow traffic. If some form of priority lane is not continued, the contraflow traffic will be added to the mixed-flow, peak-direction traffic.
- Peak-direction traffic. If contraflow traffic is added to the peak-direction flow, some increase in peak direction delay will result.

It might be noted that, due to natural traffic growth, increases in delay will occur for both peak and off-peak direction traffic regardless of what is done with contraflow. The primary intent of this analysis is to identify the incremental effect on total freeway delay that results from altering the contraflow operation.

Analytical Approach and Base Year Data

The impact of the contraflow lane on the operations of the total freeway during the PM peak period is analyzed over a 11.7 mile section from the North Belt Interchange on the north to Hogan Street near downtown. The assumption is made that the contraflow lane affects traffic flow over this entire length for 3 hours from 3:00 to 6:00 PM.[3]

[3] The peak period was considered as 3:30 to 6:30 in previous sections of this report. However, for this analysis better traffic data are available for a 3:00 to 6:00 period.

Vehicular speeds and volumes, measured during 1981, are used for base conditions to calculate total travel times, which is the principal measure of effectiveness for this analysis. A 6.8 percent annual growth factor is applied to the traffic demands, and the resultant travel speeds for future years are estimated from demand/capacity relationships.

For purposes of analysis, the freeway is divided into three segments that have significant differences in design and operational characteristics.

- North Belt to Shepherd (4.1 miles) - A 6-lane section approaching the northern terminal of the contraflow lane. The lane reduction for non-contraflow traffic in the PM southbound direction causes queueing in this section.
- Shepherd to I-610 (4.5 miles) - A 6-lane section reduced to two lanes for contraflow in the southbound direction. Ramp closures and ramp metering are applied to maintain traffic flow below the capacity of the two non-contraflow traffic lanes.
- I-610 to Hogan Street (3.1 miles) - A 6, 8, and 10-lane section approaching the downtown area. During the PM peak period, the northbound direction is heavily congested, the southbound is free flow.

This analysis examines three conditions.

1) The impact of a 6.8 percent annual growth rate on the total travel time to all users of the North Freeway.
2) The impact of discontinuing the contraflow lane and providing no alternative priority operations.
3) The impact of replacing the contraflow lane with a separate priority facility (i.e., median high-occupancy vehicle lane).

For all three conditions, the assumptions are that all traffic growth will be accommodated on the main lanes of the North Freeway. This is, in effect, a worst case assumption since, as shown previously in this report, once freeway demand equals capacity it is reasonable to assume that traffic will begin diverting to alternate routes until the capacity of those diversionary routes is utilized.

Modal split is also an issue. If modal split did not change with the removal of contraflow, a relatively small number of vehicles would be added to the peak direction flow, thereby not significantly altering delay to that traffic. If, however, modal split changes and current bus and van users begin travelling in their autos, the impact on delay can be more significant. The modal split impacts are analyzed in two manners. First, an analysis is performed assuming no change in modal split. Second, an analysis is performed assuming that 50 percent of current bus and van patrons decide to travel in autos with an average occupancy of 1.3. This type of change in modal split is consistent with what might be expected based on recent research findings.[4]

1981 Traffic Conditions

1981 is used as the base year in the analysis. Base year traffic conditions are summarized in this section.[5]

Inbound (Off-Peak) Direction, PM Peak Period

Table 11 summarizes the average speeds and traffic volumes in the 3 sections of the inbound North Freeway for a three-hour period from 3:00 to 6:00 PM.

In Section 1, the running speeds range from 55 MPH to 0 MPH as the traffic approaches the queue that forms at the lane drop at the contraflow

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[4] D. Baugh & Associates, Inc. Freeway High-Occupancy Vehicle Lanes and Ramp Metering Evaluation Study. Prepared for U.S. Department of Transportation, December 1979.

[5] In previous sections of this report, the theoretical 1800 vph/lane capacity was used. At some locations on the North Freeway, flow rates exceed that value. In this section of the report, these higher flow rates are treated as capacity.

Table 11: Inbound (Off-Peak) Direction, Base Year (1981)
Average Traffic Volumes and Speeds, PM Peak Period

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)
Peak One Hour	2800	35	3400	30	3800	55
Peak Two Hours	5500	37	6600	32	7600	55
Peak Three Hours	7900	40	9700	35	11200	55

lane terminal. The maximum queue during the peak hour is one mile. The average speed in the queue is 15 MPH (since the queue does not occupy this entire section, the average speed for the section is greater than 15 MPH, Table 11).

In Section 2, the traffic operations are stop-and-go, but with ramp control the average speeds are maintained in the 30-37 mile per hour range to achieve maximum flow rates. Capacity of Section 2 is 3800 vph.

In Section 3, the expanded roadway section, the demand is less than the capacity and the average speeds are 55 MPH.

Outbound (Peak) Direction, PM Peak Period

Table 12 summarizes the average speeds and traffic volumes in the peak direction flow for the outbound North Freeway for the three-hour PM period.

In Section 3, the roadway width changes from 10 to 6 lanes and the traffic volumes are high and speeds are low because of the two lane drops

Table 12: Outbound (Peak) Direction, Base Year (1981) Average Traffic Volumes and Speeds, PM Peak Period

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)
Peak One Hour	4800	25	5300	15	5800	20
Peak Two Hours	9000	30	9500	18	11200	24
Peak Three Hours	13000	35	13700	21	16600	28

at Main Street and I-610. An increase in traffic demands results in lower speeds in this section during the critical peak hours.

In Section 2, speeds are low because of the high demands from the I-610 interchange, and a lane drop at Airline Drive. Ramp metering is used to improve flow within the section, but the entrances at the northern end of the section at Shepherd are uncontrolled. A geometric bottleneck at this location reduces speeds in this section.

Section 1 is beyond the limit and the effect of the contraflow lane. However, operations in this section are important in the overall analysis of the effects of the 6.8 percent traffic growth. Volumes are lower and speeds are higher because of the metering effect of the bottleneck at Shepherd and the large volumes of traffic exiting the freeway in the section.

Contraflow Outbound Operation, PM Peak Period

Table 13 summarizes the usage of the contraflow lane from Hogan to Shepherd by number and type of vehicle and number of persons. The lane is operational for 2.5 hours and has an average speed of 55 MPH.

Table 13: Contraflow Operations, Base Year (1981) Average Traffic Volumes and Speeds, PM Peak Period

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles			Section No. 2 Shepherd to I-610 4.5 Miles			Section No. 3 I-610 to Hogan Street 3.1 Miles		
	Average Volume (Vehicles)		Average Speed (MPH)	Average Volume (Vehicles)		Average Speed (MPH)	Average Volume (Vehicles)		Average Speed (MPH)
	Vans	Buses		Vans	Buses		Vans	Buses	
Peak One Hour	185	35	25	192	54	55	192	54	55
Peak Two Hours	250	53	30	270	84	55	270	84	55
Peak Three Hours	255	58	35	275	90	55	275	90	55

At the end of Section 2 some vehicles exit to the Shepherd Park-and-Ride Facility or to the Stuebner-Airline arterial. The volumes and speeds of contraflow vehicles in the normal lanes of Section 1 are presented in Table 13.

Total Travel Times and Delay

Total Travel Time (TTT) is calculated for the three-hour average speeds and volumes for each of the three sections by the equation:

$$\text{TTT in Vehicle Hours} = \frac{\text{Total Volume}}{\text{Speed}} \times \text{Length of Section}$$

TTT in Person Hours = TTT in Vehicle Hours x Vehicle Occupancy

The following vehicle occupancies are used:

Passenger vehicles	1.3 persons
Van pool vehicles	8.7 persons
Buses - Peak Hour	50 persons
Buses - Total Peak Period	41 persons

Total Travel Times and travel delays for 1981 speed and volume conditions are calculated in Table 14. To determine delay, a speed is selected that represents a desired level of service. An operating speed below this speed causes delay. Since this analysis is directed to the evaluation of the contraflow lane, the operating speed of the contraflow lane, 55 MPH, is used as the basis for calculating delay. Total Travel Time in person-hours for the 3-hour volumes is calculated for the desired speed of 55 MPH. The difference between the Total Travel Times for the different speed conditions is delay. This delay value is based on the desired level of service, since 55 MPH speeds are not achievable for the existing traffic volumes and roadway capacities.

If the contraflow lane were discontinued, the inbound freeway capacity during the 3-hour period would increase by one lane and the contraflow vehicles would be added to the outbound traffic demand. The addition of contraflow traffic to the outbound flow is considered under two conditions. First, no change in modal split is assumed. Second, a more realistic assumption is made; it is assumed that 50 percent of the bus and van traffic will revert to auto travel at an average occupancy of 1.3 persons.

Impact of Discontinuing Contraflow Operations, Base Year

The following analysis is made to determine the effects of discontinuing the contraflow lane operations without provision of alternative priority operations.

Table 14: PM Peak Period (3 hour) Travel Delays, Base Year (1981), Person and Vehicle Delay

Traffic Condition	Total Travel Time in Person Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	Contraflow Traffic
Base Year Traffic Conditions (1981)	3495	8185	1382
Traffic Conditions at 55 MPH Average Speed	2618	3933	1186
Delay in Person Hours	877	4252	196
Total Delay (Person Hours)		5325	

Traffic Conditions	Total Travel Time In Vehicle Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	Contraflow Traffic
Base Year Traffic Conditions (1981)	2688	6297	87
Traffic Conditions at 55 MPH Average Speed	2014	3026	74
Delay in Vehicle Hours	674	3271	13
Total Delay (Vehicle Hours)		3958	

Inbound Direction

Average speeds in all three sections would increase to 55 MPH. From Table 14, the Total Travel Time for this traffic at 55 MPH is 2618 person hours.

Outbound Direction

The outbound analysis is performed for two modal split assumptions.

No Change in Modal Split

This assumes that all bus and van users of the contraflow will continue using buses and vans if contraflow were discontinued. Thus, the 365 contraflow vehicles with 6300 persons would be added to the outbound traffic demand. The Total Travel Time consists of two parts: (1) the additional vehicle delay, based on passenger car equivalence; and (2) the contraflow passenger travel times at the lower travel speeds.

The travel time caused by the additional vehicles is calculated as follows:

$$(365 \text{ Veh})(1.3 \text{ Persons/Veh})\left(\frac{\text{length of section}}{\text{average speed of section}}\right)$$

$$= (365)(1.3)\left(\frac{3.1}{28} + \frac{4.5}{21}\right) = 154 \text{ person hours}$$

This is added to the normal travel time of 8185 person hours for a total of 8339 person hours.

CFL persons travel time is calculated in the same manner:

For Section 2 and 3:

$$(6300 \text{ persons})\left(\frac{3.1}{28} + \frac{4.5}{21}\right) = 2048 \text{ person hours}$$

For Section 1:

$$(4597 \text{ persons})\left(\frac{4.1}{35}\right) = 539 \text{ person hours}$$

Total Travel Time = 2587 person hours

Table 15 summarizes the changes in travel times and the total delay. From Tables 14 and 15, the net effect of discontinuing the contraflow lane and requiring all contraflow traffic to use the normal freeway lanes is an additional delay of 482 (5807-5325) person hours per peak period, but a savings of 489 (3958-3469) vehicle hours per peak period.

Table 15: Effect of Eliminating Contraflow on Base Year (1981) Travel Delay, PM Peak Period Assuming No Change in Modal Split, Person and Vehicle Delay

Traffic Condition	Total Travel Time in Person Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	Contraflow Traffic
Base Year Traffic Conditions without CFL	2618	8339	2587
Traffic Conditions at 55 MPH Average Speed	2618	3933	1186
Delay in Person Hours	0	4406	1401
Total Delay (Person Hours) 5807			

Traffic Condition	Total Travel Time in Vehicle Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	Contraflow Traffic
Base Year Traffic Conditions without CFL	2014	6414	155
Traffic Conditions at 55 MPH Average Speed	2014	3026	74
Delay in Vehicle Hours	0	3388	81
Total Delay (Vehicle Hours) 3469			

50 Percent Change in Modal Split

Taking the contraflow lane away will eliminate the travel time advantage the buses and vans presently experience. Thus, the incentive for using those vehicles will be reduced. It appears reasonable to assume that half the persons presently using buses and vans will decide to travel in autos at an assumed occupancy of 1.3 persons per vehicle (see footnote 4).

The analysis of this alternative is performed in a manner similar to that shown for the no modal split alternative. With the 50 percent modal split, in

the base year, placing contraflow traffic in the peak directions lanes results in an increase of 4078 person hours per peak period and an increase of 2436 vehicle hours per peak period. These values are shown in tables included in subsequent parts of this report (Table 16).

Table 16: Travel Delays in Peak and Off-Peak Direction With and Without Contraflow on I-45N, PM Peak Period, 1981-1985

Time Period Based on 6.8% Annual Growth	Delay in Person Hours				
	With Contraflow	Without Contraflow		Difference	
		No Modal Shift	50% Modal Shift	No Modal Shift	50% Modal Shift
Base Year, 1981	5,325	5,807	9,401	+ 482	+ 4078
Year 1, 1982	6,506	6,848	10,634	+ 342	+ 4128
Year 2, 1983	9,073	9,541	15,703	+ 468	+ 6630
Year 3, 1984	11,729	11,668	18,056	- 61	+ 6327
Year 4, 1985	16,951	15,830	20,548	- 1121	+ 3597
Avg., 1981-85				+ 22	+ 4952

Time Period Based on 6.8% Annual Growth	Delay in Vehicle Hours				
	With Contraflow	Without Contraflow		Difference	
		No Modal Shift	50% Modal Shift	No Modal Shift	50% Modal Shift
Base Year, 1981	3,958	3,469	6,394	- 489	+ 2436
Year 1, 1982	4,871	4,127	7,235	- 744	+ 2364
Year 2, 1983	6,750	5,718	10,733	- 1032	+ 3983
Year 3, 1984	8,780	6,974	12,444	- 1806	+ 3694
Year 4, 1985	12,286	9,780	14,960	- 2506	+ 2674
Avg., 1981-85				- 1315	+ 3030

Impact of Future Traffic Growth

Increases in traffic will affect the different contraflow alternatives.

Alternative of Eliminating Contraflow

As indicated in Table 8, it is estimated that, from 1981 to 1985, freeway traffic in the critical analysis section will increase at an annual rate of 6.8 percent. Traffic demands shown in Tables 11, 12, and 13 were modified to reflect that growth rate. The expected changes in average speed, travel times, and delays for the 1981 to 1985 time frame are presented in tables included in the Appendix. Table 16 summarizes the travel delays in person hours and vehicle hours for the 1981-1985 analysis period.

The results indicate a significant growth in person hours and vehicle hours of delay with the increase in demand. The elimination of the contraflow lane without providing priority operations for the high-occupancy vehicles, however, results in an increase in person delay, but a decrease in vehicle delay under the assumption of no modal split. This is the result of requiring the high-occupancy vehicles to drive in the low speeds of the outbound lanes of the freeway. Under the more reasonable assumption of a 50% change in modal split, massive increases in both person hours and vehicle hours of delay result.

However, in the third year, with the no modal split alternative, the trend in person delays is reversed. This suggests that in 1983 the delays caused by the contraflow lane in the inbound direction equal the delays that would result from terminating the contraflow lane and placing that traffic in the normal lanes in the outbound direction. The increase in delay for the 50% modal split alternative begins to decrease after the third year for the same reason.

Alternative of Replacing the Contraflow Lane

With this alternative, the traffic using contraflow would use a physically separated median lane instead. All existing freeway lanes would serve mixed flow traffic and the existing contraflow traffic would not be added to the peak direction traffic lanes.

This causes the delay trends to be more straightforward (Table 17). The person delays and vehicle delays increase at an increasing rate. The major increases in delay after the 2nd year, if contraflow is not replaced, would appear to be unacceptable.

Table 17: Impacts on Delay Time of Replacing Contraflow With a Median HOV Lane, PM Peak Period

Time Period Based on 6.8% Annual Growth	DELAY IN PERSON HOURS		
	With Contraflow	Contraflow Replaced by Median HOV Lane	Difference
Base Year - 1981	5325	4406	- 919
Year 1 - 1982	6506	5208	-1298
Year 2 - 1983	9073	7261	-1812
Year 3 - 1984	11729	8851	-2878
Year 4 - 1985	16951	12411	-4540
Avg., 1981-85			-2289

Time Period Based on 6.8% Annual Growth	DELAY IN VEHICLE HOURS		
	With Contraflow	Contraflow Replaced by Median HOV Lane	Difference
Base Year - 1981	3958	3388	- 570
Year 1 - 1982	4871	4007	- 864
Year 2 - 1983	6750	5585	-1165
Year 3 - 1984	8780	6809	-1971
Year 4 - 1985	12286	9549	-2737
Avg., 1981-85			-1461

CONCLUSIONS

As stated earlier in the report, three courses of action could be taken regarding contraflow.

- Continue contraflow operations indefinitely.
- Terminate contraflow.
- Replace contraflow with a median priority lane.

This report identifies some of the consequences associated with these alternative actions.

Continue Contraflow Operations Indefinitely

Contraflow has proven itself to be highly attractive, serving some 14,000 person trips per day. During the peak hour, this contraflow lane moves the same number of persons as do two mixed-flow freeway lanes. Largely for that reason, discontinuation of contraflow would be difficult.

However, as the analyses in this report indicate, continuing to use an off-peak direction lane for more than an additional two to three years to serve peak direction travel will create considerable congestion for off-peak direction traffic. If contraflow is not eliminated within that time frame, the magnitude of traffic congestion in the off-peak direction will approach that of the peak direction. Delay costs imposed on off-peak direction traffic will become substantial. Continuing to operate contraflow will not be an economical approach to solving traffic problems on I-45N (Table 18).

Terminate Contraflow

Terminating contraflow would provide an additional freeway lane to serve off-peak direction traffic, thereby reducing delay to that traffic. However,

Table 18: Estimated Benefit/Cost Ratios Associated with Terminating or Replacing the Contraflow Lane, Change from Existing Condition (i.e., contraflow operation)

Alternative Action	Benefit/Cost Ratio	
	1990	2000
Terminate Contraflow w/o Replacement[1]	-1.7	-28.7
Replace Contraflow w/ Median HOV Lane	3.3	7.7

[1]A positive b/c is not attained since negative total benefits are associated with this alternative action.

Notes: Assumes construction in 1983.
Assumes $50 million to replace contraflow w/ median lane
10% discount rate.

Source: Highway Economic Evaluation Model.

unless the contraflow is replaced by a median high-occupancy vehicle lane, all traffic currently using contraflow would be added to the already congested peak-travel direction. The result would be a substantial increase in total roadway delay since the increase in peak-direction delay would greatly exceed the decrease in off-peak direction delay (Table 18). By adding contraflow traffic to the peak-direction mixed lanes, the traffic queue would extend an additional three to five miles during peak periods. Negative benefits would accompany terminating contraflow with no priority treatment replacing that lane.

Replace Contraflow

The third alternative is to replace contraflow with a physically separated median high-occupancy vehicle lane. It has been estimated that the construction cost of such a lane will be approximately $50,000,000.

This alternative continues to provide priority treatment. That treatment is provided in a safer, more permanent manner. By providing a median lane, the theoretical person-moving capacity of the corridor remains extremely high.

Following this approach benefits both traffic directions. The lane presently used by contraflow is returned to serve mixed flow in the off-peak direction. The peak-direction traffic using contraflow continues to use a priority lane and is not added to the congested peak-direction traffic.

In addition, from economic and traffic standpoints, this appears to be the most effective action (Table 18). A positive benefit/cost ratio (b/c = 7.7 for the 1981-2000 analysis period) accompanies this expenditure of funds.

Recommendation

Contraflow operation should not be continued for more than 2 to 4 additional years (Figure 14). A median, physically separated authorized vehicle lane should be provided to take the place of contraflow within that time frame. Contraflow should be terminated only when that replacement median authorized vehicle lane is operational. Selected characteristics of the three alternative approaches are shown in Table 19.

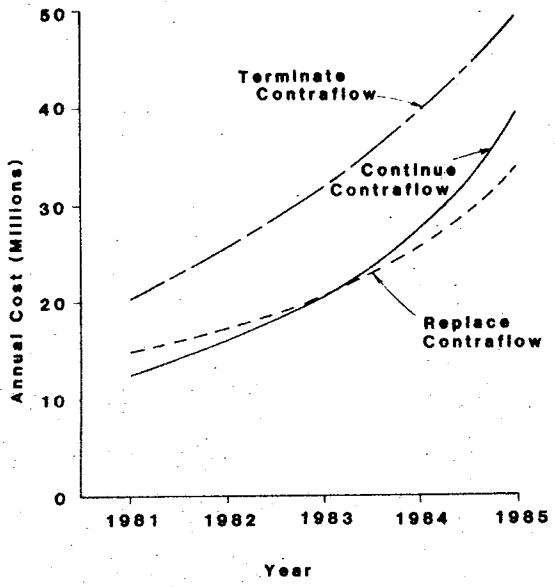

Figure 14: Estimated Annual Costs of Various Alternatives Involving the Contraflow Lane

Table 19: Major Advantages and Disadvantages to I-45N Corridor Traffic Associated with Alternative Contraflow Actions

Alternative Action	Major Advantages	Major Disadvantages
1. Continue Contraflow	• Priority treatment maintained	• High operating costs remain • Off-peak direction traffic severely impacted
2. Terminate Contraflow	• No capital or operating costs incurred for priority treatment • Improves off-peak direction traffic flow	• Massive impacts on peak direction traffic • Decreased bus productivity • Negative impact on public transportation system • Highly unfavorable net cost
3. Replace contraflow with median priority lane	• Maintains priority treatment • Improves off-peak direction flow w/o negatively affecting peak direction • Favorable benefit/cost ratio	• Initial capital cost ($50,000,000)

APPENDIX

TRAVEL TIME AND DELAY ANALYSIS

The information summarized in Tables 16 and 17 involved numerous calculations of delay to: 1) contraflow traffic; 2) off-peak direction traffic; and 3) peak-direction traffic. These calculations were made for each year from 1981 to 1985. Tables 1 through 40 in this appendix document all the individual calculations.

Table 1

Average Traffic Volumes and Speeds

Inbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Base Year 1981

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)
Peak One Hour	2800	35	3400	30	3800	55
Peak Two Hours	5500	37	6600	32	7600	55
Peak Three Hours	7900	40	9700	35	11200	55

Table 2

Average Traffic Volumes and Speeds

Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Base Year 1981

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)
Peak One Hour	4800	25	5300	15	5800	20
Peak Two Hours	9000	30	9500	18	11200	24
Peak Three Hours	13000	35	13700	21	16600	28

Table 3

Average Traffic Volumes and Speeds

CFL Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Base Year 1981

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles			Section No. 2 Shepherd to I-610 4.5 Miles			Section No. 3 I-610 to Hogan Street 3.1 Miles		
	Average Volume (Vehicles)		Average Speed (MPH)	Average Volume (Vehicles)		Average Speed (MPH)	Average Volume (Vehicles)		Average Speed (MPH)
	Vans	Buses		Vans	Buses		Vans	Buses	
Peak One Hour	185	35	25	192	54	55	192	54	55
Peak Two Hours	250	53	30	270	84	55	270	84	55
Peak Three Hours	255	58	35	275	90	55	275	90	55

Table 4

Total Travel Times

Inbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Base Year 1981

	Section No. 1 North Belt to Shepherd 4.1 Miles	Section No. 2 Shepherd to I-610 4.5 Miles	Section No. 3 I-610 to Hogan Street 3.1 Miles
Total 3 Hr. Volume (Vehicles)	7900	9700	11200
Average 3 Hr. Speed (MPH)	40	35	55
Total Travel Time (Vehicle Hours)	810	1247	631
Total Travel Time (Person Hours)	1053	1621	821

Total Travel Time in Person Hours	3495
Total Travel Time in Vehicle Hours	2688

Table 5

Total Travel Times

Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Base Year 1981

	Section No. 1 North Belt to Shepherd 4.1 Miles	Section No. 2 Shepherd to I-610 4.5 Miles	Section No. 3 I-610 to Hogan Street 3.1 Miles
Total 3 Hr. Volume (Vehicles)	13000	13700	16600
Average 3 Hr. Speed (MPH)	35	21	28
Total Travel Time (Vehicle Hours)	1523	2936	1838
Total Travel Time (Person Hours)	2980	3816	2389

Total Travel Time in Person Hours	8185
Total Travel Time in Vehicle Hours	6297

Table 6

Total Travel Times

CFL Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Base Year 1981

	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Vans	Buses	Vans	Buses	Vans	Buses
Total 3 Hr. Volume (Vehicles)	255	58	275	90	275	90
Average 3 Hr. Speed (MPH)	35	35	55	55	55	55
Total Travel Time (Vehicle Hours)	29.9	6.8	22.5	7.4	15.5	5.1
Total Travel Time (Person Hours)	260	279	196	303	135	209

Total Travel Time in Person Hours: 1382

Total Travel Time in Vehicle Hours: 87

Table 7

Travel Delays

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Base Year 1981

	Total Travel Times in Person Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Base Year Traffic Conditions	3495	8185	1382
Traffic Conditions at 55 MPH Average Speed	2618	3933	1186
Delay in Person Hours	877	4252	196

Total Delay in Person Hours 5325

	Total Travel Times in Vehicle Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Base Year Traffic Conditions	2688	6297	87
Traffic Conditions at 55 MPH Average Speed	2014	3026	74
Delay in Vehicle Hours	674	3271	13

Total Delay in Vehicle Hours 3958

Table 8

Travel Delays

I-45 North Freeway
Without CFL
PM Peak Period
3:00 - 6:00 PM

Base Year 1981

	Total Travel Times in Person Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Base Year Traffic Conditions without CFL	2618	8339	2587
Traffic Conditions at 55 MPH Average Speed	2618	3933	1186
Delay in Person Hours	0	4406	1401

Total Delay
in Person Hours 5807

	Total Travel Times in Vehicle Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Base Year Traffic Conditions without CFL	2014	6414	155
Traffic Conditions at 55 MPH Average Speed	2014	3026	74
Delay in Vehicle Hours	0	3388	81

Total Delay
in Vehicle Hours 3469

Table 9

Average Traffic Volumes and Speeds

Inbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 1 - 1982

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)
Peak One Hour	2990	35	3536	30	4058	55
Peak Two Hours	5874	34	6912	30	8117	55
Peak Three Hours	8437	39	10342	30	11962	55

Table 10

Average Traffic Volumes and Speeds

Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 1 - 1982

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)
Peak One Hour	5126	25	5610	15	6194	20
Peak Two Hours	9612	30	10146	18	11962	20
Peak Three Hours	13884	34	14632	21	17729	24

Table 11

Average Traffic Volumes and Speeds

CFL Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 1 - 1982

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)
	Vans Buses		Vans Buses		Vans Buses	
Peak One Hour	199 37	25	205 58	55		55
Peak Two Hours	267 56	30	288 90	55		55
Peak Three Hours	272 62	34	294 96	55	294 96	55

Table 12

Total Travel Times

Inbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 1 - 1982

	Section No. 1 North Belt to Shepherd 4.1 Miles	Section No. 2 Shepherd to I-610 4.5 Miles	Section No. 3 I-610 to Hogan Street 3.1 Miles
Total 3 Hr. Volume (Vehicles)	8437	10342	11962
Average 3 Hr. Speed (MPH)	39	30	55
Total Travel Time (Vehicle Hours)	887	1551	674
Total Travel Time (Person Hours)	1153	2016	876

Total Travel Time in Person Hours: 4045

Total Travel Time in Vehicle Hours: 3112

Table 13

Total Travel Times

Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 1 - 1982

	Section No. 1 North Belt to Shepherd 4.1 Miles	Section No. 2 Shepherd to I-610 4.5 Miles	Section No. 3 I-610 to Hogan Street 3.1 Miles
Total 3 Hr. Volume (Vehicles)	13884	14632	17729
Average 3 Hr. Speed (MPH)	34	21	24
Total Travel Time (Vehicle Hours)	1674	3135	2290
Total Travel Time (Person Hours)	2176	4076	2977

Total Travel Time in Person Hours 9229

Total Travel Time in Vehicle Hours 7099

Table 14

Total Travel Times

CFL Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 1 - 1982

	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Vans	Buses	Vans	Buses	Vans	Buses
Total 3 Hr. Volume (Vehicles)	272	62	294	96	294	96
Average 3 Hr. Speed (MPH)	34	34	55	55	55	55
Total Travel Time (Vehicle Hours)	33.0	7.5	24.0	7.9	16.6	5.4
Total Travel Time (Person Hours)	285	307	209	322	144	222

Total Travel Time in Person Hours 1489

Total Travel Time in Vehicle Hours 94

Table 15

Travel Delays

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 1 - 1982

	Total Travel Times in Person Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Year 1 Traffic Conditions	4045	9229	1489
Traffic Conditions at 55 MPH Average Speed	2793	4201	1263
Delay in Person Hours	1252	5028	226

Total Delay
in Person Hours 6506

	Total Travel Times in Vehicle Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Year 1 Traffic Conditions	3112	7099	94
Traffic Conditions at 55 MPH Average Speed	2149	3231	54
Delay in Vehicle Hours	963	3868	40

Total Delay
in Vehicle Hours 4871

Table 16

Travel Delays

I-45 North Freeway
Without CFL
PM Peak Period
3:00 - 6:00 PM

Year 1 - 1982

	Total Travel Times in Person Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Year 1 Traffic Conditions without CFL	2793	9409	2903
Traffic Conditions at 55 MPH Average Speed	2793	4201	1263
Delay in Person Hours	0	5208	1640

Total Delay
in Person Hours 6848

	Total Travel Times in Vehicle Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Year 1 Traffic Conditions without CFL	2149	7238	174
Traffic Conditions at 55 MPH Average Speed	2149	3231	54
Delay in Vehicle Hours	0	4007	120

Total Delay
in Vehicle Hours 4127

Table 17

Average Traffic Volumes and Speeds

Inbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 2 - 1983

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)
Peak One Hour	3194	31	3563	30	4334	55
Peak Two Hours	6273	29	7382	30	8669	55
Peak Three Hours	9011	30	11045	30	12775	55

Table 18

Average Traffic Volumes and Speeds

Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 2 - 1983

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)
Peak One Hour	5475	25	6045	15	6616	20
Peak Two Hours	10266	25	10836	15	12775	20
Peak Three Hours	14828	30	15626	18	18934	20

Table 19

Average Traffic Volumes and Speeds

CFL Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 2 - 1983

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)
	Vans Buses		Vans Buses		Vans Buses	
Peak One Hour	211 40	37	219 61	55	219 61	55
Peak Two Hours	285 60	30	308 96	55	308 96	55
Peak Three Hours	291 66	25	314 102	55	314 102	55

Table 20

Total Travel Times

Inbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 2 - 1983

	Section No. 1 North Belt to Shepherd 4.1 Miles	Section No. 2 Shepherd to I-610 4.5 Miles	Section No. 3 I-610 to Hogan Street 3.1 Miles
Total 3 Hr. Volume (Vehicles)	9011	11045	12775
Average 3 Hr. Speed (MPH)	30	30	55
Total Travel Time (Vehicle Hours)	1232	1656	720
Total Travel Time (Person Hours)	1602	2154	936

Total Travel Time in Person Hours	4692
Total Travel Time in Vehicle Hours	3608

Table 21

Total Travel Times

Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 2 - 1983

	Section No. 1 North Belt to Shepherd 4.1 Miles	Section No. 2 Shepherd to I-610 4.5 Miles	Section No. 3 I-610 to Hogan Street 3.1 Miles
Total 3 Hr. Volume (Vehicles)	14828	15626	18934
Average 3 Hr. Speed (MPH)	30	18	20
Total Travel Time (Vehicle Hours)	2026	3907	2935
Total Travel Time (Person Hours)	2634	5079	3816

Total Travel Time in Person Hours 11529

Total Travel Time in Vehicle Hours 8868

Table 22

Total Travel Times

CFL Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 2 - 1983

	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Vans	Buses	Vans	Buses	Vans	Buses
Total 3 Hr. Volume (Vehicles)	291	66	314	102	314	102
Average 3 Hr. Speed (MPH)	30	30	55	55	55	55
Total Travel Time (Vehicle Hours)	39.8	9.0	25.7	8.3	17.7	5.7
Total Travel Time (Person Hours)	346	370	224	342	154	236

Total Travel Time in Person Hours 1672

Total Travel Time in Vehicle Hours 106

Table 23

Travel Delays

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 2 - 1983

	Total Travel Times in Person Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Year 2 Traffic Conditions	4692	11529	1672
Traffic Conditions at 55 MPH Average Speed	2985	4487	1347
Delay in Person Hours	1707	7041	325

Total Delay
in Person Hours 9073

	Total Travel Times in Vehicle Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Year 2 Traffic Conditions	3608	8868	106
Traffic Conditions at 55 MPH Average Speed	2296	3452	84
Delay in Vehicle Hours	1312	5416	22

Total Delay
in Vehicle Hours 6750

Table 24

Travel Delays

I-45 North Freeway
Without CFL
PM Peak Period
3:00 - 6:00 PM

Year 2 - 1983

	Total Travel Times in Person Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Year 2 Traffic Conditions without CFL	2985	11748	3627
Traffic Conditions at 55 MPH Average Speed	2985	4487	1347
Delay in Person Hours	0	7261	2280

Total Delay
in Person Hours 9541

	Total Travel Times in Vehicle Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Year 2 Traffic Conditions without CFL	2296	9037	217
Traffic Conditions at 55 MPH Average Speed	2296	3452	84
Delay in Vehicle Hours	0	5585	133

Total Delay
in Vehicle Hours 5718

Table 25

Average Traffic Volumes and Speeds

Inbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 3 - 1984

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)
Peak One Hour	3411	24	3631	30	4629	55
Peak Two Hours	6700	20	7500	30	9258	55
Peak Three Hours	9624	19	11400	30	13644	55

Table 26

Average Traffic Volumes and Speeds

Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 3 - 1984

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)
Peak One Hour	5847	20	6456	15	7066	20
Peak Two Hours	10964	25	11573	15	13644	20
Peak Three Hours	15836	30	16689	15	20222	20

Table 27

Average Traffic Volumes and Speeds

CFL Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 3 - 1984

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles			Section No. 2 Shepherd to I-610 4.5 Miles			Section No. 3 I-610 to Hogan Street 3.1 Miles		
	Average Volume (Vehicles)		Average Speed (MPH)	Average Volume (Vehicles)		Average Speed (MPH)	Average Volume (Vehicles)		Average Speed (MPH)
	Vans	Buses		Vans	Buses		Vans	Buses	
Peak One Hour	225	43	20	234	65	55	234	65	55
Peak Two Hours	304	64	25	329	103	55	329	103	55
Peak Three Hours	311	70	30	335	110	55	335	110	55

Table 28

Total Travel Times

Inbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 3 - 1984

	Section No. 1 North Belt to Shepherd 4.1 Miles	Section No. 2 Shepherd to I-610 4.5 Miles	Section No. 3 I-610 to Hogan Street 3.1 Miles
Total 3 Hr. Volume (Vehicles)	9624	11400	13644
Average 3 Hr. Speed (MPH)	19	30	55
Total Travel Time (Vehicle Hours)	2077	1710	769
Total Travel Time (Person Hours)	2700	2223	1000

Total Travel Time in Person Hours 5923

Total Travel Time in Vehicle Hours 4556

Table 29

Total Travel Times

Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 3 - 1984

	Section No. 1 North Belt to Shepherd 4.1 Miles	Section No. 2 Shepherd to I-610 4.5 Miles	Section No. 3 I-610 to Hogan Street 3.1 Miles
Total 3 Hr. Volume (Vehicles)	15836	16689	20222
Average 3 Hr. Speed (MPH)	30	15	20
Total Travel Time (Vehicle Hours)	2164	5007	3134
Total Travel Time (Person Hours)	2813	6509	4074

Total Travel Time in Person Hours 13396

Total Travel Time in Vehicle Hours 10305

Table 30

Total Travel Times

CFL Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 3 - 1984

	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Vans	Buses	Vans	Buses	Vans	Buses
Total 3 Hr. Volume (Vehicles)	311	70	335	110	335	110
Average 3 Hr. Speed (MPH)	30	30	55	55	55	55
Total Travel Time (Vehicle Hours)	42.5	9.6	27.4	9.0	18.9	6.2
Total Travel Time (Person Hours)	370	392	238	369	164	254

Total Travel Time in Person Hours 1787

Total Travel Time in Vehicle Hours 114

Table 31

Travel Delays

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 3 - 1984

	Total Travel Times in Person Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Year 3 Traffic Conditions	5923	13396	1787
Traffic Conditions at 55 MPH Average Speed	3145	4791	1441
Delay in Person Hours	2778	8605	346

Total Delay
in Person Hours 11729

	Total Travel Times in Vehicle Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Year 3 Traffic Conditions	4556	10305	114
Traffic Conditions at 55 MPH Average Speed	2419	3685	90
Delay in Vehicle Hours	2136	6620	24

Total Delay
in Vehicle Hours 8780

Table 32

Travel Delays

I-45 North Freeway
Without CFL
PM Peak Period
3:00 - 6:00 PM

Year 3 - 1984

	Total Travel Times in Person Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Year 3 Traffic Conditions without CFL	3145	13642	4258
Traffic Conditions at 55 MPH Average Speed	3145	4791	1441
Delay in Person Hours	0	8851	2817

Total Delay
in Person Hours 11668

	Total Travel Times in Vehicle Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Year 3 Traffic Conditions without CFL	2419	10494	255
Traffic Conditions at 55 MPH Average Speed	2419	3685	90
Delay in Vehicle Hours	0	6809	165

Total Delay
in Vehicle Hours 6974

Table 33

Average Traffic Volumes and Speeds

Inbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 4 - 1985

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)
Peak One Hour	3643	15	3631	30	4629	55
Peak Two Hours	7156	15	7500	30	9258	55
Peak Three Hours	10278	15	11400	30	13644	55

Table 34

Average Traffic Volumes and Speeds

Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 4 - 1985

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)
Peak One Hour	6245	15	6895	15	7546	15
Peak Two Hours	11710	15	12360	15	14572	15
Peak Three Hours	16912	20	17824	15	21597	20

Table 35

Average Traffic Volumes and Speeds

CFL Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 4 - 1985

Time Period (Hours)	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)	Average Volume (Vehicles)	Average Speed (MPH)
	Vans Buses		Vans Buses		Vans Buses	
Peak One Hour	240 46	15	250 69	50	250 69	50
Peak Two Hours	324 68	15	351 110	50	351 110	50
Peak Three Hours	332 75	15	358 117	50	258 117	50

Table 36

Total Travel Times

Inbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 4 - 1985

	Section No. 1 North Belt to Shepherd 4.1 Miles	Section No. 2 Shepherd to I-610 4.5 Miles	Section No. 3 I-610 to Hogan Street 3.1 Miles
Total 3 Hr. Volume (Vehicles)	10257	11400	13644
Average 3 Hr. Speed (MPH)	15	30	55
Total Travel Time (Vehicle Hours)	2804	1710	769
Total Travel Time (Person Hours)	3645	2223	1000

Total Travel Time in Person Hours	6868
Total Travel Time in Vehicle Hours	5283

Table 37

Total Travel Times

Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 4 - 1985

	Section No. 1 North Belt to Shepherd 4.1 Miles	Section No. 2 Shepherd to I-610 4.5 Miles	Section No. 3 I-610 to Hogan Street 3.1 Miles
Total 3 Hr. Volume (Vehicles)	16912	17824	21597
Average 3 Hr. Speed (MPH)	15	15	20
Total Travel Time (Vehicle Hours)	4623	5347	3348
Total Travel Time (Person Hours)	6009	6951	4352

Total Travel Time in Person Hours 17312

Total Travel Time in Vehicle Hours 13318

Table 38

Total Travel Times

CFL Outbound

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 4 - 1985

	Section No. 1 North Belt to Shepherd 4.1 Miles		Section No. 2 Shepherd to I-610 4.5 Miles		Section No. 3 I-610 to Hogan Street 3.1 Miles	
	Vans	Buses	Vans	Buses	Vans	Buses
Total 3 Hr. Volume (Vehicles)	332	75	358	117	358	117
Average 3 Hr. Speed (MPH)	15	15	50	50	50	50
Total Travel Time (Vehicle Hours)	90.7	20.5	32.2	10.5	22.2	7.3
Total Travel Time (Person Hours)	789	841	280	432	193	297

Total Travel Time in Person Hours: 2632

Total Travel Time in Vehicle Hours: 183

Table 39

Travel Delays

I-45 North Freeway

PM Peak Period
3:00 - 6:00 PM

Year 4 - 1985

	Total Travel Times in Person Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Year 4 Traffic Conditions	6868	17312	2632
Traffic Conditions at 55 MPH Average Speed	3207	5117	1537
Delay in Person Hours	3661	12195	1095

Total Delay
in Person Hours 16951

	Total Travel Times in Vehicle Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Year 4 Traffic Conditions	5283	13318	183
Traffic Conditions at 55 MPH Average Speed	2466	3936	96
Delay in Vehicle Hours	2817	9382	87

Total Delay
in Vehicle Hours 12286

Table 40

Travel Delays

I-45 North Freeway
Without CFL
PM Peak Period
3:00 - 6:00 PM

Year 4 - 1985

	Total Travel Times in Person Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Year 4 Traffic Conditions without CFL	3207	17528	4950
Traffic Conditions at 55 MPH Average Speed	3207	5117	1537
Delay in Person Hours	0	12411	3413

Total Delay
in Person Hours 15830

	Total Travel Times in Vehicle Hours		
	Inbound Freeway Lanes	Outbound Freeway Lanes	CFL Traffic
Year 4 Traffic Conditions without CFL	2466	13485	327
Traffic Conditions at 55 MPH Average Speed	2466	3936	96
Delay in Vehicle Hours	0	9549	231

Total Delay
in Vehicle Hours 9780