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16. Abstract

The Houston metropolitan area is currently implementing one of the most extensive high-occupancy vehicle (HOV) priority treatment networks in the nation. The definitive function of these transitway facilities is to provide movement of large volumes of passengers in as few vehicles as possible to high density employment centers during peak periods at a high level of service (minimal delay). This objective can only be achieved and maintained by exercising control over the number of vehicle users for a given time period. While this control is critically important during peak time periods, as mainlane congestion increases in extended magnitude, it also becomes important when considering transitway use for purposes during the off-peak period.

The intent of this study was to identify and evaluate possible off-peak uses of the Houston transitway system by vehicles other than authorized HOV's. Based upon the information available at the time of this report and the analyses conducted herein, it is recommended that off-peak utilization of transitways be continued for high-occupancy requirements. It is recognized that during off-peak periods, the cost of operation currently exceeds any delay savings or other benefits. However, with increasing congestion, the HOV transitway user demand will increase, and current facility designs can serve future demands.

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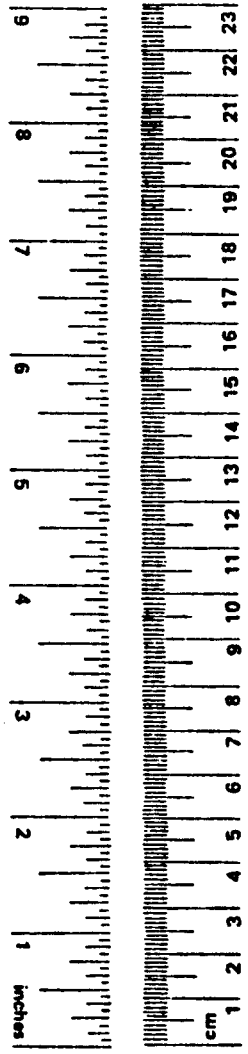
Form DOT F 1700.7 (8-69)

METRIC CONVERSION FACTORS

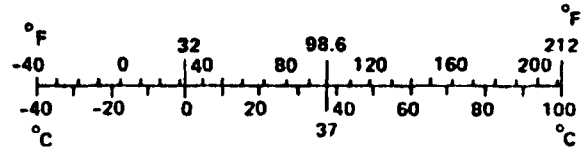
Approximate Conversions to Metric Measures

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



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



* 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.

OFF-PEAK USE OF THE HOUSTON TRANSITWAY SYSTEM

by

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Research Engineer

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Research Report 484-5

An Evaluation of the Impact of Permitting Carpools
to Use the Katy Transitway
Research Study Number 2-10-85-484

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

Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843

March 1987

ABSTRACT

The Houston metropolitan area is currently implementing one of the most extensive high-occupancy vehicle (HOV) priority treatment networks in the nation. The definitive function of these transitway facilities is to provide movement of large volumes of passengers in as few vehicles as possible to high density employment centers during peak periods at a high level of service (minimal delay). This objective can only be achieved and maintained by exercising control over the number of vehicle users for a given time period. While this control is critically important during peak time periods, as mainlane congestion increases in extended magnitude, it also becomes important when considering transitway use for purposes during the off-peak period.

The intent of this study was to identify and evaluate possible off-peak uses of the Houston transitway system by vehicles other than authorized HOV's. Based upon the information available at the time of this report and the analyses conducted herein, it is recommended that off-peak utilization of transitways be continued for high-occupancy vehicles only--transit buses, vans, and carpools meeting minimum occupancy requirements. It is recognized that during off-peak periods, the cost of operation currently exceeds any delay savings or other benefits. However, with increasing congestion, the HOV transitway user demand will increase, and current facility designs can serve future demands.

SUMMARY

The Houston Metropolitan area is currently implementing one of the most extensive high-occupancy vehicle (HOV) priority treatment networks in the nation. Over 40 miles of transitways are currently under construction with another 23 miles in the final planning and design stages. The ultimate commitment to transitways may result in over 100 miles of these facilities in operation with a total capital cost in excess of $1 billion.

The "typical" Houston transitway, is located in the median of a freeway, is one-lane reversible, is approximately 20-feet in width, and is separated from the mixed-flow traffic by concrete median barriers. Portions of transitways on I-10W (Katy) and I-45N (North) in Houston are currently operational on weekdays for use by HOVs for 3 to 3 1/2 hours per peak period. The transitways are closed during all other time periods.

Because of the public's perception that the Katy Transitway was underutilized, a proposal was made to use the transitways for purposes other than peak period commuter travel only. The objectives of this study were to identify and evaluate possible off-peak uses of the Houston transitway system by vehicles other than those HOV's currently authorized.

A review of other transitway projects revealed only two facilities which are in general, physically and operationally comparable to the Houston transitways: the Shirley Highway HOV lanes, and the El Monte Busway. Both facilities operate 24 hours a day with buses, vanpools, and carpools allowed to use the facilities during peak periods. The Shirley Highway facility is open to non-HOV traffic during off-peak periods.

Potential non-HOV user groups and alternative operating strategies examined included:

1) Allow trucks to use the transitways during off-peak periods;
2) Allow taxis to use the transitways during peak and off-peak periods;
3) Allow emergency vehicles to use the transitways on an as-needed basis;

4) Allow maintenance vehicles to use the transitways;
5) Open the transitways to the general traffic during off-peak periods;
6) Lower carpool vehicle occupancy requirements during portions of the peak-period and during off-peak periods;
7) Use transitways to by-pass incidents and/or maintenance and construction sites.

Current estimates of total off-peak user demand, as given in Table S-1, indicate that all possible freeway corridors would provide the capacity necessary with a single lane transitway. However, single lane capacity would be exceeded under normal growth projections if open access is allowed to all passenger vehicles or any combination of other possible off-peak users (2+ carpools, trucks, taxis, etc.)

Table S-1. Off-Peak Transitway Traffic Market Estimates (VPH)*

Freeway	Passenger Cars			Other	
Corridor	All	2+	3+	Trucks	Taxis
I-45N	850	170	42	390	13
I-10W	880	175	44	375	5
US 59S	1050	210	52	230	5
I-45S	665	135	34	310	10

*See Table 12 for tabular development methodology.

Estimated potential demand for truck use of transitways during the off-peak is significant in selected freeway corridors. Exclusive truck utilization of transitways during off-peak periods does provide a means of segregation of these vehicles from the normal mix of freeway traffic. However, it is highly questionable as to the actual portion of the truck population that would use the transitway in the off-peak due to minimal or no travel time savings, controlled access to direct non-truck destinations, restricted or prohibitive geometrics, and high exposure to speed enforcement. From a safety standpoint, it might be speculated that an exclusive, controlled truck lane would decrease off-peak truck accidents. However, if trucks are allowed to use the transitway in concert with other types of vehicles (buses, vans, carpools, taxis), the traffic mix would be little

different than on the freeway mainlanes. Also current single lane transitway operation would force closure under a truck breakdown on the facility.

Experience with peak-period authorization of taxis of the North Freeway (I-45N) has shown little taxi demand. Off-peak utilization of transitways by taxis would be expected to be even less. This potential user population seems to be insignificant; however, with a continued 2+ carpool definition, taxis with passengers could access transitways without a special user group qualification.

Operational experience on the Katy Transitway during the 90-day demonstration project has exhibited off-peak 2+ unauthorized demands approximately 30% less than estimated as a potential user market. This lower demand is due, in part, to delay associated with the existing terminal connections and non-congestion, free flow level-of-service on the adjacent freeway mainlanes during the off-peak time periods. Carpool demand on this particular facility would be expected to increase as the transitway is extended or if the terminal connections are modified to accommodate freeway access in an improved manner. Carpool utilization in off-peak time periods would also be expected to increase on this facility and any others as off-peak congestion is more demonstrative and prevalent under normal operations or special circumstances (construction, maintenance, special events, etc.).

A summary of study conclusions is as follows:

- During off-peak periods, the transitways currently have--and probably always will have--unused capacity. The data indicate that the incentives--trip time savings and trip time reliability--which need to exist to encourage high levels of transitway usage simply do not exist in the off-peak and, given the extent of freeway expansion currently committed, are not likely to exist to a meaningful extent in the near future.

- Since virtually no benefits are provided by using the transitway in the off-peak, demand to use the facility is likely to be low regardless of what groups of vehicles are eligible to use the

transitway. It is highly unlikely that the resulting transitway volumes will make the transitway appear "utilized" in the off-peak.

- Off-peak utilization by groups other than HOV may result in incidents occurring in the transitway during the off-peak that have not been cleared before the peak begins. This is common with incidents involving large trucks. This would adversely impact the reliability the transitway must provide during the peak period in order to accomplish its objective.

- Off-peak utilization by non HOV vehicles is likely to increase operating and enforcement costs without contributing to the principal objective of the transitways.

- A series of design and operation issues exist regarding off-peak utilization by non HOV vehicles. While no one issue by itself absolutely precludes such utilization, the combined impact of these concerns argues strongly against such usage. Signing as to when the transitway can be used at what times, and to what destinations, required to inform infrequent users of the freeway as to their eligibility/desire to use the transitway would be particularly problematical.

- The Katy Freeway experience suggests that the transitways should be left open for longer periods of operation. Carpools with 2+ occupants appears to be an appropriate user group definition for this off-peak period.

This study, based upon available information and the analyses conducted herein, recommends that off-peak utilization of transitways be continued for high-occupancy vehicles only--transit buses, vans and carpools meeting minimum occupancy requirements. It is recognized that the costs of operation currently exceed any delay savings or other benefits. However, with ever increasing congestion, the HOV transitway user demand will increase and current facility designs can serve future demands, both physically and operationally.

IMPLEMENTATION STATEMENT

Since there is relatively little experience with operating exclusive, reversible high-occupancy vehicle lanes, many of the operating procedures and approaches to be used in Houston will be developed through experience. A key operating issue involves the type of vehicles that will be allowed to utilize the special lanes.

This study was specifically undertaken to assist the Metropolitan Transit Authority and State Department of Highways and Public Transportation in the implementation and operation of the authorized vehicle lanes. The study examines the feasibility of off-peak use of the Houston Transitway System.

DISCLAIMER

ACKNOWLEDGEMENTS

Appreciation is expressed by the authors to Mr. Chuck E. Fuhs for his contribution and technical assistance in the preparation of this study report.

OFF-PEAK USE OF HOUSTON TRANSITWAY SYSTEM

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1. INTRODUCTION

1.1 BACKGROUND

1.1.1 Houston Transitway System

The Houston Metropolitan area is currently implementing one of the most extensive high-occupancy vehicle (HOV) priority treatment networks in the nation. Over 40 miles of transitways are currently under construction with another 23 miles in the final planning and design stages. The ultimate commitment to transitways may result in over 100 miles of these facilities in operation with a total capital cost in excess of $1 billion (1). The currently committed transitway system (Figure 1) will cost approximately $500 million.

While some of the transitways will be two-lane, two-direction facilities, the "typical" Houston transitway is reserved for exclusive use by authorized high-occupancy vehicles, is located in the median of a freeway, is one-lane reversible, is approximately 20-feet in width, and is separated from the mixed-flow traffic by concrete median barriers (1). A typical section is shown in Figure 2.

The first phase of the transitway on the Katy Freeway (I-10) in Houston became operational in October 1984. Approximately 6.5 miles of transitway was completed between West Belt and the West Loop (I-610). The first phase of the I-45 North transitway became operational in January 1985. The North transitway currently operates in a reduced construction width between downtown Houston and Shepherd Drive (9.6 miles).

1.1.2 Authorized Vehicle Concept

Based on experience gained from the operation of the I-45N Contraflow Lane which preceded the I-45N Transitway, only vehicles authorized by the Metropolitan Transit Authority (METRO) and the State Department of Highways and Public Transportation (SDHPT) were allowed to use the priority lanes.

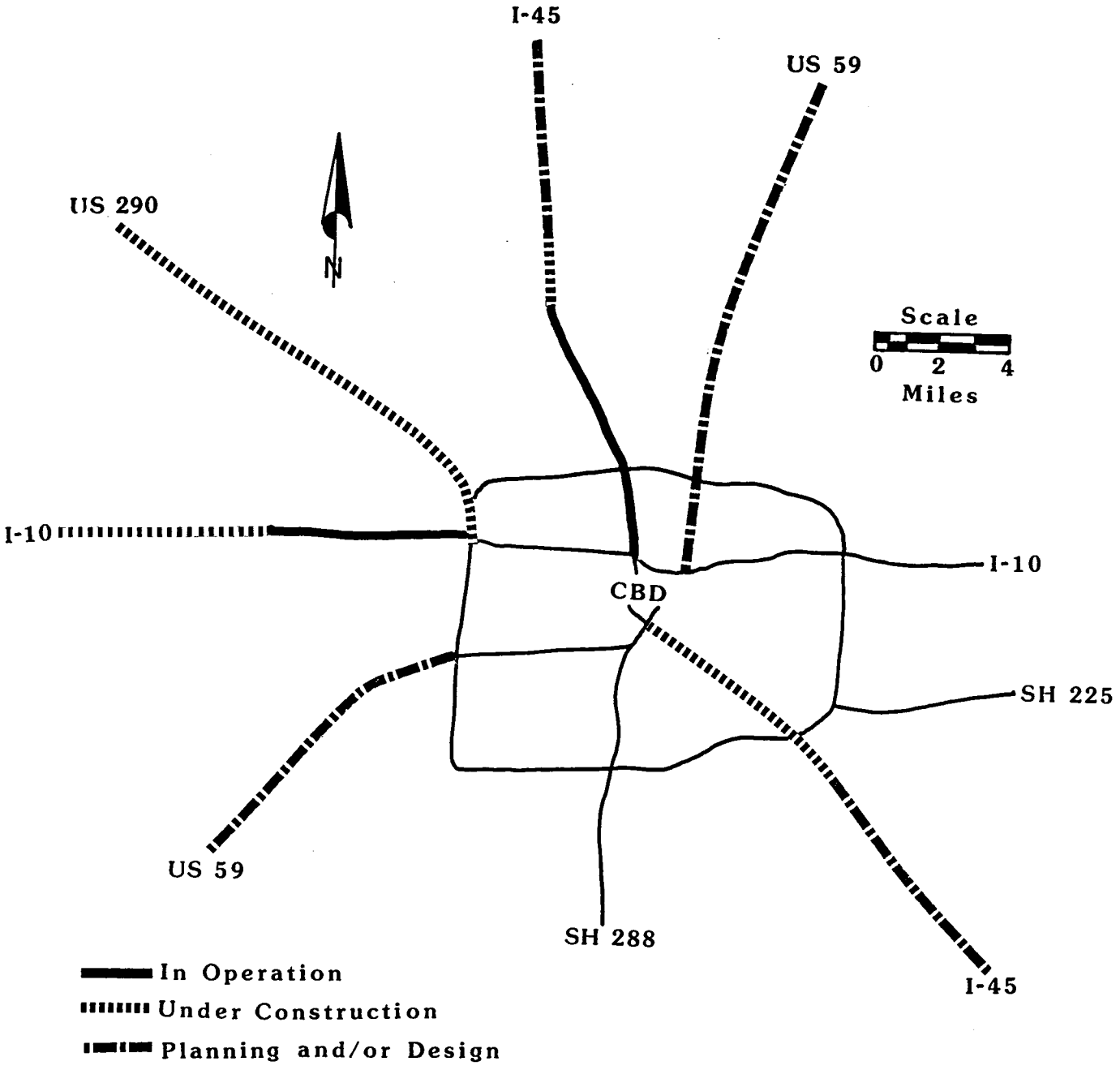
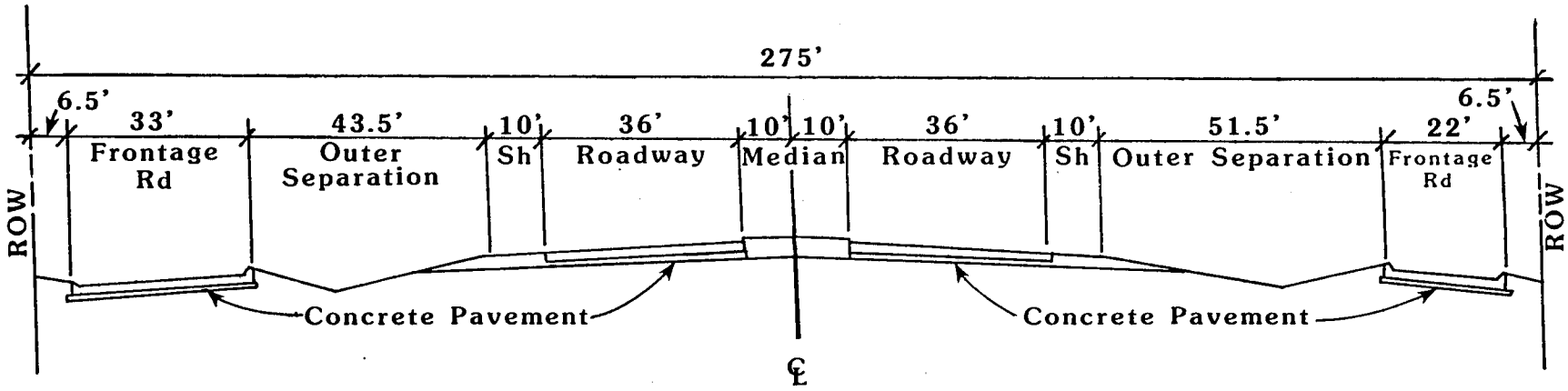
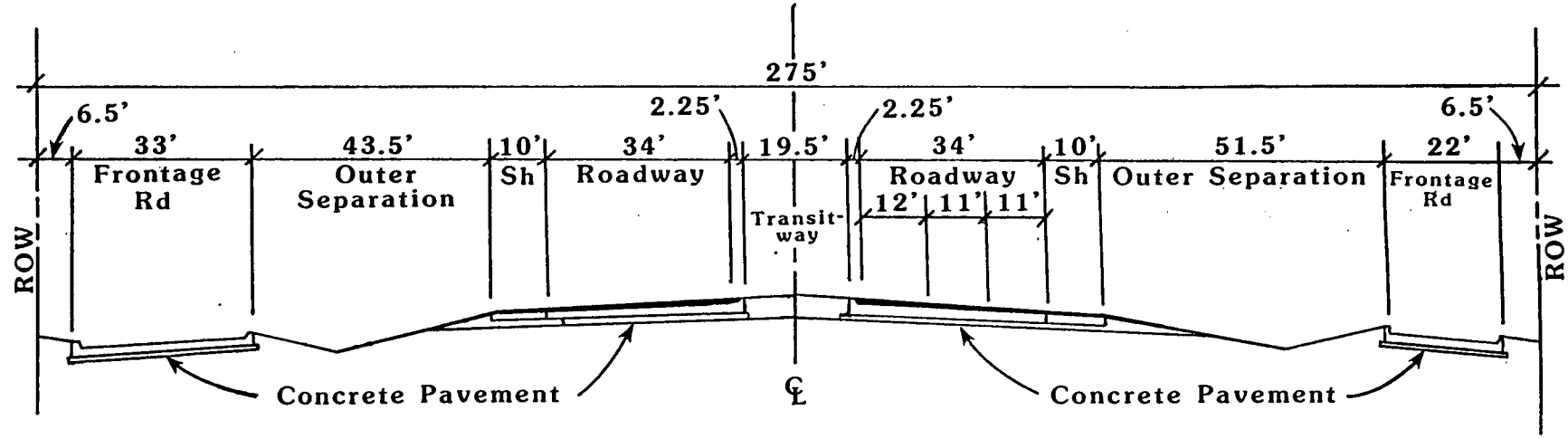


Figure 1. Committed Transitway System, Houston



Typical Section Before Transitway Construction



Typical Section After Transitway Construction

Figure 2. Typical Sections, Before and After Transitway Construction

Because of the public's perception that the transitways are underutilized, a number of proposals have been made to change transitway operating procedures. These proposals include:

1) Lowering the occupancy requirements of HOVs, and/or changing the definitions of authorized vehicles;

2) Increasing the time periods the transitways are available for use by HOVs; and

3) Using the transitways for purposes other than peak period commuter travel.

This study examines the third proposal by identifying and evaluating possible off-peak uses of the Houston transitway system by vehicles other than authorized HOVs. Specific study objectives are:

1) Identify policy and traffic management strategy issues affecting potential off-peak uses of the Houston transitway system;

2) Identify potential off-peak transitway user groups;

3) Estimate the potential demands for off-peak use of the transitway system; and

4) Evaluate the impacts of off-peak use of the transitway system in terms of design, safety, operation, and system management issues.

1.3 REVIEW OF RELATED EXPERIENCES

Other transitways in the U.S. and Canada were reviewed in terms of their off-peak operating policies (2). In addition to the Katy and North Transitways in Houston, the following exclusive, separated transitways were identified:

1) Shirley Highway HOV Lanes (Washington, DC);

2) I-66 HOV Facility (Washington, DC);

3) El Monte Busway (Los Angeles);

4) East Busway (Pittsburgh);

5) South Busway (Pittsburgh);

6) West Busway (Ottawa, Canada); and

7) East Busway (Ottawa, Canada).

The Pittsburgh and Ottawa transitways are two-lane two-direction roadways constructed in rights-of-way independent from any facility for general traffic. With the exception of the South Busway in Pittsburgh, which shares portions of the right-of-way with a trolley line, these facilities are bus-only facilities. The Pittsburgh and Ottawa transitways operate 24 hours a day. The Pittsburgh and Ottawa systems are neither physically nor operationally comparable to the Houston transitway system.

The I-66 HOV facility is a four-lane, exclusive, peak-direction HOV facility during peak periods (7-9am, 4-6pm). In the peak direction during peak periods, the facility can be used by buses, vanpools, and carpools of three or more persons. Vehicles travelling to and from Dulles Airport are also allowed on the facility during the peak periods in the peak direction. At all other times, the freeway is open to regular traffic, except heavy trucks, which are excluded from the facility at all times.

The I-66 HOV facility is unique in that it is a 10-mile section of an entire freeway which has been reserved for use by HOVs in the peak direction during peak periods. Hence, the facility is neither physically nor operational comparable to the Houston transitways.

The Shirley Highway HOV facility is a 12-mile, two-lane, reversible roadway in the median of I-395, between Springfield, Virginia and Washington, DC. The HOV lanes are open during weekdays in the inbound direction (towards Washington) between 6am - 9am, and in the outbound direction between 3:30pm - 6:00pm. Eligible users during peak periods include buses, vanpools, and 4-or-more passenger carpools. The HOV facility is open to all traffic outside the peak periods.

The El Monte Busway is an 11-mile, two-way, two-lane (one in each direction), exclusive HOV facility in the San Bernardino Freeway median. It extends west from the El Monte Bus Station to the Los Angeles CBD. It operates 24 hours a day, with buses, vanpools, and carpools of three or more allowed to use the facility.

The review of other transitway projects revealed only two facilities which are physically and operationally comparable to the Houston transitways: the Shirley Highway HOV lanes, and the El Monte Busway. Both facilities operate 24 hours a day with buses, vanpools, and carpools allowed to use the facilities during peak periods. Of these two facilities, only the Shirley Highway facility is open to non-HOV traffic during off-peak periods.

2. OFF-PEAK TRAVEL MARKET

2.1 GENERAL

Because of the perception that Houston transitways are not being fully utilized, a number of proposals have been made to change transitway operating procedures and/or eligible user groups. Potential non-HOV user groups and alternative operating strategies which have been suggested include:

1) Allow trucks to use the transitways during off-peak periods;
2) Allow taxis to use the transitways during peak and off-peak periods;
3) Allow emergency vehicles to use the transitways on an as-needed basis;
4) Allow maintenance vehicles to use the transitways;
5) Open the transitways to the general traffic during off-peak periods;
6) Lower carpool vehicle occupancy requirements during portions of the peak-period and during off-peak periods; and
7) Use transitways to by-pass incidents and/or maintenance and construction sites.

Use of the transitways by non-HOVs and during non-peak periods poses a number of difficulties which must be addressed if the operational integrity and safety of the transitways are to be maintained. The initial step in assessing off-peak use of the Houston transitway system was to develop a general profile of the potential off-peak travel market. This section of the report presents an overview of off-peak traffic and travel characteristics in each of the six freeway corridors in the currently proposed Houston transitway system (Figure 1).

The off-peak travel market is described in terms of traffic volumes, travel times, travel patterns, and accident experiences. The information is drawn from a number of sources and may not always be consistent from one corridor to another in terms of level of detail and/or time frames. The

information does, however, provide an indication of the general nature and magnitude of the off-peak travel market.

2.2 TRAFFIC VOLUMES

Table 1 summarizes weekday daily vehicle miles of travel on Houston freeways for the period 1980-85. The general increase in vehicle miles traveled on Houston freeways is indicative of increased travel demands on the Houston freeway system in recent years.

Table 1. Estimated Weekday Daily Vehicle Miles of Travel (DVMT) for Houston Freeways, 1980-85

Freeway	Segment[a] Length (Mi.)	Daily Vehicle Miles of Travel[b] (Millions)					
		1980	1981	1982	1983	1984	1985
US-59N	18.6	1.704	1.900	1.625	2.073	1.986	2.053
I-45N	14.1	1.803	1.917	2.055	2.082	2.167	2.345
US 290	13.4	0.669	0.728	0.844	1.017	1.161	1.250
I-10W	11.5	1.224	1.370	1.500	1.704	1.736	1.830
US-59S	9.0	1.150	1.264	1.343	1.327	1.326	1.476
I-45S	19.2	2.245	2.440	2.541	2.547	2.676	2.819

[a] Segment descriptions: US-59N, FM 1960 to I-45S; I-45N, Rankin Road to I-10E; US 290, FM 1960 to I-610W; I-10W, SH 6 to I-610W; US-59S, Ft. Bend County to I-610W; I-45S, FM 2351 to I-10E.
[b] Estimated from average annual weekday traffic X segment length.

Source: Texas State Department of Highways and Public Transportation.

Tables 2 and 3 summarize traffic volumes at selected locations on four Houston freeways. Table 2 shows traffic volumes by time period and direction of travel. Table 3 summarizes off-peak period traffic volumes for truck and non-truck traffic on four Houston freeways. As shown in Table 2, off-peak traffic typically accounts for roughly one-third of the total daily traffic on each of the four freeways. Additionally, trucks account for 4-10% of the off-peak traffic volumes (Table 3).

Table 4 summarizes the limited data available on taxicab traffic volumes in the I-45N and I-10W corridors.

2.3 TRAVEL TIMES AND SPEEDS

Average off-peak travel times and speeds on those freeway segments in the proposed transitway system are shown in Table 5. With the exception of portions of US-59S, off-peak speeds indicate that an acceptable level-of-service is currently being provided to off-peak period traffic.

2.4 TRAVEL PATTERNS

In assessing the potential demand for off-peak use of the transitway system, it is important to develop a general profile of corridor travel patterns. Given the line-haul nature of the proposed transitways, the issue of average trip length is of particular significance in defining the potential off-peak travel market. The typical Houston transitway is designed in such a way that users of the facility are collected at the ends of the transitway and transported to their destinations with only a limited number of intermediate exit opportunities. Hence, it is reasonable to assume that the potential off-peak travel market could be characterized in terms of trip lengths. Specifically, the travel market should consist of those individuals with an origin upstream from the entrance to the transitway and a destination at, or accessible from, the downstream end of the transitway.

Tables 6 and 7 summarize the limited data available on off-peak period trip lengths. The tables summarize entrance ramp traffic volumes with exits at I-610 or beyond for the Southwest (US-59S) and Katy (1-10W) Freeways. The

Table 2. Traffic Volume by Period and Direction, Selected Houston Freeways, 1983.

Time Period	I-45N			I-45S			US-59S			I-10W		
	In-Bound	Out-Bound	Total	In-Bound	Out-Bound	Total	In-Bound	Out-Bound	Total	In-Bound	Out-Bound	Total
6am - 9am	14907 (62) (21)	9250 (38) (14)	24157 (100) (17)	13897 (60) (23)	9283 (40) (16)	23180 (100) (20)	18236 (57) (19)	13936 (43) (16)	32172 (100) (18)	14540 (53) (20)	12842 (47) (17)	27382 (100) (19)
9am - 3pm	27613 (54) (38)	23566 (46) (35)	51179 (100) (37)	20592 (52) (34)	19324 (48) (34)	39916 (100) (34)	33078 (52) (35)	29958 (48) (34)	63036 (100) (34)	26762 (51) (37)	26154 (49) (35)	52916 (100) (36)
3pm - 6pm	8353 (42) (12)	11763 (58) (18)	20116 (100) (15)	10269 (54) (17)	8902 (46) (16)	19171 (100) (16)	20024 (52) (21)	18712 (48) (21)	38736 (100) (21)	12701 (49) (18)	13166 (51) (18)	25867 (100) (18)
6pm - 6am	21041 (49) (29)	21950 (51) (33)	42991 (100) (31)	15515 (45) (26)	18820 (55) (33)	34335 (100) (30)	23863 (49) (25)	25138 (51) (29)	49001 (100) (27)	17824 (45) (25)	21535 (55) (30)	39359 (100) (27)
Total	71914 (52) (100)	66529 (48) (100)	138443 (100) (100)	60273 (52) (100)	56329 (48) (100)	116602 (100) (100)	95201 (52) (100)	87744 (48) (100)	182945 (100) (100)	71827 (49) (100)	73697 (51) (100)	145524 (100) (100)

Key:

XXXXX Traffic Volume
(XX) Row Percent (directonal split)
(XX) Column Percent (distribution by time period)

Note: Sample locations are: I-45N at Little York; I-45S at Monroe; US-59S between Kirby and Shepherd; I-10W at Bunker Hill.

Source: TTI Surveys June 1983.

Table 3. Off-Peak[a] Truck and Non-Truck Traffic, Selected Houston Freeways

Freeway, Location and Direction	Off-Peak Traffic Volume[a] Trucks[b]	Non-Trucks[c]	Total		Percent Trucks
I-10W at Bunker Hill					
Eastbound	2272	24490	26762	(37.2)[d]	8.5
Westbound	2221	23933	26154	(35.5)	8.5
US-59S Between Kirby &Shepherd					
Southbound	1416	28542	29958	(34.1)	4.7
Northbound	1321	31757	33078	(34.8)	4.0
I-45S at Monroe					
Southbound	1812	17512	19324	(34.4)	9.4
Northbound	1944	18648	20592	(34.2)	9.4
I-45N at Little York					
Southbound	2388	25225	27613	(38.4)	8.7
Northbound	2302	21264	23566	(35.4)	9.8

[a] Off-peak period = 9:00am - 3:00pm.
[b] Vehicle with 3 or more axles, excluding buses.
[c] Passenger cars, pickups, vans, motorcycles, and buses.
[d] (XX.X) denotes percent of 24-hour volume.

Source: TTI Surveys June 1983.

tabulations of traffic destined for I-610 or beyond are intended to provide an estimate of traffic which might use a transitway if permitted to do so. The tabulations suggest that approximately 25 percent of all of the traffic entering the respective freeways seven or more miles from I-610 (the approximate length of the transitways proposed for the two corridors) has destinations at I-610 or beyond.

2.5 ACCIDENTS

Table 8 presents a general overview of traffic accident experiences on the Houston freeway system. Table 8, which summarizes freeway accidents by time period and direction, suggests that accident rates are generally highest during peak periods. Two noteworthy exceptions to this trend are I-10W and

Table 4. I-45 North Freeway and I-10 Katy Freeway Vehicle Classifications

Freeway, Direction and Time	Vehicle Classification									
	Passenger Vehicles		Heavy Trucks		Taxi Cabs		Motorcycles		Total Vehicles
	No.	%	No.	%	No.	%	No.	%	No.
I-45N									
SB (6:30-9:30 AM)	13280	96.4%	434	3.2%	32	0.2%	23	0.2%	13769
SB (10:00-11:00AM)	3289	93.8%	198	5.6%	12	0.3%	10	0.3%	3509
NB (2:00-3:00 PM)	4407	95.4%	173	3.7%	29	0.3%	12	0.3%	4621
NB (4:00-7:00 PM)	12228	97.1%	273	2.2%	71	0.6%	17	0.1%	12589
Freeway, Direction and Time	Vehicle Classification									
	Passenger Vehicles		Heavy Trucks		Taxi Cabs		Motorcycles		Total Vehicles
	No.	%	No.	%	No.	%	No.	%	No.
I-10W									
EB (6:30-9:15 AM)	12895	97.5%	310	2.5%	13	0.1%	15	0.1%	13233
WB (3:30-6:45 PM)	13073	97.9%	230	1.8%	16	0.1%	31	0.2%	13350

Source: TTI Surveys, March-July, 1986.

US-59S, where the off-peak period accident rates are comparable to the AM peak period accident rates. Also note in Table 8 that the PM peak period accident rates are consistently higher than the AM peak period accidents.

Tables 9 and 10 give more details concerning off-peak period accidents. Table 9 shows the number and type of vehicles involved in Houston freeway accidents for off-peak periods.

Of particular importance in terms of the objectives of this study is the accident experience of the individual vehicles which make up the traffic

Table 5. Off-Peak[a] Travel Times and Speeds on Houston Freeways

Freeway	Segment Description	Length (Miles)	Average Time (min) and Speed (mph)	
			Inbound	Outbound
US-59N	Between FM 1960 & I-610	14.5	(16.5)[b] 53[c]	(16.2) 54
	Between I-610 & I-10	2.8	(3.0) 56	(3.0) 56
I-45N	Between FM 1960 & I-610	15.0	(15.2) 59	(16.6) 54
	Between I-610 & I-10	2.9	(3.2) 54	(2.9) 60
US-290	Between FM 1960 & I-610	13.1	(15.0) 52	(14.3) 55
I-10W	Between Hwy 6 & I-610	11.6	(12.3) 57	(11.6) 60
US-59S	Between W. Belt & I-610	7.9	(14.2) 33	(8.5) 56
I-45S	Between FM 1959 & I-610	10.2	(10.4) 59	(10.1) 61
	Between I-610 & I-10	8.1	(9.5) 51	(10.2) 48

[a] Off-peak period = 9:30am - 3:00pm.
[b] (XX.X) = Average travel time (minutes).
[c] XX = Average speed (mph).

Source: H-GRTS Travel Time and Speed Surveys, July 1985.

Table 6. Off-Peak[a] Entrance Ramp Traffic Exiting I-610 or Farther North, Southwest Freeway

Entrance Ramp	Distance to I-610 (Miles)	Ramp Volume	Exiting I-610 or Farther North			
			Volume	Cum. Vol.	Percent	Cum. Percent
Airport	9.6	1385	328	-	23.7	-
W. Bellfort	8.7	5916	1901	2237	32.3	30.6
Bissonnet	6.5	5006	1899	4136	37.9	33.6
Beechnut	5.1	5617	2830	6966	50.4	38.9
Fondren	4.3	3232	1738	8704	53.8	41.1
Bellaire	3.8	5057	3359	12063	66.4	46.0
Hillcroft	2.6	7049	4546	16609	64.5	49.9
Westpark	2.0	4842	3536	20145	73.0	52.9
Chimney Rock	1.0	6244	4292	24437	68.7	55.1

[a] Off-peak period = 9:00am - 3:30pm.

Source: TTI O-D Survey, US-59S, July 1981.

Table 7. Off-Peak[a] Entrance Ramp Traffic Exiting I-610 or Farther East, Katy Freeway

Entrance Ramp	Distance to I-610 (Miles)	Ramp Volume	Exiting I-610 or Farther North			
			Volume	Cum. Vol.	Percent	Cum. Percent
Katy	20.9	1982	240	-	12.1	-
Mason Rd.	18.0	2487	404	644	16.2	14.1
Fry Rd.	16.0	2307	361	1005	15.7	14.8
Barker/Cypress	14.2	1887	404	1409	21.4	16.3
Addicks/SH6	15.6	5860	1855	3264	31.7	22.5
Eldridge	9.9	1362	386	3650	28.3	23.0
Dairy Ashford	9.3	4320	1365	5015	31.6	24.8
Kirkwood	8.3	3960	1334	6349	33.7	26.3
Wilcrest	7.4	4640	2020	8369	43.5	29.1
West Belt	6.6	5310	2760	11129	52.0	32.6
Gessner	5.5	4790	2749	13878	57.4	35.7
Bunker Hill	4.8	3040	1639	15517	53.9	37.0
Blalock	4.1	3456	1904	17421	55.1	38.4

[a] Off-peak period = 9:00am - 3:30pm.

Source: TTI O-D Survey, I-10W, January 1982.

stream. As shown in Table 9, vehicles in the "truck" classification constituted about 4-8% of the vehicles involved in accidents. This is roughly comparable to their 4-10% contribution to the total off-peak traffic volume (Table 3).

Table 10, which summarizes accident severity by vehicle type, suggests that trucks are involved in less than 5% of the incapacitating and fatal accidents.

2.6 DISABLED VEHICLES

A safety consideration related to traffic accidents is the problem posed by vehicle breakdowns on transitways. Given the "enclosed" nature of the transitways, the presence of a disabled vehicle in the transitway is a special concern, particularly if the disabled vehicle were to be one that is not familiar with the facility and the appropriate remedial action. Table 11

Table 8. Houston Freeway Accidents by Time Period and Direction, 1985

Freeway[a] and Direction	Accidents by Time Period[b]									
	A.M. Peak		Off-Peak		P.M. Peak		Other		Total	
	No.	Rate[c]	No.	Rate	No.	Rate	No.	Rate	No.	Rate
I-45N										
Inbound	100	1.62	72	0.62	161	4.36	158	1.77	491	1.61
Outbound	40	1.06	118	1.18	119	2.33	188	2.03	465	1.65
Total	140	1.41	190	0.88	280	3.18	346	1.90	956	1.63
I-10W										
Inbound	63	1.37	105	1.25	91	2.26	74	1.33	333	1.49
Outbound	24	0.59	83	1.03	67	1.60	75	1.10	249	1.07
Total	87	1.00	188	1.14	158	1.92	149	1.21	582	1.27
US 59S										
Inbound	65	1.72	65	1.00	147	3.65	84	1.72	361	1.88
Outbound	15	0.52	85	1.41	84	2.26	118	2.32	302	1.71
Total	80	1.20	150	1.20	231	2.98	202	2.03	663	1.80
I-45S										
Inbound	121	1.43	94	0.75	131	2.15	127	1.33	473	1.29
Outbound	78	1.38	134	1.17	132	2.54	160	1.38	504	1.49
Total	199	1.41	228	0.95	263	2.33	287	1.36	977	1.39

[a] Segment descriptions: I-45N, Rankin Road to I-10E; I-10W, SH 6 to I-610W; US-59S, Ft. Bend County to I-610W; I-45S, FM 2351 to I-10E.

[b] Time periods defined as follows: a.m. peak = 6:00a.m.-9:00a.m.; off-peak = 9:00a.m.-3:00p.m.; p.m. peak = 3:00p.m.-6:00p.m.; other = 6:00p.m.-6:00a.m.

[c] Accidents per million annual weekday vehicle miles of travel. The DVMT estimates given in Table 1 were converted to an annual basis by multiplying by 250 weekdays/year. The "distribution by time period" and "directional split" factors in Table 2 were used to factor the daily VMT estimates by time period and direction.

summarizes transitway vehicle breakdown data from the North and Katy transitways. Over a 33 month period, there were 186 disabled vehicles on the North transitway, or 5.6 per month. Over a 23 month period, there were 135 disabled vehicles on the Katy transitway, or 5.9 per month.

2.7 SUMMARY

Given the line-haul nature of Houston's transitway facilities, the majority of potential users are likely to be of a thru-traffic nature.

Table 9. Number and Type of Vehicles Involved in Houston Freeway Accidents, Off-Peak Periods[a] (1985).

Veh. Type[b]	IH-45N	IH-45S	US 59S	US 59N	I-10W	US 290	Total[c]
Passenger Car	309	279	289	224	179	74	1354
	(57.0%)[d]	(56.7%)	(64.5%)	(53.5%)	(57.6%)	(47.1%)	(57.2%)
Pick-Up	99	100	72	76	50	28	425
	(18.2)	(20.3)	(16.1)	(18.2)	(16.1)	(17.8)	(17.8)
Tractor & Semi	47	42	28	48	20	29	214
	(8.6)	(8.6)	(6.3)	(11.5)	(6.4)	(18.5)	(9.0)
Truck	36	21	22	26	20	12	137
	(6.6)	(4.3)	(4.9)	(6.2)	(6.4)	(7.7)	(5.8)
Van	26	31	21	26	22	5	131
	(4.8)	(6.3)	(4.7)	(6.2)	(7.1)	(3.2)	(5.5)
Other	14	9	13	10	9	6	61
	(2.6)	(1.8)	(2.9)	(2.4)	(2.9)	(3.8)	(2.6)
Wrecker	2	0	2	4	6	0	13
	(0.4)	(0.0)	(0.4)	(1.0)	(1.6)	(0.0)	(0.6)
Motorcycle/Moped	2	2	1	1	3	0	9
	(0.4)	(0.4)	(0.2)	(0.2)	(1.0)	(0.0)	(0.4)
Bus	2	1	0	1	2	2	8
	(0.4)	(0.2)	(0.0)	(0.2)	(0.6)	(1.3)	(0.3)
Truck & Trailer	2	3	0	0	0	1	6
	(0.4)	(0.6)	(0.0)	(0.0)	(0.0)	(0.6)	(0.3)
Police Vehicle	1	2	0	1	0	0	4
	(0.2)	(0.4)	(0.0)	(0.2)	(0.0)	(0.0)	(0.2)
School Bus	0	0	0	1	1	0	2
	(0.0)	(0.0)	(0.0)	(0.2)	(0.3)	(0.0)	(0.1)
Ambulance	0	1	0	1	0	0	2
	(0.0)	(0.2)	(0.0)	(0.2)	(0.0)	(0.0)	(0.1)
Fire Vehicle	2	0	0	0	0	0	2
	(0.4)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.1)
Other Machinery	0	1	0	0	0	0	1
	(0.0)	(0.2)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Total	542	492	448	419	311	157	2369
	(100)	(100)	(100)	(100)	(100)	(100)	(100)

[a] Off-peak period = 9:00am - 3:00pm.

[b] "Tractor and semi" and "truck" classifications include vehicles with 3 or more axles.

[c] Totals do not include approximately 5,000 vehicles of an "unspecified" type.

[d] (XX.X) denotes column percent.

Note: Segment descriptions US-59N, FM 1960 to I-45S; I-45N, Rankin Road to I-10E; US 290, FM 1960 to I-610W; I-10W, SH 6 to I-610W; US-59S, Ft. Bend County to I-610W; I-45S, FM 2351 to I-10E.

Source: Texas Department of Public Safety.

Table 10. Number of Trucks and Non-Trucks Involved in Houston Freeway Accidents by Severity, Off-Peak Period[a] (1985)

Accident Severity	US-59N			I-45N			US-290			I-10W			US-59S			I-45S		
	Non-Truck	Truck[b]	Total	Non-Truck	Truck	Total	Non-Truck	Truck	Total	Non-Truck	Truck	Total	Non-Truck	Truck	Total	Non-Truck	Truck	Total
Non-Injury	766	50	816	1174	68	1242	340	32	372	627	33	660	999	39	1038	1024	44	1068
	(93.9)	(6.1)	(100)	(94.5)	(5.5)	(100)	(91.4)	(8.6)	(100)	(95.0)	(5.0)	(100)	(96.2)	(3.8)	(100)	(95.9)	(4.1)	(100)
	(62.4)	(67.6)	(62.7)	(73.5)	(81.9)	(73.8)	(75.4)	(78.1)	(75.6)	(69.1)	(82.5)	(69.6)	(74.7)	(78.0)	(74.9)	(67.6)	(69.8)	(67.7)
Possible Injury	284	16	300	271	11	282	66	6	72	161	1	162	199	5	204	258	12	270
	(94.7)	(5.3)	(100)	(96.1)	(3.9)	(100)	(91.7)	(8.3)	(100)	(99.4)	(0.6)	(100)	(97.6)	(2.4)	(100)	(95.6)	(4.4)	(100)
	(23.1)	(21.6)	(23.0)	(17.0)	(13.3)	(16.8)	(14.6)	(14.6)	(14.6)	(17.7)	(2.5)	(17.1)	(14.9)	(10.0)	(14.7)	(17.0)	(19.1)	(17.1)
Nonincapacitating	121	5	126	128	4	132	23	1	24	102	6	108	120	6	126	180	6	186
	(96.0)	(4.0)	(100)	(97.0)	(3.0)	(100)	(95.8)	(4.2)	(100)	(94.4)	(5.6)	(100)	(95.2)	(4.8)	(100)	(96.8)	(3.2)	(100)
	(9.9)	(6.8)	(9.7)	(8.0)	(4.8)	(7.9)	(5.1)	(2.4)	(4.9)	(11.2)	(15.0)	(11.4)	(9.0)	(12.0)	(9.1)	(11.9)	(9.5)	(11.8)
Incapacitating	52	2	54	18	0	18	16	2	18	18	0	18	18	0	18	47	1	48
	(96.3)	(3.7)	(100)	(100)	(0)	(100)	(88.9)	(11.1)	(100)	(100)	(0)	(100)	(100)	(0)	(100)	(97.9)	(2.1)	(100)
	(4.2)	(2.7)	(4.2)	(1.1)	(0)	(1.1)	(3.6)	(4.9)	(3.7)	(2.0)	(0)	(1.9)	(1.4)	(0)	(1.3)	(3.1)	(1.6)	(3.0)
Fatal	5	1	6	6	0	6	6	0	6	0	0	0	0	0	0	6	0	6
	(83.3)	(16.7)	(100)	(100)	(0)	(100)	(100)	(0)	(100)	(0)	(0)	(0)	(0)	(0)	(0)	(100)	(0)	(100)
	(0.4)	(1.4)	(0.4)	(0.4)	(0)	(0.4)	(1.3)	(0)	(1.2)	(0)	(0)	(0)	(0)	(0)	(0)	(0.4)	(0)	(0.4)
Total	1228	74	1302	1597	83	1680	451	41	492	908	40	948	1336	50	1386	1515	63	1578

[a] Off-peak period = 9:00am - 3:00pm.

[b] Truck = Vehicle with 3 or more axles.

Key:
XXX No. Vehicles Involved
(XX.X) Row Percent
(XX.X) Column Percent

Note: Segment descriptions: US-59N, FM 1960 to I-45S; I-45N, Rankin Road to I-10E; US 290, FM 1960 to I-610W; I-10W, SH 6 to I-610W; US-59S, Ft. Bend County to I-610W; I-45S, FM 2351 to I-10E.

Source: Texas Department of Public Safety.

Table 11. Vehicle Breakdown Rates, Katy and North Freeway Transitways

Vehicle Group	Katy Transitway		North Transitway	
	10/29/84-9/3/86[1]	4/1/85-9/3/86[2]	8/11/85-9/3/86[4]	1/84-9/3/86
No. of Disabled Vehicles, Total	65	61	9	186
Buses	39	35	0	114
Vans	7	7	0	72
Carpools	19	19	9	---
No. of Towed Vehicles, Total[3]	22	22	7	47
Buses	8	8	0	36
Vans	1	1	0	11
Carpools	13	13	7	---
Vehicle Miles of Travel (VMT), Total	1,382,770	1,248,620	391,980	6,095,904
Buses	355,470	308,620	19,500	2,137,728
Vans	420,590	333,290	16,800	3,958,176
Carpools	606,710	606,710	355,680	---
VMT/Disabled Vehicle, Total	21,273	20,469	43,553	32,774
VMT/Disabled Bus	9,115	8,818	---	18,752
VMT/Disabled Van	60,084	47,612	---	54,975
VMT/Disabled Carpool	31,932	31,932	39,520	---
VMT/Towed Vehicle, Total[3]	62,853	56,755	55,997	129,700
VMT/Towed Bus	44,433	38,577	---	59,381
VMT/Towed Van	420,590	333,290	---	359,834
VMT/Towed Carpool	46,670	46,670	50,811	---

[1] Operating period from inception of AVL.
[2] Operating period from when carpools allowed onto AVL.
[3] Towed vehicles are a subset of disabled vehicles.
[4] Operating period since unauthorized 2+ carpools allowed onto transitway.

Limited data from the Katy and Southwest Freeway corridors suggests that roughly one-fourth of the traffic entering those freeways near the transitway termini during off-peak periods may be potential transitway users.

Assuming that the majority of trucks traveling Houston freeways in off-peak periods are thru-trucks, there may be a potential transitway truck traffic demand of 200-400 vph, if all those trucks choose to use the transitway.

Other potential user groups, such as taxis, constitute a relatively small percentage of the potential off-peak market. Potential transitway taxi traffic would probably be highest in the North corridor due to the presence of Intercontinental Airport. Limited data from the North and Katy corridors suggest that off-peak taxi volumes are on the order of 10 vph. (See Table 4)

Estimates of the potential off-peak transitway traffic market are presented in Table 12. The estimates given in Table 12 represent the total vehicles that could use the transitway. These estimates would have to be factored by some measure of how many of these vehicles would actually choose to use the transitway. As such, the values given in Table 12 represent a preliminary estimate of maximum possible demand.

In terms of the safety-related impacts associated with off-peak use of the transitways, only a general observation can be made at this time. A key issue which should be considered in evaluating possible off-peak use of the transitway system is the operational impacts of a accident/incident in the transitway. An accident on a transitway near the end of the off-peak period (i.e., near the beginning of the pm peak period operations) could delay, or even pre-empt, initiation of HOV operations.

Table 12. Off-Peak Transitway Traffic Market Estimates

Freeway Corridor	Traffic Market Estimates (VPH)				
	Passenger Cars[a]			Other	
	All	2+	3+	Trucks[b]	Taxis[c]
I-45N	850	170	42	390	13
I-10W	880	175	44	375	5
US 59S	1050	210	52	230	5
I-45S	665	135	34	310	10

[a] Passenger vehicle volumes estimated from Table 2 by assuming 50/50 directional split, a uniform hourly distribution across the six-hour off-peak period, and the following market percentages: 1) All passenger cars = 20% of total volume (source: Tables 6 and 7); 2) 2+ passenger cars = 20% of all passenger cars (source: Katy O-D Survey, TTI January 1982); and 3) 3+ passenger cars = 5% of all passenger cars (source: Katy O-D Survey, TTI, January 1982).

[b] Truck volumes estimated from Table 3 by assuming 50/50 directional split, a uniform hourly distribution across the six-hour off-peak period, and an average percentage of trucks (derived from Table 3).

[c] Estimated from Table 3 by assuming 50/50 directional split, a uniform hourly distribution across the six-hour off-peak period, and the following percentages of Taxis (Table 4): 1) I-45N and, I-45S = 0.3%; and 2) I-10W and US 59S = 0.1%.

3. IMPACTS OF OFF-PEAK USE

3.1 GENERAL

Utility of a transitway in the off-peak period for purposes different than those of the peak period presents some challenging problems. From a design standpoint, the current facilities being constructed and operated reflect compromised design geometrics and are tailored to a specific group of users traveling in relative low volumes. From an operations perspective, reversible operation, access locations, and operations techniques employed may or may not be appropriate or suitable for other potential users.

The purpose of this chapter is to identify impacts which would affect the current transitway design and operation if other users are to be considered eligible. Design and operational considerations which impact off-peak use are discussed in the first sections of this chapter. Management and jurisdictional considerations are then described. Of particular importance in the determination for including any additional user groups are safety impacts, addressed in the fourth section, followed by a brief assessment of benefits and costs.

3.2 DESIGN CONSIDERATIONS

3.2.1 Background

Transitway and exclusive high occupancy vehicle (HOV) lanes implemented elsewhere in the nation were designed, in most cases, with the same standards used for general freeway traffic. These facilities were usually constructed as part of freeway reconstruction programs or retrofitted as either two-way or reversible express lanes. Selected express lane facilities in Washington, DC and Seattle, Washington were initially operated or proposed for all freeway users and were subsequently restricted to HOV traffic, at least during peak hours. As such, the design elements employed and access ramps provided were not tailored to specific users; eligibility for facility use could be quickly changed to respond to changing demand or freeway operation characteristics without compromising safety or operation efficiency.

Transitway development in Houston has generally been restricted to implementation within the available space provided in the medians of existing freeways. This space was not adequate to provide for the full design requirements of general use traffic. Compromises were made in order to fit transitways into the limited freeway right-of-way with a minimum of disruption. These compromises represent what is believed to be the most cost effective means of providing for additional person carrying capacity on existing freeways.

However, the resulting design poses severe operating limitations to other potential users. Following are a few examples:

- Standard transitway widths are 19.5 to 20.0 feet. This inside dimension is sufficient for a bus or van to pass a stalled vehicle, but would be questionable for a full sized commercial truck.

- At selected locations, transitway widths of less than 12 feet exist around bridge columns and over viaducts leaving no available parking area should a vehicle become disabled.

- Vertical clearances exist at several locations which only meet transit bus criteria (i.e. 15' 0"); these clearances would not be acceptable for extended height trucks.

- Specific access ramps have been located and designed based on bus routings and HOV origins and destination. These locations may not match travel patterns of other users.

- Some ramps are intended for low volumes of vehicles at low speeds, and contain minimum turning radii and limited sight distances, characteristics which would compromise the safety of general use traffic.

The resulting design decisions in Houston's transitway development were based on the operational experiences of similar projects elsewhere and on tests conducted on specific METRO equipment. These decisions considered a

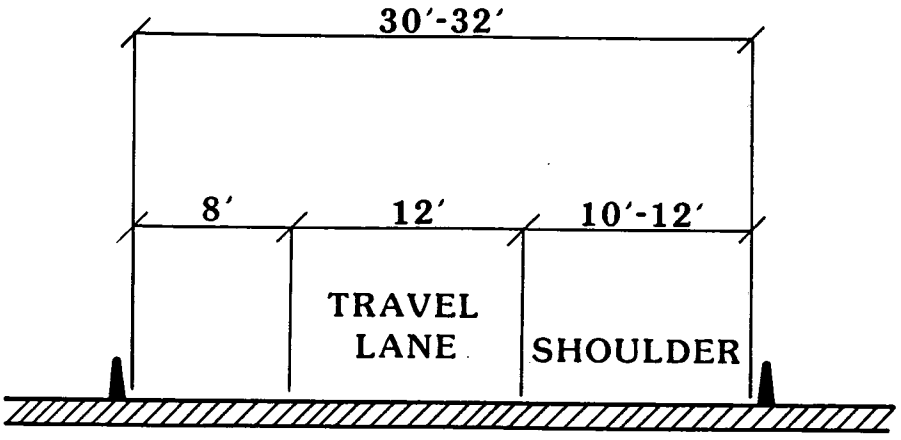
specific group of HOV design vehicles, which included most transit buses, vans, and automobiles. The following design parameters are discussed relative to applied transitway standards versus recommended general use freeway standards.

3.2.2 Transitway Width

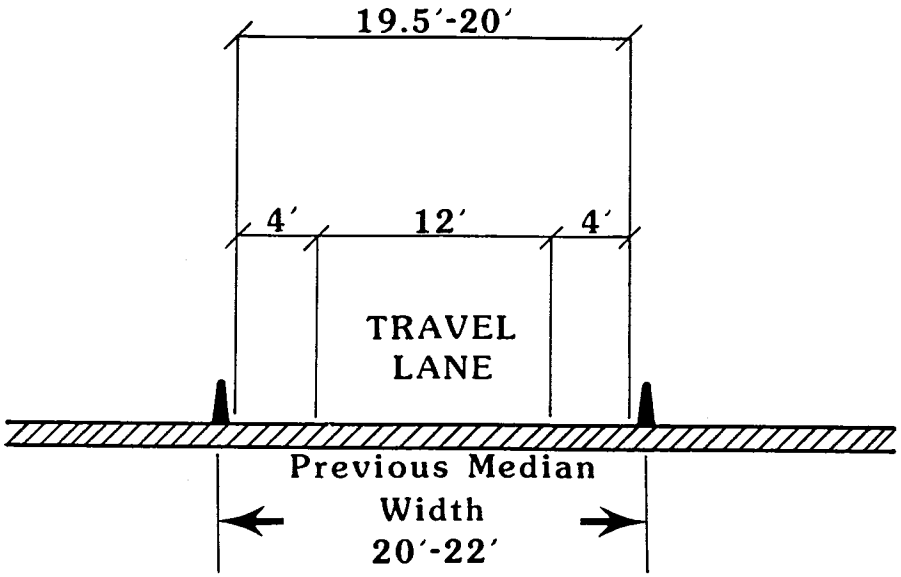
Facility width for a single freeway lane is composed of standards for the travel lane (12 feet) and lateral clearances on each side (typically 8 feet on the left and a 10 or 12 foot shoulder on the right). The resulting space requirement is 30 to 32 feet, as shown in Figure 3.

The typical transitway envelope meets only minimum passing criteria for two transit buses, with a typical cross-section containing a 4-foot lateral clearance on either side of the 12-foot reversible travel lane. Thus, the total space provided is 19.5 to 19.75 feet (24 feet including barriers) in a typical existing median width of 20 to 22 feet, shown in Figure 3. The reasoning for the transitway standard resulted from the reversible nature of the facility (in which buses would always have to pull to the left in order to discharge passengers in event of an emergency), and the common occurrence of existing median expansion joints in the center of bridge decks which were best traversed with balanced wheel path loadings.

Most barriers along at-grade segments are precast units on grout pads, which could be moved if justification warrants. However, additional width could not be obtained easily. Typical cross-sections currently include only a modest lateral clearance from freeway lanes to the transitway barrier, typically six inches to two feet. Freeway lane widths are also substandard, occasionally only 11 feet wide. Interim exceptions permitted these substandard sections; it is not likely further reductions would be permitted or that it would be prudent to request further reductions in standards. In some cases, extra width requirements to handle general purpose traffic in transitways would necessitate major freeway reconstruction and right-of-way acquisition to widen roadways and bridge structures. Greater difficulties in widening would also be encountered on segments of the transitway which are elevated on structures.



Design Standard for General Use Traffic
(e.g. single lane freeway ramp, SDHPT Design Handbook)



Applied Design Standard for Reversible Transitway,
(Katy, North, Gulf, Northwest Transitways)

Figure 3. Comparison of Transitway and General Use Traffic Envelope Standards

3.2.3 Pavement and Structures

In the process of retrofitting freeway medians as transitways, the base material was usually removed and replaced with cement stabilized base and concrete (either reinforced or unreinforced). Replacement usually occurred in conjunction with adjacent pavement rehabilitation, and the median sections were exposed to general traffic loadings during various phases of the respective traffic control plans. Accordingly, transitway pavements were designed with sufficient standards to accept the same loadings and utilization of adjacent freeway lanes. There would be no reason to anticipate pavement failure at a rate any different from the adjacent facility should additional traffic be added to the transitway.

Structure standards on all transitway designs meet the same load requirements of any other highway structure. However, the widths and geometrics considered in transitway structures were often tailored to specific HOV users and locations, and would be considered substandard for general purpose traffic. Following are two examples.

The Katy Transitway flyover structure near the eastern terminus at Post Oak road is a 19.5 foot wide bridge placed at a location in which the freeway rises out of a depressed segment under Post Oak Road. The transitway terminates within 300 feet of the flyover structure at a signalized intersection. Due to the differences in grades resulting from the freeway and transitway, it was determined that six percent grades were appropriate for the transitway. In order to minimize the number of columns and beams straddling the freeway, the flyover was also designed with unbalanced reverse curves, a condition which would not be typical on freeway ramps, but which make sense to authorized, experienced drivers approaching a signalized intersection. Finally, the structure width was designed at the same width as the rest of the transitway. Widening beyond the 19.5 feet would be very difficult without structural replacement.

A more typical example of a structural design employed at a number of transitway access locations is the Lockwood Transitway Interchange on the

Gulf Freeway near Humble. The transitway rises out of the median onto a 19.5 foot wide structure. Once clearance over the freeway is achieved, the structure flares to accommodate acceleration and deceleration lanes from a third intersecting structure perpendicular to the freeway. The three elevated structures converge in a typical "T" intersection with channelized movements from the entry and exit lanes. Geometrics developed for this structure were specifically tailored to the control vehicle, a GMC RTS-II bus, based on numerous tests. In order to minimize the length and width of the structure, grades are again six percent, turn radii are 160 feet at the channelized ramps (using a maximum ramp speed of 20 mph), and there are no extra lateral clearances provided. This design could not accommodate longer vehicles nor large numbers of vehicles through the ramps; it is atypical of SDHPT and FHWA standards for freeway entry and exit designs.

Existing and currently designed structures present impediments to general use of transitway facilities, but do not preclude off-peak use for selected users.

3.2.4 Curvatures, Grades and Superelevations

Except for grades and curves on transitway ramp structures, most of the other geometric considerations are within SDHPT guidelines. Facilities are designed for the same high speed use as the adjacent freeway. Most grades and superelevations are projections of the existing freeway, and as such, exhibit the same horizontal and vertical controls.

3.2.5 At-Grade Access Locations

There are two types of applications for at-grade access, as an intermediate access along a transitway and as a termination treatment. Both types have involved modest expenditures to implement and are usually considered interim in nature. Accordingly, entries and exits usually exhibit minimum width requirements of 12 feet between barriers. Entry openings vary from less than 300 feet for a temporary location (West Belt on the Katy AVL) to more than 500 feet where there is available space (Broadway on Gulf AVL). Entries are signed and marked so as to discourage accidental entry of

confused motorists. Establishing a minimum entry width of at least 500 feet would be desirable if other users were considered eligible. This modification would be possible at existing locations.

Exits are provided as long merge lanes into the adjacent freeway. Merge lengths of at least 750 feet are currently common, and this length appears adequate with the present utilization. This length has also been found adequate because of the nature of traffic operation in the freeway lanes during peak periods, which allows for sufficient opportunities to find an opening at slow speeds. A longer merge distance would be needed at higher speeds typical of off-peak conditions. Volumes in excess of the current projected transitway demand would also require longer merge distances in order to minimize disruption to adjacent freeway lanes. A desirable merge distance of 1000 feet would be sufficient to accommodate other users in off-peak conditions. Modifications to fit a longer exit lane would require freeway widening in one direction, with length dependent on specific characteristics of freeway operation at that location.

3.2.6 Elevated Access Locations

Planning and design criteria applied to elevated access locations may not be as easily useable for other purposes. Many of these locations contain ramps which feed directly into a transit facility, usually a park-and-ride lot or bus transfer center. While access is also provided to the street system through transit facilities, the circuity and low volume design may not be amenable to other users. This would be particularly true for interfacing with the freeway. The time savings gained by using the transitway could be easily lost in the process of using existing access designs.

At several locations there is an elevated access design provided which conveniently interfaces with the adjacent freeway. This design, locally termed a "wishbone" or "pitchfork" interchange, provides direct connection flyover ramps to each side of the freeway, accessing the frontage roads and general purpose freeway lanes. This design would be compatible with any proposed use. Unfortunately, this design is only being proposed or constructed at the following locations:

- Gulf Freeway at Choate (transitway termination)

- North Freeway at Aldine-Bender (intermediate access with the North Beltway)

Additional street and freeway ramp modifications would be needed to improve access between the transitway and freeway at other elevated interchange locations. Specific modifications would have to be determined on an individual basis, depending on the proposed users and interchange location.

3.3 OPERATIONAL CONSIDERATIONS

Transitways were planned with specific considerations for meeting high-occupancy commuter trips. In the off-peak periods, trip needs for other users are of a different nature with purposes not specifically for which transitways were intended. For that reason it is appropriate to first provide a brief background discussion of the operational issues that were considered in the development of transitway.

Transitways were intended to provide an assured level-of-service by offering an exclusive travel lane to specific vehicles. Additional person movement could be facilitated on Houston's congested radial freeways if these facilities were reserved for high occupancy vehicles. The intent is to maximize person movement. In order to include transitways into existing freeways, design features were so constrained that driver authorization appeared to be an appropriate means of assuring operational reliability and safety. Other operational issues were deemed equally important in the development of transitways and essential to maintaining efficiency and safety. These are as follows:

- Reversible Flow
  Limited space and demand characteristics dictated features which would permit reversing the direction of the transitway between morning and afternoon peak periods.

- Enforcement
  Operation and design has to account for a means of assuring eligibility compliance, and a means of safely observing, stopping, and removing violators.

- Incident response and user communication
  In order to assure facility reliability, a means of communication and operations responsiveness has to be developed which resulted in cost effective and efficient operation.

Motorist information is particularly critical from a transitways operation standpoint when considering infrequent, off-peak users. Through signing, the unfamiliar motorist has to be educated as to what the transitway is, where the transitway goes, and how the transitway operates.

Response to off-peak incidents is also a significant concern in maintaining reliability. Breakdowns on the transitways in the off-peak by selected user groups (i.e. trucks) may not be cleared by the peak period necessitating complete closure to avoid excessive transit user delay.

3.4 MANAGEMENT AND JURISDICTIONAL CONSIDERATIONS

Of primary concern in the management of the transitway facility where user groups (buses, vans, carpools, trucks, etc.) may vary by time of day is communication of motorist information. The operating status of the transitway must be clearly defined. This is especially important during off peak time periods when users may be unfamiliar with the transitway.

A clear distinction must be communicated to the user between normal freeway mainlane operations and operational requirements on transitway facilities with restrictive geometrics, unique merge/diverge areas, barrier separated controlled access, and other vehicular maneuver constraints.

Variance of authorized user groups between peak and off peak time periods may also create difficulties for enforcement of peak period

restrictions. Again, clear communication of those restrictions by time is essential for effective transitway management.

Jurisdiction within the limits of the transitway depends upon the primary user group utilizing the facility. If predominately transit-related HOV's (buses, vanpools) use the transitway, then it would follow that the transit authority would have jurisdiction. However, if the primary user group is non-transit, such as trucks using the transitway during off peak periods, the jurisdiction may reside with the responsible highway agency (i.e., SDHPT). Conceivably, however impractical, jurisdiction might vary not only be primary user group but also by time of day of use or by freeway transitway.

4. OFF-PEAK UTILIZATION OF KATY (I-10W) TRANSITWAY

4.1 GENERAL

Due to the continued perception that the Katy (I-10W) Transitway was under utilized, a three-part decision was made by the State Department of Highways and Public Transportation and the Metropolitan Transit Authority in August, 1986 to increase utilization. First, the mandatory authorization requirement for transitway usage was eliminated. Second, the occupancy requirement for carpools was lowered to a minimum of two or more occupants per vehicle on the transitway. And, third, transitway operating hours were extended beyond the peak periods for all vehicles until 11:00am in the morning inbound and beginning at 2:00pm in the afternoon outbound. This decision was implemented on August 11, 1986 as a demonstration project for a 90-day period. Based on an analysis of transitway utilization during this demonstration period, subsequent policy is to be established. This section addresses, the off-peak operations on the transitway during the 90-day project.

4.2 DEMAND AND LEVEL-OF-SERVICE

Transitway off peak utilization for the months August-November, 1986 is shown by sample date, type of vehicle and time period in Table 13. These total demand values are depicted graphically in Figure 4.

The impacts of de-authorization, in combination with occupancy requirement reductions to two or more persons per vehicle, is shown in Table 14. This data presents 2+ vehicle volumes (carpools and vanpools) by sample date, day of week, and time period. Summary totals are given for AM versus PM time, peak versus off-peak periods and peak hour. Figure 5 illustrates this information.

Vehicle distribution during transitway hours of operation is indicated in Figure 6 for a sample date in October 1986. Note the sharp peaking characteristics in both commuter periods contrasting with the much lower

Table 13. Off-Peak Transitway Utilization (9:30 - 11:00 AM; 2:00 - 3:30 PM)

Survey Date	AM Vehicles				PM Vehicles			
	Bus	Vanpool	Carpool	Total	Bus	Vanpool	Carpool	Total
11 August 1986	0	0	63	63	0	0	48	48
2 September 1986	2	0	97	99	2	1	86	89
7 October 1986	1	1	135	137	4	0	112	116
6 November 1986	3	1	123	127	6	0	145	151
Survey Date	**AM Passengers**				**PM Passengers**			
	Bus	Vanpool	Carpool	Total	Bus	Vanpool	Carpool	Total
11 August 1986	0	0	201	201	0	0	109	109
2 September 1986	20	0	207	227	40	8	199	247
7 October 1986	10	8	285	303	70	0	259	329
6 November 1986	30	5	270	305	80	0	334	414

Source: TTI Surveys

Table 14. I-10 Katy Freeway Transitway 2+ Vehicle Volumes

Survey Date	Week Day	AM Peak Period	AM Peak Hour	Off-Peak AM	PM Peak Period	PM Peak Hour	Off-Peak PM	Survey Total
8/11/86	Monday	1177	572	89	1149	560	50	2326
8/25/86	Monday	1621	712	136	1521	687	70	3142
9/98/86	Monday	1945	950	97	1658	740	91	3603
9/22/86	Monday	1930	890	107	1818	783	126	3748
10/06/86	Monday	2118	1040	131	1925	841	113	4043
10/20/86	Monday	2075	1066	124	1949	848	137	4024
11/03/86	Monday	2136	1175	114	1849	887	109	4208

Source: METRO Weekly Transitway Reports

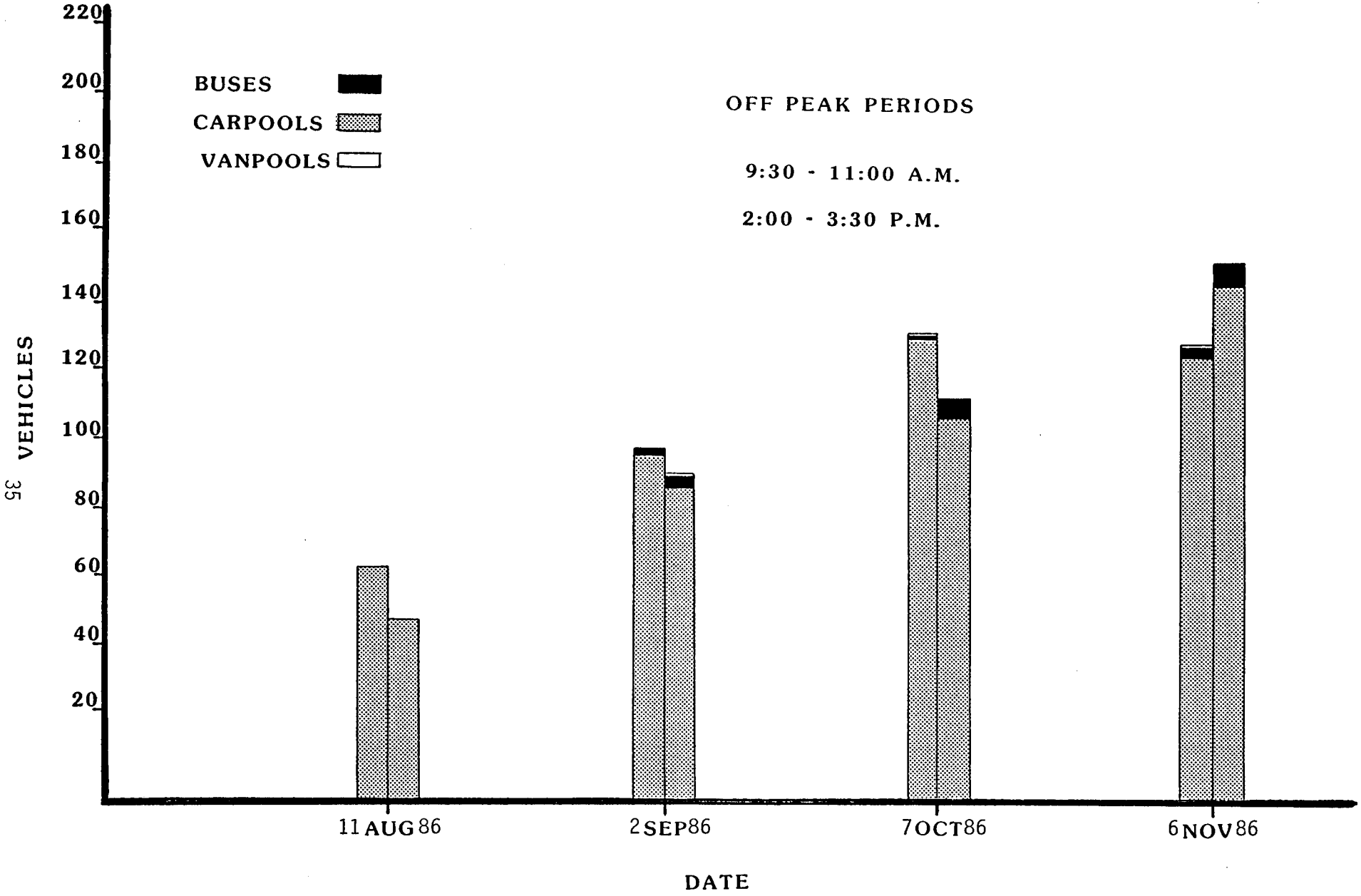


Figure 4. Off-Peak Transitway Utilization

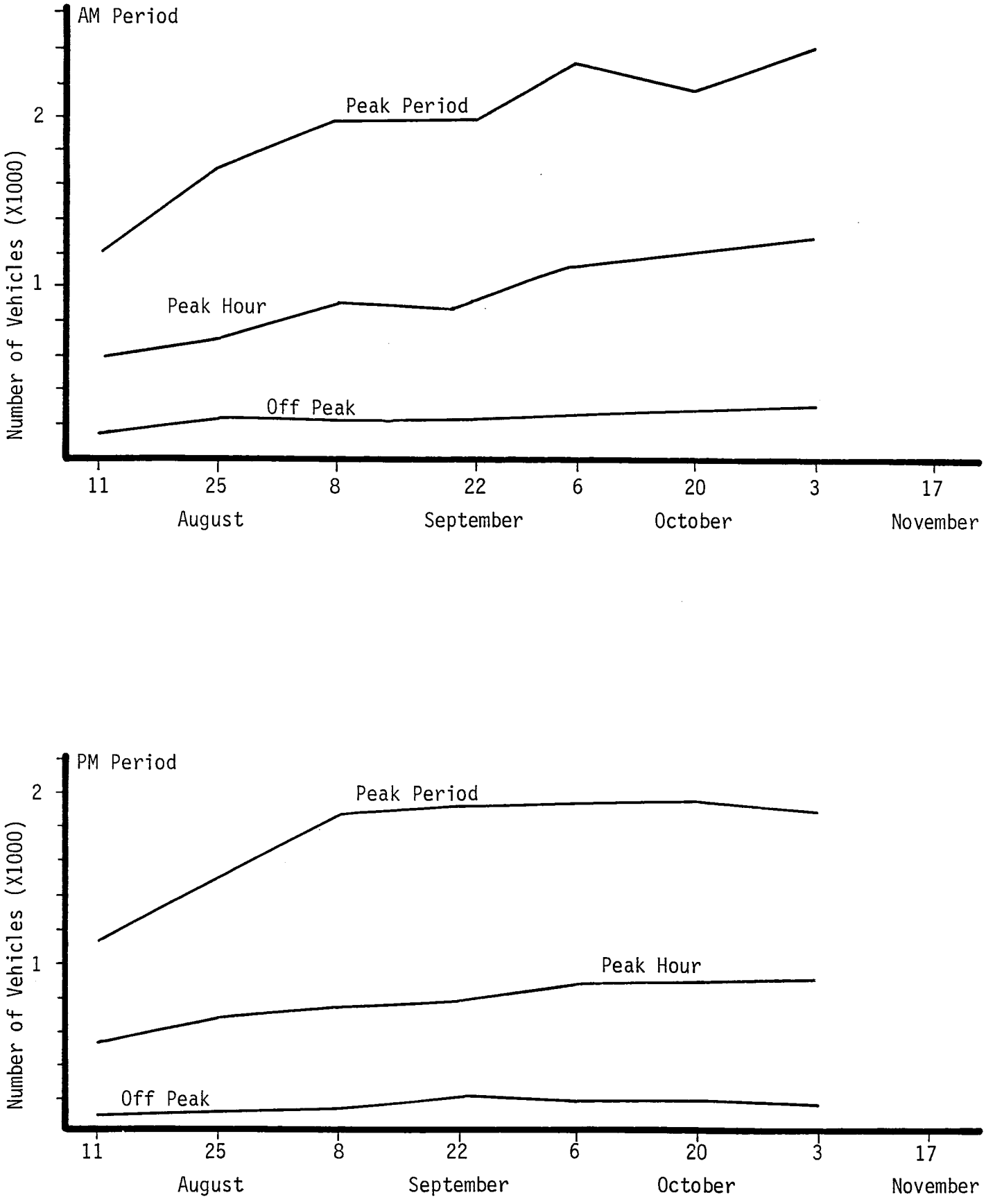


Figure 5. I-10 Katy Transitway 2+ Vehicles

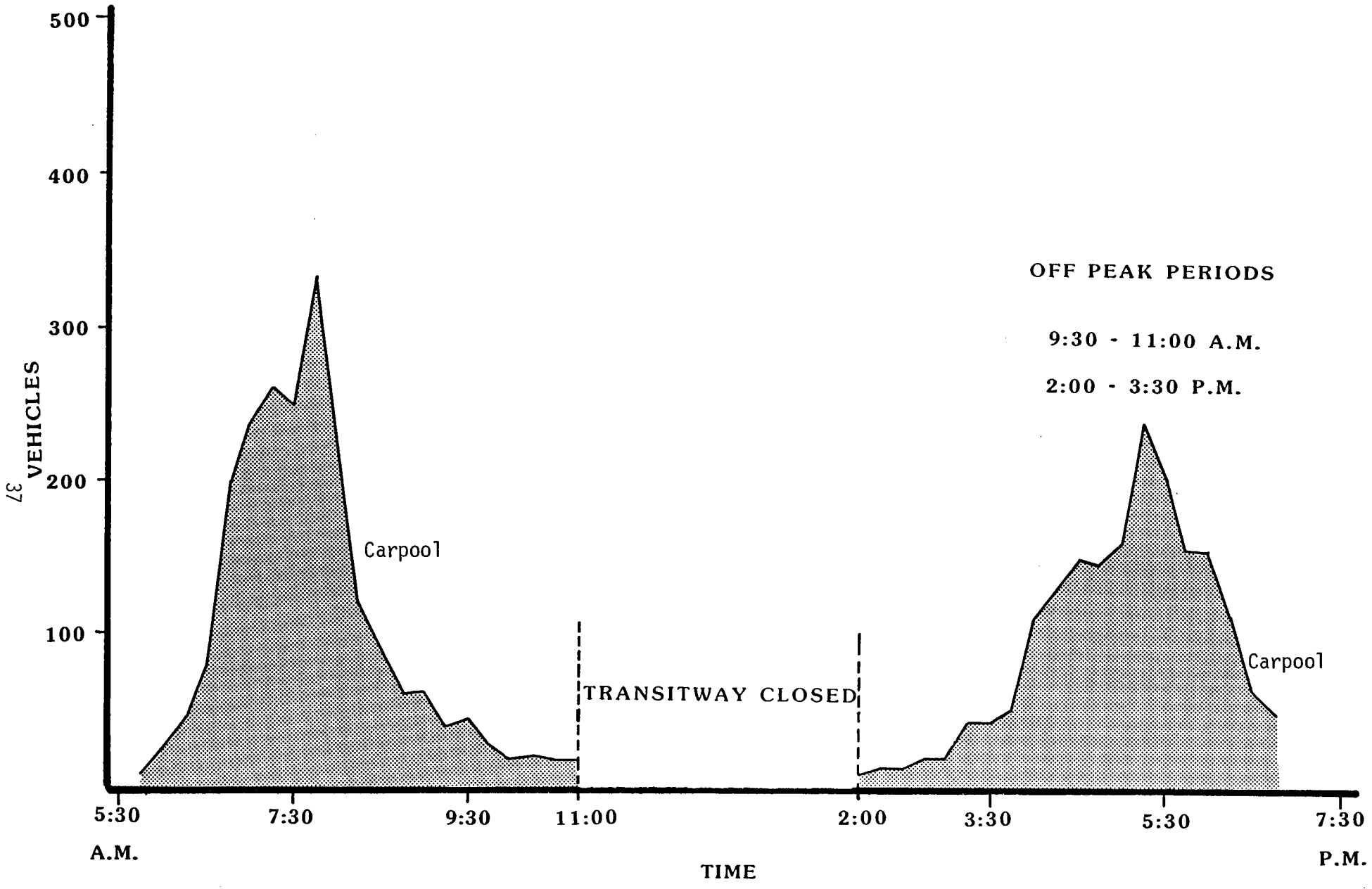


Figure 6. Katy Transitway Vehicle Distribution October 1986

levels of usage during the off peak periods. This pattern is reflected in both carpool and total vehicle demand.

As given previously in Tables 13-14, off peak demand on the Katy Transitway in November was approximately 100 vehicles per hour for the single lane. This is level-of-service "A" operation with speeds of 55+ MPH. The adjacent freeway mainlanes are also relatively free flow; however, there is a slight speed suppression of 5-7 MPH during the periods 9:30-10:00am and 3:30-4:00pm. This represents about one hour out of the total three hours of off peak transitway operation.

4.3 ACCIDENTS AND INCIDENTS

During the 90-day demonstration project period from August to November, 1986 there were a total of 52 disabled vehicles on the Katy Transitway. Of this total, four incidents occurred during off peak time periods resulting in potential delay to other transitway users. Two of these incidents involved collisions with the CMB walls on the transitway; while two other incidents were disabled vehicles in violation of occupancy restrictions (Driver Only). The average time delay experienced in clearing these incidents was approximately 17 minutes.

4.4 BENEFITS VERSUS DISBENEFITS

As stated in Section 4.2, approximately 100 transitway vehicles per day in the off peak periods currently save about 1.0 minute in delay over motorists in the freeway mainlanes between W. Belt and the flyover ramp connection (6.5 miles). This delay savings, however, is obviated by the additional travel time necessary for transitway users to proceed from the flyover ramp to re-enter the Katy Freeway mainlanes. This time delay, approximately 1.5 to 2.0 minutes, is essentially twice the savings. Therefore, off-peak transitway users incur travel time disbenefits in utilizing the transitway under typical current conditions of freeway mainlane level-of-service. Freeway mainlane speeds would have to be suppressed to near 35 MPH from W. Belt to the flyover ramp for at least one half of the off-peak time

periods, regardless of transitway volumes, for travel time savings and delay to be equal.

During the 90-day demonstration project, over 100,000 vehicle-miles were traveled on the transitway during off peak time periods with two reported minor accidents. Both of these accidents involved collision with the CMB walls and resulted in no injuries or fatalities. Probable cause in both cases was loss of control; however, one accident did occur in the West Belt slip ramp entry. No valid conclusions can be determined relative to safety in off peak transitway utilization from this limited data.

During the same August-November project period, only two vehicles were reported as breakdowns during the off-peak transitway operation. Again, the data is limited; however, one breakdown per 50,000 miles is slightly less than would be typically expected for peak-period transitway operation.

There is a cost of operation in extending the transitway "open" time an additional three hours beyond the peak periods. This represents an approximate 25% increase in work hours for 2 to 3 persons plus equipment costs. The equipment normally consists of one police sedan, one heavy wrecker, and, at times, one standard wrecker. No exact cost figures were available relative to the off peak transitway operations at the time of this report.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Current estimates of total off-peak user demand, as previously given in Table 12, indicate that all possible freeway corridors would provide necessary capacity under a single lane transitway configuration. However, single lane capacity would be exceeded under nominal growth projections if open access is allowed to all passenger vehicles or any combination of other possible off peak users (2+ carpools, trucks, taxis, etc.). Operational experience on the Katy Transitway during the 90-day demonstration project has exhibited off-peak 2+ unauthorized demands approximately 30% less than estimated as a potential user market. This lower demand is due, in part, to delay associated with the existing terminal connections and non-congestion, free flow level-of-service on the adjacent freeway mainlanes during the off peak time periods. Carpool demand on this particular facility would be expected to increase as the transitway is extended or if the terminal connections are modified to accommodate freeway access in an improved manner. Carpool utilization in off-peak time periods would also be expected to increase on this facility and any others as off-peak congestion on the freeway mainlanes is more demonstrative and prevalent under normal operations or special circumstances (construction, maintenance, special events, etc.).

Estimated potential demand for truck use of transitways during the off peak is significant in selected freeway corridors. Exclusive truck utilization of transitways during off-peak periods does provide a means of segregation these vehicles from the normal mix of freeway traffic. However, it is highly questionable as to the actual portion of the truck population that would use the transitway in the off-peak due to minimal or no travel time savings, controlled access to directed non-truck destinations, restricted or prohibitive geometrics, and high exposure to speed enforcement.

From a safety standpoint, it might be speculated that an exclusive, controlled truck lane would decrease off peak truck accidents. However, if trucks are allowed to use the transitway in concert with other types of vehicles (buses, vans, carpools, taxis), the traffic mix would be little

different than on the freeway mainlanes. Also current single lane transitway operation would force closure under a truck breakdown on the facility.

Experience with peak-period use authorization of taxis of the North Freeway (I-45N) has shown little taxi demand. Off peak utilization of transitways by taxis would be expected to be even less. This potential user population seems to be insignificant; however, with a continued 2+ carpool definition, taxis with passengers could access transitways without a special user group qualification.

A summary of study conclusions is as follows:

- During off-peak periods, the transitways currently have--and probably always will have--unused capacity. The data indicate that the incentives--trip time savings and trip time reliability--which need to exist to encourage high levels of transitway usage in the off-peak simply do not exist and, given the extent of freeway expansion currently committed, are not likely to exist to a meaningful extent in the near future.

- Since virtually no benefits are provided by using the transitway in the off-peak, demand to use the facility is likely to be low regardless of what groups of vehicles are eligible to use the transitway. It is highly unlikely that the resulting transitway volumes will make the transitway appear "utilized" in the off-peak.

- Off-peak utilization by groups other than HOV may result in incidents occurring in the transitway during the off-peak that have not been cleared before the peak begins. This is common with incidents involving large trucks. This would adversely impact the reliability the transitway must provide during the peak period in order to accomplish its objective.

- Off-peak utilization by non HOV vehicles is likely to increase operating and enforcement costs without contributing to the principal objective of the transitways.

- A series of design and operation issues exist regarding off-peak utilization by non HOV vehicles. While no one issue by itself absolutely precludes such utilization, the combined impact of these concerns argues strongly against such usage. Signing as to when the transitway can be used, at what times, and to what destinations required to inform infrequent users of the freeway as to their eligibility/desire to use the transitway would be particularly problematical.

- The Katy Freeway experience suggests that the transitways should be left open for longer periods of operation. Carpools with 2+ occupants appear to be an appropriate user group definition for this off-peak period.

5.2 RECOMMENDATIONS

The definitive function of transitway facilities is to provide movement of large volumes of passengers in as few vehicles as possible along routes to designated high density employment centers during peak periods. This travel is to be inherently accommodated on the transitway at a high level of service (minimal delay), with reliability and in a safe manner. This objective can only be achieved and maintained by exercising control over both the number of vehicle users. While this control is critically important during peak time periods, as mainlane congestion increases in extended magnitude, it may become important during off-peak time periods.

Based upon the information available at the time of this report and the analyses conducted herein, it is recommended that off-peak utilization of transitways be continued for high-occupancy vehicles only--transit buses, vans, and carpools meeting minimum occupancy requirements. It is recognized that the costs of operation currently exceed any delay savings or other benefits at this time. However, with ever increasing congestion, the HOV transitway user demand will increase and current facility designs can serve future demands, both physically and operationally.

6. REFERENCES

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