Report No. FHWA-RD-77-148

TRAFFIC CONTROL OF CAR POOLS AND BUSES ON PRIORITY LANES ON INTERSTATE 95 IN MIAMI

August 1977

Final Report

Prepared for

ERAL HIGHWAY ADMINISTRATION
ces of Research & Development
Washington, D. C. 20590

FOREWORD

This research report will be of particular interest to traffic and highway engineers who are involved in the design and operation of carpool and bus lanes on freeway facilities. The report presents the findings of a series of research efforts which were undertaken when a carpool-bus lane was added in each direction to I-95 in Miami. The lane was restricted to buses and carpools of three or more persons during peak periods. Later the carpool definition was changed to two or more persons because of political pressure.

The research conducted included the evaluation of the operation of the total freeway facility before and after the carpool-bus lane was opened to traffic. Some sign and marking studies were conducted in order to determine what control devices were most effective. The accident experience was monitored to determine the operational safety of the facility. Public opinion was sampled to indicate the public's attitudes towards high occupancy vehicle facilities.

Sufficient copies of this report are being distributed by FHWA to provide two copies to each regional office, two copies to each division office, and two copies to each State highway agency. The State and division office copies are being sent directly to each division office.

Charles F. Scheffey
Director, Office of Research

NOTICE

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16. Abstract

This report covers the evaluation of a bus/car pool priority project using a newly constructed lane on Interstate 95 in Miami, Florida as a priority lane for high occupancy vehicles (HOV's). The physical and operational aspects of the system are described and the results of several studies are presented. Field studies were carried out to determine the effect of variations in signing and marking parameters. Questionnaire studies were performed to assess the attitudes of various road user groups regarding the operation of the system. The safety-related aspects (violations, enforcement, and accidents) were also investigated. It was concluded in general that the system produced significant operational improvement. It was well accepted by the public although the enforcement of the car pool occupancy requirement proved to be a major problem. Minor variations in signing and marking parameters showed little, if any, measurable effect on the operation of the system.

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PREFACE

This report was prepared by the Transportation Research Center of the University of Florida. Principal technical contributors were K.G. Courage (Principal Investigator), T.H.Culpepper, C.E.Wallace, J.A. Wattleworth, R.D. Bowman, E.R. Benton, and G.J. Viele.

This constitutes the final report for a project supported by the Federal Highway Administration in cooperation with the Florida Department of Transportation, under the Federally Coordinated Program of Research and Development in Highway Transportation (Category 2D). The contract managers were Mr. H.H. Bissell (FHWA) and Mr. R.E. Magahey (Florida DOT).

The I-95/NW 7th Avenue Bus/Car Pool Systems Demonstration Project was a large scale undertaking of numerous organizations and individuals. The authors are sincerely appreciative of the extensive support given both the Project in general and the Evaluation Program in particular. Space does not permit the naming of all the individuals involved in the Project, but the agencies they represent certainly deserve both the thanks of and acknowledgement from the Research Team.

We are particularly indebted to several governmental agencies for their technical support and assistance in data collection activities. These include the Florida DOT's Mass Transit and Traffic Operations Divisions, both at the Headquarters level (Tallahassee) and at District IV (Fort Lauderdale and Miami); the Metropolitan Dade County Transit Agency; the Metropolitan Dade County Department of Traffic and Transportation; and the Florida Highway Patrol.

Several individuals were instrumental in the success of this evaluation project and they deserve our special thanks. These are Messrs. Gary Price (FDOT), Mike Miller (FDOT), Bob Deuser (FDOT), Mark Lopatin (FDOT), and Al Gianna (Sperry Systems Management).

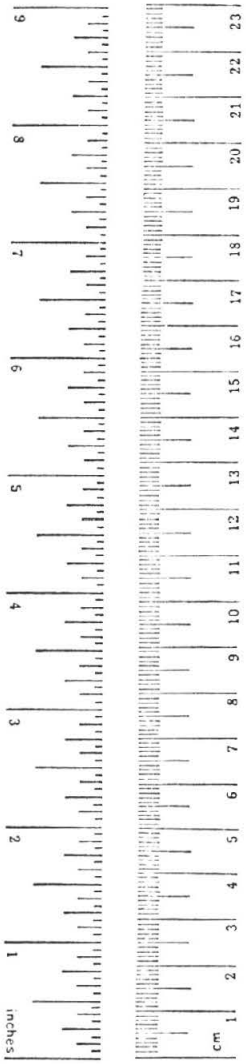
Without the outstanding assistance of these organizations and individuals (including many unnamed), neither the Project itself nor the results reported herein could have been possible.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

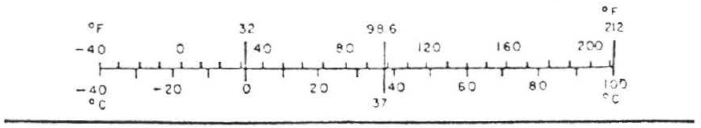
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2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



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CHAPTER ONE

PROJECT DESCRIPTION

A. INTRODUCTION

A three and a half year demonstration project was established in Miami in September, 1973 to develop more efficient people-moving capabilities in the I-95/NW 7th Avenue corridor. The agencies which participated in the Demonstration Project are:

- -Florida Department of Transportation
  - -Mass Transit Division
  - -Road Operations Division
- -U. S. Department of Transportation
  - -Urban Mass Transportation Administration
  - -Federal Highway Administration
- -Metropolitan Dade County Department of Traffic and Transportation
- -Metropolitan Dade County Transit Agency

An evaluation of the Project was performed by the University of Florida Transportation Research Center.

The Project was divided into two phases. The first phase involved the implementation and evaluation of several bus priority techniques on NW 7th Avenue and the second phase involved the implementation and evaluation of a reserved bus/car pool lane in each direction of Interstate 95 (I-95). A 967 car parking lot was constructed in the Golden Glades Park 'n' Ride Facility. Thirty, full sized passenger buses were purchased for the Project and were used as directional peak-period express buses which operated between the Golden Glades Park 'n' Ride Facility and one of three major service areas. The express bus system was advertised as the "Orange Streaker" service.

This report covers a portion of the evaluation of the second phase of the Demonstration Project, in which buses and car pools operated on the newly constructed lanes on I-95. Specifically, the traffic operational aspects are examined in detail and the effects of the operating parameters on the system performance are identified.

B. DESCRIPTION OF THE BUS/CAR POOL PRIORITY SYSTEM

1. Location

The transportation corridor traversed by the system is illustrated in

Figure 1.1. The corridor services the residential areas in north Dade and south Broward Counties through the Golden Glades terminal into the three service areas of the Miami Central Business District, the Civic Center area and NW 36th Street employment/Miami International Airport areas.

2. Golden Glades Terminal

The layout of the Golden Glades Terminal is shown in Figure 1.2. The terminal contains provisions for park 'n' ride activities using the Orange Streaker Service and for car pool staging. Under the initial design of the facility, buses and car pools used the surface streets for connection to and from I-95. A flyover ramp was subsequently constructed as indicated on Figure 1.2 to provide a direct connection between the restricted lanes on the freeway and the terminal area.

3. Geometrics on Interstate 95

Three typical lane configurations were found within the study corridor along Interstate 95 prior to the beginning of the Demonstration Project. A six lane section existed north of the 135th Street Interchange, an eight lane facility from the 135th Street Interchange to the Airport Expressway and a ten lane facility south of the Airport Expressway. Figure 1.3 shows a schematic diagram of the freeway indicating the location of the interchanges etc.

As the Demonstration Project proceeded, an extra lane was constructed in the median in both the north and south directions of I-95 from the Golden Glades Interchange to the Airport Expressway. An existing lane south of the Airport Expressway was joined with the constructed lane to form the continuation of this lane throughout I-95. A typical cross section of the bus/car pool reserved lane is shown in Figure 1.4. Each of the lanes on the freeway were 12 feet wide with an eight foot outside shoulder and a 2 foot inside shoulder to the raised median barrier. The added lane formed the bus/car pool reserved lane within the project area. The general appearance of the freeway is illustrated photographically in Figure 1.5.

4. Traffic Control Devices

Proper utilization of the reserved lane on I-95 was controlled primarily by fixed message signs, supported by pavement markings. The overhead signs, which were of the type shown in Figure 1.5, were installed at one half mile intervals

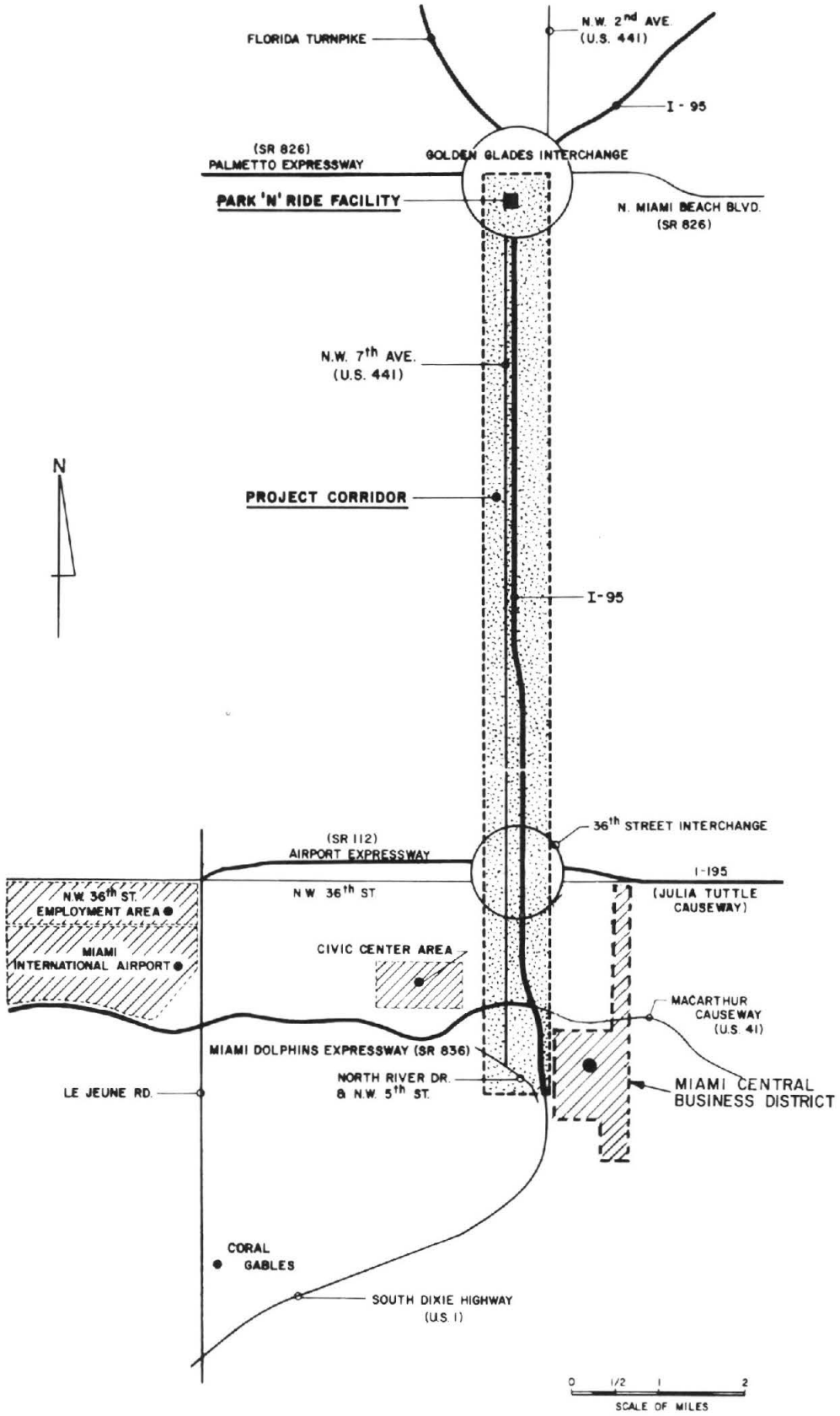


FIGURE 1.1. THE PROJECT CORRIDOR - I-95/NW 7TH AVENUE BUS/CAR POOL SYSTEMS DEMONSTRATION PROJECT.

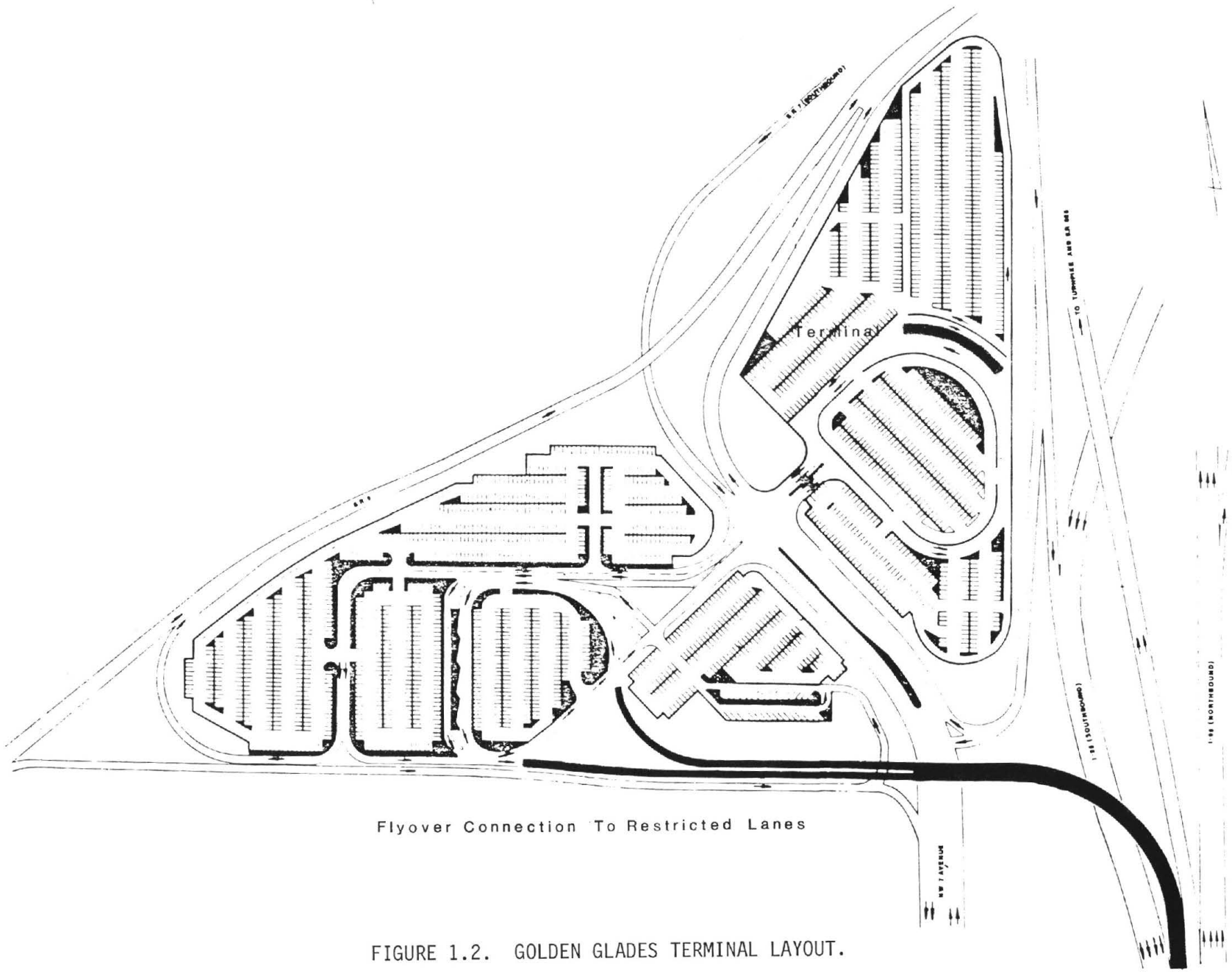


FIGURE 1.2. GOLDEN GLADES TERMINAL LAYOUT.

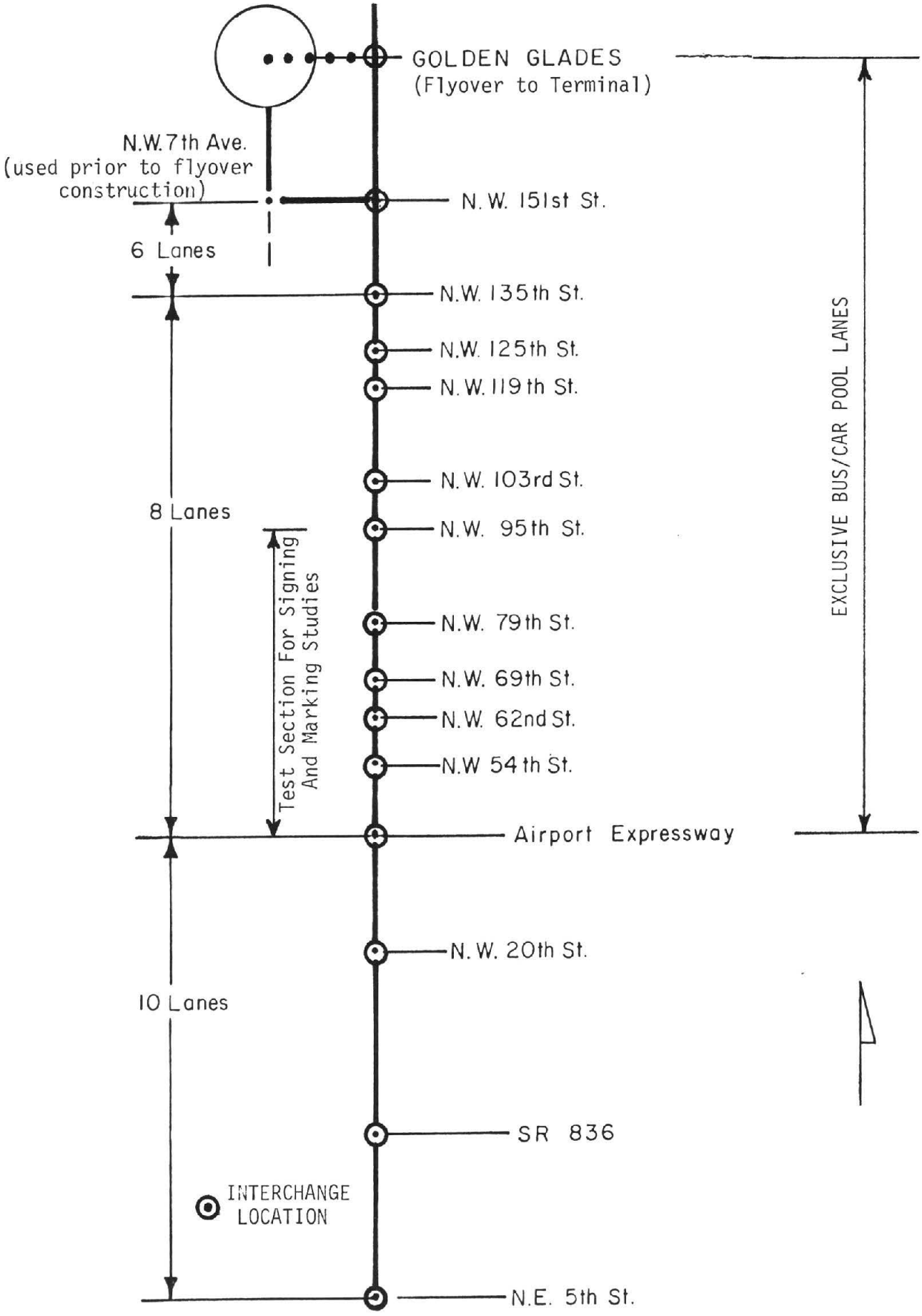


FIGURE 1.3. SCHEMATIC REPRESENTATION OF THE PROJECT AREA.

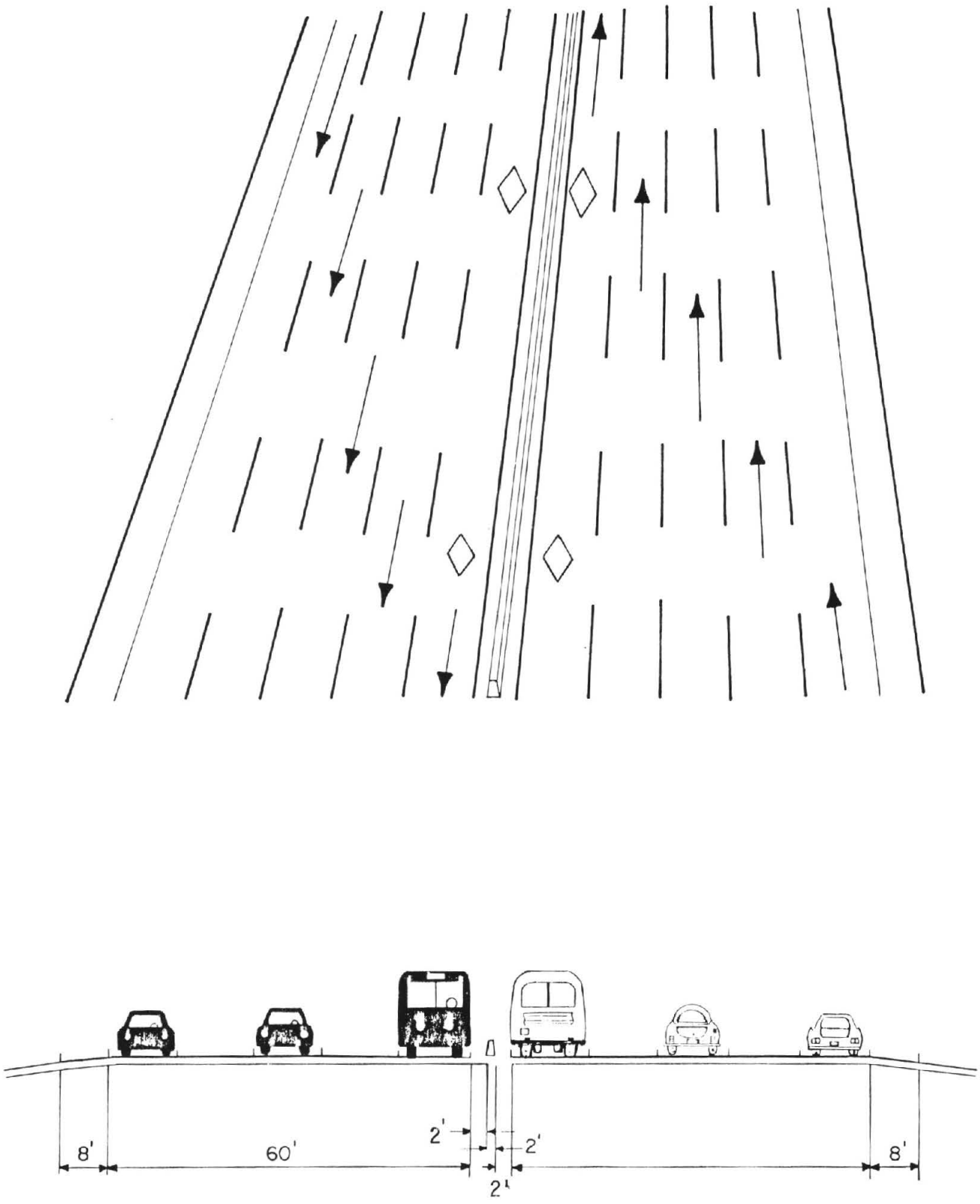


FIGURE 1.4. TYPICAL SECTION OF BUS/CAR POOL RESERVED LANE.

a. Exclusive Lane on the Freeway

b. Golden Glades Terminal

FIGURE 1.5. GENERAL APPEARANCE OF I-95 BUS/CAR POOL PRIORITY SYSTEM.

on the freeway. The sign messages were reinforced by advanced warning signs and by the diamond symbol located both on the sign and on the pavement within the exclusive lane. White pavement markings were used in compliance with the MUTCD. Solid and skip lines were applied to the pavement during different stages of the Demonstration Project to compare their relative effectiveness.

Two types of supplementary traffic control signs were installed:

- "No Stopping On Pavement" on the street lighting poles in the median barrier
- "Watch For Buses Changing Lanes" on overhead supports at critical points of access to the restricted lane.

C. SYSTEM EVALUATION

The objective of the evaluation project discussed in this report was to investigate the effect of the following control measures on the performance of the system:

1) Marking and Delineation
2) Signing
3) Entry/exit strategies
4) Enforcement activities
5) Weaving control and assistance measures
6) Car pool occupancy requirements.

Both analytical and experimental techniques were used in the research effort. The following measures of effectiveness were used in describing the system performance:

1) Passenger carrying capacity,
2) Vehicle and passenger travel times,
3) Traffic volumes and passenger occupancies,
4) Violation rates for exclusive lane use,
5) Road user acceptance and understanding,
6) Bus schedule adherance,
7) Trip comfort measures,
8) Accident rates,
9) Lane changing volumes,
10) Lane changing difficulties,
11) Level of enforcement activities.

The data collection and analysis methodology for these measures of effectiveness are described in Reference 1.

D. SUMMARY OF THE REPORT

This report presents the major findings of the traffic operational studies carried out in connection with the I-95 Bus/Car Pool Demonstration Project. The discussion focuses on the interpretation of the results and, where appropriate, more detailed supporting analyses are confined to technical appendices which are included in a separate unpublished volume submitted to the Federal Highway Administration.

Chapter 2 deals with the general operating characteristics of the system, including volumes, occupancies, travel times, etc. A comparison is made between three project stages: the "before" stage; the intermediate stage, during which buses operated on NW 7th Avenue while the new lanes were under construction; and the final stage, during which buses and car pools operated in the restricted lane on I-95.

Chapter 3 presents the results of the studies of the effect of signing and pavement marking on the system performance. Most of these studies were performed within a short test section of the freeway where several signing and marking parameters were varied to identify pertinent relationships.

Chapter 4 treats the public safety aspects of the project, including enforcement, violations and accident experience. Enforcement and violations are strongly interrelated and several practical problems were experienced in this area. Accidents are examined in terms of accident rates, types and causative factors.

Chapter 5 presents an analysis of several questionnaire surveys which were administered to various road user groups. Bus and car pool passengers were questioned as to their perception of the benefits and problems associated with the reserved lane. General road users were questioned as to their understanding and acceptance of the HOV priority concept. Bus drivers were asked to assess the operational benefits and problems in greater detail.

Chapter 6 examines the effect of changing the car pool definition parameter from three persons to two persons and of the opening of the flyover ramp for direct connection to the Golden Glades Terminal. These two important changes were implemented at the end of the evaluation project and are, therefore, analyzed separately.

Chapter 7 presents a summary of the major findings of all of the project studies. Where possible, specific conclusions are drawn and recommendations are offered.

CHAPTER TWO

OPERATIONAL CHARACTERISTICS

A. INTRODUCTION

1. General

This chapter deals with the overall operational characteristics of the bus/car pool priority system on I-95. These characteristics are described in terms of several measures of effectiveness including:

Traffic volumes,
Speeds and travel times for buses and automobiles,
Delay,
Trip comfort measures,
Schedule adherence, and
Macroscopic system performance measures.

Where appropriate, the major operational stages of the Bus/Car Pool Demonstration Project are identified for general comparison purposes including:

1) The initial "mixed mode" stage which occurred prior to implementation of any HOV priority treatments;
2) The intermediate stage, in which buses operated in a reversible exclusive lane on NW 7th Avenue under signal preemption control; and,
3) The final stage in which an exclusive lane for buses and car pools with 3 or more occupants was provided on I-95 as an HOV priority measure.

More detailed comparisons of the effect of various operating parameters within these stages will be found in subsequent chapters.

2. Data Collection Methodology

The data collection techniques followed the standard procedures which were used throughout the evaluation of the Bus/Car Pool Demonstration Project in the I-95 corridor. These procedures are described in detail in Reference 1. The specific data sources are listed as follows.

	DATA	SOURCE
1.	24 hour Volumes	Loop Detector Traffic Count Stations
2.	Peak Period Volumes and Vehicle Occupancy	Manual Volume and Occupancy Studies
3.	Bus Speeds and Travel Times	1) On-Board Bus Instrumentation 2) Manual Travel Time Observations
4.	Transit Delay and Passenger Comfort	On-Board Bus Instrumentation

5.	Bus Schedule Adherence	Manual Observation at Golden Glades Terminal (provided by Metropolitan Transit Agency)
6.	Bus Passenger Counts	Metropolitan Transit Agency Records

B. TRAFFIC VOLUMES

Traffic volume counts were obtained at three automatic counting stations on the freeway, located at 62nd Street, 111th Street and 151st Street.

Bi-directional 24 hour traffic volume profiles are shown for both the exclusive lane and the general lanes at these locations in the following figures:

62nd Street	Figure 2.1
111th Street	Figure 2.2
151st Street	Figure 2.3.

It is observed that these profiles followed a typical pattern for a multi-lane freeway, with the peak flow rate approaching the capacity of the roadway inbound (SB) during the morning peak and outbound (NB) during the evening. It is also noted that the exclusive lane volumes were relatively low even during the peak periods. The operation in the exclusive lane seldom deteriorated below level of service "B".

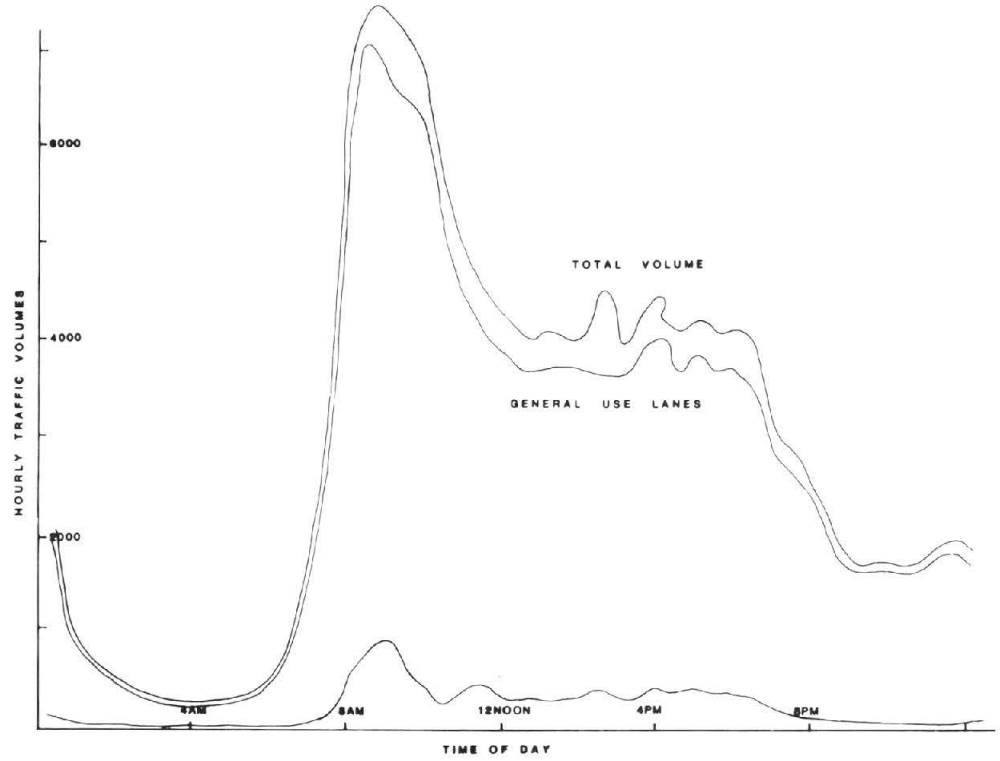
C. PUBLIC TRANSIT OPERATIONS

1. Service Area Travel Times

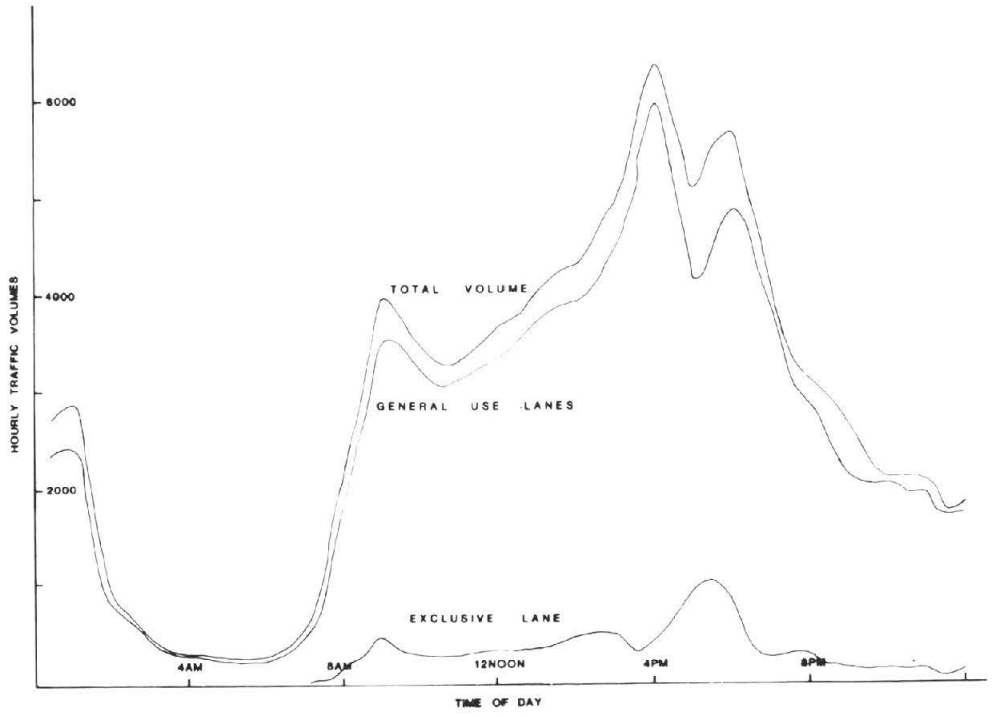
A summary comparison of bus travel times by operational stage is presented in Figure 2.4 for both peak periods and each of the destination routes.

The shortest travel times for each destination route during the morning peak period occurred after the reserved lane on I-95 was in operation. The highest morning peak travel times for all destinations occurred when the buses operated on NW 7th Avenue. This indicates that the buses using the reserved lane (C) were able to avoid much of the traffic congestion on the freeway. It also suggests that the mixed mode operation on I-95 (A) was preferrable from a travel time point of view to the signal preemption system on NW 7th Avenue (B) during the morning peak.

During the afternoon peak period, as illustrated in Figure 2.4, the lowest travel times for all of the destination routes were found with the exclusive lane (C). This signifies, similar to the morning peak, the reduction of travel times by bypassing major congestion.

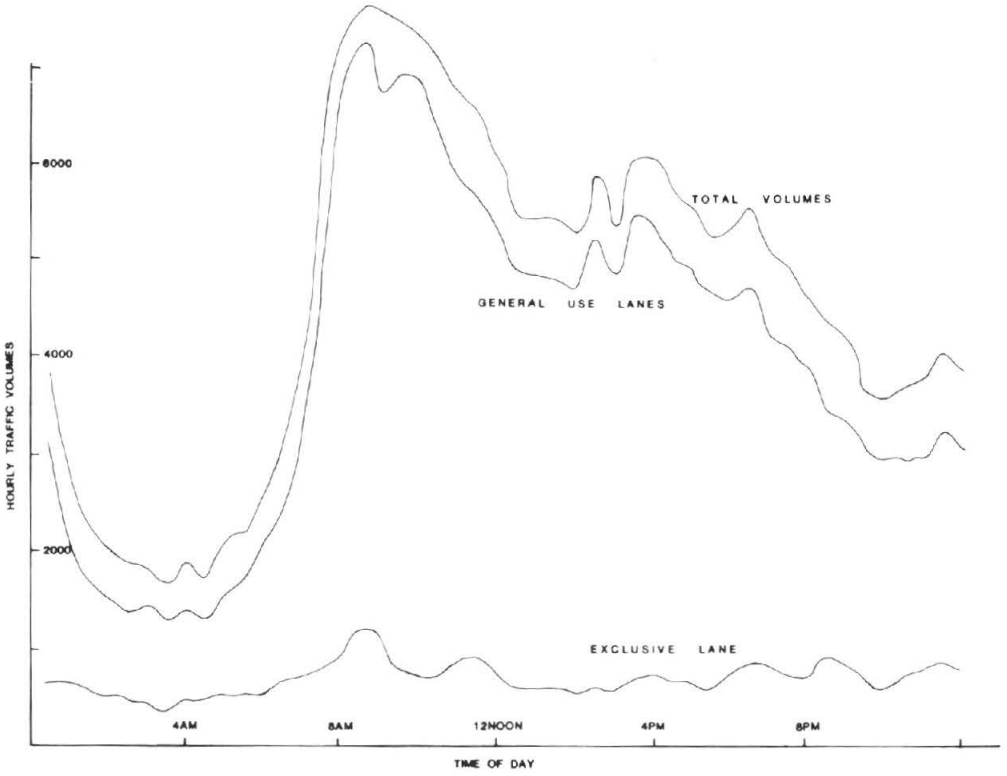


a. Southbound

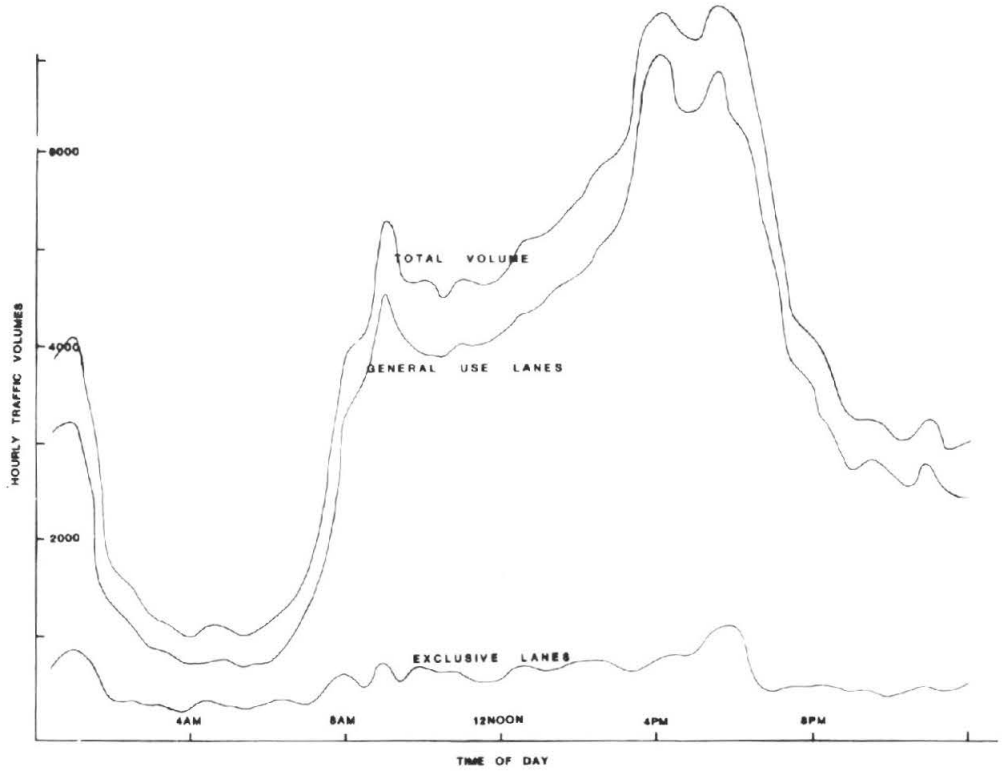


b. Northbound

FIGURE 2.1. TRAFFIC VOLUMES (VEHICLES PER HOUR) AT 62ND STREET.

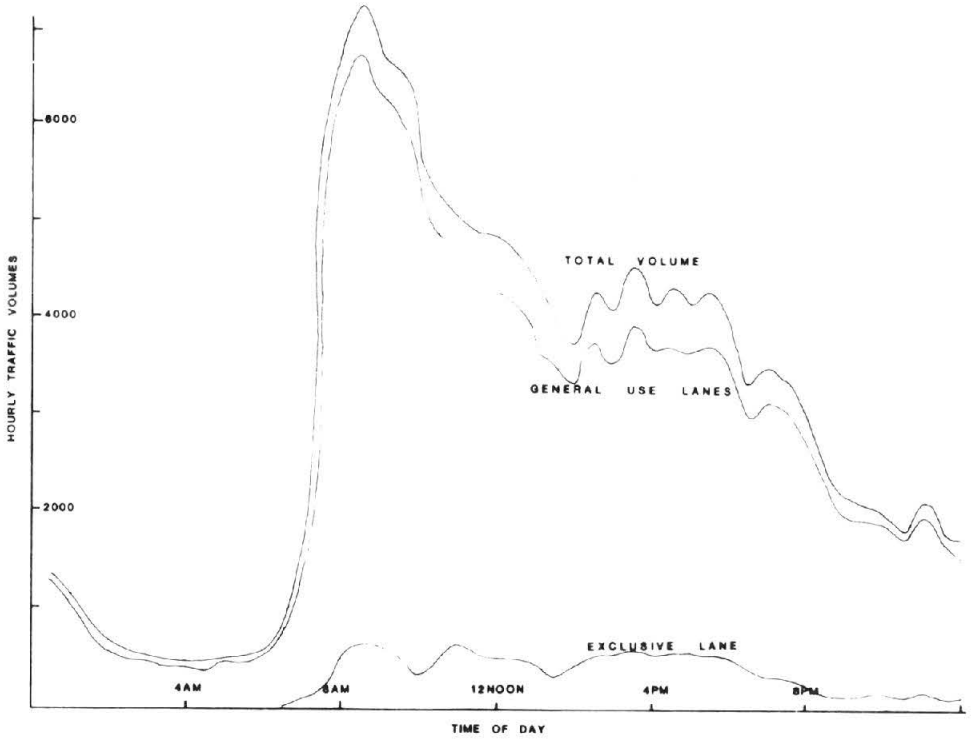


a. Southbound

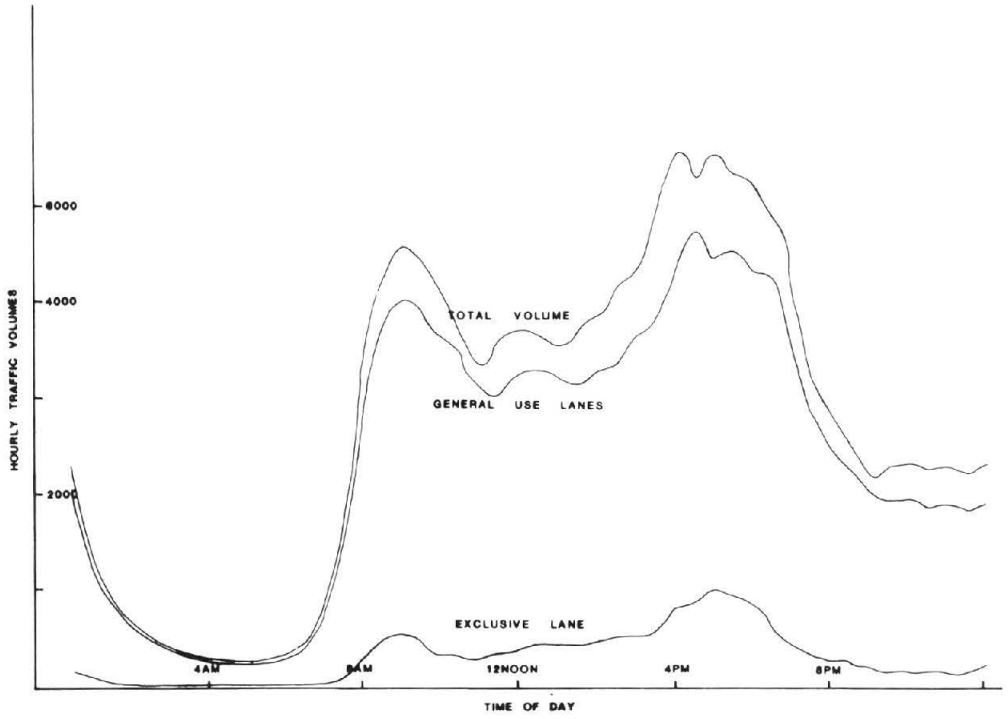


b. Northbound

FIGURE 2.2. TRAFFIC VOLUMES (VEHICLES PER HOUR) AT 111ST STREET.

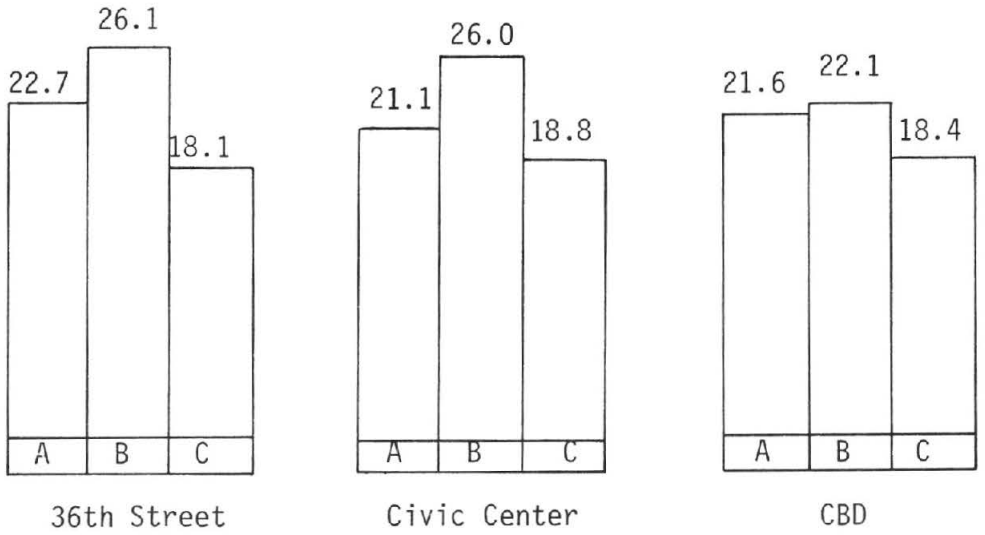


a. Southbound



b. Northbound

FIGURE 2.3. TRAFFIC VOLUMES (VEHICLES PER HOUR) AT 151ST STREET.



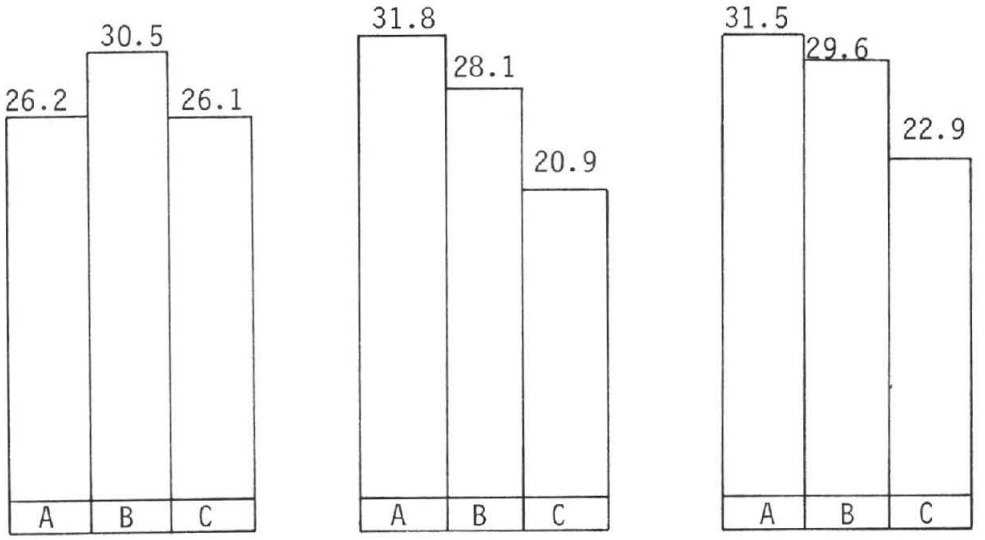
a. AM Peak

KEY TO STAGES

A) "Before" (Mixed Mode) Conditions on I-95

B) Operation on NW 7th Avenue during construction of freeway lanes

C) Operation in Bus/Car Pool Lane on I-95



b. PM Peak

FIGURE 2.4. ORANGE STREAKER TRAVEL TIMES (MINUTES PER TRIP) BY SERVICE AREA.

The PM comparison between the mixed mode operation on I-95 (A) and the signal preemption route on NW 7th Avenue (B) did not, however, follow the same trend as the AM comparison. In this case, two of the three service areas demonstrated shorter travel times on NW 7th Avenue. Since the PM conditions tended to be much more congested, it appears that the potential benefits of the signal preemption system (together with the reserved lane) on NW 7th Avenue were more fully realized when traffic speeds on the freeway were normally quite low.

2. Speed Profiles on I-95

Speed profiles for I-95 are illustrated in Figures 2.5 and 2.6 for the morning peak period and the afternoon peak period, respectively. The profiles show the 95% confidence intervals for the mixed mode bus operation superimposed on the bus operation with reserved lane and 3 person car pools.

Within both peak periods, the speeds of the buses were consistently higher on I-95 when the buses operated in the reserved lane. This would be expected due to the capability of the buses to bypass congestion in the adjacent general lanes.

In addition to higher speeds, the reserved lane operation resulted in less variable bus speeds on I-95, even in the most congested areas. Figure 2.6 dramatically represents this difference in operation as it is readily apparent the bus operation was much improved with the introduction of the reserved lane. A comparison of the two peak periods further emphasizes the more congested nature of the PM peak, as indicated previously.

3. Delay to Orange Streaker Buses

The total delay and stopped delay for the Orange Streaker buses on I-95 and 7th Avenue are illustrated in Figure 2.7.

The delay figures were consistent with the travel time results presented previously. In the morning peak period the buses operating on NW 7th Avenue (B) incurred significantly more delay than either of the I-95 stages. This delay increase would be expected for the buses using an arterial street with a signal system. During the PM peak, the mixed mode operation on I-95 (A) showed a substantial effect on the Orange Streaker delay during the "Before" stage.

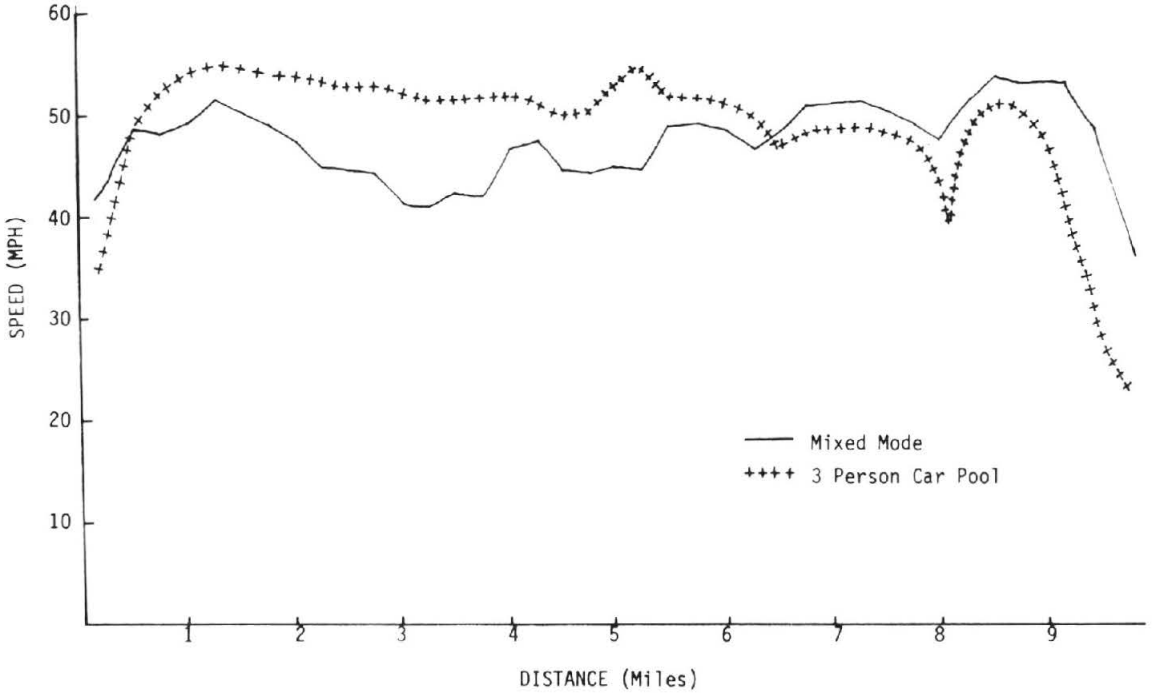


FIGURE 2.5. DISTANCE/SPEED PROFILES FOR BUSES ON I-95 DURING THE AM PEAK PERIOD.

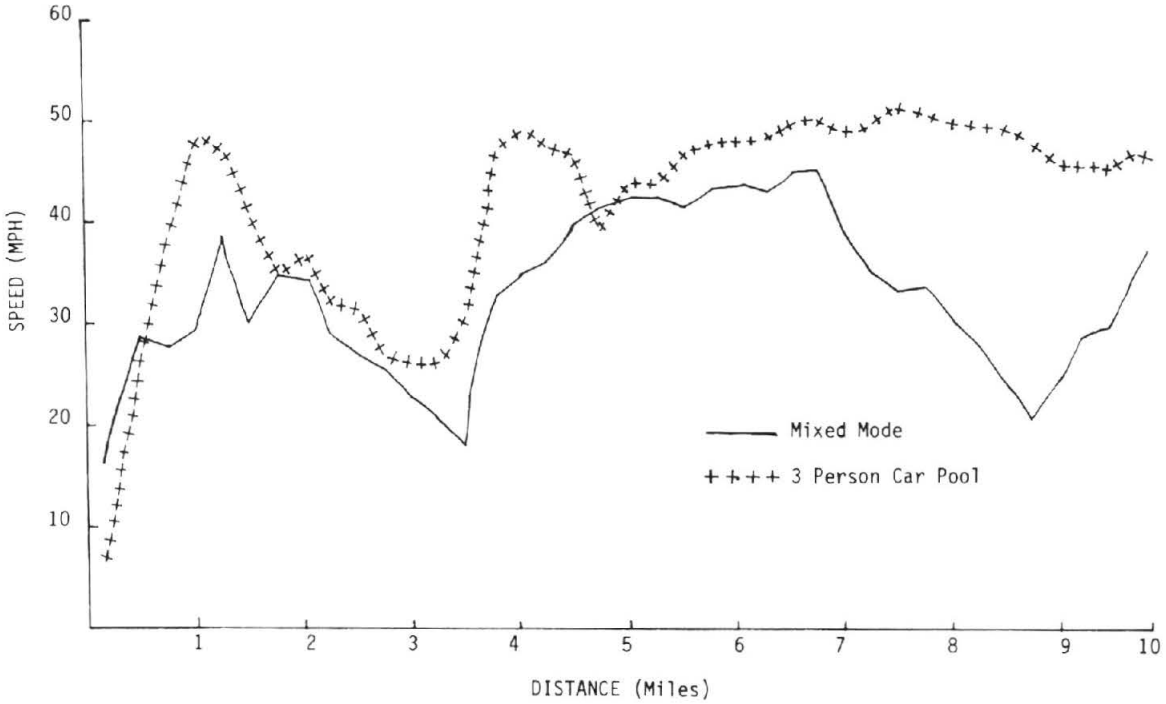
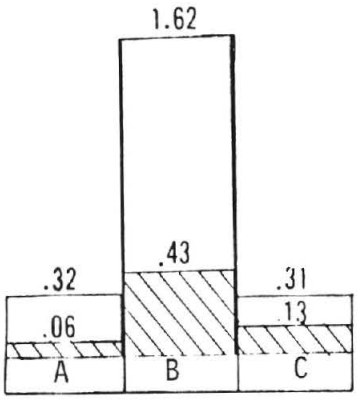
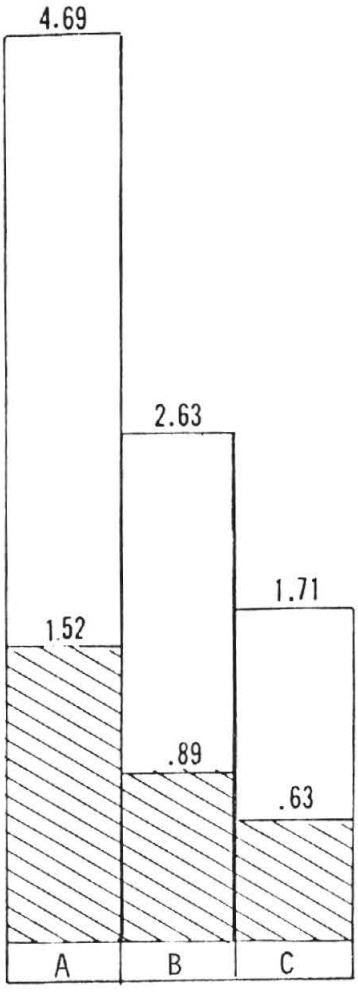


FIGURE 2.6. DISTANCE/SPEED PROFILES FOR BUSES ON I-95 DURING THE PM PEAK PERIOD.



AM PEAK



PM PEAK

NOTE: Shaded area indicates stopped delay

KEY TO STAGES

A) "Before" Conditions on I-95

B) Operation on NW 7th Avenue during construction of freeway lanes

C) Operation in Bus/Car Pool Lane on I-95

FIGURE 2.7. ORANGE STREAKER DELAY (MINUTES PER TRIP) BY DEMONSTRATION PROJECT STAGE.

4. Measures of Passenger Comfort

The primary measure of passenger comfort as suggested in Reference 2 was speed noise, defined as the coefficient of variation of the bus speed in a given section. This measure is illustrated in Figure 2.8. Comparison of the two peak periods indicates that the speed noise was reduced on the freeway with the exclusive lane only during the PM peak. It appears, therefore, that while the travel time was improved during the AM period, the generally less congested operation experienced during the morning did not lend itself to further improvements in passenger comfort.

The comparison between I-95 and NW 7th Avenue indicated, on the other hand, a lower speed noise on the freeway in both peaks. This demonstrates that although the travel time was lower on NW 7th Avenue (B) than on the mixed mode I-95 (A) during the PM peak, the trip was less "comfortable" probably due to occasional stops caused by mid-block perturbations etc., inherent in a surface street operation.

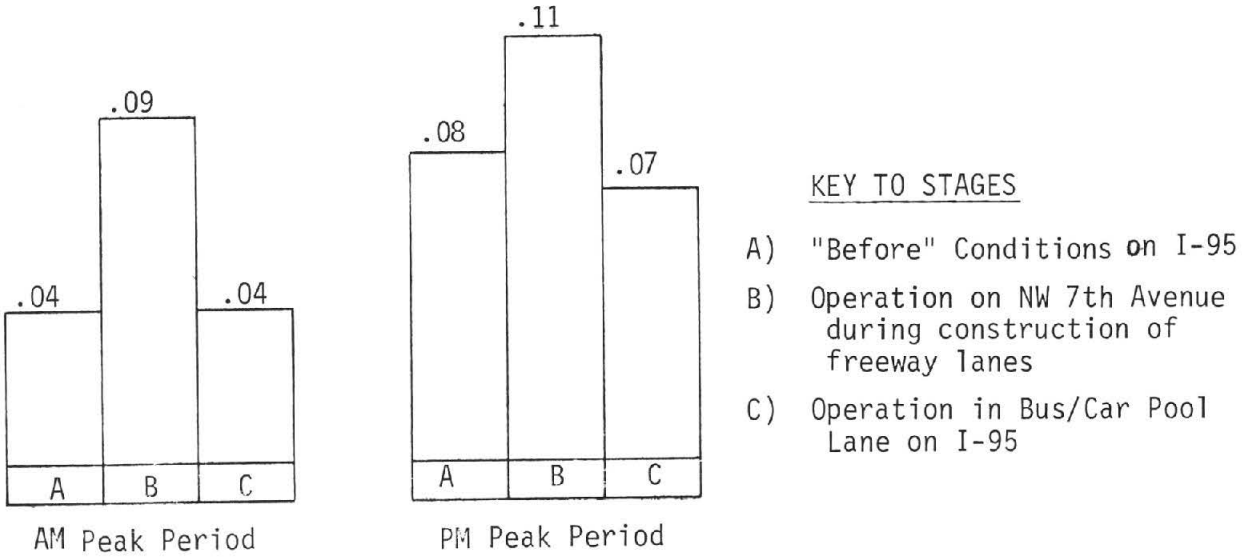


FIGURE 2.8. AVERAGE SPEED NOISE EXPERIENCED BY BUSES DURING THE AM AND PM PEAK PERIODS.

5. Bus Schedule Adherence

The arrival time discrepancy for a particular bus is expressed in terms of the actual arrival time minus the scheduled arrival time. The distribution of this measure for the operational stages is illustrated in Figure 2.9. The dispersion of the distributions (the standard deviation) reflects the degree of schedule adherence with a more dispersed distribution representing a lower degree of adherence.

It is observed that the exclusive lane operation produced the greatest dispersion of arrival time discrepancy even though the mean value was the smallest of the three stages. This suggests the possibility that the buses using the exclusive lane tended to travel at a speed closer to the desired speed of the operator, rather than the speed dictated by the traffic stream. This effect is consistent with a similar study performed on NW 7th Avenue described in Reference 3.

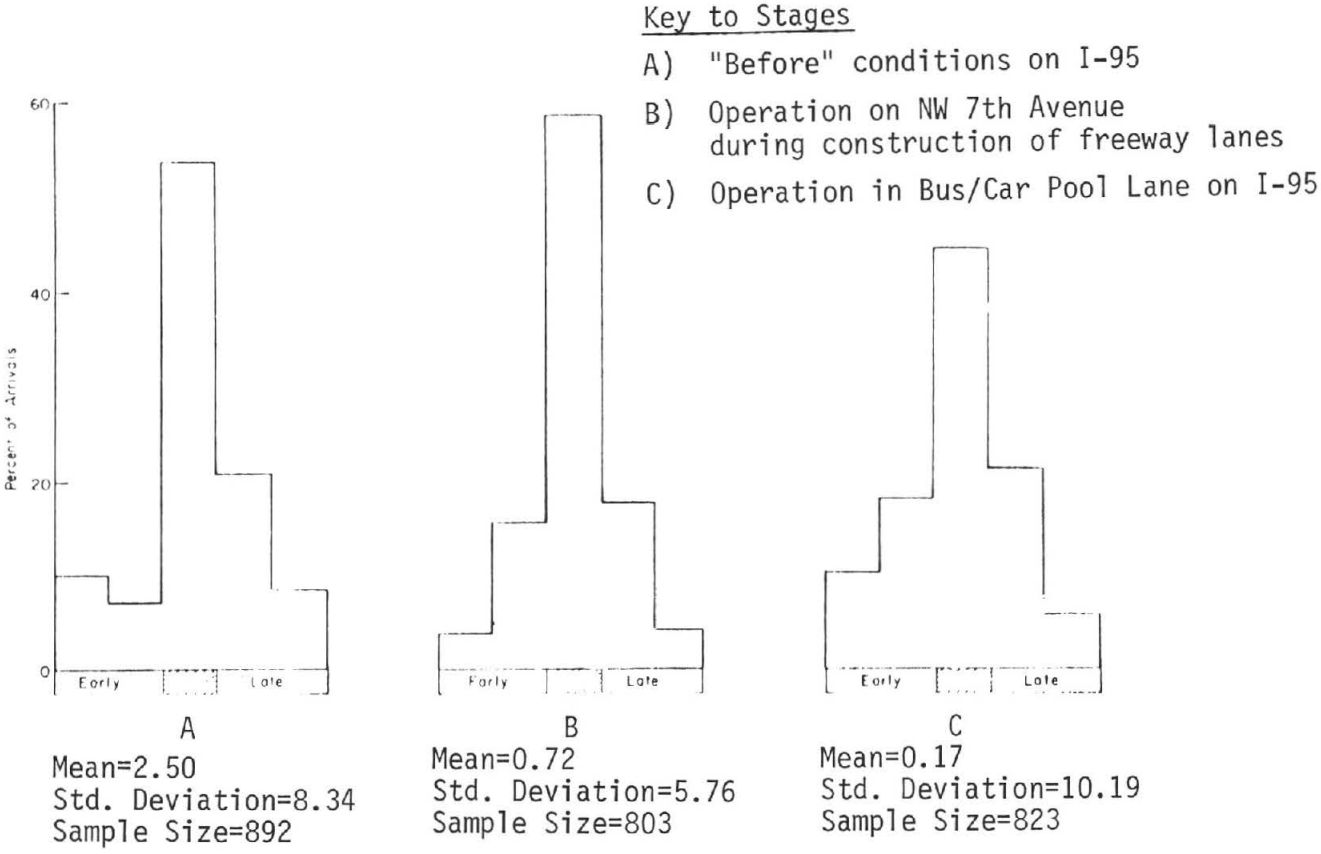


FIGURE 2.9. DISTRIBUTION OF DIFFERENCE BETWEEN ACTUAL AND SCHEDULED ARRIVAL TIMES FOR ORANGE STREAKER BUSES AT THE GOLDEN GLADES TERMINAL.

D. SYSTEM OPERATING CHARACTERISTICS

The operational characteristics of the system were compared for two sets of conditions:

- -Mixed mode operation, which occurred prior to the implementation of the exclusive lane on I-95; and,
- -HOV priority operation, in which only buses and 3 person car pools were permitted to use the newly constructed median lanes.

To develop these comparisons, field data were collected to determine:

- average traffic volumes on I-95 during each of the peak periods;
- average passenger occupancy for exclusive lane autos and autos traveling in the general lanes;
- travel times for each mode of travel; and
- bus passenger volumes.

The section of freeway used for comparison purposes included the entire reserved lane section between the airport expressway and 151st Street. This section was 6.7 miles in length.

From the field data, the following measures of effectiveness were calculated for each peak period:

1) Total vehicular demand on the freeway (vehicle miles)
2) Total passenger demand (passenger miles)
3) Total vehicular travel time on the freeway (vehicle hours)
4) Total passenger travel time on the freeway (passenger hours)
5) Average vehicle speed (vehicle miles ÷ vehicle hours = m.p.h.)
6) Average passenger speed (passenger miles ÷ passenger hours = m.p.h.)

7) Passenger movement index
(passenger miles ÷ vehicle hours = m.p.h.)

8) HOV priority index
(average passenger speed ÷ average vehicle speed)

Note that measures 5, 6, and 7 share the same dimensions (miles per hour). The vehicle and passenger speeds are relatively simple from a conceptual point of view. The Passenger Movement Index (PMI) is defined for purposes of this study as the number of passenger miles of travel per vehicle hour of travel time. It is suggested that this measure provides the most meaningful relationship between the service provided by the facility, in terms of passenger throughput, and the cost of providing that service, in terms of traffic congestion.

Another derived measure of effectiveness is termed the "HOV Priority Index". This measure, is defined for purposes of this study as the ratio of average passenger speed to average vehicle speed. An HOV Priority Index of 1.0 would indicate that no travel time advantage was experienced by high occupancy vehicles. To achieve an index greater than 1.0 it would be necessary to move vehicles carrying larger numbers of passengers at higher speeds than vehicles with fewer occupants.

These measures are summarized for both operating conditions in Table 2.1. It is observed that, in general, the HOV Priority Indices were very low (in the range of 1.01) for all stages. This indicates that the average passenger was travelling 1% faster than the average vehicle. The low Priority Index was achieved because the vast majority of the vehicles were low occupant types and the travel time advantage for HOV's is relatively small. It is also observed that while the introduction of the reserved lane did not increase the HOV Priority Index appreciably, it did result in a more favorable Passenger Movement Index, with a gain of approximately 25% registered in both peak periods. This indicates that conditions were improved for both high and low occupancy vehicles.

TABLE 2.1

COMPARISON OF OPERATIONAL CHARACTERISTICS

AM PEAK

Item	Mixed Mode Operation	Bus/Car Pool Priority Operation		
		Exclusive Lane	General Lane	Total
Auto Volume	14,853	653	14,909	15,562
Auto Occupancy	1.258	1.967	1.249	1.279
Auto Passengers	18,685	1,284	18,621	19,905
Bus Passengers	568	827	---	827
Total Vehicle Miles	94,507	4,337	94,672	99,009
Total Vehicle Hours	3,002	82	2,485	2,567
Total Passenger Miles	122,257	13,408	118,248	131,654
Total Passenger Hours	3,856	271	3,104	3,375
Average Vehicle Speed	31.5	52.9	38.1	38.6
Average Passenger Speed	31.7	49.5	38.1	39.0
Passenger Movement Index	40.7	163.5	47.6	51.3
HOV Priority Index	1.01	---	---	1.01

PM PEAK

Item	Mixed Mode Operation	Bus/Car Pool Priority Operation		
		Exclusive Lane	General Lane	Total
Auto Volume	16,047	943	17,675	18,618
Auto Occupancy	1.317	2.115	1.313	1.354
Auto Passengers	21,134	1,994	23,207	25,201
Bus Passengers	533	783	---	783
Total Vehicle Miles	102,089	6,179	112,236	118,415
Total Vehicle Hours	3,456	124	3,152	3,276
Total Passenger Miles	137,585	17,637	147,366	165,003
Total Passenger Hours	4,658	359	4,138	4,497
Average Vehicle Speed	29.5	49.8	35.6	36.7
Average Passenger Speed	29.5	49.1	35.6	36.7
Passenger Movement Index	39.8	142.2	46.8	50.4
HOV Priority Index	1.00	---	---	1.02

CHAPTER THREE

OPERATIONAL EFFECTS OF SIGNS AND PAVEMENT MARKINGS

A. INTRODUCTION

Several experimental studies were carried out during the course of the Project to assess the effects of signing and pavement marking parameters on the operation of the exclusive lane. Most of these studies were concentrated in a designated test section of the northbound roadway during the afternoon peak period. This test section illustrated in Figure 3.1 was approximately 2½ miles in length. Signing and marking parameters which were varied on this section included:

1. spacing of the exclusive lane sign messages;
2. provision of the advance warning sign for the exclusive lane;
3. width of the pavement markings; and
4. spacing of the intra-lane diamond symbol.

Other parameters which were studied elsewhere in the system included:

1. type of pavement marking line (solid vs. skip) which was examined over the entire length of the exclusive lane; and
2. overhead signs to facilitate lane changing by buses, which were studied in an area of heavy bus weaving, located outside of the test section.

The primary measures of effectiveness used in these studies included:

1. rate of violation by non-qualified vehicles in the reserved lane;
2. frequency of weaving into and out of the reserved lane; and
3. travel time in the reserved lane.

B. DATA COLLECTION METHODOLOGY

The study techniques used for data collection and analyses are discussed in detail in Reference 1. These techniques are summarized briefly as follows.

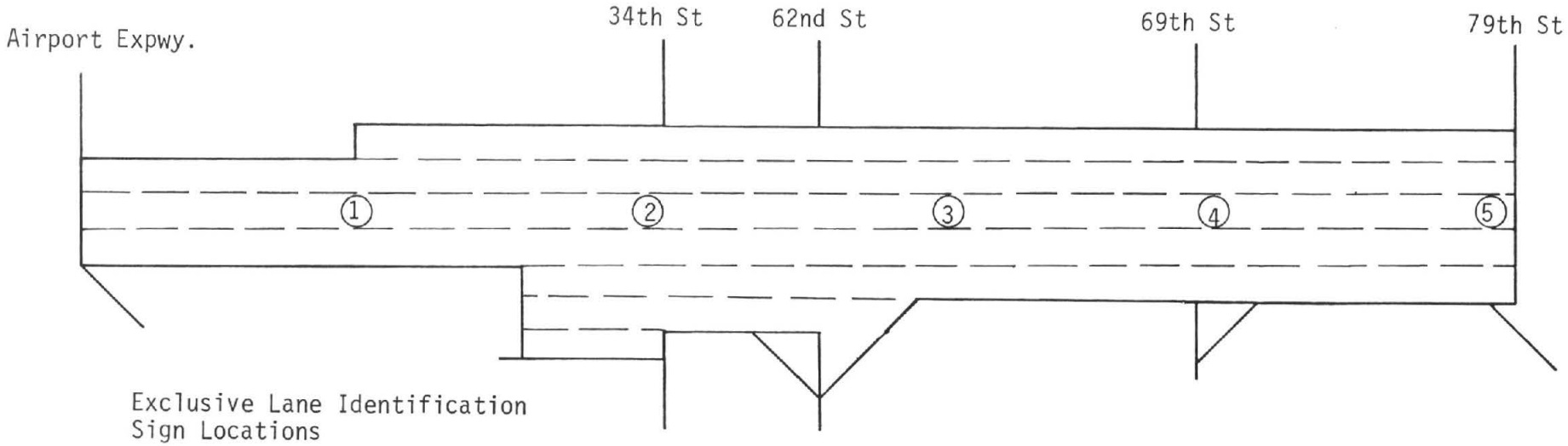


FIGURE 3.1. NORTHBOUND (PM) TEST SECTION FOR SIGNING AND PAVEMENT MARKING STUDIES.

1. Weaving Studies

Data used in weaving analyses were obtained from time lapse photographic studies. The specific weaving measure was expressed in terms of the number of lane changing movements per unit of traffic volume in the lane from which the weave initiated. For example, in the case of weaving maneuvers out of the exclusive lane, the appropriate measure would be the number of weaves from the exclusive lane to the adjacent lane divided by the exclusive lane volume. Therefore, the weighted weaving measure actually represents the probability of a vehicle weaving from the lane in which it is travelling.

The time lapse photography stations were concentrated in the northbound test section. Since the number of films obtained at each location varied between the individual signing and marking techniques, a study was conducted to determine whether weighted weaving maneuvers varied significantly between locations. Results showed that there did exist significant differences between sections and that high density locations were preceded by an area of significantly greater weaving into the exclusive lane and succeeded by an area of significantly greater weaving out of the exclusive lane.

Because of this effect, a factorial experimental design was applied. This statistical procedure tested for significant differences in the mean weaving rates between two comparable priority strategies while also testing for locational effects and location/marking interactions.

2. Violation Studies

Data points for the violation percentages, violator flow rates and car pool flow rates were obtained by observation from a moving vehicle.

The statistical procedure was controlled for individual sections as well as for the three time periods in which the violation runs were made (before 4:30, 4:30 to 5:30, after 5:30). Therefore, the statistical analysis contained three factors about which inferences could be made.

3. Travel Time Studies

Individual data points were obtained from an instrumented travel time and delay study technique. The raw data consisted of a series of times corresponding to each increment of distance traveled by the test vehicle. It also included information which established where the run began, ended and the actual distance

represented by each increment. This technique was applied to two specific studies:

- Overall travel time in the exclusive lane test section under various experimental conditions, and
- Difficulty experienced by buses in changing lanes, with and without the "yield to buses" signs on the freeway.

C. RESULTS OF THE STUDY

This study involved several detailed statistical analyses, each requiring a large amount of data. For the most part, the results show little if any statistically significant differences among the various experimental treatments which were compared. In other words, it has been scientifically demonstrated that the signing and marking parameters which were studied did not exert a profound effect on the performance of the system. Therefore, the statistical aspects of this phase of the study have been confined to Appendix A of this report and only a summary of the findings will be presented in this chapter.

1. Marking Parameters

The marking parameters and their effects on system performance are summarized on Table 3.1. The following trends were observed.

a. Width of Marking

A skip line of 4" and 8" width was studied in the test section. No significant effect on any of the measures of effectiveness was noted.

b. Type of Marking (Solid vs. Skip Line)

A comparison was made between 8" solid and 8" skip line markings throughout the entire length of the exclusive lane. This comparison showed no effect on the travel time, but a tendency toward higher weaving activity and violation rates was observed in the case of the skip line. A possible conclusion here is that the solid line tends to discourage both lane changing and violations. Some caution must be used in this interpretation, however, since the violation rates increased erratically as the project progressed and the motorists became aware of the enforcement problems. This subject is treated in greater detail in the next chapter of this report.

TABLE 3.1

COMPARISON OF MARKING PARAMETERS

PARAMETER	STUDY CONDITIONS	MEASURES OF EFFECTIVENESS		
		Weaving	Violations	Travel Time
Width of Marking	A) 4" Skip Line B) 8" Skip Line	No Significant Effect	No Significant Effect	No Significant Effect
Type of Marking	A) 8" Solid Line B) 8" Skip Line	Weaving activity tended to be greater across the skip line than the solid line (95% significance)	Violation rates tended to be greater with the skip line (95% significance)	No Significant Effect
Diamond Spacing	A) 1000' B) 250'	No Significant Effect	Violation rates tended to be higher with the closer spacing (99% significance)	No Significant Effect

c. Diamond Spacing

An increase in violation rates was also observed with the closer diamond spacing. The opposite tendency would be anticipated, and it is suggested, therefore, that the difference in violation rates was more closely related to the general deterioration of enforcement which occurred during this phase of the Project.

2. Signing Parameters

The signing parameters and their effects on system performance are summarized in Table 3.2. The following trends were observed.

a. Advance Warning Sign

The system performance was studied both before and after the installation of an advance warning sign advising the motorist of the exclusive lane regulations. No significant effect on any of the measures of effectiveness was observed.

b. Exclusive Lane Sign Spacing

The exclusive lane identification sign was presented to the motorist within the test section at five locations, as shown in Figure 3.1. By controlling the order in which these signs were installed, a three stage experiment was established.

- Locations 1 and 5 were installed first, giving an effective spacing of approximately two miles between signs.
- Location 3 was added next, reducing the spacing to approximately one mile.
- Locations 2 and 4 were added last, reducing the spacing to the final 1/2 mile configuration.

During the course of this experiment, appropriate destination-oriented guide signs were installed in place of the "missing" exclusive lane identification signs (see Figures 3.2 and 3.3) to avoid the appearance of an unused sign structure.

The only significant relationship observed in this study was the tendency towards increased weaving out of the exclusive lane with one mile spacing of the signs. In the absence of supporting evidence of any relationships between sign spacing and any of the other measures of effectiveness, it is suggested that the observed tendency was caused by factors beyond the control of the study.

TABLE 3.2

COMPARISON OF SIGNING PARAMETERS

PARAMETER	STUDY CONDITIONS	MEASURES OF EFFECTIVENESS			
		Weaving	Violations	Travel Time	Speed Noise
Advance Warning Sign Presence	Before & After	No Significant Effect	No Significant Effect	No Significant Effect	N/A
Exclusive Lane Sign Spacing	1) 2 mile 2) 1 mile 3) 1/2 mile	1 Mile Spacing showed significantly higher weaving out of exclusive	No Significant Effect	No Significant Effect	N/A
"Yield to Buses Sign"	Before & After	N/A	N/A	N/A	Speed noise was reduced significantly after sign was installed.

FIGURE 3.2. TEMPORARY REPLACEMENT OF "MISSING" EXCLUSIVE LANE SIGN AT LOCATION TWO.

FIGURE 3.3. TEMPORARY REPLACEMENT OF "MISSING" EXCLUSIVE LANE SIGN AT LOCATION FOUR.

3. "Watch For Buses Changing Lanes" Sign

Studies conducted before and after the installation of the "Watch for Buses Changing Lanes" sign shown in Figure 3.4 indicated a significant reduction of speed noise within the weaving area immediately downstream of the sign. Speed noise is a measure of the variability of speed and, therefore, provides an indication of the general difficulty of the driving task at a particular location. The improvement in this measure of effectiveness suggests that the overhead sign was beneficial to the buses executing the lane changing maneuver.

4. Other Weaving Assistance Techniques

Two additional weaving assistance techniques were implemented on this Project.

a. Large flashing signals located on the right rear of the bus (see Figure 3.5) near the roof, to supplement the turn signal indicators.

b. Advertising messages saying "CARPOOLS FOLLOW ME" carried on the rear of selected buses, also illustrated in Figure 3.5.

The implementation schedule precluded a formal evaluation of the benefits of these techniques. It is noted, however, that the transit agency management indicated a high degree of satisfaction with the flashing signals and considered them "indispensable" to the safe operation of the express buses in the reserved lane.

D. CONCLUSIONS

In spite of the large amount of data collected and analyzed, it is difficult to draw strong conclusions based on the operational effects of signing and pavement marking techniques. Many of the parameters studied did not present conspicuous differences to the motorist. Furthermore, unanticipated developments related to the implementation of the Project (schedule delays, deterioration of enforcement, safety hazards, etc.) caused some "contamination" of the experimental stages. Within these limits, the following conclusions are offered:

1. The solid pavement marking delineating the exclusive lane appeared to discourage both weaving and occupancy violations in the exclusive lane to a greater extent than the skip line.

2. The overhead "yield to buses" signs appeared to facilitate lane changing maneuvers by transit vehicles.

FIGURE 3.4. OVERHEAD SIGN FOR BUS LANE CHANGING.

FIGURE 3.5. REAR VIEW OF BUS WITH CAR POOL ASSISTANCE SIGN AND OVERSIZE TURN SIGNALS.

Additional investigation would be required to establish or confirm definite relationships between the other variables which were examined. It is suggested, however, that the studies described in this chapter were carried out in sufficient detail to identify any conspicuous relationships which existed.

CHAPTER FOUR

SAFETY CONSIDERATIONS: VIOLATIONS ENFORCEMENT AND ACCIDENTS

A. INTRODUCTION

This chapter covers the public safety aspect of the I-95 Bus/Car Pool Priority System. This aspect is extremely important to the success of a project of this nature, and must be carefully considered in the design and operation of HOV priority lanes.

The rate of violation of the minimum occupancy requirement for exclusive lane use developed into one of the major issues of the Demonstration Project. The main problem was the difficulty of providing the degree of enforcement required to discourage the abuse of this lane by unqualified vehicles. The studies discussed in this chapter focused on the development of relationships between violations and other operational variables, and on the enforcement activities including level of enforcement, enforcement problems and the attitudes of the enforcement officers towards the operation of the facility.

Accident studies were also carried out in connection with this Project. A comparison of accident rates was performed under various operational stages and a detailed analysis of the accidents related to the exclusive lane was prepared.

B. LEVEL OF ENFORCEMENT

The level of enforcement of the exclusive lane regulations can be quantified either in terms of the personnel assignments or the number of violators apprehended. Approximate values were established for both of these measures.

1. Personnel Assignments

The freeway facility fell into two Florida Highway Patrol (FHP) enforcement zones and separate personnel were assigned to each zone. Six FHP officers were assigned to each zone during each peak period. The proportion of time spent within the project area by each officer is difficult to determine precisely, however, informal discussions with troop leaders suggested that 60% would be a reasonable figure. The assigned level of enforcement could then be expressed as:

$$\frac{\text{12 officers x 60\%}}{\text{7.8 miles (total project length on I-95)}} = .923 \text{ officers per mile}$$

The assigned personnel level remained constant throughout the duration of the Project.

The actual number of officers in the project area could be expected to drop below the assigned level occasionally due to uncontrollable factors such as court appearances, illness, vehicle maintenance, etc. On the other hand, additional enforcement was provided on an incidental basis by local municipal and county police who had occasion to use the freeway in connection with other duties.

2. Tickets Issued

Both warning and citation tickets were issued by the enforcement officers on the freeway. The offenses fell generally into three categories:

- Violation of the minimum occupancy requirement
- Stopping in the exclusive lane, and
- Accident related offenses.

The record keeping procedures of the various agencies involved in processing these tickets did not lend themselves to analysis of the enforcement activities in the project area. It was found in all cases that the project-related offenses were inseparably aggregated with the area-wide enforcement records. It was necessary, therefore, to conduct a questionnaire survey of the Florida Highway Patrol officers to determine the number of warnings and citations which were issued. A total of 59 FHP officers participated in the survey.

In addition to other questions which will be discussed later, each officer was asked:

"How many tickets did you issue last month for,

A) Having less than 3 persons per vehicle in priority lane during restricted hours?

B) Illegal standing or stopping in priority lane (at ANY time)?

C) Causing an accident involving priority lane vehicles or resulting from priority lane operations?"

Monthly averages for citations in each of the offense categories are presented in Figure 4.1 for the period covering August 1976 to February 1977. A gradual reduction was observed in the number of citations issued as the project progressed. This was especially apparent in the case of offenses involving violation of the minimum occupancy requirement for the exclusive lane. It is noted that by the last month of the survey, the "violation" citations approached the same level as citations for illegal stopping and for accident-related offenses.

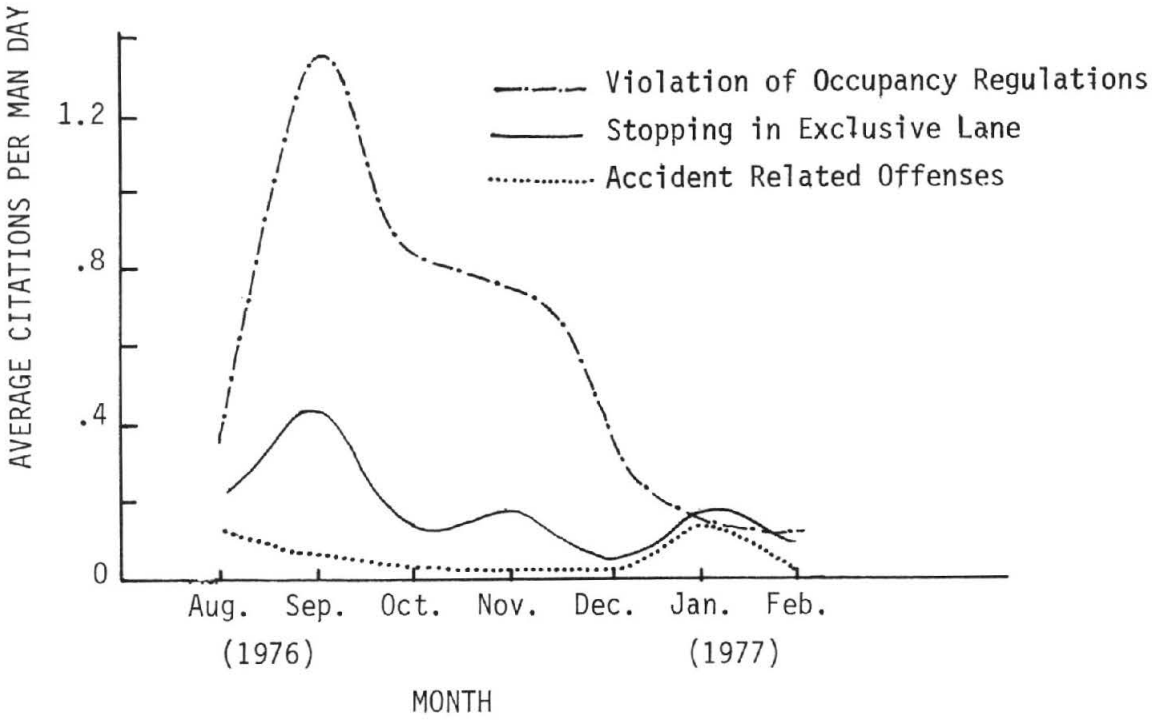


FIGURE 4.1. ENFORCEMENT LEVELS THROUGHOUT THE DEMONSTRATION PROJECT.

In general, enforcement proved to be a major problem as a result of several factors:

- There was insufficient space to provide enforcement areas in the geometric design of the exclusive lane.
- Transferring violators from the exclusive lane to a safe stopping location proved to be extremely hazardous and disruptive to the operation of the freeway, especially during congested periods.
- Fewer officers were assigned to the Project than originally intended because of financial and institutional limitations.
- Financial constraints also eliminated the intended use of innovative enforcement techniques such as photography, etc.
- Some judicial opposition was encountered, which increased the problems of convicting violators.
- The Florida Department of Highway Safety and Motor Vehicles ruled that penalty points should not be assessed to convicted violators' drivers licenses.

The enforcement situation was further aggravated by news media coverage which publicized the problem of enforceability of the minimum occupancy regulations. The net result was somewhat disappointing in terms of the violation rates in the exclusive lane.

C. VIOLATION RATES

Violation rates were determined by field observations made from a moving vehicle driving in the opposite direction to the exclusive lane movement. Studies carried out during the first six months of the exclusive lane operation showed the violation rate to be relatively constant and in the range of 50 - 55%. The need to repeat these studies became apparent as the Project progressed and the public awareness of the enforcement problems increased. A second group of studies was, therefore, carried out approximately ten months after the beginning of operation. These studies indicated that the violation rate had risen to approximately 75%.

D. EFFECT OF OPERATIONAL CHARACTERISTICS ON VIOLATION RATES

A detailed statistical analysis of the relationships between violation rates and operational characteristics is presented in Appendix D of this report. This chapter will, therefore, include only a brief discussion of the major results of the statistical analysis.

1. Effect of Volume and Density

Traffic volumes (being an ambiguous indicator of congestion) did not demonstrate a strong effect on violation rates. Density in the general lanes, on the other hand, showed a consistently high correlation with violation rates, with violations increasing in areas of higher density.

While exclusive lane violation rates increased monotonically with density in the general lanes, it was observed that lane changing movements tended to increase only until the density reached a point where lane changing became difficult. The maximum lane changing activities were observed at densities of 87 and 134 vehicles per lane per mile in the AM and PM peaks, respectively.

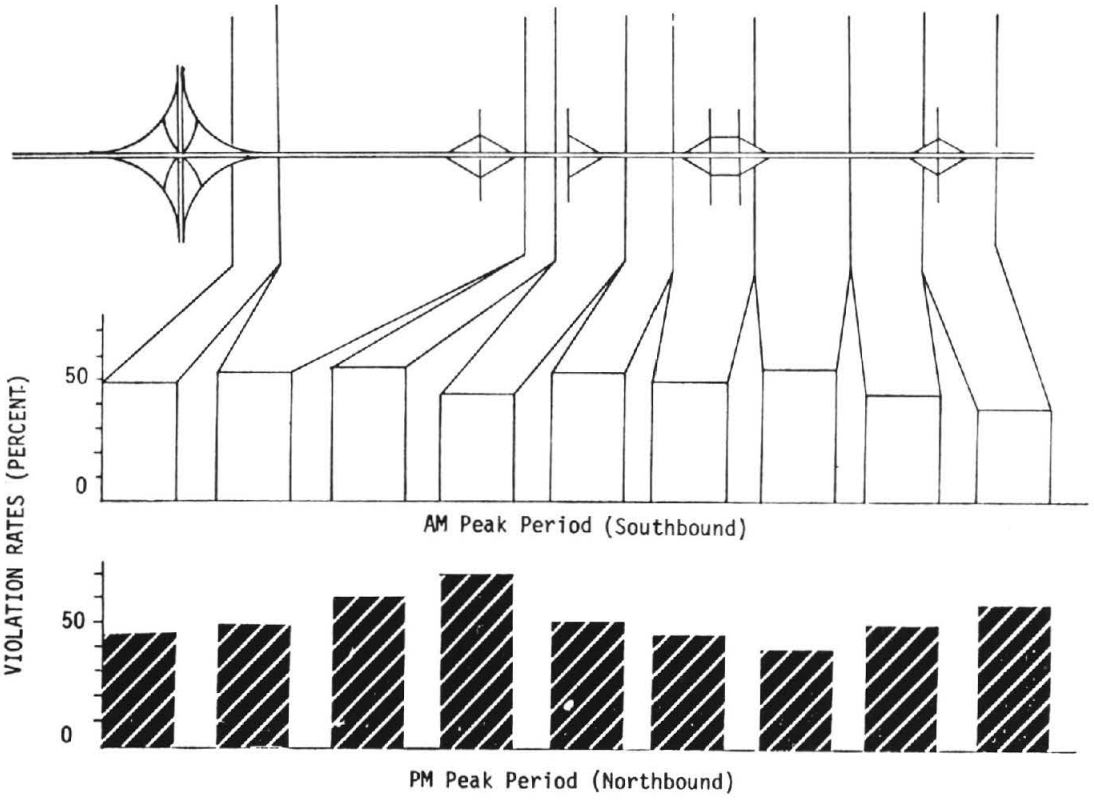
2. Violation Profiles

Violation profiles which illustrate the variation in exclusive lane violation rates with locations on the freeway are presented in Figure 4.2. These profiles indicate that the violation rate was relatively constant during the AM peak period. This period was generally less congested than the PM peak, in which two areas of heavy concentration were observed. These areas coincided generally with known bottleneck locations. This provides further support for the argument that violation rates are influenced by the degree of congestion on the facility.

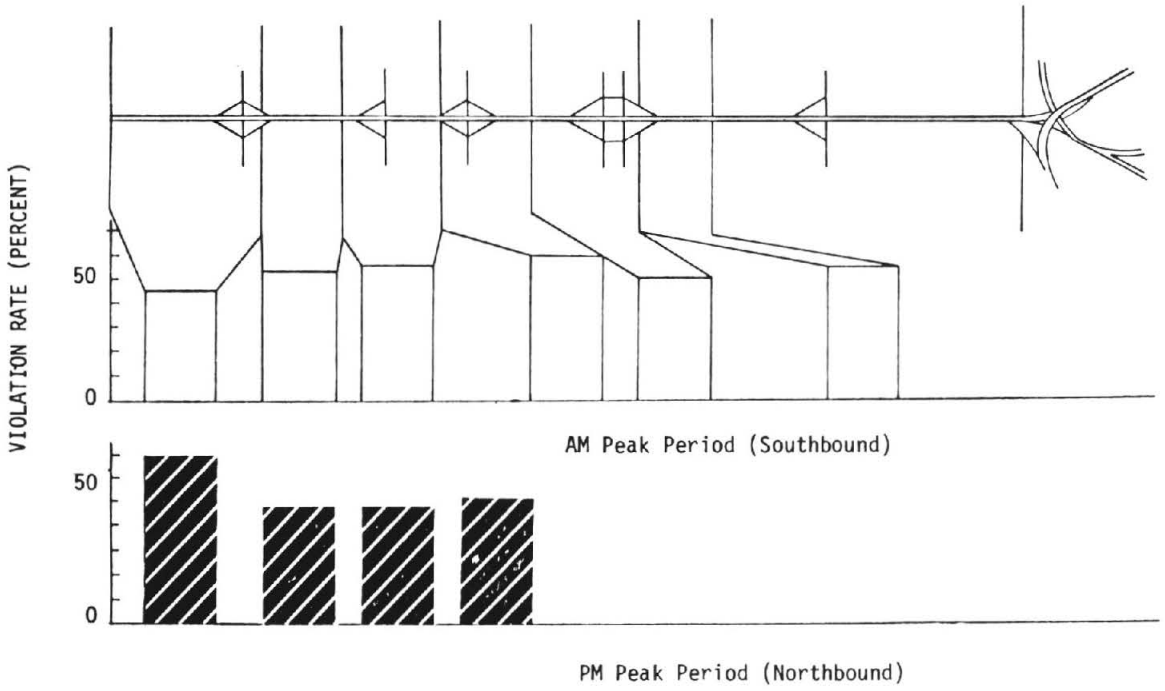
E. EFFECT OF ENFORCEMENT ON VIOLATION RATES

1. General Observations

The effect of enforcement (or lack of enforcement) on violation rates in the I-95 exclusive lane became quite apparent as the project progressed. Further quantification of this relationship was not possible with the enforcement data available.



a. South Section



b. North Section

FIGURE 4.2. MINIMUM CAR POOL OCCUPANCY VIOLATION PROFILES .

The following general observations are, however, offered:

a. The actual violation rate is likely to depend to a large extent on the available capacity in the exclusive lane. This parameter is, of course, specific to each project. It is interesting to note that although violation rates were extremely high, the priority lane still operated with a definite travel time advantage.

b. Further evidence of respect for the exclusive lane regulations is apparent in Chapter 6 of this report, which evaluates the operational changes resulting from a lowering of the car pool requirement to 2 persons per vehicle. A substantial number of 2 person vehicles shifted to the exclusive lane when the restrictions were relaxed.

c. Although the violation rate rose significantly as the Project progressed, the enforcement level as determined by the assigned number of officers did not change. This suggests that public perception of the enforcement situation is more important than the actual enforcement activities in promoting compliance with the regulations.

2. Effect of Presence of a Patrol Vehicle on Violations

The field studies of violations described previously also took note of the presence of highway patrol vehicles in the traffic stream. A statistical comparison of the violation rates as a function of distance from the highway patrol vehicle was carried out over a distance of one mile upstream and downstream of the vehicle. The results showed that the legitimate car pool volumes in the exclusive lane were not (at the 95% level of significance) influenced by the distance from the police vehicle. The "violator" volumes, on the other hand, tended to decrease significantly (at the 95% level) as the vehicles approached the enforcement point. The rate of decrease was 5.5 vehicles per hour per 100 feet of distance. No corresponding statistical decrease was, however, observed on the downstream side of the highway patrol vehicle. It could be argued in this case that the motorist driving improperly in the exclusive lane is more likely to notice a highway patrol vehicle ahead of him because of the flashing beacon and other distinguishing features. It could also be argued that once a violator has left the exclusive lane, he is not likely to return immediately after passing the enforcement vehicle. These arguments would help to explain the observed effect.

F. ROAD USER ATTITUDES TOWARD VIOLATION AND ENFORCEMENT

Road user attitudes towards the exclusive lane concept in general are discussed in detail in Chapter 5 of this report. Four classes of road users were studied:

- Bus Passengers;
- Car Poolers;
- Bus Operators; and
- General Public.

Occasional comments were received from the general public and bus passengers regarding abuse of the exclusive lane by non-qualified vehicles, although this subject was not addressed directly in the surveys. The car poolers and the bus drivers were asked to rate the severity of the violation problem and both groups expressed more concern over this problem than any other problem associated with the exclusive lane operation. Approximately three quarters of the bus drivers rated the violation problem as "severe".

G. HIGHWAY PATROL ATTITUDES TOWARD VIOLATIONS AND ENFORCEMENT

1. Assessment of Problems

Each highway patrol officer participating in the survey mentioned previously was asked to rate the following problems:

A. Violations of the priority lane restrictions

B. Use of the priority lane as a breakdown lane

C. Accidents related to priority lane operations

The survey was administered on a monthly basis. Officers responding for the first time were asked to rate the problem as "severe", "moderate", or "no problem". In subsequent responses, officers were asked to indicate whether

the problem was increasing, decreasing or unchanged.

A summary of the first time responses is presented in Figure 4.3. The occupancy violation problem drew the highest "severe" response, with 56% of the 59 officers indicating that category. This suggests a high degree of concern for the problem. However,it is interesting to note that a much larger proportion (75%) of bus operators ranked the problem as "severe".

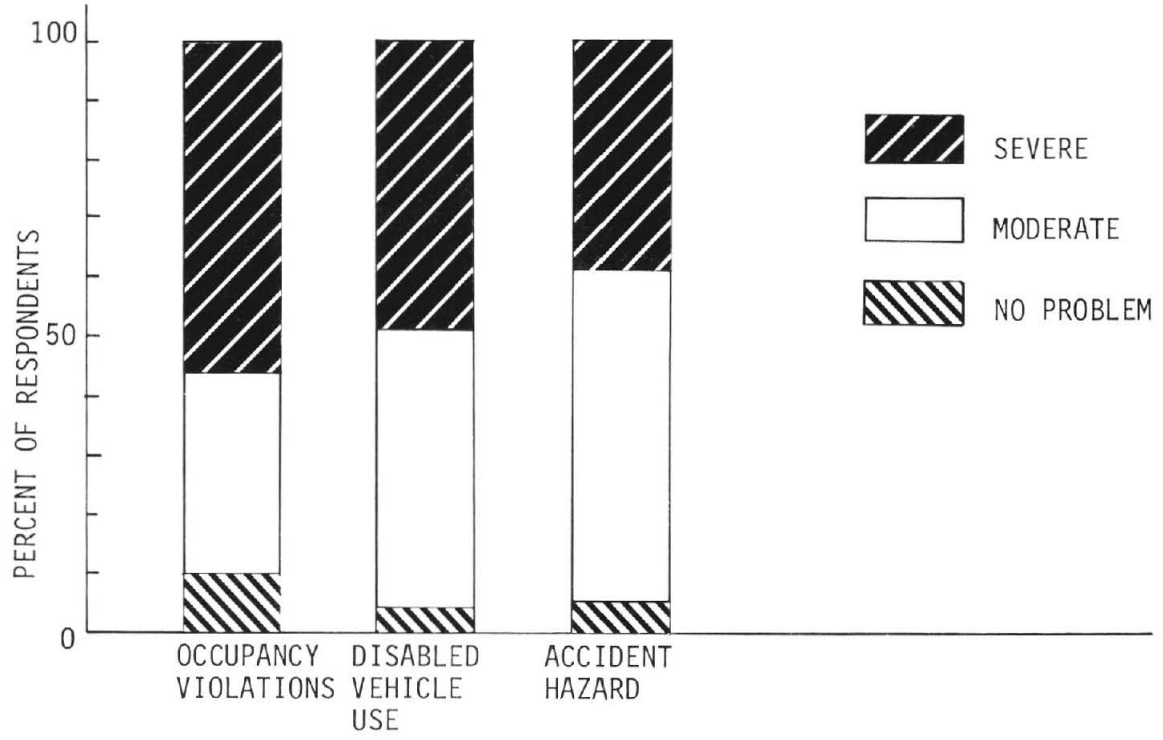


FIGURE 4.3. FLORIDA HIGHWAY PATROL RATINGS OF EXCLUSIVE LANE OPERATING PROBLEMS (FIRST-TIME RESPONSES).

The use of the exclusive lane as a refuge for disabled vehicles was ranked as a slightly smaller problem by the highway patrol, although a substantial proportion of officers (49%) indicated a "severe" rating. This problem became apparent shortly after the exclusive lane was opened to traffic. At that time, the physical appearance of the lane differed somewhat from the general lanes (lighter pavement, lack of oil stains,etc.). Furthermore, the solid white line used as a pavement marking to emphasize the "priority" nature of the exclusive lane apparently increased the tendency to mistake the exclusive lane for a refuge

area, especially during off peak periods. Several serious accidents occurred (including 4 fatalities) in the early stages of the Project in which the use of the priority lane for disabled vehicles appeared to be a factor. As a counter measure, the pavement was restriped with a standard skip line, to make the reserved lane markings compatible with the remainder of the roadway. A photographic comparison of these two pavement marking techniques is shown in Figure 4.4.

No further fatalities were experienced following the change in pavement markings. An increase in car pool occupancy violation activities was, however, observed in the peak periods (see Chapter 3). This increase was attributed to the reduction in the "identity" of the exclusive lane.

The survey of highway patrol officers was conducted after the pavement marking changes were implemented. The rating of the severity of the accident problem should not, therefore, reflect the earlier hazards which were apparent. As evident in Figure 4.3 a relatively smaller degree of concern was expressed for the accident situation than for violations or breakdown problems.

A summary of follow-up responses in these three problem areas is presented in Figure 4.5. In this figure, the relative degree of change, as perceived by the officers for each problem area,is indicated on a monthly basis. A value of +1.0 would indicate that all officers were of the opinion that the problem had deteriorated. Conversely, a value of -1.0 would indicate a unanimous opinion that the problem had improved. A problem of constant magnitude would be reflected by a zero value. It would be anticipated that the zero value would be approached eventually, assuming that the problem could not keep improving or deteriorating forever.

According to Figure 4.5, both the accident and breakdown problems seem to have approached a generally stable condition as perceived by the highway patrol. The violation problem, on the other hand, appears to have remained in a somewhat transient state. A dramatic improvement was noted in January, 1977 when the car pool requirements were redefined to allow 2 person car pools to use the exclusive lane. The effect of this change in regulations is discussed in greater detail in Chapter 6.

a. Solid Line

b. Skip Line

FIGURE 4.4. COMPARISON OF SOLID AND SKIP LINE PAVEMENT MARKINGS FOR THE EXCLUSIVE LANE.

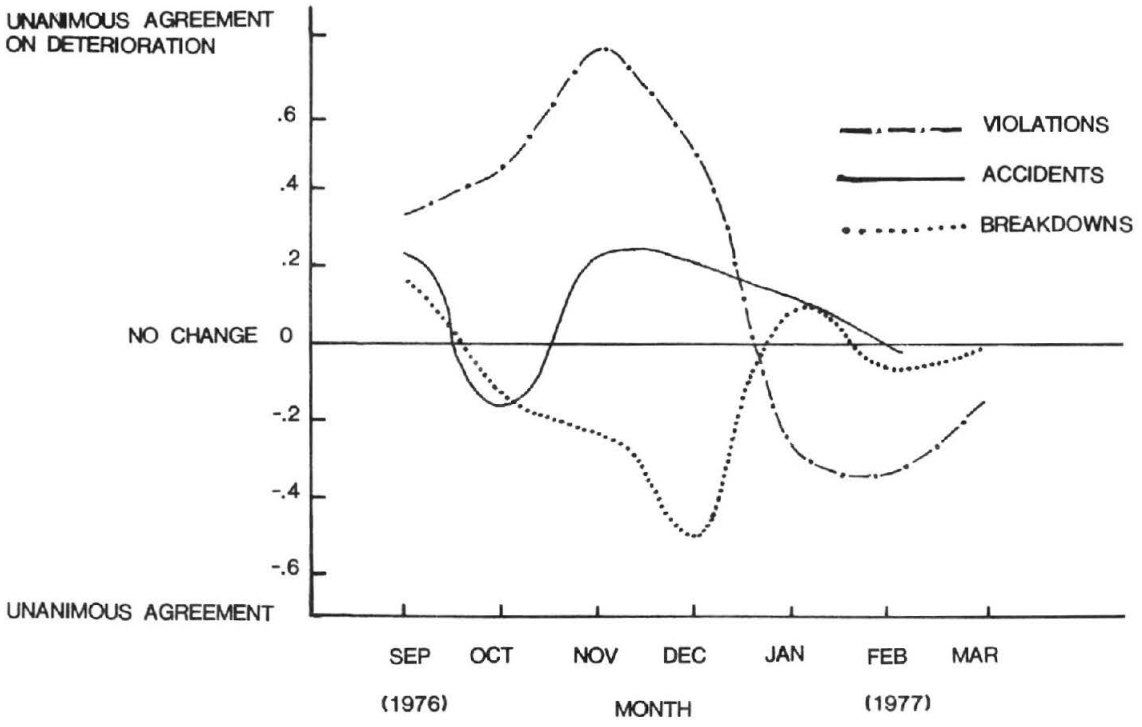


FIGURE 4.5. FLORIDA HIGHWAY PATROL PERCEPTION OF RELATIVE CHANGE IN OPERATING PROBLEMS THROUGHOUT THE DEMONSTRATION PROJECT.

2. Highway Patrol Comments

Comments and suggestions were solicited from the FHP officers by the following question:

"Please give us your comments and/or suggestions on any problems you associate with the priority lane operation?"

The verbatim replies are listed in Appendix B of this report. A review of these replies indicated that the "comment" type responses could be generally classified as follows:

COMMENT	NO. OF REPLIES
excessive speed in exclusive lane	5
excessive violations of exclusive lane regulations	7
high hazard potential	3
problem with disabled vehicles due to lack of refuge area	19
other comments related to operational problems	9

In addition to the above comments, the following types of suggestions for improvements were received.

SUGGESTION	NO. OF REPLIES
Convert to general use lane	6
Convert to disabled vehicle lane (full time)	5
Convert to disabled vehicle lane (off peak)	2
Install additional signing and/or marking	5
Improve enforcement techniques	2
Other suggested improvements	5

H. ACCIDENT EXPERIENCE

1. Accident Rates

Accident data for the freeway, obtained from computerized records compiled by the Dade County Department of Public Safety were analyzed for each of the Demonstration Project stages.

1) The intial "mixed mode" stage which occurred prior to implementation of any HOV priority treatments;

2) The intermediate stage, in which buses operated in a reversible exclusive lane on NW 7th Avenue under signal preemption control; and,

3) The final stage in which an exclusive lane for buses and car pools with 3 or more occupants was provided on I-95 as an HOV priority measure.

To minimize the effect of extraneous factors, the analysis focused on accidents which had the following indicated characteristics:

- Location on the freeway in the same geographical area as the exclusive lane,
- Time of occurrence during either the morning or evening peak period of a normal weekday, and
- Direction of travel of the predominant peak period movement (southbound in the AM, northbound in the PM).

The accident rates were expressed in terms of "accidents per day" with one full day defined to include both peak periods. This definition is better suited to a peak period oriented study of this nature than the more conventional "per million vehicle miles" approach to determine accident rates because of the non-linear relationship between vehicle miles of travel and vehicle hours of travel time which occurs on congested urban freeways.

The following accident rates were observed:

STAGE	ACCIDENTS	NO. OF DAYS	RATE (accidents/day)
Initial (No HOV Priority)	103	129	.797
Intermediate (HOV Priority Lanes Lanes under Construction)	333	413	.806
Final (with Buses and Car Pools in HOV Lanes)	249	290	.858

Statistical tests performed on these observations indicated that the differences were not statistically significant. In other words, it could not be demonstrated that the accident rates during the peak period were influenced by the exclusive lane treatment. Because of the lack of significance in the comparison of the overall rates, no more detailed comparisons (which would have reduced sample sizes even further) were attempted.

2. Accident Types

The peak period accidents were distributed as follows:

Rear end collisions	81%
Sideswipe	17%
All others	2%

The same distributions applied to the AM and PM peak periods and no significant variations were observed from stage to stage.

3. Priority Lane Related Accidents

A more detailed analysis of accidents related to the operation of the exclusive lane was performed. Each such accident was treated as a separate case study. From the description provided on the accident report, an attempt was made to identify the major contributing factors inherent in the operation of the exclusive lane. Each potential contributing factor was classified according to the degree of implication as a causative factor in the accident. A summary of this analysis is presented in Table 4.1 which identifies the potential contributing factors and defines criteria for assessment of the degree of implication. The number of accident cases which fell into each assessment category is also indicated in Table 4.1. The two most significant factors were the lack of median refuge area and the lane changing activities associated with the exclusive lane operation.

I. SUMMARY AND CONCLUSIONS

Violations and enforcement of the exclusive lane regulations became one of the major issues of the I-95 Bus/Car Pool Demonstration Project. In recent months, the number of citations issued for violation of the car pool occupancy requirements has been reduced to a very low level. The highway patrol officers, bus drivers and car poolers all expressed more concern over violation rates than any other problem.

Violation rates, based on a 3 person minimum occupancy increased to approximately 75%. The rate of violation was strongly influenced by the density of traffic in the general use lanes and was affected to a lesser degree by the presence of a highway patrol vehicle.

Accidents throughout the course of the Project were observed at the rate of approximately 4 per week. This rate was independent of the project stage. Approximately 80% of the accidents were rear end collisions and the remainder were nearly all sideswipes as a result of lane changing. Of those accidents which were related to the exclusive lane operation, the lack of a suitable distress area in the median appeared to be the strongest contributing factor, followed closely by lane changing activities required for access to the exclusive lane.

TABLE 4.1

ANALYSIS OF PRIORITY LANE-RELATED ACCIDENTS ON I-95

POTENTIAL HAZARD	DEGREE OF IMPLICATION	
	Primary	Secondary
Median Barrier	3 Cases Barrier struck by single vehicle out of control with no other apparent cause	18 Cases Barrier struck by vehicle as a result of avoidance maneuver, or collision with another vehicle
Lack of Refuge in Median	21 Cases Disabled vehicle in the exclusive lane was apparent cause of accident	46 Cases Accident description suggested that accident may have been avoided if a safe refuge had been available
Speed Differential between Exclusive Lane and General Lanes	10 Cases Accident involved a vehicle merging into exclusive lane because of congestion in general lane	None
Lane Changing	25 Cases Accident was a direct result of vehicle changing lanes voluntarily	29 Cases Accident resulted from lane changing as part of an avoidance maneuver
Enforcement Activities	3 Cases Presence of police caused vehicle to change lanes to avoid possible prosecution	No Cases Identified Enforcement activities created congestion which resulted in an accident
Congestion in the Exclusive Lane	15 Cases Rear end collision in exclusive lane with lead vehicle stopped because of congestion	5 Cases Sideswipe accident involving vehicle leaving the exclusive lane because of congestion
Exclusive Lane Construction	4 Cases Vehicle struck construction barrier without any other apparent cause	No Cases Identified Vehicle struck construction barrier with other causative factors present

CHAPTER FIVE

ROAD USER ATTITUDES

A. INTRODUCTION

This chapter presents an analysis of the response of several road user groups who participated in questionnaire surveys related to the bus/car pool priority operation on I-95. The road user groups included:

1. Bus passengers, who were surveyed to determine their perception of the effect of the exclusive lane on the Orange Streaker operation.

2. Car poolers, who were surveyed to determine their perception of the effectiveness of the exclusive lane in providing priority for car pools.

3. General users of the I-95 corridor (telephone interview) who were surveyed to determine their degree of familiarity with the exclusive lane, as well as their level of enthusiasm for the HOV priority concept.

4. I-95 drivers (Exit Ramp Survey) who were questioned as to their knowledge of the existence and meaning of the Diamond Symbol used to identify the exclusive lane.

5. Orange Streaker bus drivers who were questioned about their attitudes towards specific operational benefits and problems associated with the exclusive lane.

In some cases the surveys dealt with the broad aspects of the Bus/Car Pool Demonstration Project. Copies of the complete questionnaire are included in Appendix B. The discussion contained in this chapter is limited to those parts of the surveys which addressed the operational aspects of the exclusive lane.

B. BUS PASSENGER SURVEY

A questionnaire survey of bus passengers was carried out in connection with the Orange Streaker Demonstration Project. Survey forms were distributed to the passengers as they boarded the bus and were collected during the course of the trip. The questionnaire dealt with all aspects of the Orange Streaker Service and a complete analysis of the response is presented in Reference 4. Five specific questions related to the exclusive lane on I-95 were included in the survey. These five questions addressed the following topics:

1. Relative preference for the exclusive lane on the freeway vs. NW 7th Avenue reserved lane previously used by the Orange Streaker buses.

2. Reaction to certain physical and operational features of the exclusive lane.

3. Relative importance of the exclusive lane compared with other system features.

4. Estimated time savings.

5. Overall reaction to the exclusive lane.

A total of 838 responses were received. These responses were analyzed and the following results were obtained.

1. Relative Preference for the Exclusive Lane

The specific question was:

How would you compare the I-95 Bus/Carpool exclusive lane system the N.W. 7th Avenue reversible lane system?

1. ☐ I-95 far superior
2. ☐ I-95 somewhat better
3. ☐ No significant difference
4. ☐ N.W. 7th Avenue was superior
5. ☐ I had no experience on N.W. 7th Avenue
6 ☐ No opinion

The response, as shown in Figure 5.1 was overwhelmingly in favor of the exclusive lane on the freeway. Three-fourths of the respondents rated the freeway lane "far superior" to the surface street, 92% expressed some degree of preference for the freeway lane and less than one percent indicated a preference for the NW 7th Avenue system.

2. Reaction to Physical and Operational Features

The question was worded as follows:

Do you feel uncomfortable or unsafe when your bus is traveling in the exclusive lane?

1. ☐ No
2. ☐ Yes, because (check as many as apply):
   - ☐ Speeds in exclusive lane are faster than those in the adjacent lane.
   - ☐ There is no shoulder on the left side of lane.
   - ☐ The bus is too near the concrete barrier wall.
   - ☐ The bus has to change lanes so many times to get to and from the exclusive lane.
   - ☐ Other _____ (please specify)

Responses to this question indicate that each problem category generated discomfort in about 5% of the respondents. A total of 18% indicated concern

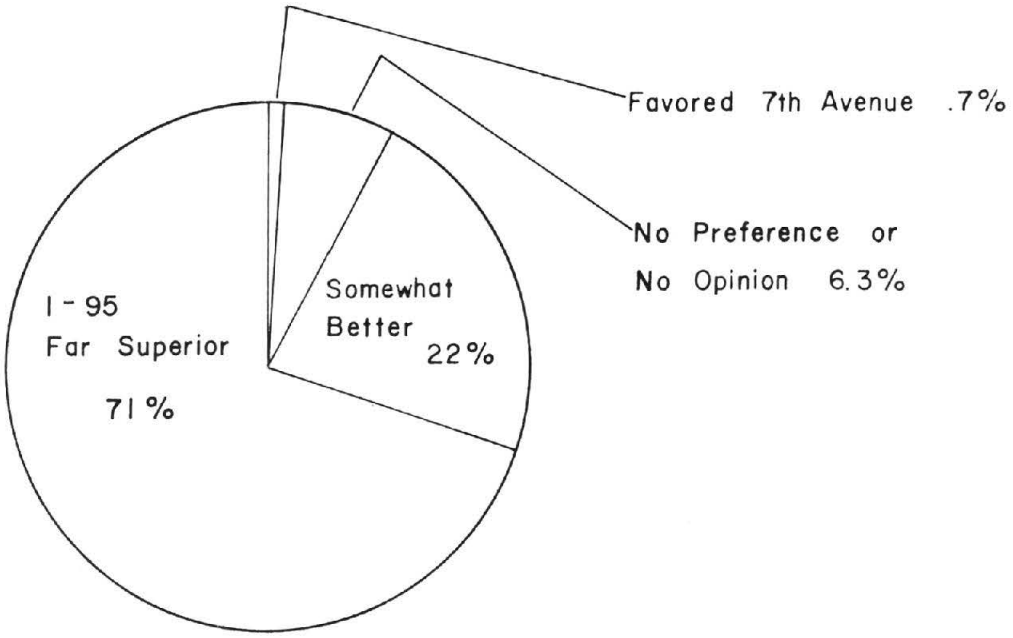


FIGURE 5.1. RELATIVE PREFERENCE OF BUS PASSENGERS FOR THE I-95 BUS/CAR POOL LANE VS. THE NW 7TH AVENUE BUS PRIORITY SYSTEM.

TABLE 5.1

BUS PASSENGERS' RATINGS OF THE DEGREE OF IMPORTANCE OF ORANGE STREAKER PROJECT FEATURES

	Very Imp.	Somewhat Imp.	Not Imp.	No Opinion	Total
Express Bus Service	89%	9%	1%	1%	100%
Exclusive Lane	74%	21%	4%	1%	100%
Park'n'Ride Facility	65%	20%	12%	3%	100%
Bus Comfort	56%	37%	5%	2%	100%

for at least one of the problems mentioned. The "other" category drew a 9% response. A summary of the verbal responses to this question is included in Appendix C. A frequent complaint in this category referred to the excessive weaving activity into and out of the exclusive lane by other drivers. Many of the complaints were not specifically related to the exclusive lane operation (e.g., bus driver too aggressive ,etc.).

3. Relative Importance of the Exclusive Lane

To provide an insight into the degree of importance placed by the motorist on the various Orange Streaker project features, the following question was asked:

For each of the following items please indicate their importance to you in using the Bus/Car pool project?

	Very Important	Somewhat Important	Not Important	No Opinion
Express Bus Service	☐	☐	☐	☐
Exclusive Lane on I-95	☐	☐	☐	☐
Park-n-Ride Facility	☐	☐	☐	☐
Comfort of Busses	☐	☐	☐	☐

The results of this question are presented in Table 5.1. These results suggest that the exclusive lane ranked second in importance as perceived by bus passengers. The only feature considered more important was the provision of the bus service itself. Both the Park 'n' Ride facility and the comfort of the buses were considered to be of lesser significance than the exclusive lane provision.

4. Estimated Time Savings

Bus passengers were asked to provide an estimate of the amount of time saved by the exclusive lane:

How much time per trip do you save by using the exclusive lane as compared with people who are not using it?

1. ☐ ____ minutes per trip (average AM and PM)
2. ☐ no savings
3. ☐ no estimate

Of the total sample of 838 passengers, 64% indicated some degree of perceived time savings, 13% saw no saving and 23% offered no opinion.

The distribution of the perceived time saving is illustrated in Figure 5.2.

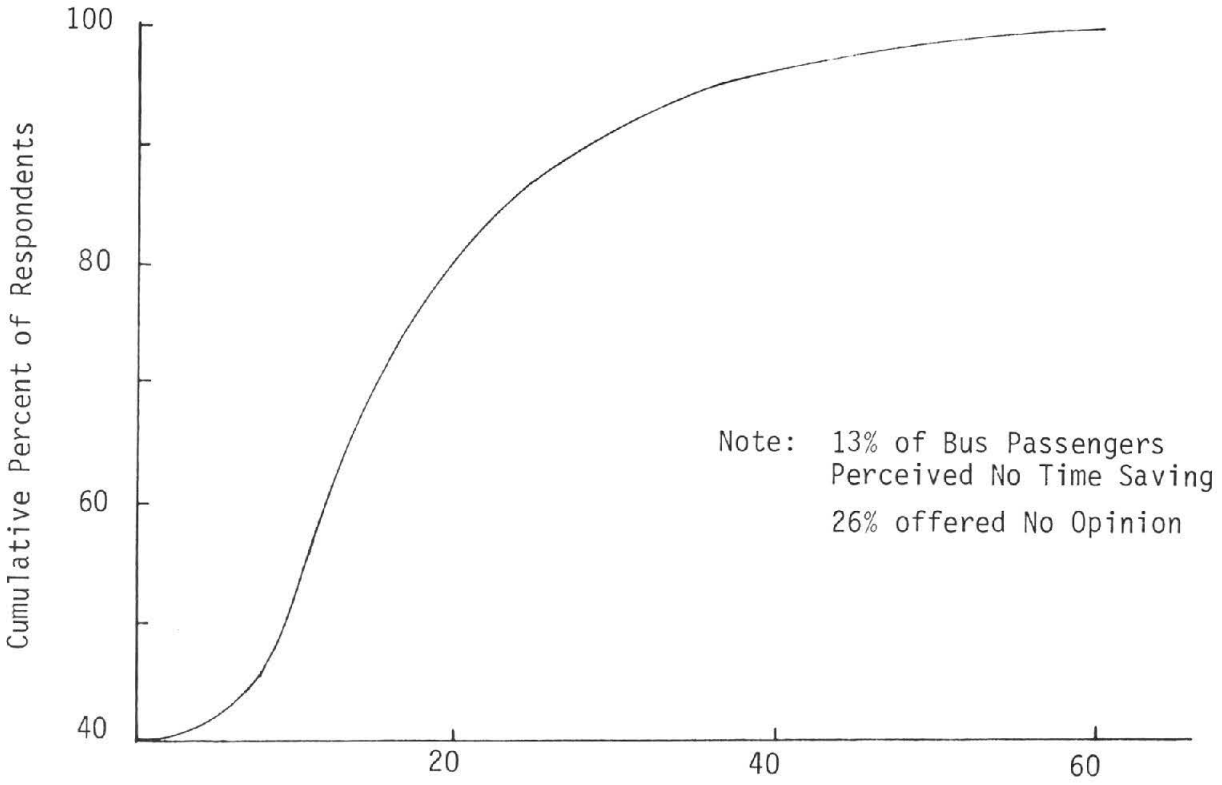


FIGURE 5.2. DISTRIBUTION OF BUS PASSENGER PERCEIVED TIME SAVINGS DUE TO THE EXCLUSIVE LANE.

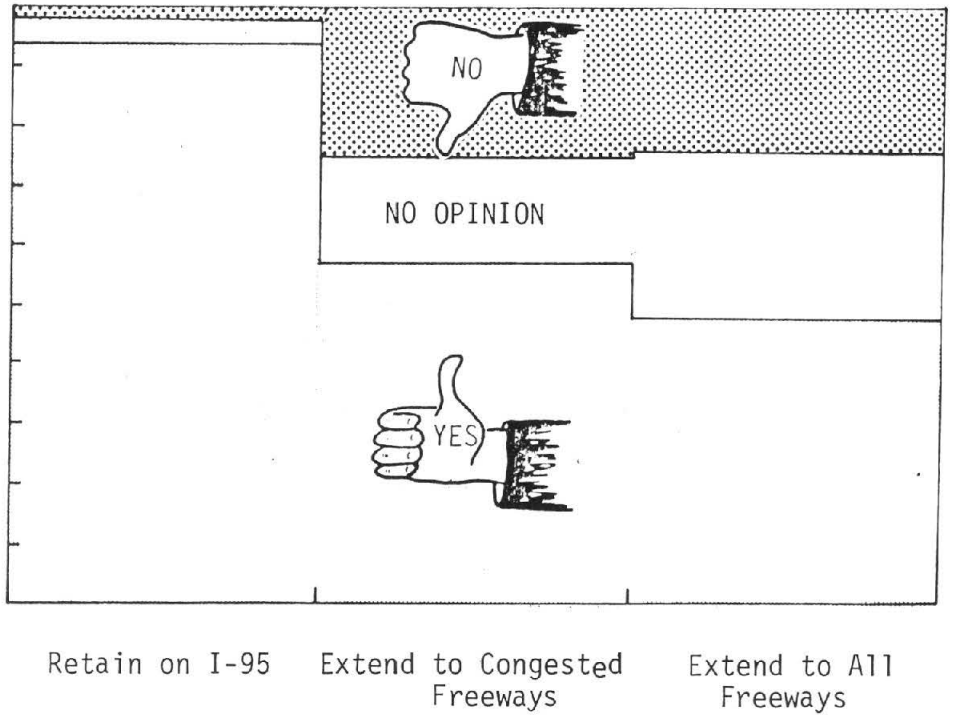


FIGURE 5.3. BUS PASSENGER ATTITUDES TOWARD RETENTION AND EXTENSION OF THE BUS/CAR POOL LANE.

5. Overall Reaction to the Exclusive Lane

To assess the overall reaction to the exclusive lane, the following question was asked:

> Considering all the advantages and disadvantages of the exclusive bus/carpool lane (not the express bus service as a whole), do you feel that this type of system should (answer all three):
>
> | | Yes | No | No opinion |
> |---|---|---|---|
> | Remain on I-95? | ☐ | ☐ | ☐ |
> | Be installed on all highly congested freeways? | ☐ | ☐ | ☐ |
> | Be installed on all urban freeways? | ☐ | ☐ | ☐ |

The response to this question, as summarized in Figure 5.3 was highly favorable. A favorable response would, however, be anticipated in this case since the respondents, being express bus passengers, were all receiving some benefit from the exclusive lane. Of the 838 passengers responding, 94% felt that the express lane should remain on I-95 and only 2% felt that it should be discontinued. The degree of enthusiasm for extending the concept to other facilities was also reasonably high, with 57% favoring extension to freeways with congested operations and 48% favoring extension to all urban freeways.

C. CAR POOL SURVEY

A separate survey was conducted among car pool participants by distributing a mail-back questionnaire to each occupant of every vehicle with 2 or more occupants leaving the Golden Glades parking lot during a selected morning peak period. A total of 42 responses were returned. The questionnaire, a complete copy of which is included in Appendix B, dealt with several aspects of interest to the Orange Streaker Demonstration Project. Five specific topics related to the exclusive lane operation on the freeway were addressed:

1) Utilization of the exclusive lane,

2) Reaction to physical and operational features,

3) Estimated time savings,

4) Relative importance of the exclusive lane with respect to other features, and

5) Overall reaction to the exclusive lane.

1. Utilization of the Exclusive Lane

The degree of utilization of the exclusvie lane was addressed by the following question:

In general, when making this trip, do you:

1. ☐ Normally use the exclusive bus/carpool lane on I-95?
2. ☐ Normally use I-95 but not the exclusive bus/carpool lane
3. ☐ Rarely or never use I-95?

Of the total response, 66% indicated that they normally used the exclusive lane, 31% indicated that they normally drive in the general lanes on I-95 and 3% indicated that they did not use I-95.

2. Reaction to Physical and Operational Features

Because certain physical and operational features of the exclusive lane create potential sources of discomfort for the road user,the following question was asked:

In general, do you feel uncomfortable or unsafe when traveling in the exclusive lane?

1. ☐ No
2. ☐ Yes, because (check as many as apply)
   - ☐ Speeds in exclusive lane are faster than in adjacent lane.
   - ☐ There is no shoulder on the left side of exclusive lane.
   - ☐ You must drive or ride too close to the concrete barrier wall.
   - ☐ You must cross too many lanes to get into and out of the exclusive lane.
   - ☐ Other _____ (please specify)

A summary of the responses to this question is presented as follows:

Accessibility of lanes	38%
Lack of shoulder	33%
Speed differential	29%
Proximity of barrier	10%
*Other	43%
Any of the above	71%

*"Other" category comments dealt primarily with the abuse of the exclusive lane by other drivers.

Comparing these results with the corresponding responses from the express bus passengers presented previously, it was observed that the degree of concern was considerably higher among automobile occupants. It is noted,for example,

that 71% of the car poolers expressed concern over at least one item as opposed to only 18% expressing concern among the bus passengers. The increased concern could probably be attributed to the fact that the auto occupants were somewhat "closer" to the problems than the bus passengers.

3. Estimated Time Savings

Each exclusive lane user was asked to estimate the amount of time saved by using the exclusive lane. The question was posed as follows:

How much time per trip do you save by using the exclusive lane as compared with people who are not using it?

1. ☐ _____ minutes per trip (average AM and PM)
2. ☐ no savings
3. ☐ no estimate

The distribution of estimated time savings is presented in Figure 5.4. The mean estimated saving was 12.6 minutes. This compares with measured savingsof approximately 3 minutes, indicating that the perceived saving was substantially greater than the actual saving. The measured time difference, determined by moving vehicle field studies,was discussed in greater detail in Chapter 2 of this report.

4. Relative Importance of the Exclusive Lane

This topic was addressed by two specific questions:

1. For each of the following items please indicate their importance to you in using the Bus/Car Pool project.

	Very important	Somewhat important	Not important	No opinion
Exclusive Lane on I-95	☐	☐	☐	☐
Park-n-Ride Facility	☐	☐	☐	☐
Flyover Ramp to I-95	☐	☐	☐	☐

☐ Don't use Bus/Carpool Lane

2. What single factor has most influenced you to use carpools? (check one)

1. ☐ Cost of driving alone
2. ☐ No automobile available for the trip
3. ☐ Lack of parking places
4. ☐ Cost of parking
5. ☐ Time advantage of the exclusive lane
6. ☐ Concern for energy conservation
7. ☐ Other

The response to the first question is summarized in Table 5.2. It is observed that the three physical attributes of the system (Park 'n' Ride Lot, Flyover and Exclusive Lane) were regarded with more or less equal importance by car poolers. Approximately seventy percent regarded each attribute as being "very important", and fewer than 6% suggested that any attribute was "not important".

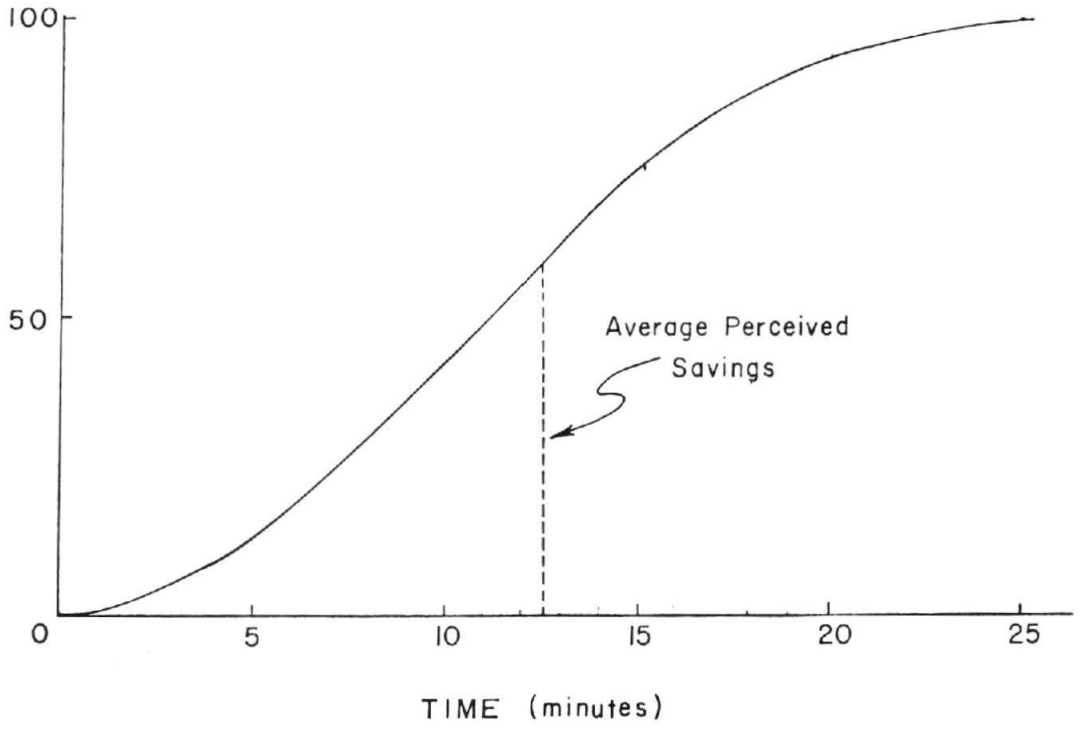


FIGURE 5.4. DISTRIBUTION OF ESTIMATED TRAVEL TIME SAVINGS BY CAR POOLERS USING THE PRIORITY LANE ON I-95.

TABLE 5.2

IMPORTANCE OF BUS/CAR POOL PRIORITY FEATURES TO CAR POOLERS

	Exclusive Lane	Park'n'Ride Lot	Flyover
Very important	71%	71%	72%
Somewhat important	18%	26%	11%
Not important	5%	3%	6%
No opinion	5%	6%	11%

The response to the second question is illustrated in Figure 5.5. It is apparent in this case that about half of the respondents were motivated towards car pools primarily by cost factors, and about one quarter were motivated primarily by time savings due to the exclusive lane. This suggests that, in the case of the I-95 system, cost factors were roughly twice as important to car pool formation as the potential time saving.

5. Overall Reaction to the Exclusive Lane

As an indication of the overall reaction to the exclusive lane on I-95, each car pooler was asked to indicate his preference for continuation and future expansion of the exclusive lane concept:

Considering all of the advantages and disadvantages of the exclusive bus/carpool lanes, do you feel that this type of system should:

	Yes	No	No opinion
A) Remain on I-95	☐	☐	☐
B) Be installed on other highly congested freeways	☐	☐	☐
C) Be installed on all urban freeways	☐	☐	☐

The response to this question is illustrated in Figure 5.6. The response pattern was similar to the pattern generated by the bus passenger survey, (Figure 5.3) i.e., a very high proportion (86%) favored the continuation of the reserved lane on I-95 and a substantial, but smaller, proportion favored extension of the concept to other congested freeways (60%) and to all urban freeways (53%). The smaller proportion of car poolers favoring continuation of the existing operation compared to bus passengers (86% vs 94%) suggests a slightly lower degree of enthusiasm among the car poolers. This probably reflects the generally higher degree of discomfort expressed by car poolers about the physical and operational problems with the exclusive lane.

D. HOME INTERVIEW STUDY

A telephone survey was conducted using a sample of 1903 persons selected on the basis of license tag numbers observed using the Orange Streaker corridor both on I-95 and on the alternate arterial streets. This survey was comprehensive in nature and dealt with a wide range of topics related to the Orange Streaker Demonstration Project. A complete analysis of the results of this survey is presented in Reference 4.

It was not possible in a study of this type to address the exclusive lane features in great detail. Three specific questions were, however, asked to

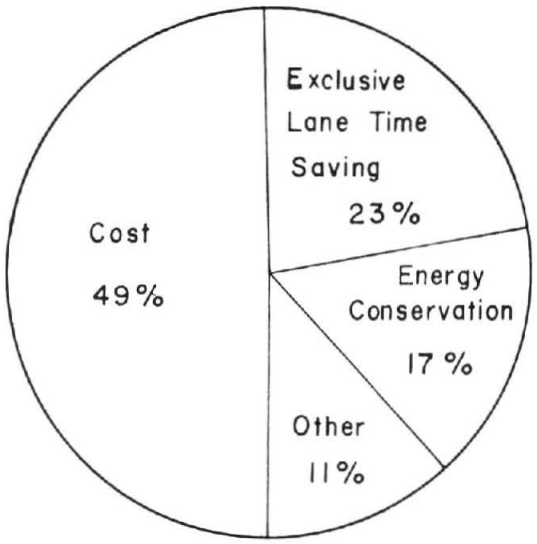


FIGURE 5.5. PRIMARY FACTOR IN DECISIONS TO FORM CAR POOL.

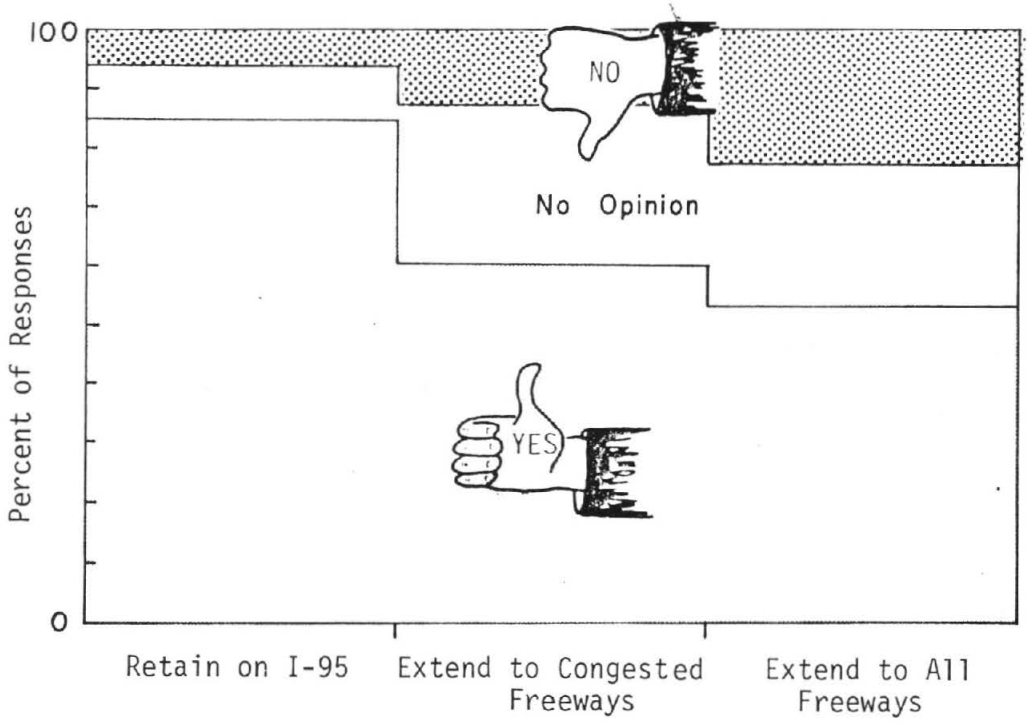


FIGURE 5.6. CAR POOLER ATTITUDES TOWARD RETENTION AND EXTENSION OF THE BUS/CAR POOL LANE.

assess the following characteristics:

1) awareness of the existence of the lane,

2) extent or use of the lane,and

3) general reaction to the concept.

1. Respondent Categories

For analysis purposes, the respondents were separated into two categories:

a) Market Area Respondents, who indicated a trip origin in the market area and a destination in one of the three service areas of the project corridor.

b) Non-Market Area Respondents, who did not qualify as Market Area Respondents by the above definition.

A further division of each category was made with two sub-categories.

a) Target Cases whose original license tag observations were made on I-95 and who indicated that they were aware of the exclusive lane.

b) Non-Target Cases who did not qualify as Target Cases by the above definition.

2. Awareness of the Exclusive Lane

The question was worded as follows:

Are you aware of the Exclusive Bus/Car Pool Lanes on I-95?

YES ____

NO ____

The Market Area Respondents demonstrated a predictably higher awareness than the Non-Market Area Respondents. Of the Market Area Respondents, 99.4% indicated an awareness of the exclusive lane. In addition, 86.5% of the Non-Market Area Respondents indicated a knowledge of the exclusive lane, which suggests a very high awareness among both respondent categories.

3. Utilization of the Exclusive Lane

The target cases from both categories were asked to indicate their utilization of the exclusive lane by the following question:

Do you use these exclusive lanes?

YES _____

NO _____

This question was put to all Market Area Respondents who indicated that they car pooled at least occasionally. Market Area Respondents who indicated that they drove alone were not asked whether they used the exclusive lane. This question was avoided to eliminate the possible fear of self-incrimination on the part of the respondent. All Non-Market Area Respondents were questioned on exclusive lane usage, since this group was not asked about their car pooling habits.

Thirty-five percent of the Market Area Respondents used the exclusive lane, while only 12% of the Non-Market Area Respondents used the exclusive lane. These figures are not directly comparable because of the elimination of the single occupant users from the Market Area Respondents sample. Furthermore, it cannot be inferred from the 35% utilization by Market Area Respondent car poolers that the non-utilization rate was 65% because, at the time of the survey, two occupant car pools were not permitted to use the exclusive lane.

4. General Acceptance of the Exclusive Lane

The home interview respondents were asked to indicate their general acceptance of the exclusive lane concept by the same question as the bus riders and car poolers:

"Considering all the advantages and disadvantages of the Exclusive Bus/Car Pool Lanes, do you feel that this type of system should (√) (Read all three):

	Yes	No	D.k. No Opinion
a) Remain on I-95?	☐1	☐2	☐3
b) Be installed on all congested freeways?	☐1	☐2	☐3
c) Be installed on all urban freeways?"	☐1	☐2	☐3

The response to this question is summarized by sub-category in Table 5.3. A statistical comparison supports the following inferences:

1) There was no significant difference in any responses between Market Area Respondents and Non-Market Area Respondents.

2) The target cases tended to be more favorable towards the concept as evidenced by a smaller proportion of negative responses than the non-target cases.

3) The non-target group tended to be less certain about its opinion as evidenced by the larger proportion of "don't know" responses than the target group.

TABLE 5.3

CORRIDOR USER ATTITUDE TOWARDS RETENTION AND EXTENSION OF THE EXCLUSIVE LANE CONCEPT

		MARKET AREA RESPONDENTS		NON-MARKET AREA RESPONDENTS		COMBINED SAMPLE
		TARGET CASES	NON-TARGET CASES	TARGET CASES	NON-TARGET CASES	
Remain on I-95	Yes	50%	50%	50%	50%	50%
	No	32%	27%	32%	27%	29%
	?	18%	23%	18%	23%	21%
Extend to Congested Freeways	Yes	40%	38%	40%	39%	39%
	No	35%	32%	35%	32%	34%
	?	25%	30%	25%	29%	27%
Extend to All Freeways	Yes	31%	30%	31%	31%	31%
	No	39%	38%	39%	39%	39%
	?	30%	32%	30%	30%	30%

Apart from the statistical testing, an inspection of Table 5.3 indicates that the actual differences among the various groups were relatively small. The opinions of the road users as a whole can, therefore, be appropriately represented by the combined aggregate of all the groups. These values are also shown in Table 5.3, and in Figure 5.7. Comparing Figure 5.7 with Figures 5.6 and 5.3 representing the car poolers and bus passengers respectively, it is observed that, while the same overall response pattern is apparent, the general road user was about 40% less inclined to favor the continuation and/or extension of the exclusive lane concept.

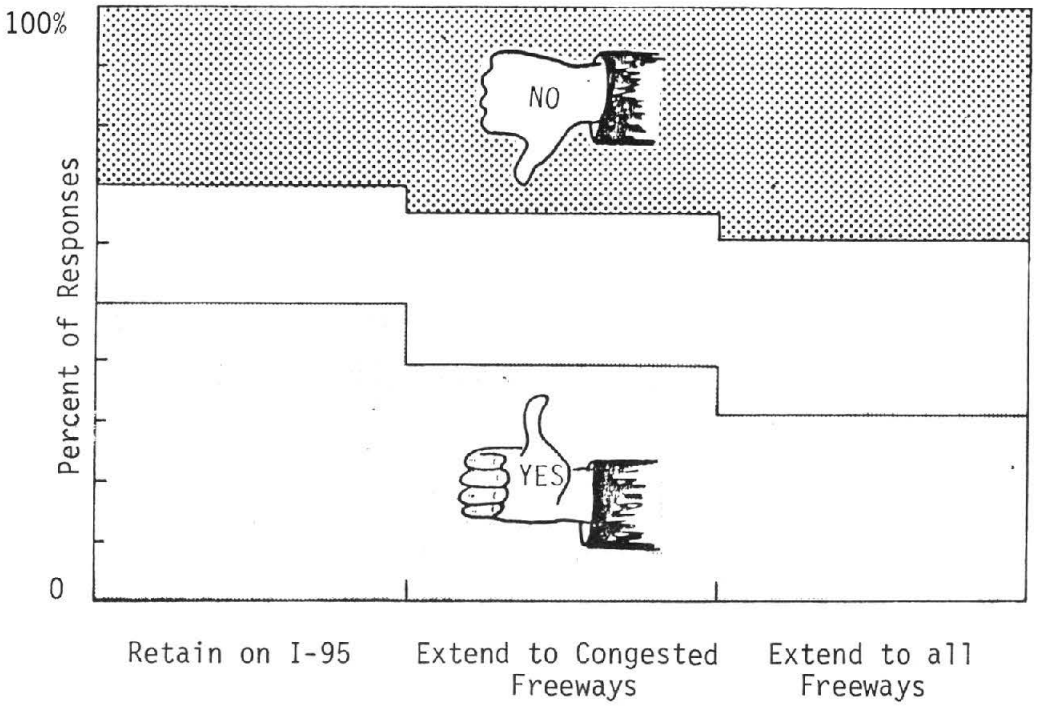


FIGURE 5.7. GENERAL ROAD USER ATTITUDES TOWARD RETENTION AND EXTENSION OF THE BUS/CAR POOL PRIORITY LANE.

TABLE 5.4

DIAMOND RECOGNITION SURVEY
SUMMARY OF DESCRIPTIVE PARAMETERS

		EARLY SURVEY	LATER SURVEY
A.	Total No. of Responses	437	341
B.	Survey Location Breakdown		
	62nd Street Exit	46%	50%
	135th Street Exit	54%	50%
C.	Proportion from Dade/Broward County Area (Local Drivers)	95%	93%
D.	Average Occupancy (Passengers per vehicle)	1.50	1.46

E. DIAMOND SYMBOL RECOGNITION STUDY

1. Study Description

A driver interview study was carried out on two exit ramps during the PM peak period to assess the degree of recognition of the diamond symbol as a traffic control device. This study was administered immediately after the application of the pavement markings, and was repeated approximately 3 months later. The descriptive parameters of the survey are summarized in Table 5.4.

Drivers were approached while stopped on the exit ramp in a queue from a downstream traffic signal. Each driver was shown a chart which presented three different shapes, illustrated in Figure 5.8:

1. The diamond symbol used on the freeway to identify the exclusive lane.
2. An elongated triangle of approximately the same proportions as the diamond.
3. An angular "hourglass" symbol of approximately the same proportions as the diamond.

Neither the hourglass nor the triangle were used on the freeway for traffic control purposes. The charts were changed from time to time to present the symbols in a different order to eliminate any bias which could have been caused by the order of presentation.

Each driver was asked the following questions:

1. "Where did you get on I-95 for this trip?"
2. "Did you notice any of these three shapes being used as traffic symbols on the freeway?"
3. "What does this symbol mean to you?"

Each vehicle was categorized as follows by observation of the license tag:

1. Local (Dade/Broward County)
2. Non-local Florida (Other than Dade/Broward County)
3. Out of state
4. Rental.

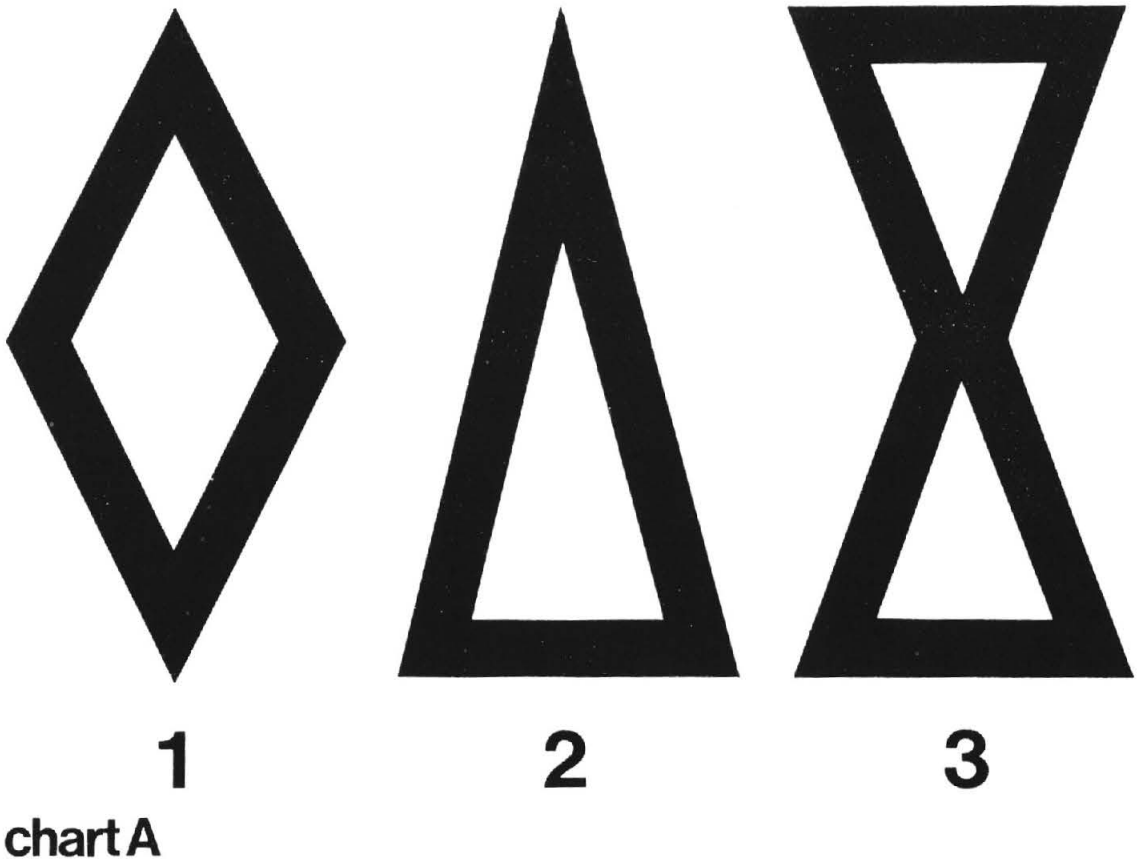


FIGURE 5.8. SYMBOLS PRESENTED TO DRIVERS IN DIAMOND RECOGNITION SURVEY.

2. Recognition of the Diamond Symbol

The degree of recognition of the various symbols is illustrated in Figure 5.9. It was noted that nearly one-third of the drivers recognized the diamond symbol in both the early and later study. Recognition was increased in the later study by approximately 15%. While the change was statistically significant at the 95% level, the actual number who recognized the diamond was surprisingly low considering the degree of exposure. At the time of the later study, the symbol was visible on the pavement at approximately 100 locations and on overhead signs at an additional 40 locations.

The diamond was, however, recognized by substantially more drivers than the two fictitious symbols. The fictitious symbols combined received less than 1/5 of the degree of recognition of the diamond.

3. Meaning of the Diamond Symbol

Those who recognized the diamond were asked to identify the meaning of this symbol. The results of this question are summarized in Figure 5.10. It was observed that the proportion of motorists who said they did not know the meaning of the symbol dropped substantially, from 44% in the early study to 10% in the later study. The proportion of correct answers rose from 49% to 62% between these studies, however, the incorrect answers increased by a larger proportion from 6% to 28%.

4. Effect of Study Location

The study was carried out at two locations:

- 62nd Street Exit Ramp
- 135th Street Exit Ramp.

The study results are summarized by ramp location in Table 5.5.

The following statistical inferences can be drawn from these results.

- The study location did not influence the degree of recognition of the diamond symbol as a traffic control device.
- The drivers leaving the freeway at the 135th Street exit who recognized the diamond symbol were more familiar with its' meaning than those who left at 62nd Street. (99% level of significance).

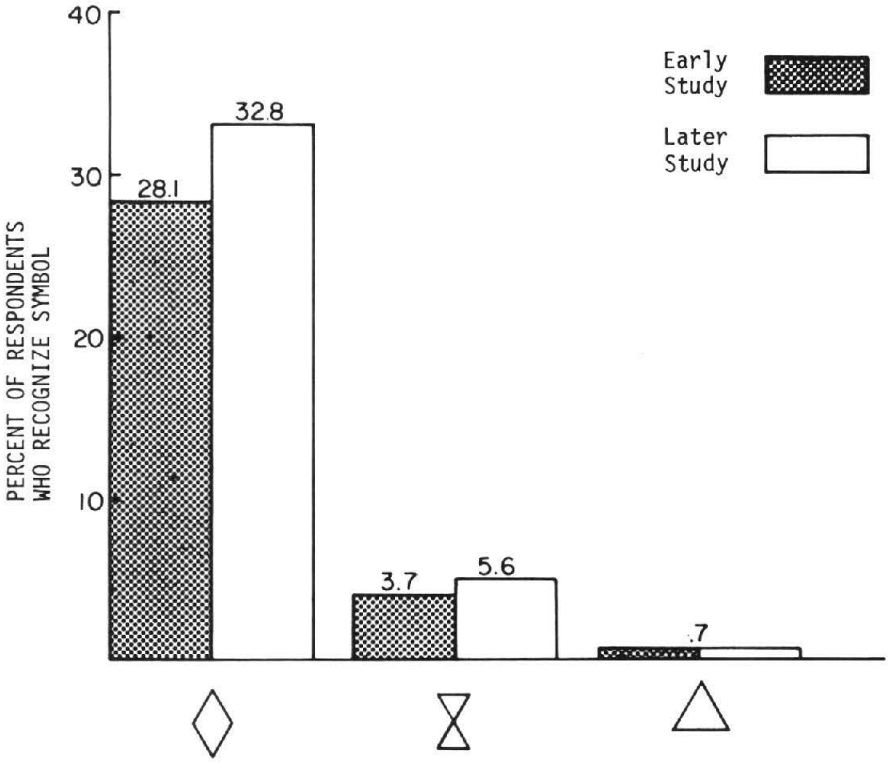


FIGURE 5.9. DEGREE OF RECOGNITION OF SYMBOLS.

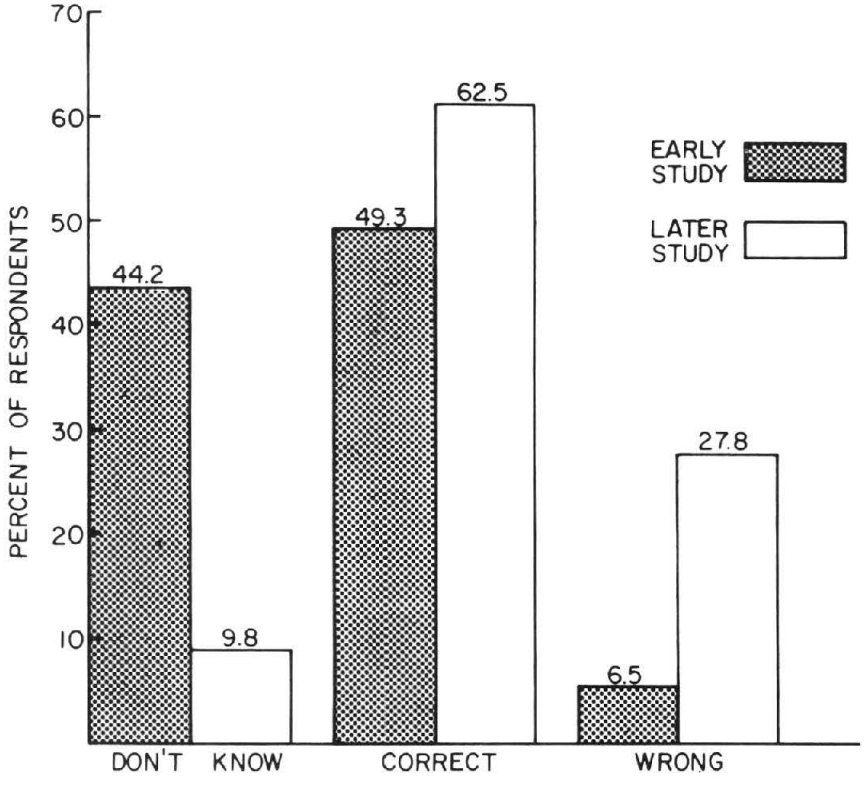


FIGURE 5.10. IDENTIFICATION OF DIAMOND SYMBOL MEANING.

TABLE 5.5

EFFECT OF STUDY LOCATION

	RECOGNIZED		MEANING		
	no	yes	wrong	don't know	correct
62nd Street Exit	265	104	20	30	44
135th Street Exit	282	135	19	31	85

TABLE 5.6

EFFECT OF VEHICLE OCCUPANCY

	RECOGNIZED		MEANING		
	no	yes	wrong	don't know	correct
No Car Pool	483	207	35	57	106
Car Pool	63	32	4	4	23

TABLE 5.7

EFFECT OF TRIP LENGTH

	RECOGNIZED		MEANING		
	no	yes	wrong	don't know	correct
Less than 3 miles	288	114	22	31	51
More than 3 miles	259	125	17	30	78

5. Effect of Vehicle Occupancy

The sample was categorized by number of occupants: 1) car pools containing three or more occupants and 2) non-car pools containing two of fewer occupants. The study results are summarized by vehicle occupancy in Table 5.6. The following statistical inferences can be drawn from these results:

- The vehicle occupancy did not affect the degree of recognition of the diamond symbol as a traffic control device.

- Drivers of vehicles qualified to use the exclusive lane who recognized the diamond symbol were more familiar with it than drivers of non-car pool vehicles (95% level of significance).

6. Effect of Trip Length

The sample also was categorized by length of trip in the exclusive land section of the freeway. Two categories were established with a threshold trip length of three miles. The study results are summarized by trip length in Table 5.7. The following statistical inferences can be drawn from these results:

- The trip length did not affect the degree of recognition of the diamond symbol as a traffic control device.

- Drivers with longer trip lengths who recognized the diamond symbol were more familiar with its meaning than drivers with shorter trip lengths (99% level of significance).

F. BUS OPERATOR SURVEY

The operators of the Orange Streaker buses were surveyed separately to determine their reaction to the exclusive bus/car pool lane. A total of 117 bus operators participated in this questionnaire study which addressed the following topics:

1. Degree of difficulty of weaving into and out of the exclusive lane at specific entrance and exit points on the freeway.
2. Magnitude of problems created by physical and operational features of the exclusive lane.
3. Operating conditions under which the exclusive lane achieves its maximum benefits.
4. Assessment of bus passenger comments with regard to the express bus service.
5. Overall reaction to the exclusive lane concept.

1. Weaving Difficulty

The entry and exit points for the express buses were identified and the drivers were asked to indicate whether weaving at each point posed a severe problem, a moderate problem, or no problem:

In general, how much of a problem is changing lanes in the following situations?	Severe [1]	Moderate [2]	None [3]	No Experience [4]
A) Entering I-95 in the morning.	[ ]	[ ]	[ ]	[ ]
B) Exiting I-95 at Airport Expressway (SR 112) in the morning.	[ ]	[ ]	[ ]	[ ]
C) Exiting I-95 at East West Expressway (SR 836) in the morning.	[ ]	[ ]	[ ]	[ ]
D) Entering I-95 at Airport Expressway (SR 112) in the evening.	[ ]	[ ]	[ ]	[ ]
E) Entering I-95 at East-West Expressway (SR 836) in the evening.	[ ]	[ ]	[ ]	[ ]

The responses to this question are summarized in Figure 5.11. The weaving locations are rank-ordered by inspection, according to the degree of problem. The least difficulty apparently was experienced entering the exclusive lane from the airport expressway during the PM peak. This was rated as a "severe" problem by 26% of the drivers. The greatest difficulty was observed leaving the freeway at the same location in the AM peak. Twice as many "severe" ratings were assigned to this movement. It is noted that the exit from the freeway at

the northern terminus of the exclusive lane is not represented in Figure 5.11. This movement would probably have presented the greatest difficulty, however, the weaving problem was avoided by routing the express buses through the Golden Glades Interchange to eliminate the need for lane changing in the congested area.

In general, it appears that the bus operators regarded weaving as a substantial problem. Depending on the location, between one-quarter and one-half of the drivers rated the problem as "severe", and a much smaller proportion (4% to 21%) indicated that no problem existed.

2. Physical and Operational Features

The operators were also asked to rate the problems experienced with the potentially troublesome features of the exclusive lane:

In general, how much difficulty is caused by:		Great [1]	Moderate [2]	None [3]	No Experience [4]
A)	Hazard due to sudden or unexpected stops in the priority lane.	☐	☐	☐	☐
B)	Hazard due to other vehicles cutting into the priority lane.	☐	☐	☐	☐
C)	Traffic in lane adjacent to the priority lane moving at a lower speed.	☐	☐	☐	☐
D)	Nearness of the concrete barrier wall.	☐	☐	☐	☐
E)	Violations of the priority lane restrictions.	☐	☐	☐	☐
F)	Delay due to other traffic using the priority lane.	☐	☐	☐	☐

The responses to this question are summarized in Figure 5.12. The various features are rank-ordered by inspection according to the magnitude of the problem. The proximity of the concrete median barrier was apparently of least concern to the operators with only 18% indicating a severe problem and 50% indicating no problem. At the other end of the scale, violation of the exclusive lane was viewed as a serious problem by 75% of the respondents and only 4% indicated that no problem was experienced with violators.

The magnitude of a particular problem may also be expressed conveniently in terms of the ratio of "severe problem" to "no problem" responses. This measure is defined for purposes of this study as the "severity ratio" and is represented on Figures 5.11 and 5.12. It is noted that in only one case (promixity of the median barrier) was the severity ratio less than 1.0. In all other cases, more bus operators rated the problem severe than non-existent. The highest ratio was observed in the case of the exclusive lane violations in

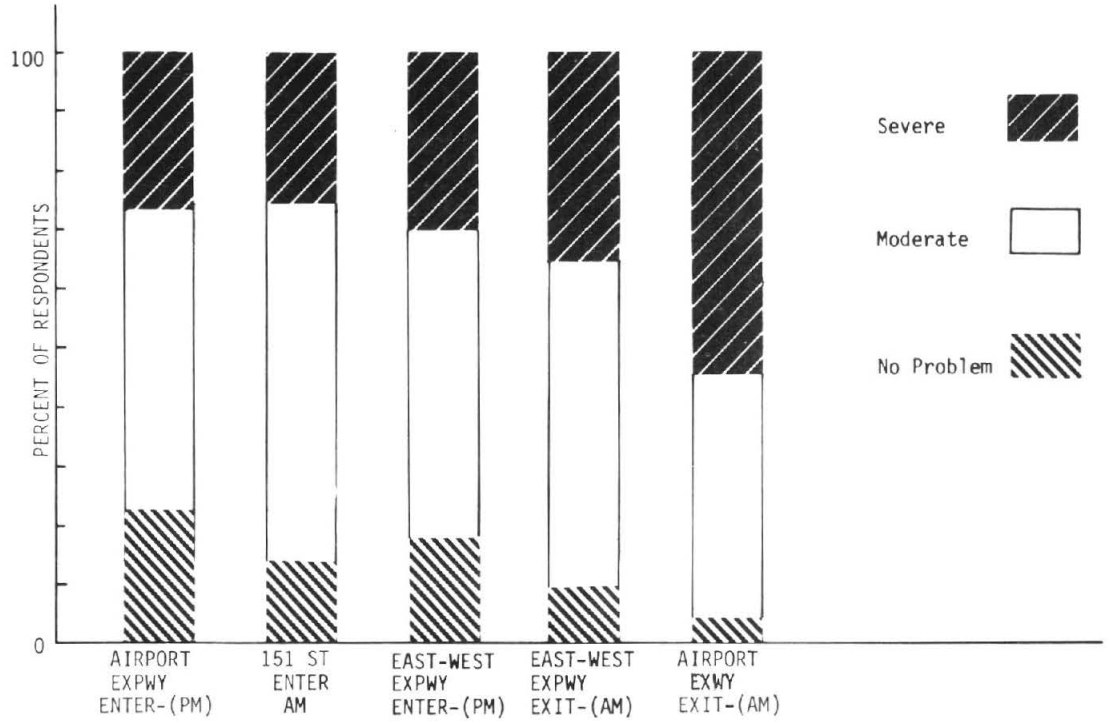


FIGURE 5.11. BUS OPERATOR PERCEPTION OF LANE CHANGING DIFFICULTY AT ENTRY AND EXIT POINTS.

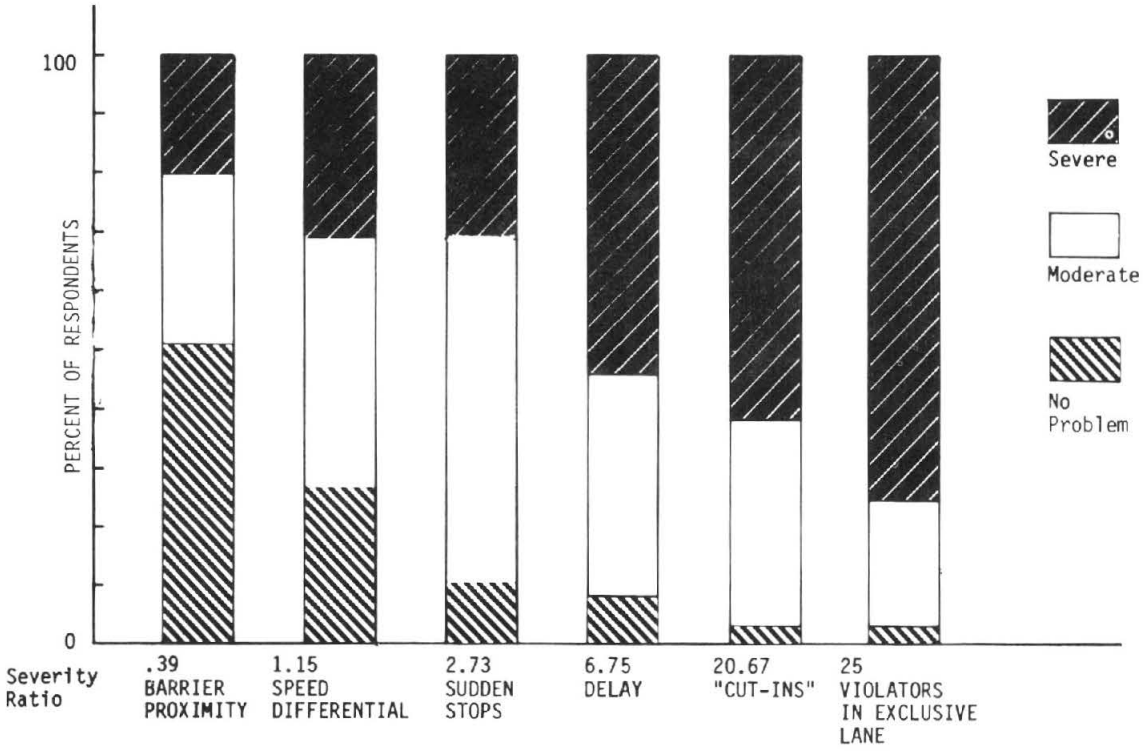


FIGURE 5.12. BUS OPERATOR PERCEPTION OF THE SEVERITY OF EXCLUSIVE LANE PROBLEMS.

which 25 respondents perceived a severe problem for each respondent who perceived no problem. Based on the severity ratios, it could be concluded that the bus operators were, as a group, significantly concerned about the potential problems associated with the use of the exclusive lane. This concern was more apparent in the problem areas involving misuse of the lane by other drivers (violators, weaving, etc.). The inherent physical and operational characteristics such as proximity of the median barrier, speed differential, turbulence,etc. were viewed with less disfavor.

3. Effect of Operating Conditions

The bus operators were asked to assess the degree of assistance provided by the exclusive lane under various operating conditions:

In general, how helpful has the priority lane been to you under the following conditions?

		Great [1]	Moderate [2]	None [3]	No Opinion [4]
A)	In the morning	[ ]	[ ]	[ ]	[ ]
B)	In the evening	[ ]	[ ]	[ ]	[ ]
C)	In light traffic (morning or evening)	[ ]	[ ]	[ ]	[ ]
D)	In heavy traffic (morning or evening)	[ ]	[ ]	[ ]	[ ]
E)	When an incident (breakdown, accident etc.) causes heavy congestion in the other lanes.	[ ]	[ ]	[ ]	[ ]
F)	During bad weather	[ ]	[ ]	[ ]	[ ]

The responses to this question are summarized in Figure 5.13.

No apparent differences were observed between the AM and PM operations as illustrated in Figure 5.13a. In other words, the operators perceived an equal degree of benefit from the exclusive lane in both peak periods.

The operating conditions represented in Figure 5.13b ranked in ascending order of perceived amelioration from the exclusive lane include:

- bad weather;
- traffic incidents;
- heavy traffic.

The operators perceived about the same degree of benefit from the exclusive lane under conditons of "heavy traffic" as they did under the more general conditions of AM and PM peak period represented in Figure 5.13a. In the case of bad weather and incidents, the perceived benefit was noticeably reduced.

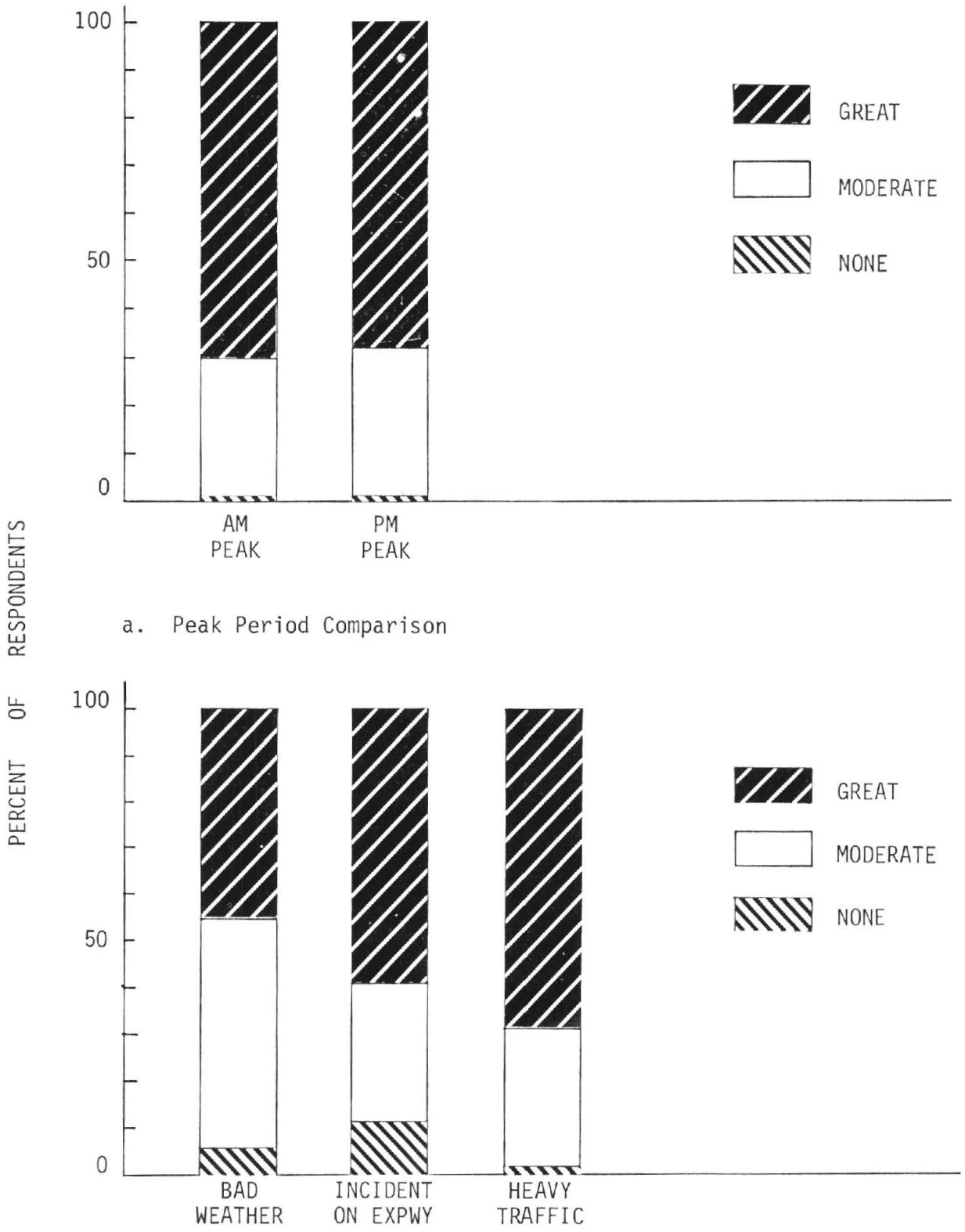


FIGURE 5.13. BUS OPERATOR PERCEPTION OF THE DEGREE OF ASSISTANCE PROVIDED BY THE EXCLUSIVE LANE.

4. Assessment of Passenger Comments

The operators were asked for a subjective assessment of the nature of comments received from express bus passengers.

> Based on the comments of your passengers, do you feel that their general attitude toward the I-95 priority bus/carpool lane is:
>
> [1] [ ] Mostly favorable
> [2] [ ] Mixed Opinion
> [3] [ ] Mostly unfavorable
> [4] [ ] No comments received from passengers

The responses to this question are summarized in Figure 5.14. Nearly two thirds of the drivers felt that passenger comments were mostly favorable. A very small proportion (2%) indicated that passenger comments were predominately negative. These findings are generally consistent with the results of the bus passenger survey.

5. Overall Reaction to the Exclusive Lane

As an indication of the overall reaction to the exclusive lane, each bus operator was asked to indicate a preference for continuation and/or extension of this concept:

> Considering all of the good points and bad points, do you feel that the bus/carpool priority lanes should:

		Yes [1]	No [2]	No opinion [3]
A)	Remain on I-95?	[ ]	[ ]	[ ]
B)	Be installed on other highly congested freeways?	[ ]	[ ]	[ ]
C)	Be installed on all urban freeways?	[ ]	[ ]	[ ]

The response to this question is summarized in Figure 5.15. A strong preference for continuation of the I-95 system is evident, with 89% responding in the affirmative and 7% in the negative. Enthusiasm for extension of the concept to other facilities followed the same general response pattern as the other groups who were asked this question (bus riders, car poolers, etc.). More than half of the express bus drivers were in favor of implementing additional exclusive lane systems. It was observed that more drivers favored the extension of the concept to "all" facilities than to congested facilities only.

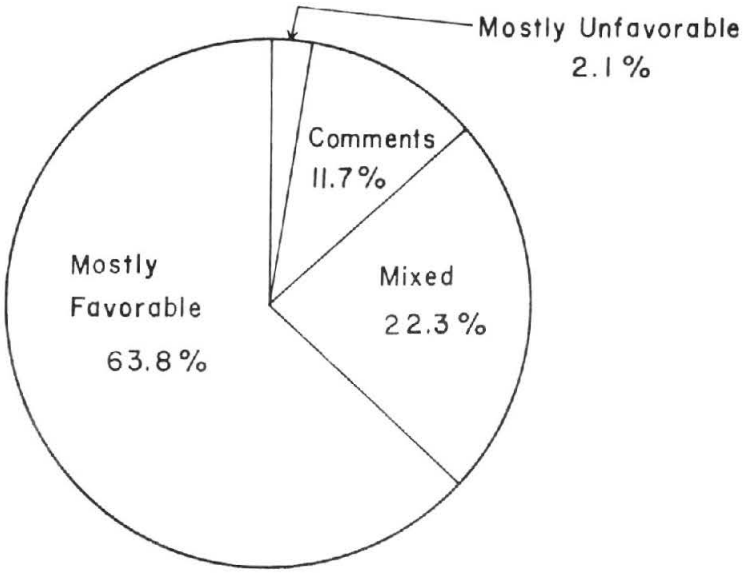


FIGURE 5.14. BUS DRIVER ASSESSMENT OF COMMENTS RECEIVED FROM BUS PASSENGERS.

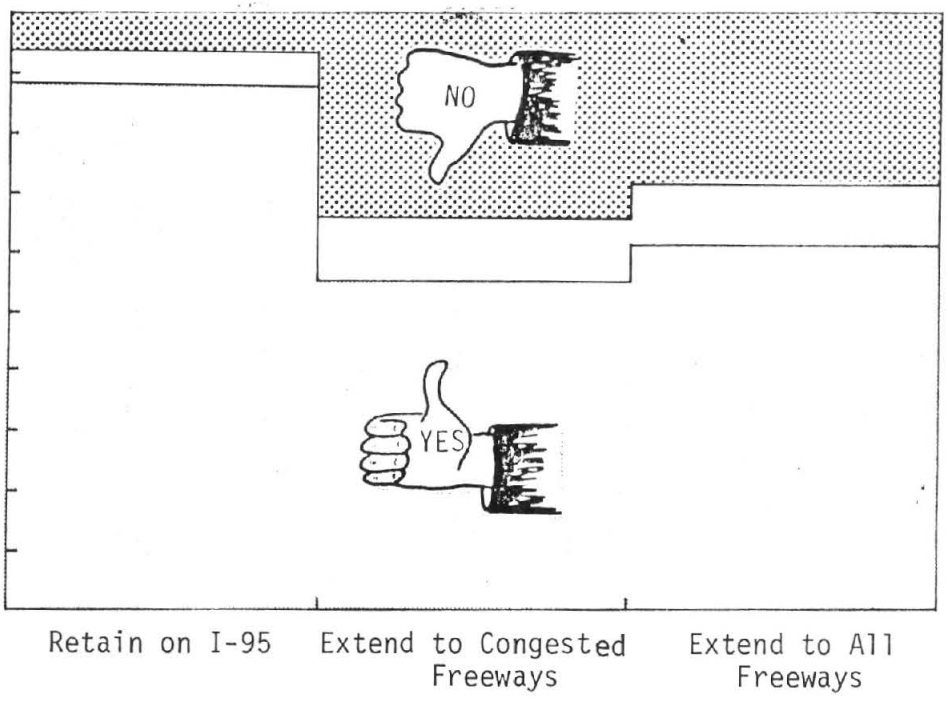


FIGURE 5.15. BUS DRIVER ATTITUDES TOWARD RETENTION AND EXTENSION OF THE BUS/CAR POOL PRIORITY LANES.

This response is not internally consistent and suggests some misinterpretation of the question. Another interesting observation is that a relatively low "no opinion" response was received from the bus driver group than the other roadway user groups. This suggests that the bus drivers' attitudes to the system were more strongly developed as a result of their greater familiarity with the system.

6. Bus Driver Comments

Subjective comments were solicited from the bus drivers by the following question:

> What is the most important recommendation you have for improving the ORANGE STREAKER service?
>
> _____
>
> _____
>
> _____

These comments are listed in detail in Appendix C of this report. In general the suggestions fell into the following categories:

1) Improve passenger service by such methods as increasing the the number of buses and frequency of service, publishing schedules, etc. (14 cases)

2) Improve promotional efforts through marketing and other PR activities. (5 cases)

3) Implement traffic control system changes such as hours of operation, exclusive lane use regulations, speed limits, lane changing regulations, etc. (9 cases)

4) Reduce automobile use of the exclusive lane. A total of 28 comments fell into this category, of which 23 made specific reference to violations of the occupancy requirements, of which 12 made specific reference to the need for improved enforcement to reduce violations.

G. CONCLUSIONS

As a result of these user surveys, the following conclusions are offered regarding the public reaction to the Bus/Car Pool Priority Lanes on I-95.

1. System Acceptance

The bus/car pool priority concept appeared to be well accepted by the road user groups who were surveyed. Approximately 1/3 of the general road users expressed opposition to the priority lane. At the other end of the scale, only two percent of the bus passengers felt that the operation should be discontinued. A generally positive attitude was also expressed toward the extension of this concept to other facilities.

Bus passengers rated the exclusive lane second in importance among all of the Orange Streaker features. The provision of the bus service itself was the only feature which was rated of greater importance. The I-95 system was favored over the NW 7th Avenue bus priority system by 93% of the bus passengers.

Car poolers also rated the express lane second in importance. In this case, the reduced cost of car pooling was indicated as the most important benefit. Both the bus passengers and car poolers tended to overestimate the time saving due to the exclusive lane by an appreciable amount.

2. Operational Problems

All of the road user groups who were surveyed in the questionnaire studies indicated a high degree of concern for abuse of the priority lane by violators. This was rated as the most significant problem by all of the user groups which participated in the survey. Additionally, car poolers expressed more concern about the physical and operational features than the bus passengers. Bus drivers expressed a greater degree of concern than either of these groups. The bus driver concern was concentrated more on the operational features rather than the physical features.

3. Familiarity with the System

The existence of the bus/car pool priority lane was well established in the minds of the road user groups who were surveyed but the knowledge of the existence and meaning of the diamond symbol was somewhat low. Over 99% of the corridor users with an origin in the market area and destination in one of the service areas were familiar with the exclusive lane. On the other hand, only 1/3 of the drivers recognized the diamond symbol as a traffic control device. Of those recognizing the diamond, 1/3 were unable to give a correct indication of its meaning. Drivers with greater exposure and drivers of qualified car pools expressed a higher degree of recognition.

CHAPTER SIX

EFFECT OF CHANGES IN EXCLUSIVE LANE CONTROL PARAMETERS

A. INTRODUCTION

After approximately one year of operation, two important control parameter changes were introduced in the exclusive lane on I-95.

First, the car pool occupancy requirement was reduced from three persons to two persons along with a reduction in the hours of operation of the exclusive lane. This change was made in response to steadily increasing public concern over the apparent under-utilization of the exclusive lane. The traffic control system modifications were limited in this case to a simple change in the exclusive lane identification sign messages to indicate the new minimum occupancy requirement and times of operation. An example of the modified sign message is presented in Figure 6.1.

The second operational change, which was implemented approximately two months after the reduction in occupancy requirements involved the opening of a flyover ramp which connected the exclusive lane directly to the Golden Glades parking lot and bus terminal. The flyover eliminated the need to cross three lanes of freeway traffic for entry to and exit from the exclusive lane. Also eliminated was the need to use approximately 1.5 miles of surface streets to gain access to the Golden Glades terminal. The flyover lanes are shown at the point of connection to the freeway in Figure 6.2.

This chapter examines the effects of these changes on the bus/car pool priority system. Specific areas addressed include the effect on transit and automobile operations, the effect on the overall system performance measures, and the effect on accident experience.

B. ANALYSIS OF ALTERNATIVE CONTROL PARAMETERS

The analytical treatment of the optimal car pool definition and priority lane entry/exit strategy presented in the separate technical appendices provide some interesting points of comparison for the reduction of the minimum car pool requirement from 3 persons per vehicle (ppv) to 2 ppv. These considerations are primarily related to the degree of preferential treatment that is provided

FIGURE 6.1. EXCLUSIVE LANE IDENTIFICATION SIGN MODIFIED FOR TWO PASSENGER CAR POOLS.

FIGURE 6.2. FLYOVER CONNECTION BETWEEN EXCLUSIVE LANES AND THE GOLDEN GLADES TERMINAL.

for high-occupancy vehicles and the preferred priority lane entry/exit strategy for the alternative car pool definitions.

With regard to the investigation of the optimal car pool definition for the I-95 system, it was found that in practically all freeway subsections, the "best" minimum car pool requirement was between 2 and 3 persons per vehicle as is shown in Figure 6.3. Additionally, these analyses indicated that a car pool definition of 2 ppv would result in both minimum vehicle-hours and passenger-hours of travel. However, it was also observed that the 2 ppv requirement would fail to provide any level of preferential treatment for priority vehicles, as shown in Figure 6.4. In fact, it was evident that under this lower requirement the priority lane could be expected to effectively operate as general use, freeway lane under "user equilibrium".

The priority lane entry/exit analysis that was performed demonstrated that substantially different strategies should be considered under each of the alternative car pool definitions. For the 2 ppv requirement, it was found that a discrete entry/exit strategy would be superior. In this case, priority lane access or egress was required in only 13 of the 19 analysis sections as shown in Table 6.1. On the other hand, the 3 ppv definition would require entry/exit provisions in all but 1 analysis section. The optimal strategy for this alternative is shown in Table 6.2.

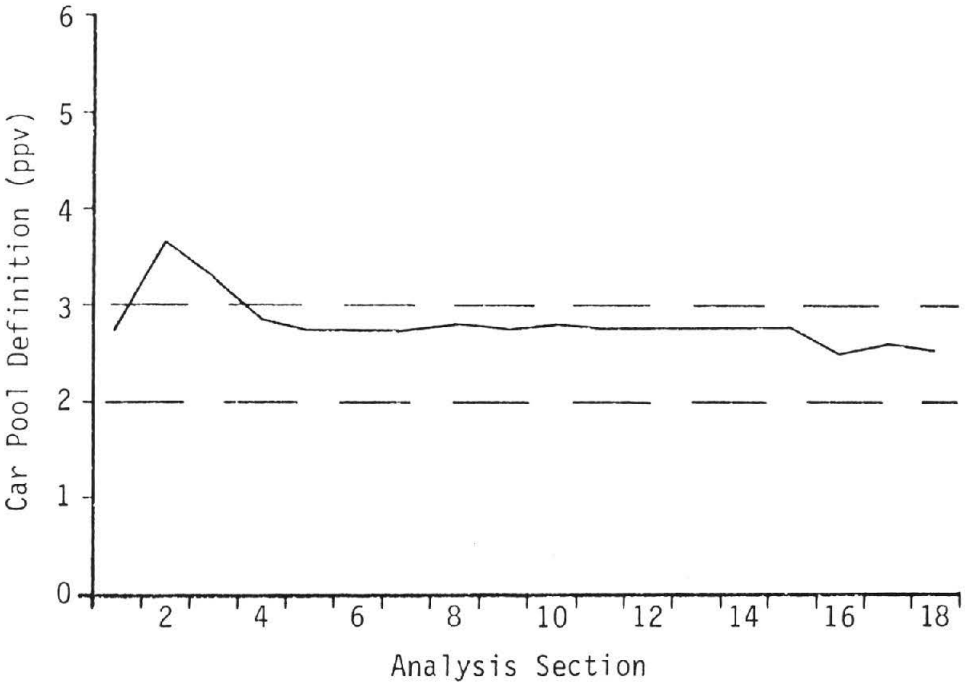


FIGURE 6.3. OPTIMUM CAR POOL DEFINITIONS FOR MINIMUM PASSENGER HOURS DURING THE PERIOD 3:30 TO 6:30 PM.

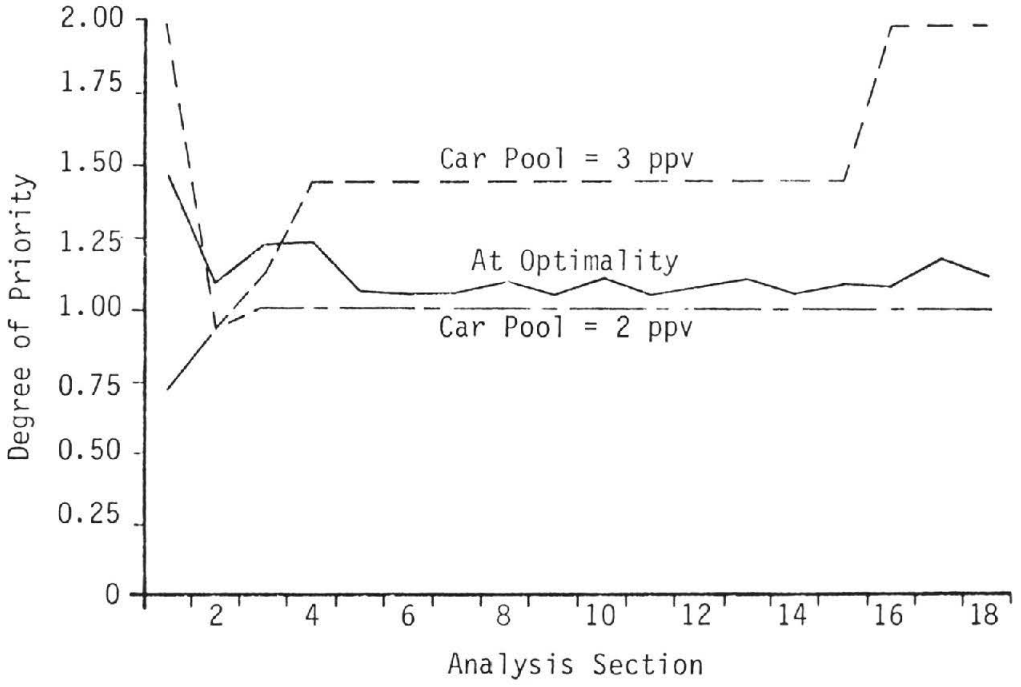


FIGURE 6.4. DEGREE OF PRIORITY FOR MINIMUM PASSENGER HOURS DURING THE PERIOD 3:30 TO 6:30 PM.

TABLE 6.1

OPTIMAL PRIORITY LANE ENTRY/EXIT STRATEGY FOR MINIMUM CAR POOL REQUIREMENT OF 2 PERSONS PER VEHICLE

Section		Candidate Entry/ Exit Strategy	Optimal Entry/Exit Strategy						
No.	Description		Total Peak Period	3:30 to 4:00	4:00 to 4:30	4:30 to 5:00	5:00 to 5:30	5:30 to 6:00	6:00 to 6:30
1	Begin Exclusive Lane	Entry							
2	Airport Expressway On	Entry							
3	Lane Drop	Entry							
4	62nd Off	Exit							
5	62nd On	Entry							
6	69th On	Entry							
7	79th Off	Exit							
8	81st On	Entry							
9	95th Off	Exit							
10	95th On	Entry							
11	103rd Off	Exit							
12	103rd On	Entry							
13	119th Off	Exit							
14	125th Off	Exit							
15	125th On	Entry							
16	135th Off	Exit							
17	135th On	Entry							
18	151st Off	Exit							
	End Exclusive Lane	Exit							

Note: Shading indicates sections with no entry or exit provisions.

TABLE 6.2

OPTIMAL PRIORITY LANE ENTRY/EXIT STRATEGY FOR MINIMUM CAR POOL REQUIREMENT OF 3 PERSONS PER VEHICLE

Section		Candidate Entry/ Exit Strategy	Optimal Entry/Exit Strategy						
No.	Description		Total Peak Period	3:30 to 4:00	4:00 to 4:30	4:30 to 5:00	5:00 to 5:30	5:30 to 6:00	6:00 to 6:30
1	Begin Exclusive Lane	Entry							
2	Airport Expressway On	Entry							
3	Lane Drop	Entry							
4	62nd Off	Exit							
5	62nd On	Entry							
6	69th On	Entry							
7	79th Off	Exit							
8	81st On	Entry							
9	95th Off	Exit							
10	95th On	Entry							
11	103rd Off	Exit							
12	103rd On	Entry							
13	119th Off	Exit							
14	125th Off	Exit							
15	125th On	Entry							
16	135th Off	Exit							
17	135th On	Entry							
18	151st On	Exit							
	End Exclusive Lane	Exit							

Note: Shading indicates sections with no entry or exit provisions.

C. DATA COLLECTION METHODOLOGY

The data collection techniques followed the standard procedures which were used throughout the evaluation of the Demonstration Project in the I-95 corridor. These procedures are described in detail in Reference 1. The specific data sources are listed as follows.

DATA	SOURCE
Peak period volume and vehicle occupancy	Manual volume and occupancy studies
Bus travel times	Manual travel time observations
Bus schedule adherence	Manual observations at the Golden Glades Terminal (provided by the Metropolitan Transit Agency)
Auto travel times and comfort measures	Instrumental moving vehicle studies
Exclusive lane occupancy violators	Moving vehicle observations
Weaving difficulty	Instrumental moving vehicle studies
Bus passenger counts	Metropolitan Transit Agency records
Accident history	Dade County accident records

D. EFFECT ON TRANSIT OPERATIONS

1. Bus Travel Time

The effect of the 2 person car pool on bus speeds and travel times in the reserved lane section of I-95 is summarized as follows:

TRAVEL TIME (minutes)	AM PEAK	PM PEAK
3 person car pool requirement	8.58	8.11
2 person car pool requirement	8.58	9.79
AVERAGE SPEED (m.p.h.)		
3 person car pool requirement	49	52
2 person car pool requirement	49	43

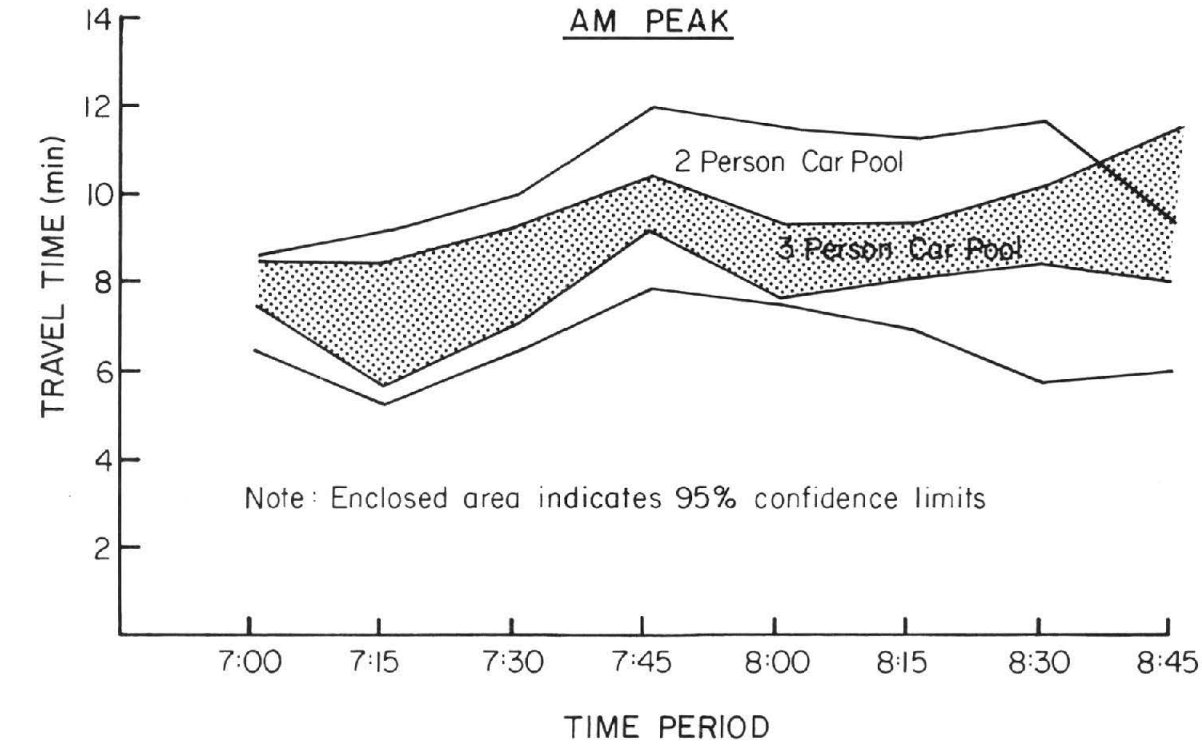
The difference was not statistically significant in the AM peak. The travel times represent the portion of the bus trip on I-95 between 36th Street and 151st Street, which includes the entire exclusive lane section. These results indicate that the change in regulations had no measurable effect on the average travel time in the morning, but that travel times were increased by approximately 44% during the afternoon peak period.

A more detailed analysis of the bus travel times is presented in Figure 6.5, which shows the effect of time of day on the variation of travel times. It is observed, for example, in the AM peak that the travel times remained more or less constant during the entire peak period. It is interesting to note that, although the average travel times were not altered by the change in regulations, the variation in travel time as indicated by the width of the shaded areas was noticeably greater when 2 person car pools were allowed in the exclusive lane.

In the afternoon peak, on the other hand, the 2 person regulation resulted in an increase in both the average travel time and the variability of travel time. Furthermore, a stronger "peaking" trend is evident in the 2 person case during the more congested portion of the PM period.

2. Schedule Adherence

Bus schedule adherence studies were conducted during the PM peak period throughout the course of the Demonstration Project and comparisons between other operational stages are presented in Reference 3 and in Chapter 2 of this report. The primary measure of effectiveness was the difference between the scheduled arrival time and the actual arrival time for buses at the Golden Glades terminal. This measure is termed the "arrival time discrepancy". The distributions of arrival time discrepancy representing the 3 person and 2 person car pool stages are presented in Figure 6.6. The dispersion of the distribution reflects the degree of schedule adherence with a more dispersed distribution representing a lower degree of adherence. Another measure of schedule adherence is expressed in terms of the average "lateness" of the buses. It is observed for example in Figure 6.6 that the average bus arrived 4.4 minutes late at the Golden Glades terminal under 2 person car pool operation and 0.2 minutes late with 3 person car pools. This difference agrees generally with the difference in travel times observed on the freeway. The dispersion of arrival time discrepancies between these two stages of operation dropped, however, by approximately 20% indicating that, although travel times were longer,



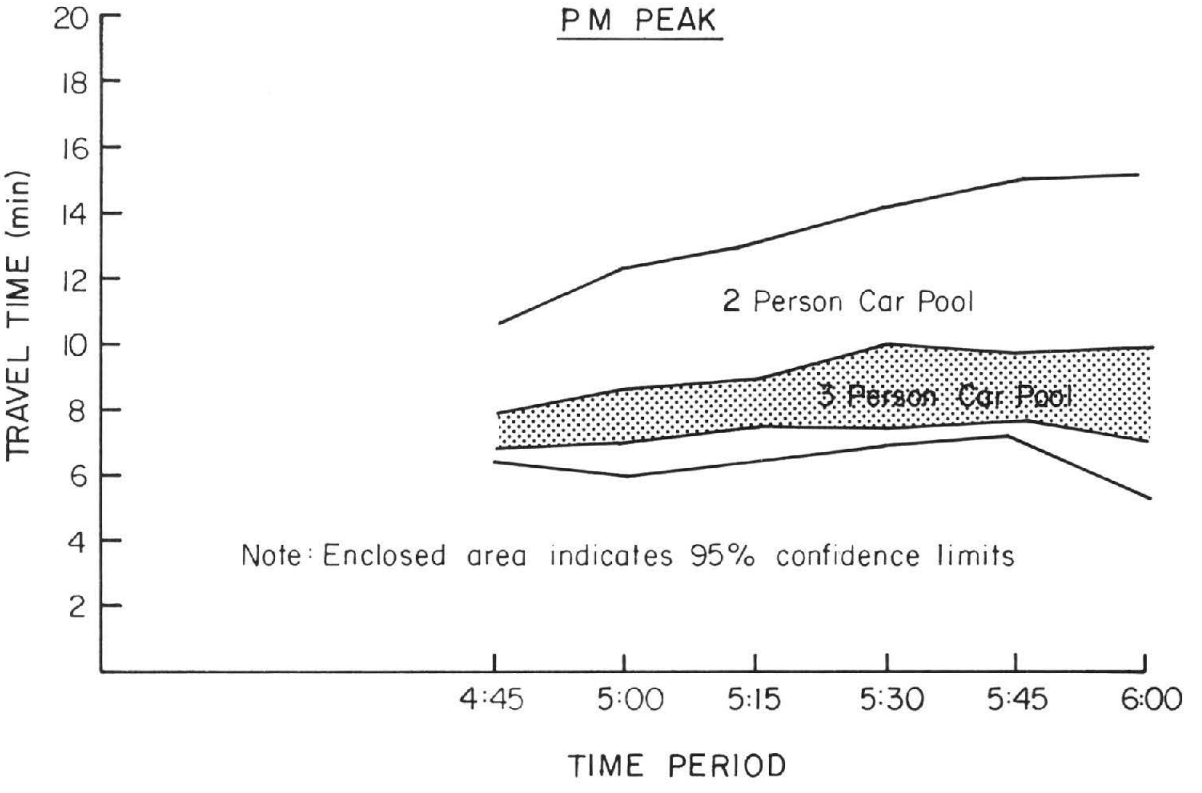


FIGURE 6.5. VARIATION IN EXPRESS BUS TRAVEL TIMES IN THE PEAK PERIODS.

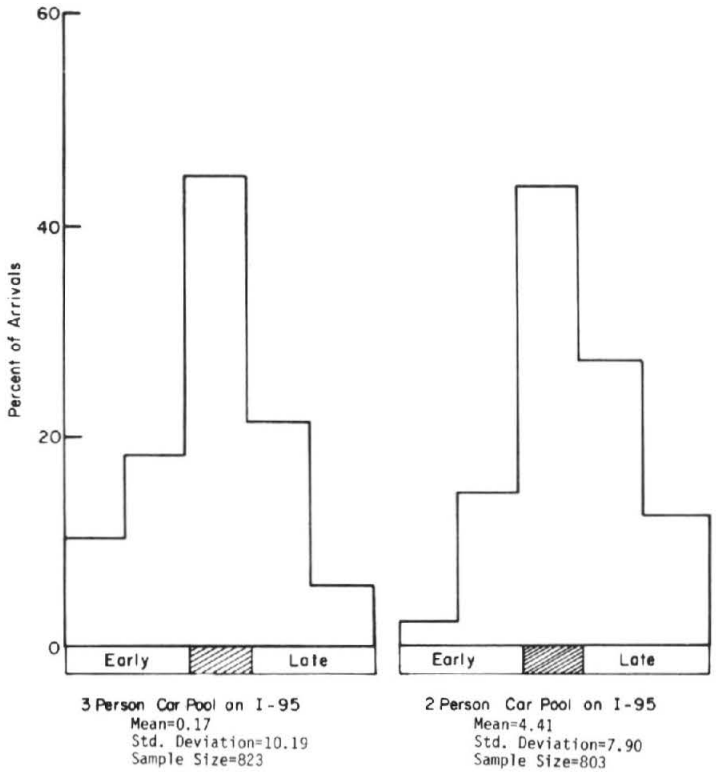


FIGURE 6.6. DISTRIBUTION OF DIFFERENCES BETWEEN ACTUAL AND SCHEDULED ARRIVAL TIMES FOR ORANGE STREAKER BUSES AT THE GOLDEN GLADES TERMINAL.

predictability was improved, primarily because fewer buses arrived earlier than scheduled.

E. EFFECT ON AUTOMOBILE OPERATIONS

1. Travel Time

The effect of the 2 person car pool on automobile travel times on I-95 is summarized as follows:

	AM PEAK PERIOD	PM PEAK PERIOD
EXCLUSIVE LANE Travel Time (minutes)		
3 person car pool	7.14	7.62
2 person car pool	7.13	7.55
GENERAL LANES Travel Time (minutes)		
3 person car pool	10.0	10.7
2 person car pool	10.2	9.15

The only comparison in the above summary which proved to be statistically significant at the 95% level was the improvement in travel time in the general lanes during the PM peak period. The automobile travel time comparisons during the AM peak were consistent with the bus travel time comparisons: i.e., no noticeable change occurred with the reduced car pool requirement. It, therefore, may be concluded that AM peak operations were not substantially affected by the operational changes which were implemented.

During the PM peak, on the other hand, noticeable changes were observed in the bus travel times, which increased by 44% and in the automobile travel times in the general lanes, which decreased by approximately 15%. Some increase in automobile travel times in the exclusive lane would be anticipated, in view of the relatively large increase in bus travel times, however, no such increase was recorded in the field. The average speed for automobiles in the exclusive lane remained at approximately 50 miles per hour throughout both stages of the study. This is generally consistent with a level of service "B"

operation. The corresponding travel time in the general lanes was 42 m.p.h. which represents level of service "C".

The large difference between the bus travel times and the automobile travel times in the exclusive lane may be due to a number of factors, including the concentration of bus travel during the more heavily congested portion of the peak period and the difference in general maneuverability between these two classes of vehicles. It is interesting to note that the average bus travel time (presumably in the exclusive lane) under 2 person car pool operation actually exceeded the average automobile travel time in the general lanes during the PM peak period. This suggests that, with the reduced car pool requirement, the system fell into "user equilibrium" during the congested portion of the peak period, and, therefore, the potential benefits of the exclusive lane did not materialize during that period.

2. Trip Comfort

The most relevant measure of trip comfort, for purposes of this study, was identified in Reference 2 as speed noise. This measure, defined as the coefficient of variation of individual vehicle speeds, provides an indication of the variability of speed as the vehicle proceeds along the route. A trip which was made at constant speed would experience no speed noise. A value which exceeds 1.0 generally reflects a noticeable "stop and go" operation.

Speed noise measurements were carried out for automobiles using both the general and exclusive lanes on I-95 during both peak periods. The results followed the same pattern as the travel time studies, i.e., no statistically significant differences were observed, except in the case of the general lanes during the PM peak period when speed noise was reduced by 35% under the 2 person car pool regulations. This indicates that a generally more comfortable trip was experienced under this condition.

Bus travel time measurements were carried out by manual observations of departure and arrival times. It, therefore, was not possible to provide a quantitative speed noise comparison. Some deterioration in transit passenger trip comfort would, however, be anticipated during the PM peak period in view of the increased travel times experienced by buses when the car pool regulations were relaxed.

3. Exclusive Lane Occupancy Violations

The reduction in passenger occupancy requirements for the exclusive lane changed the definition of a "violator" substantially. A reduction in violation rates was anticipated.

A comparison of car pool volume, violator volume, total traffic volume and violation rates for both peak periods is presented in Table 6.3.

TABLE 6.3

COMPARISON OF TRAFFIC VOLUMES AND VIOLATION RATES IN THE EXCLUSIVE LANE

	AM PEAK PERIOD	PM PEAK PERIOD
PEAK HOUR CAR POOL Volume (veh. per hour)		
3 person minimum	158	258
2 person minimum	726	977
% increase	365%	278%
PEAK HOUR VIOLATOR Volumes (veh. per hour)		
3 person minimum	514	622
2 person minimum	357	344
% decrease	30%	45%
TOTAL PEAK HOUR VOLUME		
3 person minimum	670	879
2 person minimum	1083	1321
% increase	62%	50%
VIOLATION RATES		
3 person minimum	78%	72%
2 person minimum	37%	28%

The same trends were evident in these comparisons during both peak periods. Car pool volumes more than tripled (largely as a result of the new definition of a car pool), and violator volumes decreased by an average of 38% (largely as a result of the new definition of violator).

While these two effects tended to offset each other, the net result was an appreciable increase in total exclusive lane volume (approximately 56% on the average), indicating a substantially greater usage of the exclusive lane. All of the comparisons presented in Table 6.2 were statistically significant at the 99% level.

4. Lane Changing Problems

One of the potential problems of the HOV priority lane concept is the difficulty of crossing several congested lanes of traffic to gain access to the priority lane. Studies were carried out to assess the degree of difficulty of the weaving maneuver under both car pool definitions (3 persons vs. 2 persons). The measures of effectiveness, obtained by moving vehicle studies using an instrumented vehicle, were the time and distance required to complete the weaving maneuver. The entry movements were studied downstream of an entrance ramp within the most congested area of the freeway during each peak period. The exit movements were studied upstream of the last exit ramp in the system, where the majority of weaving activities were concentrated in each case.

The results, as summarized in Table 6.4, indicated that reducing car pool requirements from three to two persons per vehicle significantly decreased both the time and distance required in executing the lane changing maneuver during the PM peak. The AM peak showed a slight reduction in the time necessary to complete the weaving maneuvers but not the distance.

There appears, therefore, to be a strong indication that, during the evening peak, a reduction in car pool requirements from three to two persons per vehicle altered the lane distribution to the point that weaving maneuvers were significantly easier to perform. This conclusion is based on significantly lower times and distances required to perform weaves from an entrance ramp to the exclusive lane as well as from the exclusive lane to an exit ramp.

The same phenomenon did not hold true for the morning peak as the times and distances associated with weaving across the freeway showed no statistical difference. The lack of difference during the morning peak period was due primarily to the fact that no particular lane changing problem was experienced at this time of day.

TABLE 6.4

COMPARISON OF TIME AND DISTANCE REQUIRED FOR ENTRY TO AND EXIT FROM THE EXCLUSIVE LANE

	AM PEAK PERIOD		PM PEAK PERIOD	
	ENTRY	EXIT	ENTRY	EXIT
TIME required to weave across all general lanes (seconds)				
3 person car pool requirement	46	46	62	47
2 person car pool requirement	36	53	45	29
level of significance of statistical comparison	95%	N.S.	99%	99%
DISTANCE required to weave across all general lanes (feet)				
3 person car pool requirement	2400	2600	3300	3100
2 person car pool requirement	2200	2500	2300	1500
level of significance of statistical comparison	N.S.	N.S.	99%	99%

F. EFFECT ON SYSTEM OPERATING CHARACTERISTICS

The operational characteristics were compared in Chapter 2 for two stages of the Bus/Car Pool Demonstration Project:

- Mixed mode operation which occurred prior to the implementation of the exclusive lane on I-95; and,

- HOV Priority Operation, in which buses and 3 person car pools were permitted to use the newly constructed median lanes.

The reduction in car pool requirement for the priority lane generated a third experimental stage for comparison purposes.

To develop these comparisons, field data were collected to determine:

1. average traffic volumes on I-95 during each of the peak periods;
2. average passenger occupancy for exclusive lane autos and autos travelling in the general lanes;
3. travel times for each mode of travel; and,
4. bus passenger volumes.

The section of freeway used for comparison purposes included the entire reserved lane section between the airport expressway and 151st Street. This section was 6.7 miles in length.

From the field data, the following measures of effectiveness were calculated for each peak period:

1. Total vehicular demand on the freeway (vehicle miles)
2. Total passenger demand (passenger miles)
3. Total vehicular travel time on the freeway (vehicle hours)
4. Total passenger travel time on the freeway (passenger hours)
5. Average vehicle speed (vehicle miles÷vehicle hrs = mph)
6. Average passenger speed (passenger miles÷passenger hours = mph)
7. Passenger movement index (passenger miles÷ vehicle hours = mph)
8. HOV priority index (average passenger speed÷average vehicle speed)

Note that measures 5, 6, and 7 share the same dimensions (miles per hour). The vehicle and passenger speeds are relatively simple from a conceptual point of view. The Passenger Movement Index (PMI) is defined for purposes of this study as the number of passenger miles of travel per vehicle hour of travel

time. It is suggested that this measure provides the most meaningful relationship between the service provided by the facility, in terms of passenger throughput, and the cost of providing that service, in terms of traffic congestion.

Another derived measure of effectiveness is termed the "HOV Priority Index". This measure is defined for purposes of this study as the ratio of average passenger speed to average vehicle speed. An HOV priority index of 1.0 would indicate that no travel time advantage was experienced by high occupancy vehicles. To achieve an index greater than 1.0 it would be necessary to move vehicles carrying larger numbers of passengers at high speeds than vehicles with fewer occupants.

The results from each of the operational stages are summarized in Table 6.5 . It is observed that, in general, the system performance measures were not changed substantially in the AM peak period. The passenger movement index (passenger miles/vehicle hour) increased by approximately 6%. A slight improvement was also noted in the HOV priority index (passenger speed/vehicle speed). This improvement resulted primarily from the ability of the system to accommodate the transfer of additional 2 person vehicles to the priority lane during this period.

In the PM peak, the changes were more pronounced. A 25% improvement in the passenger movement index for the 2 person car pool stage was observed. This improvement was, however, achieved at the expense of the degree of priority given to High Occupancy Vehicles. It is noted that the HOV priority index for the 2 person car pool stage was reduced to 1.0, indicating that the system was in "user equilibrium". Some advantages were gained by car pools using the priority lane during the PM peak, but this advantage was offset by the operational difficulties apparently experienced by the buses, whose scheduled movements tended to concentrate in the more congested portion of the peak period.

G. EFFECT ON ACCIDENT RATES

The accident rate was defined in Chapter 2 of this report in terms of accidents per day of operation, in which one day was represented by the combinations of the AM and PM peak periods. This reflects a more realistic assessment of accident exposure on a congested urban freeway than the more conventional "million vehicle miles" technique because of the non-linear

TABLE 6.5a

COMPARISON OF OPERATIONAL CHARACTERISTICS
(AM PEAK PERIOD)

ITEM	EXCLUSIVE LANE		GENERAL LANES		TOTAL	
	3 Person Minimum	2 Person Minimum	3 Person Minimum	2 Person Minimum	3 Person Minimum	2 Person Minimum
Auto Volume	653	2,316	14,909	13,400	15,562	15,716
Auto Occupancy	1.967	1.778	1.249	1.252	1.279	1.330
Auto Passengers	1,284	4,118	18,621	16,777	19,905	20,895
Bus Passengers	827	843	——	——	827	843
Total Vehicle Miles	4,337	14,897	94,672	85,090	99,009	99,987
Total Vehicle Hours	82	279	2485	2278	2567	2557
Total Passenger Miles	13,408	31,501	118,246	106,533	131,654	138,034
Total Passenger Hours	271	610	3,104	2,852	3,375	3,462
Average Vehicle Speed	52.9	53.4	38.1	37.4	38.6	39.1
Average Passenger Speed	49.5	51.6	38.1	37.4	39.0	39.9
Passenger Movement Index	163.5	112.9	47.6	46.8	51.3	54.0
HOV Priority Index			——	——	1.01	1.02

TABLE 6.5b

COMPARISON OF OPERATIONAL CHARACTERISTICS
(PM PEAK PERIOD)

ITEM	EXCLUSIVE LANE		GENERAL LANES		TOTAL	
	3 Person Minimum	2 Person Minimum	3 Person Minimum	2 Person Minimum	3 Person Minimum	2 Person Minimum
Auto Volume	943	3,216	17,675	15,586	18,618	18,802
Auto Occupancy	2.115	1.758	1.313	1.365	1.354	1.432
Auto Passengers	1,994	5,654	23,207	21,275	25,201	26,929
Bus Passengers	783	787	——	——	783	787
Total Vehicle Miles	6,179	20,612	112,236	98,971	118,415	119,583
Total Vehicle Hours	124	411	3,152	2,377	3,276	2,788
Total Passenger Miles	17,637	40,898	147,366	135,096	165,003	175,994
Total Passenger Hours	359	839	4,138	3,244	4,497	4,083
Average Vehicle Speed	49.8	50.2	35.6	41.6	36.1	42.9
Average Passenger Speed	49.1	48.7	35.6	41.6	36.7	43.1
Passenger Movement Index	142.2	99.5	46.8	56.8	50.4	63.1
HOV Priority Index			——	——	1.02	1.00

relationship between vehicle miles of travel and vehicle hours of travel time.

A comparison of accident rates, obtained from the computerized records of the Dade County Department of Public Safety is presented as follows:

MINIMUM CAR POOL REQUIREMENT	AM PEAK	PM PEAK	TOTAL
3 persons (290 days)	.365	.493	.858
2 persons (103 days)	.330	.281	.611

The slight decrease in accident rates (10%) in the morning peak period was not statistically significant, however, the decrease observed in the afternoon (43%) was significant at the 99% level. The overall decrease for the sum of the two peaks (29%) was also significant. These results are consistent with other comparisons of the two levels of car pool definitions (i.e. appreciable changes in PM operation, accompanied by a much smaller difference during the AM peak).

H. EFFECT OF THE FLYOVER ON TRAVEL TIMES

Travel time studies were taken before and after the opening of the flyover which connected the exclusive lanes on the freeway directly to the Golden Glades Terminal. The results of these studies are summarized as follows:

	AM PEAK	PM PEAK
Automobile Travel Time Savings (minutes per trip)	1.7	2.75
Bus Travel Time Savings (minutes per trip)	.78	4.02

The largest travel time savings were experienced by buses during the PM peak. In this case the flyover shortened the route considerably by substituting the direct access to the terminal for a circuitous route previously used to avoid the hazards of changing lanes at the last freeway exit before the Golden Glades Terminal. In the AM peak, on the other hand, the automobiles received more

benefit from the flyover than the buses. The buses still experienced reduced travel times with the flyover, but they lost their previous advantage over the autos due to their ability to preempt the traffic signals on NW 7th Avenue. The flyover eliminated this portion of the route.

I. SUMMARY AND CONCLUSIONS

The operational changes on the I-95 bus/car pool priority system were implemented largely in response to public concern over the apparent under-utilization of the facility. The initial car pool minimum requirement of three persons per vehicle was based on analysis which demonstrated that no substantial high occupancy vehicle advantage would materialize if the car pool definition were set at a lower level. The same analysis indicated, however, that the lower level would result in a higher passenger carrying capability due to more effective utilization of the freeway capacity by lower occupancy vehicles.

Field studies which compared the two operational strategies indicated that the degree of utilization of the exclusive lane by qualified vehicles was somewhat lower than anticipated. This factor has maintained a consistent travel time advantage in the exclusive lane throughout the AM peak period and though the non-congested portions of the PM peak, even with the reduced car pool requirement. During the more heavily traveled portion of the PM period, however, the system falls into "user equilibrium" (i.e., the general lanes became equally attractive from the users' point of view). The express buses experience particular difficulty under these conditions since their maneuverability is more limited than the automobiles. Travel times, delays and overall trip comfort deteriorated during the PM peak for high occupancy vehicles in general and for buses in particular.

On the other hand, some appreciable benefits have resulted from the reduction in car pool occupancy requirements. Overall travel times and delays have been reduced. The passenger throughput per vehicle hour of delay has been improved by 25%. Lane changing problems have been significantly reduced. The problems of enforcement have been greatly alleviated by eliminating the two person car pool as a violator of the traffic control regulations. Accident rates have also improved appreciably. While the two person car pool requirement

has compromised, to some extent, the original high occupancy vehicle priority, it has also improved traffic operations and safety on this important transportation facility.

CHAPTER SEVEN

SUMMARY AND CONCLUSIONS

Based on the studies and analyses performed in connection with this Project, the following conclusions are offered:

1. Passenger Throughput

The addition of the bus/car pool priority lane improved the passenger carrying capability of the freeway corridor in all cases. Travel times on the freeway were reduced and the number of passenger miles of travel per vehicle hour of travel time were increased substantially. While the additional lanes were being constructed on the freeway, the bus priority system on the adjacent surface streets provided a slightly higher level of service during periods of heavy congestion. However, throughout a large portion of the nominal three hour peak period the mixed mode operation on the freeway was preferable from a travel time point of view.

2. Effect of Signing and Marking

The exclusive lane operations were not heavily influenced by the signing and marking parameters. The only noticeable effects were:

a. The solid pavement marking tended to discourage lane changing and violations in the exclusive lane to a greater degree than skip line marking.

b. The overhead "Watch for Buses Changing Lanes" signs provided some degree of assistance to buses entering and leaving the exclusive lane.

3. Enforcement and Violations

Enforcement of the car pool regulations and abuse of the exclusive lane by non-qualified vehicles were a major issue in the Demonstration Project. Violation rates at the 50% level were observed when the priority lane operation was initiated. This figure increased to approximately 75% as the Project progressed and the lack of enforcement became evident to the motoring public.

Violation rates were influenced mainly by the density of traffic in the general use lanes. The presence of a highway patrol vehicle in the traffic stream was observed to have slight effect on the level of violation.

All of the road user groups who were surveyed in the questionnaire studies indicated a high degree of concern for abuse of the priority lane by violators. This was rated as the most significant problem by all of the user groups which participated in the survey.

4. Disabled Vehicles

There was a tendency, particularly at the earlier stages of the Project, for disabled vehicles to use the priority lane as a breakdown lane. This was attributed to the lack of refuge in the median in combination with the tendency on the part of the driver to mistake the intended function of the priority lane. Several serious accidents (including 4 fatalities) occurred shortly after the new lanes were opened. This problem was of greatest concern during off-peak periods. The conversion of the solid lane marking separating the priority lane from the general lanes to a skip line appeared to be effective in reducing the accident problem. The skip line was, however, less effective in the peak periods in controlling violation and lane changing activities.

5. Accident Rates

Accident rates were not heavily influenced by the stage treatment throughout the Demonstration Project. Notable exceptions were:

a. The high initial experience attributed to the disabled vehicle usage of the priority lane.

b. A reduction in accident rates was observed during the PM peak period when the car pool occupancy requirements were relaxed to allow 2 person car pools to use the priority lane.

Accidents occurred during the peak periods at the rate of approximately four per week. Rear end collisions accounted for approximately 80% of the accidents and sideswipes accounted for a substantial portion of the remaining 20%. Lane changing activities and lack of refuge area were the major contributing factors in these accidents.

6. Median Barrier

The priority lanes were constructed in close proximity (3 feet) to a concrete median barrier which separated the two directions of travel. No particular problems were observed with this operation. Very little concern for the problem was evident in the road user surveys. Analysis of reserved lane

accidents indicated very little degree of implication of the median barrier as a causative factor. Other causative factors predominated in practically all cases where a vehicle struck the median barrier.

7. System Acceptance

The bus/car pool priority concept appeared to be well accepted by road user groups who were surveyed. Approximately 1/3 of the general road users expressed opposition to the priority lane. At the other end of the scale, only two percent of the bus passengers felt that the operation should be discontinued. A generally positive attitude was also expressed toward the extension of this concept to other facilities.

Bus passengers rated the exclusive lane second in importance among all of the Orange Streaker features. The provision of the bus service itself was the only feature which was rated of greater importance. The I-95 system was favored over the NW 7th Avenue bus priority system by 93% of the bus passengers.

Car poolers also rated the express lane second in importance. In this case the reduced cost of car pooling was indicated as the most important benefit. Both the bus passengers and car poolers tended to overestimate the time saving due to the exclusive lane by an appreciable amount.

8. Operational Problems

The major item of concern was the abuse of the priority lane by non-qualified vehicles. Car poolers expressed more concern about the physical and operational features than the bus passengers. Bus drivers expressed a greater degree of concern than either of these groups. The bus driver concern was concentrated more on the operational features rather than the physical features.

9. Familiarity with the System

The existence of the bus/car pool priority lane was well established in the minds of the road user groups who were surveyed but the knowledge of the existence and meaning of the diamond symbol was somewhat low. Over 99% of the corridor users with an origin in the market area and destination in one of the service areas were familiar with the exclusive lane. On the other hand, only 1/3 of the drivers recognized the diamond symbol as a traffic control device. Of those recognizing the diamond, 1/3 were unable to give a correct indication of its meaning. Drivers with greater exposure and drivers of qualified car pools expressed a higher degree of recognition.

10. Non-Utilization of the Exclusive Lane

In spite of an encouraging level of acceptance as expressed by the surveys, the degree of non-utilization of the exclusive lane was higher than anticipated. The high violation rates were probably the major cause of this problem.

11. Reduction of Car Pool Occupancy Requirements

The relaxation of the car pool occupancy requirement to allow 2 person car pools to use the priority lane resulted in a passenger throughput increase of approximately 25%. Other benefits included lower accident rates, easier lane changing and reduced enforcement problems due to the re-definition of what constitutes "violator". The improvements were concentrated in the PM peak period.

These benefits were offset by a substantial loss in the degree of priority, also in the PM peak period. Buses operating under the new scheme experienced definite operating problems. An appreciable increase in bus travel times was observed. Bus movements tended to concentrate at the heaviest part of the peak when the greatest effects were evident.

GUIDELINES FOR FUTURE HOV PRIORITY SYSTEMS

Many of the conclusions presented in this section apply specifically to the I-95 project site in Miami, and some judgement must be used in extrapolating these findings to other locations. It is suggested, however, that experience with the Miami Demonstration Project supports the following general guidelines.

1. The concept of reserving the median lane on an urban freeway for buses and car pools during peak periods offers substantial benefits in terms of increased passenger throughput and HOV priority.

2. The potential benefits may not be realized without adequate enforcement of the minimum occupancy requirements. This problem must be addressed at the operational, institutional and legislative levels.

3. Public acceptance of the HOV regulations is likely to be substantially higher when the lane is added to the facility as opposed to the designation of an existing lane for this purpose.

4. The use of the HOV lane as a breakdown lane poses a serious hazard during the off-peak periods, particularly if there is no median shoulder or refuge area. Special delineation schemes which set the HOV lane apart from the rest of the facility (e.g., solid pavement markings) should, therefore, be avoided, even though this may compromise the peak period operation to some

extent.

5. The diamond symbol established as a standard for intra-lane marking for HOV lanes does not convey an inherent meaning to the motorist. Therefore, extensive local publicity should accompany a reserved lane project to establish the meaning of the symbol.

6. The designation of the minimum car pool size should be carefully considered before a project of this nature is implemented. The car pool definition model developed for the Miami project should be useful for this purpose.

7. The possibility of a high degree of violation of the occupancy regulations should be considered, along with the possibility of a high degree of non-utilization of the HOV lane by otherwise qualified vehicles.

8. The trade-off between HOV priority and passenger throughput should also be recognized. The maximum throughput may well be achieved when the system falls into "user equilibrium", especially during the least congested portions of the peak period. Higher accident rates are also likely to be experienced with higher degrees of HOV priority due to increased speed differential between the HOV lane and the general lanes.

9. The designation of the hours of operation of the HOV lanes should also be carefully considered. It must be recognized that a policy which is unnecessarily restrictive promotes unused capacity in the system. This creates the dual problem of reduced efficiency and increased public opposition to a project of this type.

10. In evaluating the performance of a reserved lane system, measures of effectiveness should be chosen which reflect both the passenger throughput and the degree of HOV priority. Two such measures, described in this report, and defined as the "Passenger Movement Index" and the "HOV Priority Index", are suggested as promising candidates for this purpose.

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Traffic control of car pools and buses on priority