OPERATIONAL EXPERIENCE WITH CONCURRENT FLOW RESERVED LANES

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ABSTRACT

This report presents an evaluation of the concurrent flow reserved lane concept to improve the capacity of urban traffic facilities in metropolitan areas. The purpose of this effort is to evaluate the applicability of this concept to urban freeways in Texas.

The concurrent flow reserved lane concept is described, and some of the advantages and limitations of the concept are identified. To date, January 1, 1977, several projects have been implemented. These projects are individually summarized and collectively analyzed. Based on the review of these data, the evaluation of what capability the concurrent flow reserved lane has for improving increased person movement on urban freeways is presented.

SUMMARY

By utilizing both carpools and transit buses, concurrent flow reserved lanes theoretically have potential for moving more people on typical urban freeways than are now being moved on these freeways. These lanes also have the potential of reducing total vehicular travel, conserving energy, and reducing pollution emissions. In addition, they offer considerable flexibility in both implementation and operation. However, the concurrent flow reserved lane has the definite disadvantage of requiring a change in travel style from the private auto to multi-occupant vehicles (carpool or transit bus).

The potential advantages of concurrent flow reserved lanes have been recognized by both the federal and state governments. Federal financial assistance and state appropriated monies have financed all of the demonstrations to date.

Summary of Existing Projects

As of January 1, 1977, six concurrent flow reserved lane projects have been implemented; five are still in operation. Two additional demonstrations are planned for the near future. Actual experience with the concurrent flow reserved lane concept has verified both its advantages and limitations. Data from the various projects are given.

Analysis of Several Project-Related Factors

Available data indicate that carpools showed more significant gains than did bus ridership. In addition, all projects experienced the problem of restricted lane violators.

Another problem common to all projects is how to protect the level-of-service offered by the restricted lane, and at the same time move the most people possible on the lane. If the restrictions are too strict, the lane appears to be underutilized. However, if the restrictions are too lax, the lane could become crowded and would no longer afford the desired level-of-service.

Conclusion

Analysis of existing and past reserved lane-concurrent flow projects does not encourage immediate implementation of such projects in Texas.

IMPLEMENTATION STATEMENT

The primary purpose of this research project (Study 2-10-74-205) is to provide data and develop guidelines that will be useful to the State Department of Highways and Public Transportation as well as the various cities in Texas in designing and implementing priority treatment projects on highway facilities. Thus, the total focus of this study is aimed toward implementation.

The City of Houston has adopted a transit improvement program which emphasizes the use of buses on existing facilities. Priority treatment projects on several freeways in Houston are currently being planned under a demonstration project. The findings contained in this report have already been used in developing plans in Houston.

The City of Austin and the Dallas/Fort Worth Urban Transportation Steering Committee have also recently adopted transit improvement plans that include priority treatment for buses on certain highway facilities. Other cities in Texas will probably follow similar plans. Hence, the results of this study would have broad applicability in Texas and in other states.

I. INTRODUCTION

Scope of the Report

Continually increasing demand for additional capacity on urban traffic facilities in the state's metropolitan areas, during peak periods of use, is not a new problem. Those corridors experiencing this problem in the past, however, were more traditionally improved by designing and constructing additional lanes or by expanding the number of freeways radiating from city centers. But, with growing complications concerning the feasibility of new right-of-way acquisition, dwindling funding sources, and increasingly longer times required between design and completion of facilities, it has become apparent that other approaches should be considered.

One such approach appears to be the application of priority treatment concepts to an existing freeway to accommodate a larger number of person movements. This approach gives priority travel advantages to certain vehicles transporting significantly more people than is typical. The operational benefits gained from this approach are time-flexible and may be restricted only to those peak periods when demand for additional capacity is most needed. During non-restricted periods, the freeway could operate in its customary manner.

A companion report (Research Report 205-1) contains a comparison of the five following concepts for priority treatment:

1. Exclusive busways (protected by barriers),
2. Reserved lanes - contraflow,
3. Reserved lanes - concurrent flow,
4. Freeway control with priority entry, and
5. Use of service roads.

Because so much attention has recently been given to concurrent flow

reserved lanes, this report is devoted entirely to that concept to aid in determining if this concept is applicable to Texas urban freeways. The concurrent flow reserved lane concept is described in the first section of this report. Some of the inherent advantages and limitations of the concept are identified.

Several cities have recently demonstrated the concurrent flow lane concept on selected urban freeways. Because of the significant amount of operational data collected from these projects, it is now possible to reach some preliminary assessments regarding the effectiveness such a concept offers. The second section of this report summarizes each demonstration project to date and collectively analyzes the concept's influences on freeway operations.

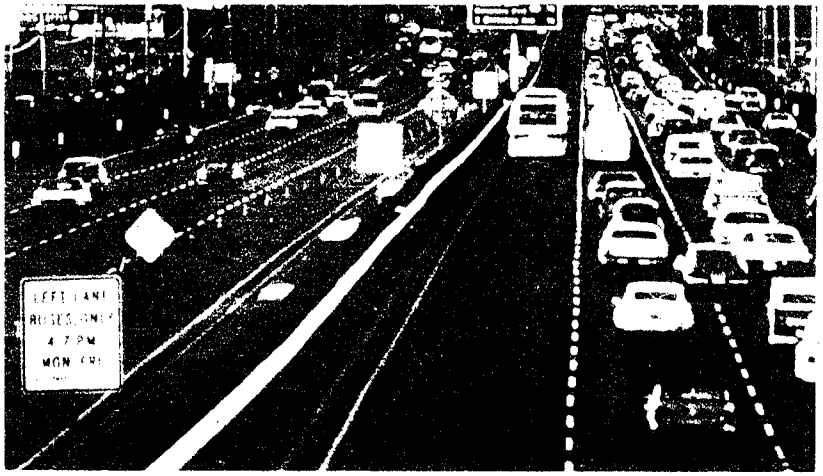
Concurrent flow reserved lanes theoretically have the potential for moving larger numbers of people than are now being transported on typical freeway lanes. Questions arise involving what effects current vehicle occupancies have on optimizing lane use, and what capabilities the reserved lane has for increasing person movement. This evaluation is presented in the third section of the report.

The conclusions reached on the applicability of concurrent flow reserved lanes on Texas urban freeways are presented in the fourth section.

Concept Description

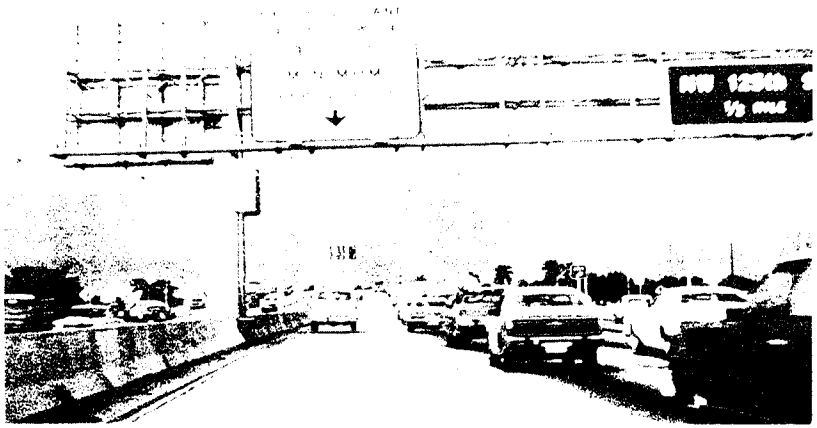
The concept for concurrent flow reserved lanes is simple. It merely entails the designation of one of the lanes of a freeway as a priority lane reserved for use by buses and carpools only. The photographs shown in Figure 1 show examples of concurrent flow reserved lanes in operation in four different locations within the nation.

Each of the examples shown in Figure 1 utilize the left lane (the lane

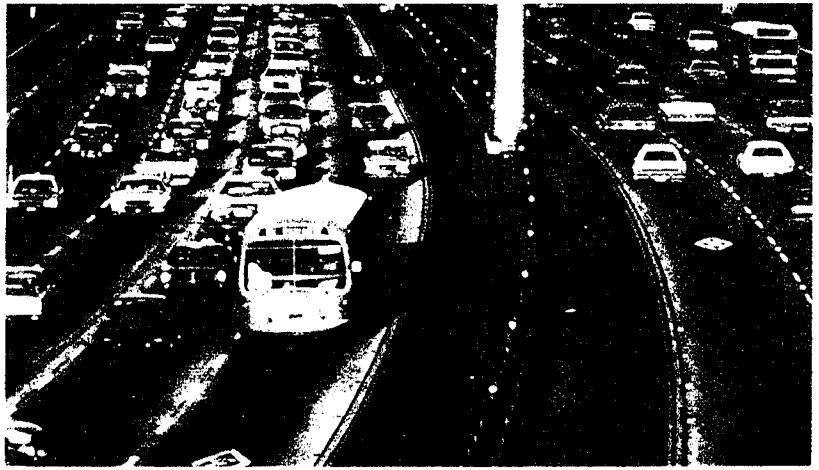


Redwood Highway, San Francisco (P. 15)

Banfield Freeway, Portland (P. 20)



North-South Freeway, Miami (P. 27)



Santa Monica Freeway, Los Angeles (P. 31)

FIGURE 1: EXAMPLES OF CONCURRENT FLOW RESERVED LANES

nearest the median barrier) as the reserved lane. The left lane is the logical choice on most freeways because it is the only lane that no other traffic would have to merge through in order to use the remaining lanes of the freeway. However, the presence of left-hand entrance or exit ramps would nullify this situation. Consequently, the concurrent flow reserved lane concept could not be readily adapted to freeways that have both left-hand ramps and right-hand ramps.

Of course, buses and carpools would have to merge through other lanes of traffic in order to get to the reserved lane. Thus, in order to enable the priority vehicles to get to the reserved lane, it must begin well upstream of any bottleneck location that creates traffic congestion. Otherwise, fly-over ramps or some similar device must be provided to enable buses and carpools to get to the left-hand lane.

When compared to other concepts for priority treatment, the concurrent flow reserved lane offers the following advantages:

1. It is the least costly to implement;
2. It can easily be used by both buses and carpools; and
3. Qualified vehicles can merge into or out of the lane at any location along the freeway.

These inherent advantages make the concurrent flow reserved lane appear to be a highly attractive choice as a method of providing priority treatment; however, this concept does have some limitations and problems that diminish its overall attractiveness.

One major problem is the enforcement of vehicle restrictions. Because no physical barrier divides the reserved lane from other traffic lanes, only a strong enforcement program will deter the drivers of other vehicles from

using the lane. In addition, effective enforcement is difficult to accomplish on the left lane of a freeway.

Very few freeways in the nation carry a sufficient number of buses to effectively utilize the vehicle-moving capacity of an entire freeway lane. The primary purpose of permitting carpools to share the lane with buses is to gain better overall utilization of the total capacity of the lane. However, the attractiveness of this move is limited by the fact that too few cars carry three or more occupants (usually 2 to 6 percent), and too many carry two or more occupants (21 to 30 percent of the total traffic nationwide). Thus, depending upon where the limitation concerning the number of occupants needed to qualify as a "carpool" is established, the reserved lane either remains underutilized or can become as congested as the other freeway lanes.

Actual experience with the concurrent flow reserved lane concept has verified both its advantages and limitations. Data from various concurrent flow reserved lane projects around the nation are reported in the following section.

II. SUMMARY OF EXISTING PROJECTS

The first concurrent flow reserved lane on a freeway was implemented in 1974. Since then, six freeway projects in five cities have become operational (1)*. Only one project has been terminated, and numerous others are currently being proposed or are in various stages of implementation. Concurrent flow projects have been introduced in metropolitan areas as small as Portland, Oregon and as large as Los Angeles. Locations for these efforts are equally diverse, ranging from Miami to Honolulu. Common denominators for their justification do not rest upon geographic locale or city size, but upon the characteristics of each respective freeway system. If similar justification exists for concurrent flow lanes in Texas, an inventory of existing projects will help determine whether this approach would be feasible or even desired by the public.

Table 1 (pages 10 and 11) presents data concerning the design and operation of six concurrent flow freeway demonstration projects as of November 1976. Only one, the Santa Monica Freeway project, has been terminated. Numerous projects are being proposed, particularly in the San Francisco and Los Angeles area. Two of these proposals contain sufficient design details to be included in the table.

Most freeway projects now or recently in operation were termed demonstration efforts. As such, significant data have been collected and are being evaluated by the respective project sponsors to determine whether this concept has been instrumental in effecting a mode shift on their freeway systems. Since most projects have not been opened more than one year, the longer term

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*Denotes number of reference listed at end of report.

benefits of this concept are still unknown. Final assessments have not been released on any reserved lane to date. Initial opening periods have also been plagued by frequent alterations in design and operation (in large part attributable to underutilization), lack of public acceptance, and enforcement problems.

Table 2 (pages 12 and 13) reflects some preliminary operational data available from four different concurrent flow projects. However, it is important to keep in mind when comparing these data that data collection procedures for each may be quite different. Definitions regarding hours of operation, peak periods, and daily totals vary widely. Abbreviated codes following each listing are keyed to a legend appearing at the bottom of the table. Three categories of data from each comparable characteristic are included where possible. These include "before" project information obtained sometime during the 12 months preceding the opening of each project. "Initial" counts were taken during the first three months of operation. "After 4-6 months" counts were included to help determine the longer term effects of project implementation. Since one of the four operations illustrated in Table 2 was terminated after five months and two others have not been opened a full year, comparable long-term effects of the concurrent flow concept are still not known.

The primary problem associated with the concurrent flow reserved lane concept is the difficulty associated with enforcing the vehicle restrictions for the lane. No physical barrier prevents automobiles from freely moving into and out of the reserved lane; consequently, lane use restrictions are frequently violated. Another problem appears to be an increase in accident rates associated with implementation of concurrent flow reserved lanes. Data pertaining to violation rate and accident rate experience on four projects are presented in Table 3 (page 14).

Table 1: Summary of Existing, Recent, and

	Honolulu Moanalua Frwy.	Richardson Bay - Greenbrae, Ca. U.S. 101 (Redwood Hwy.)	Portland I.H. 80 N (Banfield Frwy.)	Miami I.H. 95 (North-South Frwy.)
Operations				
• When Completed	October, 1974	December 20, 1974	December 15, 1975	December, 1975
• Hours of Operation	24 hrs. both directions	6:00-9:00 AM, Southbound 4:00-7:00 PM, Northbound	6:30-9:30 AM, Westbound 3:30-6:30 PM, Eastbound	6:30-10:00 AM, Southbound 3:00-7:00 PM, Northbound
• Eligible Users	Buses and 3+ Occupant Carpools	Buses and 3+ Occupant Carpools	Buses and 3+ Occupant Carpools	Buses and 3+ Occupant Carpools
• Number of Users	11 buses and 1500 Carpools during 2-hour AM peak period	96 buses and 475 carpools during peak hour	33 buses during peak period and 183 carpools during peak hour	40 buses during peak period and 334 carpools during peak hour
• Time Savings Reported	10 minutes inbound	3-6 minutes initially, none presently	1.2 minutes westbound 0.5 minutes eastbound	7-10 minutes
Design				
• Length	2.7 miles inbound 1.4 miles outbound	4 miles	3.3 miles westbound 1.7 miles eastbound	7.5 miles
• Number of Adjacent Lanes	-	3 during peak periods	2-3 during peak periods	3-4 during peak periods
• Reserved Lane - Origin	-	Lane addition	Lane addition	Park & ride flyover ramp
Termination	-	Merge into adjacent lanes	Merge into adjacent lanes	Merge into adjacent lanes
• Modification Required to Provide Reserved Lane		Widened freeway in median & striped as reserved lanes (additional lanes)	Widened freeway in median & right shoulders, resurfaced, and restriped. (additional lanes)	Widened freeway in median & striped as reserved lanes (additional lanes)
Other				
• Costs - Implementation	$36,500	-	$1.8 million including new barrier median & repaving	$18.5 million including freeway reconstruction
• Problems Noted	-	(None noted)	• Underutilization • Public Acceptance	• Safety • Enforcement
• Major Agencies Involved	Hawaii Dept. of Transportation, Federal Highway Administration	California Dept. of Transportation, Golden Gate Bridge, Highway, & Transportation Dist., Marin County.	Oregon Dept. of Transportation, City of Portland, Multnomah County, Federal Highway Administration.	Florida Dept. of Transportation, Metropolitan Dade County, Urban Mass Transportation Administration, Federal Highway Administration.

Source: References (1)-(9), (11)-(21).

Proposed Concurrent Flow Reserved Lane Projects

	Los Angeles - Santa Monica, I.H. 10 (Santa Monica Frwy.)	San Francisco I.H. 280 (Southern Frwy.)	PROPOSED Castro Valley - Dublin, Ca., I.H. 580 (Castro Valley Frwy.)	PROPOSED San Rafael, Ca. U.S. 101 (Redwood Hwy.)
	March 15, 1976 (Terminated August 9, 1976)	Spring, 1976	1977-1978	1978
	6:30-9:30 both directions 3:00-7:00 both directions	24 hours	24 hours both directions	4:00-7:00 PM northbound
	Buses and 3+ Occupant Carpools	Buses and 3+ occupant carpools	Buses and 3+ occupant carpools	Buses only
	170 buses and 4592 carpools daily	12-15 buses and 200 carpools during peak hour	-	56 buses expected
	2.5 - 4 minutes eastbound 5 - 6.5 minutes westbound	None	None expected	2-3 minutes
	12.5 miles	2 miles southbound only	3 miles	2.5 miles northbound only
	3-4 during peak periods	3 during peak periods	2 not including buffer lane	3 during peak period
	Reserved lane designation	Lane addition	Lane addition	Lane addition
	Merge into adjacent lanes	At freeway termination	Merge into adjacent lanes	Merge into adjacent lanes
	Removed left lanes from mixed flow	Reserved existing left lanes	Reserved existing left lanes	Widened freeway in median & stripe as reserved lane (additional lane)
	$3.1 million including new buses and park & ride lot	-	-	-
	• Public Acceptance	• Underutilization • No time savings	• No time savings expected	(None noted)
	California Dept. of Transportation, Southern California Association of Governments, Southern California Rapid Transit District, Urban Mass Transportation Administration.	California Dept. of Transportation	California Dept. of Transportation	California Dept. of Transportation, Golden Gate Bridge, Highway, and Transportation District, Marin County.

Table 2: Summary of Concurrent Flow Reserved

		San Francisco (Marin County) U.S. 101 (Redwood Hwy.)
Reserved Lane Vehicular Movement:		
Number of Buses	(A) Before project	-
	(B) Initially	-
	(C) After 4-6 Months	96 PH
Number of 3+ Carpools	(A) Before project	-
	(B) Initially	-
	(C) After 4-6 Months	475 PH
Reserved Lane Person Movement:		
Carpoolers	(A) Before project	800-900 PH (Estimate)
	(B) Initially	-
	(C) After 4-6 Months	1773 PH (Estimate)
Bus Ridership	(A) Before project	3468 PH $^{\Delta}$
	(B) Initially	-
	(C) After 4-6 Months	3922 PH $^{\Delta}$
Reserved Lane Vehicle Occupancy		
	(B) Initially	-
	(C) After 4-6 Months	-
Combined Movement (All lanes, peak direction)		
Vehicles	(A) Before project	6534$^{\Delta}$ PH
	(B) Initially	-
	(C) After 4-6 Months	6247$^{\Delta}$ PH
Combined Movement (All lanes, peak direction)		
Person Movement	(A) Before project	13579$^{\Delta}$ PH
	(B) Initially	-
	(C) After 4-6 Months	13840$^{\Delta}$ PH
Vehicle Occupancy	(A) Before project	2.08 ppv PP_3
	(B) Initially	-
	(C) After 4-6 Months	2.22 ppv PP_3

$^{\Delta}$ Counts made at Golden Gate toll plaza

Abbreviations Used

PH Peak Hour
PP_2 Peak Period, subscripted number representing hours included daily
ppv persons per vehicle
* Southern California Rapid Transit Buses
** Santa Monica Municipal Buses

Source: References (1)-(9), (11), (13)-(15), (17)-(20).

Lane Effects on Person-Movement Capacity

Portland I.H. 80 N (Banfield Hwy.)	Miami I.H. 95 (North-South Frwy.)	Los Angeles I.H. 10 (Santa Monica Frwy.)
16-17 PP_3		35 * PP_7
24 Tri-Met, 33 Total PP_3		180 *, ** PP_7
24 Tri-Met, 33 Total PP_3	40 PP_4 (20 buses PH-est.)	170 *, ** PP_7
58 PH	-	1785 PP_7
161 PH	-	3737 PP_7
183 PH	334 PH (See Appendix B)	4592 PP_7
117 PH	-	6248 PP_7
484 PH	-	13080 PP_7
549 PH	-	16070 PP_7
-	1474 Daily (Project buses only)	1260 * PP_7
586 PH	1573 Daily (Project buses only)	3184 *, ** PP_7
643 PH	1608 Daily (Project buses only)	3817 *, ** PP_7
2.85 ppv PH	2.59 ppv PH	4.15 ppv PP_7 (Excluding Violators)
3.16 ppv PH	2.68 ppv PH	4.18 ppv PP_7 (Excluding Violators)
3415 PH	-	96950 PP_7
3864 PH	-	80655 PP_7
3877 PH	-	83950 PP_7
4297 PH	-	118750 PP_7
5545 PH	-	105550 PP_7
5706 PH	-	113370 PP_7
1.26 ppv PH	-	1.22 ppv PP_7
1.31 pv PH	-	1.31 ppv PP_7
1.33 ppv PH	-	1.35 ppv PP_7

(Survey periods for "before," "initial," and "after 4-6 months" are identified in Appendix A.)

Table 3: Summary of Concurrent Flow Reserved Lane Violation and Accident Experience

	San Francisco (Marin County) U.S. 101 (Redwood Hwy.)	Portland IH-80N (Banfield Frwy.)	Miami IH-95 (North-South Frwy.)	Los Angeles IH-10 (Santa Monica Frwy.)
Mixed-Flow Volumes Per Lane/Hour				
A. Before Project	--	1708 vph PH	--	1530 vph PP_3
B. Initially	--	1811 vph PH	--	1280 vph PP_3
C. After 4-6 Months	1843 vph PP_2	1829 vph PH	--	1300 vph PP_3
Speeds-Mixed Flow				
A. Before Project	--	34 mph PH (55 kmph)	--	38 mph PP_7 (61 kmph)
B. Initially	--	36 mph PH (57 kmph)	--	33 mph PP_7 (54 kmph)
C. After 4-6 Months	27 mph PH (43 kmph)	37 mph PH (60 kmph)	--	38 mph PP_7 (61 kmph)
Reserved Lanes				
B. Initially	--	43 mph PH (69 kmph)	--	--
C. After 4-6 Months	38 mph PH (61 kmph)	43 mph PH (70 kmph)	--	--
Violation Experience				
Qualified Reserved Lane Vehicles				
B. Initially	--	193 PH	229 PH	3917 PP_7
C. After 4-6 Months	571 PH	205 PH	354 PH	4762 PP_7
Total Reserved Lane Traffic				
B. Initially	--	273 PH	402 PH	4636 PP_7
C. After 4-6 Months	656 PH	242 PH	571 PH	5662 PP_7
Violators				
B. Initially	--	28% PH	43% PH	16% PP_7
C. After 4-6 Months	13% PH	16% PH	47% PH	16% PP_7
Accident Experience				
Total All Lanes				
A. Before Project	7 Monthly PP_6	10 Monthly	--	57 Monthly PP_7
B. Initially	--	24 Monthly	110 Monthly	168 Monthly PP_7
C. After 4-6 Months	10 Monthly PP_6	16 Monthly	80 Monthly	87 Monthly PP_7
Related to Reserved Lane Operation	1 Monthly PP_6	--	6 Monthly	6 Monthly PP_7

Abbreviations Used

PH Peak Hour
PP_6 Peak Period, subscripted number representing hours included daily
vph Vehicles Per Hour
mph Miles Per Hour
kmph Kilometer Per Hour
(Survey periods for "before," "initial," and "after" are identified in Appendix A.)

Source: References (1)-(9), (11), (13)-(15), (17)-(20).

Each project appearing in Table 1 was justified because of a number of factors that made its implementation desirable. Following is a discussion of the interesting and unique features of each, listed chronologically according to the date each was completed.

Moanalua Freeway, Honolulu, Hawaii

Opened October, 1974.

The first example of a concurrent flow reserved lane was demonstrated, on the Moanalua Freeway in Honolulu. Because neither the inbound nor outbound reserved lane is longer than three miles (4.8 km), it more aptly represents a bottleneck bypass than a line-haul improvement. However, according to Mr. Tanaka of the Hawaii Department of Transportation, priority vehicles save an average of 5 minutes and sometimes as much as ten minutes because of this reserved lane.

When a short portion of this freeway was widened from 4 lanes to 6 lanes, the inside lane on each side was reserved for buses and for carpools containing three or more people. At the end of the widened portion, where the freeway narrows again to 4 lanes, vehicles in the reserved lane have priority and other traffic merges left as the opportunity occurs. Vehicle restrictions on the reserved lane are enforced by the city police. Data concerning the utilization of this lane are shown in Table 4.

Redwood Highway, Richardson Bay, San Francisco, California

Opened December 20, 1974.

This endeavor marked the first freeway application of a major line-haul improvement. The project was originally designed as an extension of a contraflow

Table 4: Utilization of Reserved Lane on Moanalua Freeway

Reserved Lane Vehicular Volume				
Date	Total Volume*	Carpools*	Buses*	Violation Rate
October 1974	6000	525	11	∿20%
After 2 wks.	6000	1000	11	
January 1975	9000	1500	11	9%
March 1976	7500	1600	11	

*6:00 a.m. to 8:00 a.m. INBOUND.

Source: Hawaii Department of Transportation (Mr. Tanaka).

reserved lane* provided farther south for buses in the evening peak period. The Redwood Highway provides the only land access into San Francisco from Sausalito, Tiburon, San Rafael, and all other communities in Marin County; thus, it has become a key link for commuters, handling about 14,000 person-trips each peak hour (2). As shown in Figure 2 (page 18), reserved lanes in both directions were constructed in the freeway median between Richardson Bay and Greenbrae, a distance of four miles (3).

For the first 16 months, the concurrent flow facility was operated as a demonstration project restricted to buses, but the number of buses, an average of about 100 during each peak hour, left the facility underutilized. Due to the nature of congestion on adjacent lanes, heavy enforcement was required

* In a contraflow reserved lane, buses travel against the normal flow of traffic in one of the off-peak lanes. This lane is usually separated from adjacent oncoming traffic by temporary traffic cones.

to discourage unauthorized vehicles from entering the preferential lanes; and the public soon became resentful of the project. In April, 1976, a bus strike was called against the Golden Gate Bridge, Highway, and Transportation District, the agency responsible for bus operations in the reserved lanes. This action served as a catalyst for permitting carpools with three or more occupants to benefit from the preferential facility. They were not, however, permitted to operate on the contraflow improvement farther south. The mixed bus and carpool use has worked rather well since then (3). Current operating periods are from 6 to 9 a.m. inbound and 4 to 7 p.m. outbound.

Few transportation planners anticipated a significant increase in accident rates because of the implementation of a concurrent flow reserved lane. However, the data presented in Table 5 indicate a significant increase in accidents during afternoon operation with no increase in accident rates during morning operation. The two accidents involving buses resulted from cars swerving into the bus lane from the adjacent mixed flow lane in order to avoid stopped traffic ahead.

There are several unique features about the Richardson Bay project that set it apart from more recent demonstration efforts. This improvement continues to transport a much larger person movement, about 4000 bus riders and 1800 carpool occupants during each peak hour, than any other project. Note should be made, however, that about 90 percent of this patronage existed before reserved lane implementation (2). It is the only project to be integrally linked with another concept of priority treatment, a bus contraflow lane. The crossover design between these two projects is shown in Figure 3.

While the project provided an initial time savings over mixed-flowing traffic, additional improvements to the freeway have reduced such savings to insignificant levels; yet, the facility is planned to continue in operation (3).

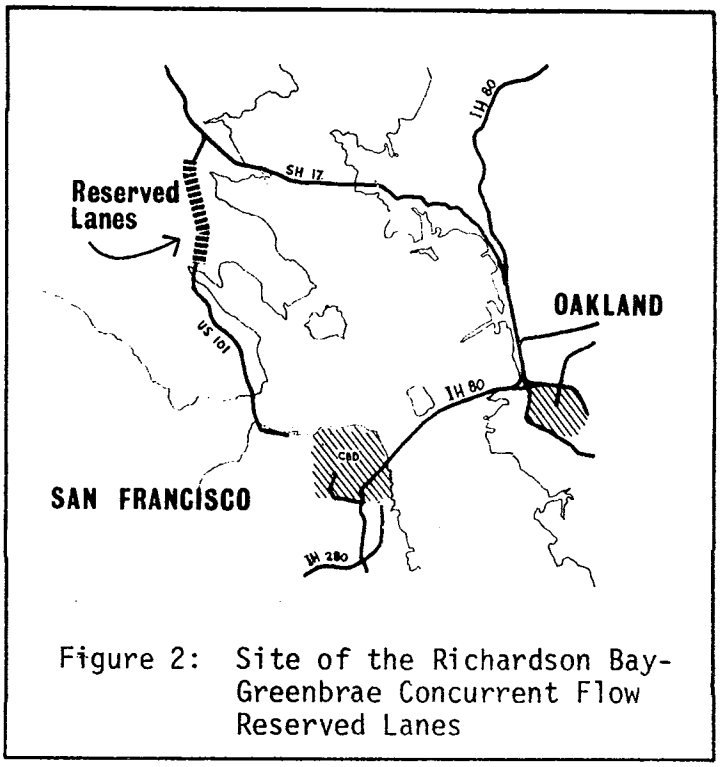

Figure 2: Site of the Richardson Bay-Greenbrae Concurrent Flow Reserved Lanes

Source: Reference (2).

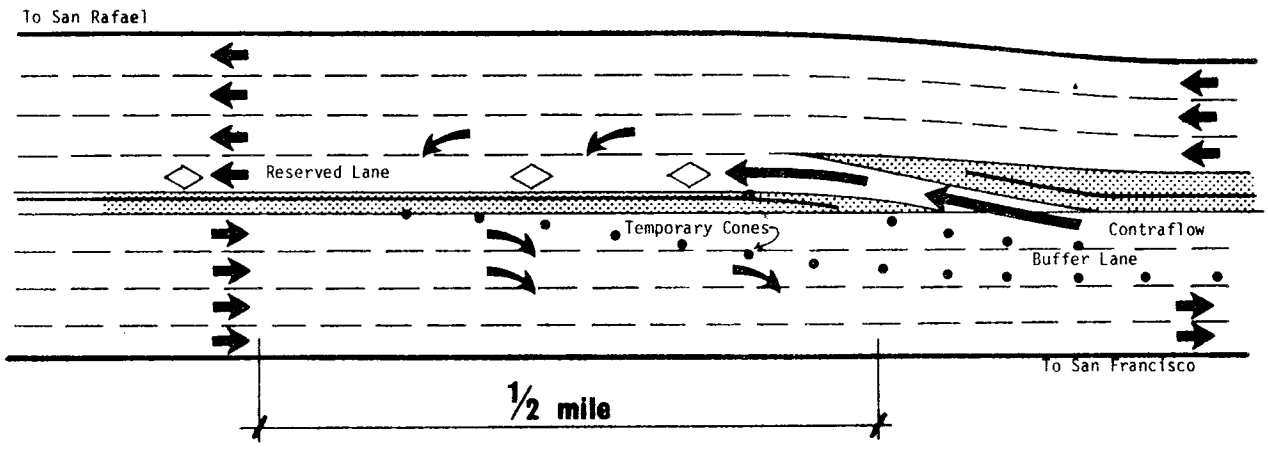

Figure 3: Origin/Termination Design Used Between Concurrent Flow and Contraflow Reserved Lane Projects on the Redwood Highway at Richardson Bay

Source: References (3), (4).

Table 5: Accident Summary For Redwood Highway

	Northbound Time 4:00-7:00 p.m.		Southbound Time 6:00-9:00 a.m.	
	Before 12-20-73 to 06-19-74	After 12-20-74 to 06-19-75	Before 12-20-73 to 06-19-74	After 12-20-74 to 06-19-75
TOTAL ACCIDENTS (Acc/Mvm)* [Acc/Mvkm]*	30 (3.0) [1.9]	51 (5.1) [3.2]	12 (1.5) [0.9]	9 (1.2) [0.8]
Rearend	26	46	8	7
Sideswipe	1	4	0	1
Other	3	1	4	1
Injuries (persons)	4	8	4	7
Fatalities	0	0	1	0
ACCIDENTS IN BUS LANE	-	5	-	2
Involving Buses	-	1	-	1
Injuries (persons)	-	2	-	2

*Accident rate per million vehicle miles for all urban freeways in District 04 was 1.13 during 1974 [0.7/million vehicle kilometer].

Source: Reference (2).

Justification for continuance is interesting because the directional volume split for peak movement is 80 percent against 20 percent in the off-peak. Such a directional split suggests that an extension of the contraflow lane might have been more beneficial than implementation of a concurrent flow reserved lane in this location. Finally, despite periodic public resentment, this project recorded the lowest overall violation rates, 4 to 13 percent, for a line-haul facility of its type throughout the past two years.

The contraflow and concurrent flow reserved lanes on the Redwood Highway are part of a much broader plan to provide priority treatment improvements on the Golden Gate corridor from San Francisco northward. Another concurrent flow proposal identified later in this report is planned in the San Rafael area on the same freeway (3).

Banfield Freeway, Portland, Oregon

Opened December 15, 1975.

The Banfield Freeway winds rather circuitously eastward from the east bank of Willamette River, the point at which it connects to both Interstate 5 and the downtown street system. Banfield is the only freeway facility bisecting the eastern half of the Portland metropolitan area, a region that is experiencing rapid growth. Average daily traffic on this 4-6 lane facility had increased from 26,000 vehicles in 1958 to 100,000 in 1975 (5). Speeds during rush periods sometimes averaged only 35 mph (56 km/hr), and adjacent parallel arterials were also reaching capacity. The Oregon State Highway Division abandoned plans in 1974 for constructing another East-West freeway in the corridor, therefore, making it imperative to upgrade the Banfield. But, upgrading in this case was extremely difficult. Grade separations and limited right-of-way were constraints. In addition, no unused off-peak

directional capacity was available. However, a fairly continuous eight-foot (2.4 m) parking shoulder and ten-foot (3 m) median were positive elements that could be adapted into a preferential treatment design (11).

In early 1975, a modification that included an inbound reserved lane 3.3 miles (5.3 km) long and an outbound lane 1.7 miles (2.7 km) in length was approved. Locations of these lanes are shown in Figure 4. The design focused upon a midpoint segment in which the total number of lanes reduced from six to four, causing congestion and merge problems. This plan was intended to initially serve more as a bottleneck bypass with minimal time savings than a line-haul facility. If the design was found desirable, the reserved lanes would be extended westward into the central business district and eastward to Interstate 205, an outer loop (11).

The initial design was constrained in length by bridge structures and an adequate merge distance for vehicles approaching the Interstate 5 interchange. No logical origin or termination points were available (11); but, concrete median barriers and restriping were placed to facilitate safer channelized movement at entries, as illustrated in Figure 5 (10). Concurrent flow lanes were added in each direction by absorbing extra median and shoulder widths and restriping to narrower lanes (7). New emergency parking bays were then constructed wherever possible along the right lanes (12).

While construction modification continued, the reserved lanes were opened to buses and to carpools with three or more persons on a 24-hour basis in December, 1975. A significant marketing campaign preceded this opening. Park-and-ride lots were completed and express buses carried commuters, via the reserved lanes, into downtown Portland during rush hours (5), (7).

However, accident rates on the Banfield Freeway proved to a problem. They more than doubled, jumping from 0.88 to 2.08 accidents per (Mvm) (0.54 to 1.29

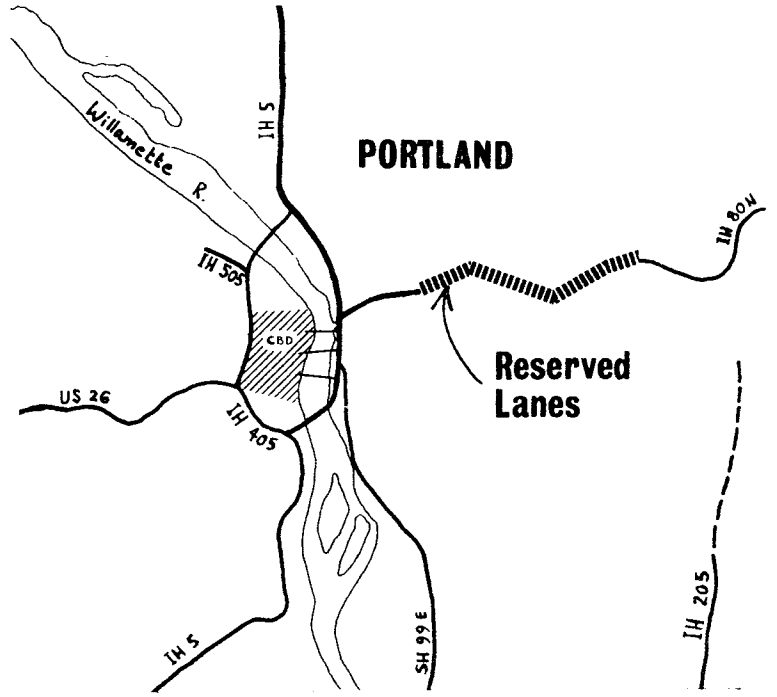

Figure 4: Site of the Banfield Freeway Concurrent Flow Reserved Lanes

Source: Reference (5).

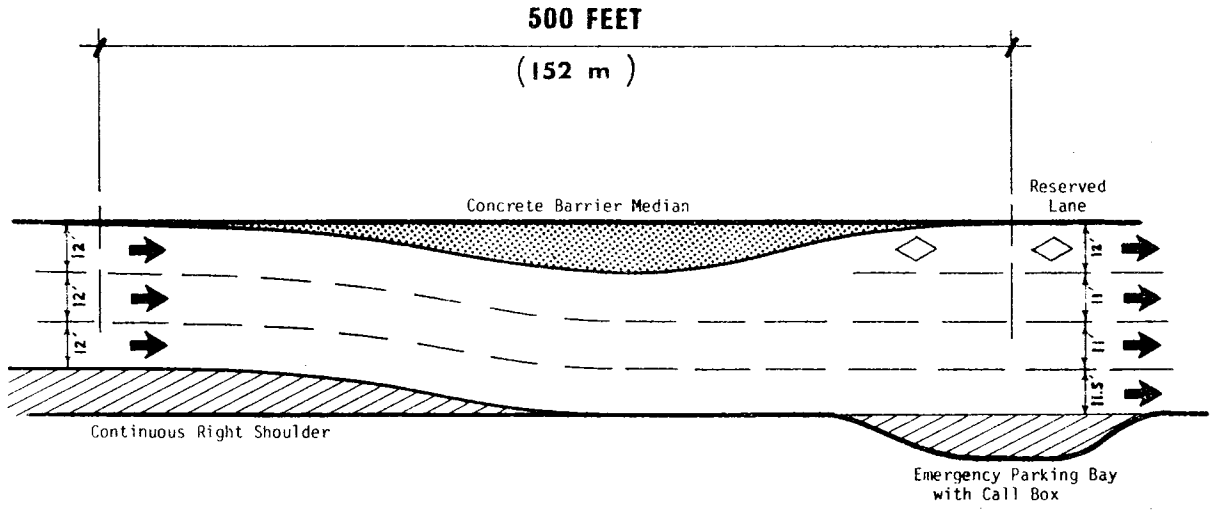

Figure 5: Channelized Entry Design Used on the Banfield Concurrent Flow Reserved Lanes

Source: References (5), (10), (12).

per Mvkm), during the first four months following project implementation (see Table 6). Some of this increase could be attributed to other factors. Construction modifications to Banfield were not completed until March, 1976, three months after the lanes were opened. During this interval, construction equipment sometimes blocked or hampered normal freeway traffic. More importantly, entry ramp acceleration lanes onto Banfield proved to be inadequately short, resulting in a series of rear-end collisions. This problem was soon corrected by extending ramp lengths (11). By June 1976, the accident level appeared to have stabilized at 1.4 per Mvm (0.9 per Mvkm), about sixty percent higher than before project implementation. It is still difficult to determine how much of this increase is due to the inclusion of priority lanes.

Enforcement problems were foreseen as a potentially formidable negative aspect of the concurrent flow concept. Were it not for strong interagency cooperation between local and state authorities, this high violation rate would not have been reduced as much (11). Initially, the lanes were restricted in both directions 24-hours daily; however, benefits accrued to users only during peak periods, primarily in the peak direction. At other hours an acceptable level-of-service was evident in all lanes. Hence, the reserved lanes were essentially not utilized except during morning and afternoon peaks. Even during the peaks, concurrent flow volumes did not adequately utilize the facility; underutilization promoted violations. In the first five months each lane averaged about 80 violators* during peak hours, a figure representing about 29% of all vehicles using the lanes. The Oregon State Police were requested to significantly increase enforcement along the project. Enforcement procedures included periodic patrolling of the 3.3 mile (5.3 km) distance with

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*Reflects person-count averaged from data in reference (8).

Table 6: Accidents On The Banfield Freeway In Portland

Month and Year	Million Miles (Kilometers) Traveled	Number of Accidents	Avg. Number of Vehicles/ Accident	Accidents/ Million Miles (Kilometers)
06/74	N/A	11	2.91	N/A
07/74	N/A	16	2.00	N/A
08/74	11.25 (18.1)	5	2.60	0.44 (0.28)
09/74	10.33 (16.6)	11	2.64	1.06 (0.66)
10/74	10.70 (17.2)	8	2.50	0.75 (0.47)
11/74	10.16 (16.3)	13	1.92	1.28 (0.80)
12/74	10.51 (16.9)	N/A	N/A	N/A
01/75	10.06 (16.2)	6	1.83	0.60 (0.37)
02/75	9.02 (14.5)	7	2.00	0.78 (0.48)
03/75	10.78 (17.3)	10	2.00	0.93 (0.58)
04/75	10.49 (16.9)	9	1.89	0.86 (0.53)
05/75	10.95 (17.6)	13	2.00	1.19 (0.74)
06/75*	11.16 (18.0)	8	2.00	0.72 (0.44)
07/75*	11.10 (17.9)	19	2.11	1.71 (1.06)
08/75*	11.20 (18.0)	20	2.35	1.79 (1.11)
09/75*	10.32 (16.6)	14	2.57	1.36 (0.84)
10/75*	10.69 (17.2)	30	2.50	2.81 (1.74)
11/75*	10.09 (16.2)	41	2.29	4.06 (2.53)
12/75*	10.39 (16.7)	34	2.18	3.27 (2.04)
01/76	10.03 (16.1)	14	2.29	1.40 (0.87)
02/76	9.47 (15.2)	15	2.53	1.58 (0.98)
03/76	10.11 (16.3)	11	2.18	1.09 (0.67)
04/76*	11.36 (18.3)	28	2.13	2.46 (1.53)
05/76	11.03 (17.7)	19	2.08	1.72 (1.07)
06/76	11.62 (18.7)	12	1.93	1.03 (0.64)
07/76	11.48 (18.5)	8	2.50	0.70 (0.43)
08/76	11.96 (19.2)			

*Construction work in progress.
Note: Bus lanes opened on December 15, 1975.
Source: Reference (9).

as many as eight patrols three days each week. Violators were normally directed through two or three lanes of adjacent traffic onto one of the emergency parking bays (11). Saturated patrols continued over a 2-1/2 month period. netting a sizeable improvement in violation rates. The number of peak hour violators was reduced by about 60%. During these months the public became somewhat critical of the restricted use of reserved lanes during off-peak hours. In March 1976, time restrictions were drastically reduced to peak directions only from 6:00-10:00 a.m. and 3:00-7:00 p.m. Times were further reduced by another 25 percent in October 1976, to 6:30-9:30 a.m. and 3:30-6:30 p.m. The Banfield is currently functioning under this schedule (11).

While bus and carpool demand for this facility improvement did not approximate that of the Golden Gate corridor, Banfield multiple occupancy vehicle counts have gradually risen. During peak hours, Tri-Met Transit altered routes to take advantage of the lanes, and new bus routes were established to serve remote park-and-ride lots (7). In all, 33 buses benefit from reserved lane improvements during peak hours. Just prior to lane opening, only about two percent (about 58 carpools) of the peak hour automobile drivers transported enough passengers to be eligible as reserved lane vehicles. After six months of operation, the lanes were transporting about 180 eligible carpools, still only about five percent of all peak hour traffic volumes. But at the same time, total peak hour volumes rose from 3400 to 3900 vehicles. As noted in Table 3, speed profiles on reserved as well as mixed-flow lanes increased, bus occupancies increased, and vehicles occupancies on all lanes increased from 1.25 to 1.31 during the first half year of operation.

The Portland project also has several unique characteristics that should be noted. It is the only existing project for which extensions on either end are currently being planned. Contracts may soon be released for up to $100

million to rebuild freeway bridge structures to accommodate additional lanes for transit all the way from the Portland central business district to IH-205, a bypass loop. Eventually, the concurrent flow lanes may be converted to a barrier-protected busway.

This preferential improvement effort is a good example of cooperative agreements reached between and within local and state authorities to reduce congestion and to increase vehicle occupancy. A technical advisory committee, comprised of representatives from the City of Portland; Multnomah County, Oregon Department of Public Transportation, Tri-Met Transit, State Department of Environmental Quality, the Oregon State Police, local business, and citizen groups, was organized to monitor planning and construction and to review day-to-day project operations (7).

Months before the concurrent flow lanes were to be opened, an aggressive marketing program was launched. This program focused upon news conferences, major local media informing the public, distribution of promotional brochures, erection of 22 billboards at strategic locations, and presentations to civic groups and public functions (7). An example of one such brochure is shown in Figure 6.

Figure 6: Portland Brochure

Thus, by the time the project opened, the general public was aware of its purpose and how they might benefit from its operation.

Banfield is also the only project attempted that successfully arrested

what had become a staggering violation problem; however, such corrective measures were not accomplished without a threefold increase in state highway patrols.

North-South Freeway, Miami, Florida

Opened December, 1975.

While reserved lanes in Miami have only been open about one year, planning for demonstration of this concept began much earlier. In 1970 the U.S. Department of Transportation was searching for possible sites to provide an initial demonstration of concurrent flow lanes on a freeway. While Cleveland was turning down possibilities for such corridor demonstration funding, Miami was evaluating the concept's viability for its IH-95/N.W. 7th Ave. corridor. IH-95 (North-South Freeway), a six-to eight-lane artery radiating from the downtown area northward, required extensive modification to accommodate additional traffic demand. A proposal was submitted and approved to construct additional lanes on I-95 and to operate them as concurrent flow reserved lanes as a part of a corridor demonstration project.

Priority improvements were staged in two phases. The first phase was slated to simultaneously provide demonstration of reversible flow reserved bus lanes and signal preemption technology on a city street, while at the same time provide interim relief for buses using IH-95. With an expenditure of $1.3 million, express bus operation was established August 1974, on a reversible flow, reserved median lane on N.W. 7th Ave., a major thoroughfare roughly paralleling IH-95. A six-minute time savings was realized by bus patrons. The interim improvement was 9.9 miles (15.9 km) long, operated only during peak periods, and cost $2400 a month to operate. It had a logical origin near a newly constructed park-and-ride lot and terminated in the central business district.

Bus ridership increased 42 percent to 1,650 daily passengers during the first phase, due to the combined incentives of improved bus service, park-and-ride facilities, and an express line-haul facility. In the meantime, design and construction was progressing on the second phase, an $18.5 million project involving addition of two traffic lanes for preferential vehicles in the median of IH-95 (North-South Freeway) (1).

During the summer and fall of 1975, various segments of the improved IH-95 freeway were opened to traffic, but the lanes were not fully completed and operational until December 1975. Orange Streaker buses did not begin operation on IH-95 until March 1976. Secondary impacts on potential bus ridership, however, were not felt until fall 1976, when an additional park-and-ride lot was opened at Golden Glades. As shown in Figure 7, concurrent flow lanes were included along eight miles (12.9 km) of freeway median. At the origin, a median flyover ramp enabled express bus operation directly from the park-and-ride lots. Along the line-haul portion of the facility, periodic overhead and median signing stipulate restrictions for reserved lane usage. A four-inch (10.2 cm) white line is striped between the reserved lanes and adjacent lanes. The reserved lane is fourteen feet (4.3 m) wide compared to a twelve-foot (3.7 m) width for normal lanes (13), (16).

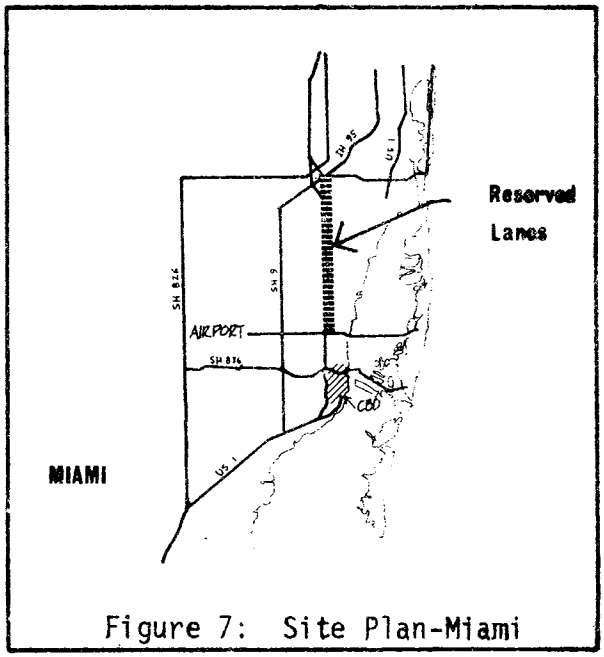

Figure 7: Site Plan-Miami
Source: Reference (13)

Concurrent flow lanes on IH-95 are currently open from 6:00-10:00 a.m.

and 3:00-7:00 p.m. in the peak direction for buses and for carpools with three or more occupants. Unlike the interim reversible-flow lane, no operating expenses are being incurred on this project. Signs and pavement markings communicate all relevant operational information (15).

Because of the staggered openings of the reserved freeway lanes to carpools and buses and the expansion of park-and-ride facilities, initial operation data are probably not as meaningful as longer term results from the project. After four months of shared usage, about twenty buses and an estimated 330 carpools* (13) were benefiting from a time savings of seven to ten minutes during peak hour operating periods (15). Ridership on project related buses had stabilized since earlier first phase movements at about 1,575 daily trips, but this average may increase from the effects of a recent park-and-ride lot opening (13).

Problems affecting the Miami concurrent flow lanes have been numerous since their inception, and few of the factors causing these problems appear to have been significantly altered. Underutilization was expected at first since only 5 to 7 percent of the previous composition of mixed-flow traffic qualified. During the months of April through July 1976, between 400 to 600 vehicles utilized the lanes during peak hours; but only about sixty percent of these vehicles were eligible. While public criticism somewhat subsided over the "vacant" appearance of the lanes, and drivers adjusted to the new characteristics of freeway operation, underutilization has continued to be a problem for project planners. In the fall of 1976, a study was started to investigate the possibilities of including carpools with two or more occupants as qualified users of the exclusive lanes. Although a tentative assessment

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*Procedures used in determining this estimate are identified in Appendix B.

revealed that 25 to 30 percent of the total peak hour traffic, enough to overcrowd and congest it, might then be eligible for reserved lane use. A final decision on two+ carpools is still pending (15).

A parallel problem that usually occurs as a result of underutilization is violations. Since buses and carpools began sharing the lanes, violation rates have held constant at around 40 percent, higher than any other reserved lane project. In contrast to the Portland experience, enforcement has not been actively pursued in Miami. In the viewpoint of local police and state law enforcement officers, reserved lane violations are of minimal significance when compared to other more potentially hazardous traffic problems occurring on IH-95 during rush hours (15).

Underlying law enforcement indifference are three issues. The first is insufficient police manpower to adequately patrol IH-95; at present, only two patrol officers are assigned to the project segment of the freeway. The second issue cited is difficulty in apprehending violators, since no left shoulder is provided. The lanes are longer than those in Portland; thus, trailing a violator to the termination of the reserved lane is time-consuming. The adjacent freeway cross-section includes three or four mixed-flow lanes; it is, therefore, difficult to pull violators onto right shoulders. Finally, difficulties between state police and project operations agencies have thwarted attempts at establishing the cooperative agreements needed to reduce the high violation rate (15).

The third major problem, the lack of safety, has remained in the forefront of public criticism. Prior to project implementation, shoulders bordered each direction of traffic on both sides. Discontinuous left shoulders were forfeited entirely when two additional lanes were added, leaving only right shoulders along an 8-10 lane freeway. Drivers of disabled cars, seeing the

reserved lane underutilized, have sometimes used it for emergency parking; thereby, creating a serious hazard to preferential vehicles traveling 50 miles per hour (80 km/hr.). Two fatalities recently occurred outside the four-hour operational periods when a vehicle stopped in the left lane (15). While the average number of monthly accidents declined from 110 to 80 after four months of operation, as much as 28 percent of the accidents directly or indirectly involved the exclusive lanes (see Table 7). Continued use of the left lanes as shoulders may be a result of misinformed motorists, due either to a lack of adequate communication devices (signing and striping) or a misunderstanding of the devices.

Miami's IH-95 corridor demonstration project appears to have been unsuccessful in accomplishing some of the achievements noted in other projects. While this project is the longest example in operation in the nation and includes such positive design features as direct access flyover ramps from park-and-ride lots, it has also been the most expensive to implement. Ridership on buses has not increased significantly in the first six months of operation, and time savings advantages over the first phase preferential treatment on N.W. 7th Ave. are quite modest. The lanes are still underutilized by preferential vehicles; violators account for 40 percent of all traffic in the lanes. All of these factors, as well as three fatal accidents, have resulted in increased public criticism of the project.

Santa Monica Freeway, Los Angeles, California

Opened March 15, 1976.

Terminated August 9, 1976.

The most ambitious and controversial of all concurrent flow projects was implemented on the Santa Monica Freeway (IH-10), between Los Angeles and

August 6, 1976
Revised September 16, 1976

TABLE 7: ACCIDENT EXPERIENCE IN MIAMI--
INTERSTATE 95 EXCLUSIVE LANE OPERATION

	DEC. 1975	JAN. 1976	FEB.	MARCH	APRIL	MAY	JUNE
I. Number of accidents with							
A. Exclusive Lane directly involved	20	16	15	14	16	18	19
B. Exclusive Lane indirectly involved	5	3	2	0	2	4	6
C. Exclusive Lane not involved	90	86	67	56	59	54	62
TOTAL ACCIDENTS	115	105	84	70	77	76	87
II. Number of exclusive lane related accidents							
A. During exclusive lane time periods (6-10 AM, S.B.; 3-7 PM N.B.; Mon-Fri)	13	3	0	1	4	4	10
B. Not during exclusive lane time periods	12	14	17	12	13	18	15
III. Number of exclusive lane related accidents by type.	--						
A. Rear end	8	6	8	9	9	9	7
B. Side swipe	5	1	3	3	5	9	5
C. Fixed object (median wall predominately)	9	12	4	2	2	4	11
D. Other	3	0	2	0	2	0	2
IV. Number of exclusive lane related accidents by injury.							
A. No injury	13	13	11	10	11	14	20
B. Possible injury	5	3	2	3	3	1	2
C. Non incapacitating injury	5	2	1	0	3	2	2
D. Incapacitating injury	2	1	2	1	1	4	0
E. Fatality	0	0	1	0	0	1	1
V. Number of exclusive lane related accidents by direction							
A. Southbound	8	10	8	6	11	9	15
B. Northbound	17	9	9	8	7	13	10

December 2, 1975 - Exclusive Lanes opened.
March 15, 1976 - Orange Streaker buses began traveling I-95 Exclusive Lanes (27 buses/peak).

Source: Reference (14).

Santa Monica (See Figure 8), early in 1976. This East-West freeway approaches the heaviest utilization of any in the country, and other methods of priority treatment, most notably preferential entry ramps for buses and carpools, had already been employed. The proposal to establish concurrent flow lanes on the freeway was part of a much broader plan to demonstrate four different general approaches of priority treatment improvements on as many as eight different freeways in the Los Angeles area (22).

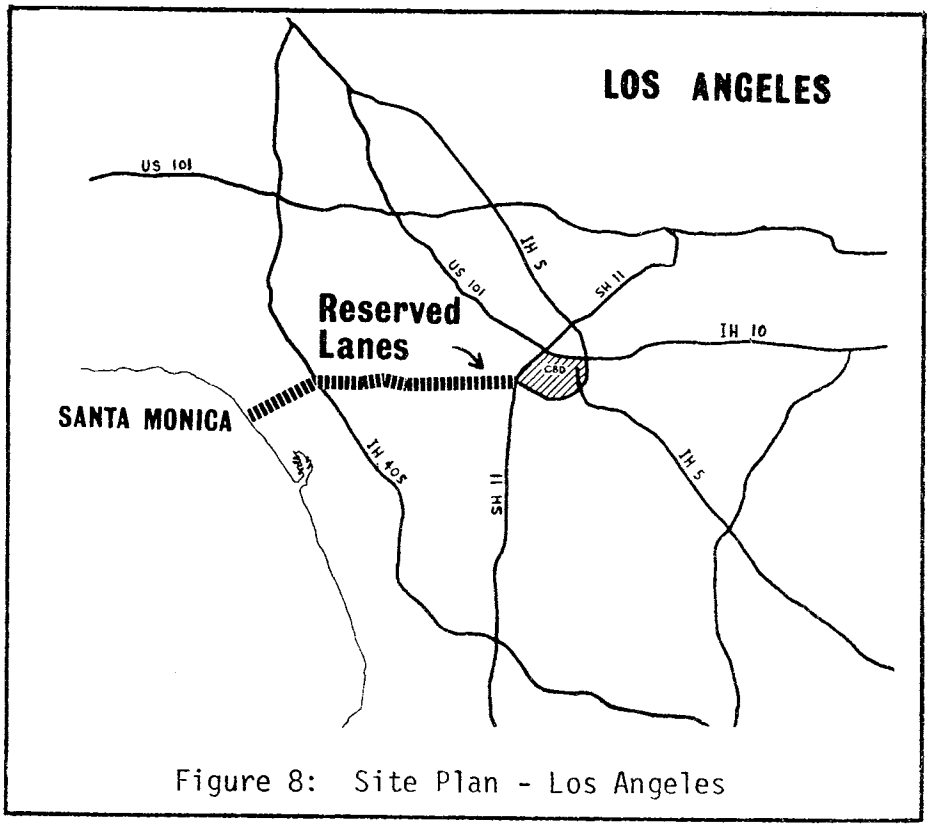

Figure 8: Site Plan - Los Angeles

Source: Reference (18).

The plan was brought about in part by a rather stringent air quality control plan promulgated in 1973 by the U.S. Environmental Protection Agency upon transportation in the Southern California Basin. This plan, created in the absence of a state-submitted control plan required by the 1970 Clean Air Act, proposed limitation measures never tried before. Some of the limitations

on gasoline consumption alone, if implemented, threatened to reduce auto usage by 80 percent. The California Department of Transportation (Caltrans) counter-proposed a series of priority treatment demonstration efforts, four of which involved the use of concurrent flow for buses and carpools. Three of the efforts involved similar treatments previously described in other U.S. projects, namely increasing the number of peak direction lanes by improving median shoulders. A fourth effort, however, called for an existing lane of the Santa Monica Freeway to be reserved exclusively for multiple occupant vehicles.

Because one of the existing lanes of the Santa Monica Freeway was reserved for buses and carpools, the vehicle-carrying capacity of the total freeway was reduced. Initially, only three percent of the vehicles using the freeway qualified as carpools; thus, initial lane volumes were expected to be modest. As people shifted from lower to higher occupancies, reserved lane volumes were expected to increase, but it was unlikely that capacity could be reached. In the meantime, unless there was a significant shift to carpools or buses, it was likely that unreserved freeway lanes and the adjacent street system would experience worse levels of congestion. The unique feature of this approach, then, was its simultaneous coupling of incentives for multiple-occupant vehicles and disincentives for all others. Carpools and buses were rewarded by a time savings, while mixed-flow traffic was penalized by a lower level-of-service due to the loss of a lane (22). Only limited signing and striping were necessary for implementation of concurrent flow lanes on a 12.5 mile (20.1 km) segment of the Santa Monica Freeway between Lincoln Avenue and Harbor Freeway near downtown Los Angeles; consequently, the project was placed into operation rather rapidly. Objectives of the project were: 1) to conserve energy and improve air quality by means less disruptive than those proposed

by the U.S. Environmental Protection Agency; and 2) to demonstrate that more efficient use could be made of existing transportation facilities without significant costs (22). Lane usage was restricted to buses and to carpools of three or more persons. Although the exclusive lanes were originally proposed for 24 hour operation, when the project opened, the hours of operation were from 6:00-10:00 a.m. and 3:00-7:00 p.m. both directions (17). Morning hours were reduced to 6:30-9:30 a.m. when an evaluation showed that multiple-occupant vehicles had not increased in number at either end of the morning peak period (18).

The ensuing weeks of operation resulted in predictable underutilization of the reserved lanes and consequential congestion on adjacent freeway lanes and nearby streets. There erupted a massive public outcry and news media criticism. Local public officials became divided over the concept, and Caltrans was forced into the position of having to defend its project on Santa Monica Freeway and other projects yet to be implemented. Los Angeles City Councilman Zev Yaroslavsky led a citizens' committee in filing a Federal court suit to get the exclusive lane operation stopped (23). Finally, on August 9, 1976, Judge Matthew Byrne of the U.S. District Court in Los Angeles halted the project and ordered additional environmental impact studies prior to its continuation (18). Since that time, Caltrans has released rather substantial amounts of data collected during the 21 weeks of project operation for public scrutiny, and has simultaneously flagged out some of the project's more noteworthy accomplishments.

To more accurately determine what effects this approach had upon freeway vehicular and person movements, a few trends should be identified. Within the seven hours operating period, "before" volumes reflected each lane carrying about 1500 vehicles. Initial project averages showed a sizeable reduction to

1275 vehicles. Toward the end of the project, lane vehicle volumes had increased to about 1300 per hour, or about 85 percent of "before" levels. Lowering vehicle volumes was one of the objectives of this approach, since an overall lowering of vehicle-miles of travel could reduce fuel consumption, and thus improve air quality. But the approach was supposed to simultaneously uphold and even provide an increase in person-movement, as more people shifted to higher occupancy vehicles. In reality, the initial freeway person movement during the first five weeks of reserved lane operation dropped to 105,550 during daily peak periods, roughly 89 percent of "before" volumes, and the final volume only increased to about 95 percent of the original level. Thus, contrary to some proponents' claims, the project was never able to provide increased person movement above that level attained prior to implementation. However, average automobile occupancies did indicate a modest improvement from 1.23 persons per vehicle to 1.35 after 20 weeks of operation.

Caltrans claimed the number of carpools more than doubled and bus ridership tripled during the project period (18); as data indicate, carpools did increase from an average of 1800 "before" to 4600 daily after several months. Almost 70 percent of this increase apparently occurred in the first month of operation. Bus ridership also jumped from 1260 daily trips to about 3800, a 200 percent increase, but not without significant increases in the levels of bus service. Indeed, the number of daily bus trips jumped from 35 to a high of 188 during the first two months of project operation, representing better than a 400 percent increase in service. Santa Monica even established its own bus operation during this period, making between 20 and 25 runs daily on the freeway (18). Comparing the significance of these peak period ridership gains to total peak person movement, buses were transporting only about 3 percent of all persons in the latter weeks before project termination.

Because existing left shoulders were unaffected in reserved lane operation, highway patrol officers had convenient locations to pull violators off the lanes. Only a moderate level of enforcement was required to sustain a 15 percent violation record. This percentage seldom varied throughout the duration of the project. Accidents did reflect an increase of 200 percent during the first month of operation, up from 11.5 to 33.6 weekly, but as noted in Table 8, this number dropped back to slightly above preproject levels.

During its brief 21-week operation, the Santa Monica reserved lane project was unique in many respects. This was the only concurrent flow project to remove an existing mixed-flow lane and place it under restricted operation. As a result of this approach, it was the only project that netted overall effects of decreasing total vehicular and person movement on the freeway. Partially as a reflection of these effects, it has been the only project thus far to be terminated after less than six months of operation. Not only were the Santa Monica concurrent flow lanes the longest ever implemented on a freeway, they were the only ones to operate in both directions, peak as well as off-peak, during each restricted period. Santa Monica also marks the first freeway to contain two different general types of priority treatment to be used simultaneously, concurrent flow lanes as well as preferential ramp entries. Carpools of two or more occupants have and will continue to benefit from this latter provision at twelve of thirty selected entry locations (18).

While improved air quality was the most important objective of the Santa Monica project, the lack of public acceptance became the most significant problem. Trends appear to indicate that increased person movement could have been accomplished within another five months of operation, but interim inconveniences polarized public attitudes, effecting the eventual demise of this particular approach as well as the reserved lane concept in Los Angeles.

Table 8: Accidents on the Santa Monica Freeway

Total Weekly - 7-Hour Peak Periods Only			
WEEK	PDO*	INJURY	TOTAL
Avg. Before	9	2.5	11.5
1	36	18	54
2	29	8	37
3	21	8	29
4	14	6	20
5	19	9	28
6	26	6	32
7	25	1	26
8	15	2	17
9	14	6	20
10	24	12	36
11	8	1	9
12	17	3	20
13	21	3	24
14	20	5	25
15	21	4	25
16	20	3	23
17	6	8	14
18	12	2	14
19	14	2	16
20	20	7	27
21	14	2	16
TOTAL	396	116	512

*PDO: Property Damage Only.

Source: Reference (18).

Southern Freeway, San Francisco, California

Opened spring, 1976.

Several shorter reserved lane projects are either being planned or are operating in California. One project, implemented largely for demonstration purposes only, is located in a southbound lane of Southern Freeway. As shown in Figure 9, this transportation artery reaches downtown San Francisco from the south. An outbound left lane was striped on the shoulder for buses and three or more person carpools in early spring 1976. Seldom is time savings accrued by using the lane, but its present restrictions reserve its use 24 hours daily. During evening peak hours, as many as 200 carpools and 15 buses have been observed using the lane, though it is one of the shortest projects in operation--2 miles (3.2 km).

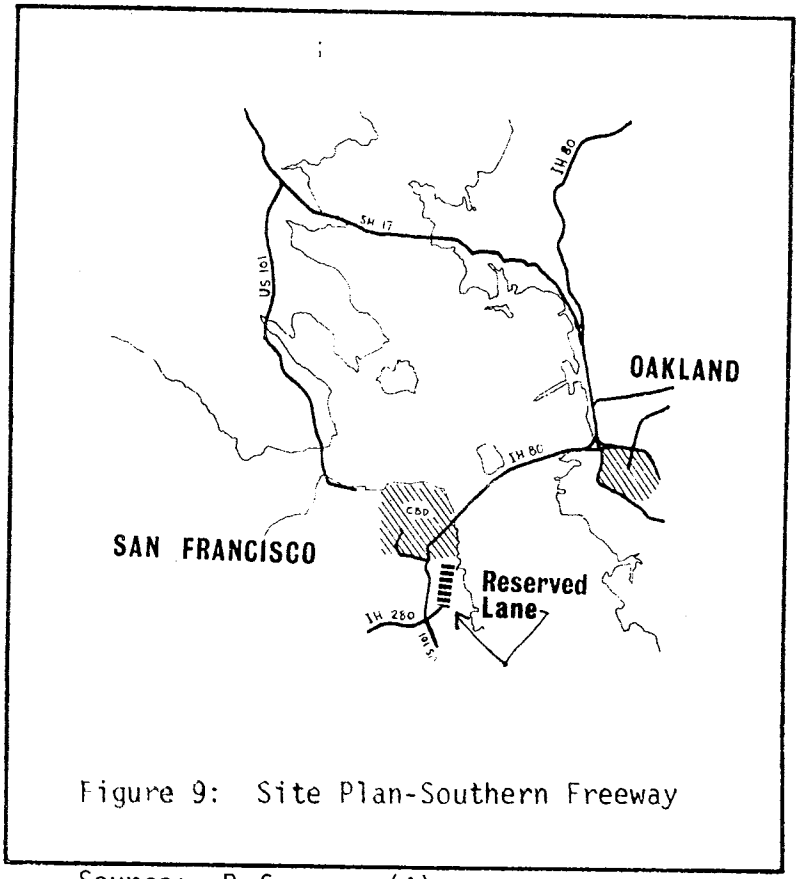

Figure 9: Site Plan-Southern Freeway

Source: Reference (4).

Castro Valley Freeway, Castro Valley, California

To be completed 1977-78.

In the Bay Area, two proposals are currently being considered for concurrent flow application. The first was conceived as a result of a compromise from recent court action. Caltrans was under contract to widen a portion of IH-580, an east-west freeway connecting Dublin and other East Bay communities to Castro Valley. This particular portion of IH-580 provides the only principle access from far eastern suburbs into Oakland, San Francisco, and cities bordering the south and east Bay Area. The route's importance to sustained development eastward was, therefore, essential. Caltrans released a contract to reconstruct the transportation facility from four to eight lanes. The Sierra Club brought suit against Caltrans claiming any increase in roadway lanes would spur development to the east with possible harm to the environment. A court ruling against the reconstruction prevailed, and a compromise was then reached in lieu of forced closing of four lanes. The compromise prevented mixed-flow traffic on the two left lanes once the facility was opened, but the innermost left lane could be reserved for buses and carpools with the next adjacent lane serving as a buffer. Thus, concurrent flow reserved lanes were chosen as a halfway measure of benefiting from some use of a very costly improvement that would have otherwise been closed to traffic, while at the same time providing some increase in capacity (4).

These lanes, shown in Figure 10, will be approximately three miles (4.8 km) long and operate in both directions 24 hours daily (4). The project will probably net little, if any, time savings. Reconstruction is continuing, and the opening date is uncertain.

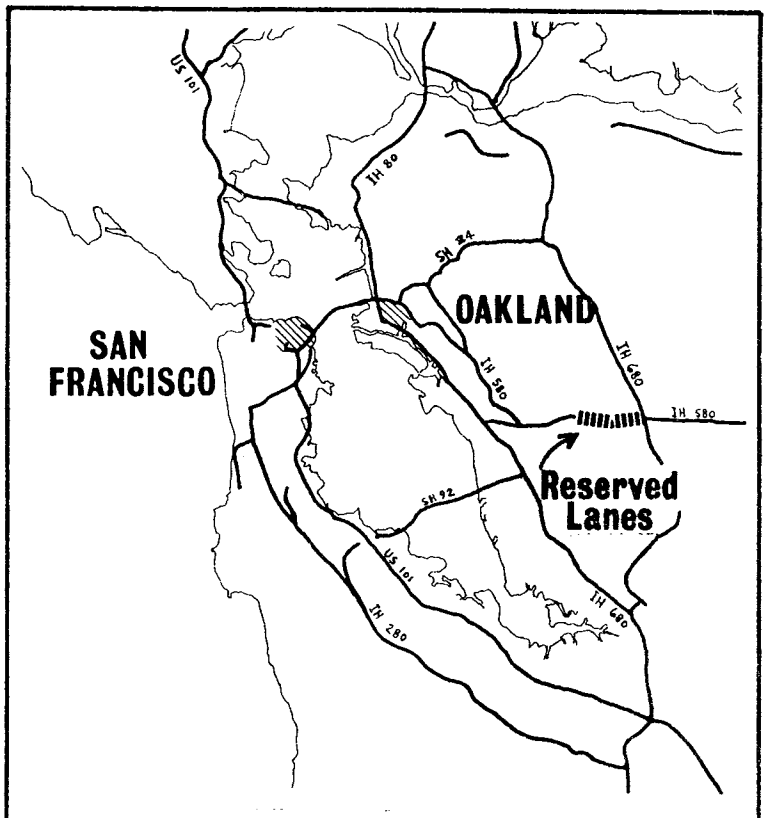

Figure 10: Proposed Site Plan-Castro Valley

Source: Reference (4).

Redwood Highway, San Rafael, California

To be completed 1978.

As mentioned previously in this report, the Golden Gate corridor is a high transit attractor because it provides the only primary access into San Francisco for Marin County commuters. The Redwood Highway has been a primary candidate for various priority treatment measures that have potential for increasing person-moving capacity. A second proposal is presently being prepared which includes another concurrent flow lane, shown in Figure 11, stretching 2.5 miles (4 km) through San Rafael (3). Similar to the operation at Greenbrae, the freeway median will be absorbed to gain an additional lane

in the northbound direction. The principal objective in the project is to provide a sizeable number of buses a two- to three-minute time savings around congestion in the immediate area during the evening peak period. While this reserved lane will improve higher occupancy incentives along the Golden Gate preferential treatments further south, completion of the segment depends on available funding (3, 4).

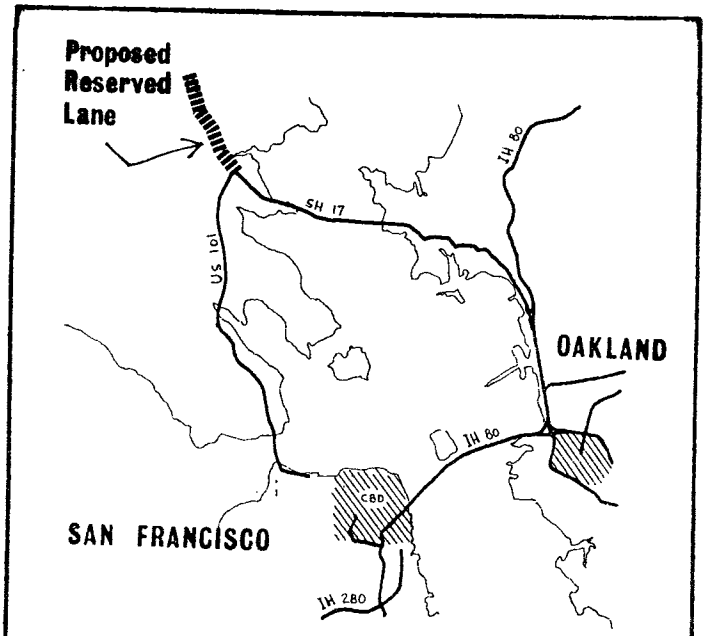

Figure 11: Proposed Site Plan-
San Rafael

Source: Reference (3).

III. ANALYSIS OF SEVERAL PROJECT-RELATED FACTORS

Effects on Freeway Person Movement

As mentioned earlier in this report, the approach Caltrans used on the Santa Monica Freeway in Los Angeles to provide concurrent flow reserved lanes by removing an existing mixed-flow lane in each direction was radically different from approaches tried elsewhere involving preferential lane additions. Each approach has had predictably different effects on total freeway person movement, probably the most important factor each project was trying to improve. While data to make this comparison are not available on all projects, the Portland, Banfield and Los Angeles-Santa Monica reserved lanes reflect the different approaches mentioned and provide sufficient person-movement information over an extended comparable period.

As shown in Figure 12, once the Banfield reserved lanes were implemented, a gradual increase in person-movement resulted over time from a continually growing number of higher-occupancy vehicles. As enforcement increased on the Banfield lanes, some of this increase was lost as the number of violators was reduced. Yet the lanes still appear to have expanded total person-movement in the daily peak two hours by about 20 percent. However, if these lanes had been opened to mixed-flow traffic, they might have had the immediate potential of providing an increase in person movement of between 25 to 50 percent, (assuming a latent traffic demand of that magnitude was present); but no long-term increases above that level would have been possible without preferential designation.

In the Los Angeles-Santa Monica example, closing existing mixed-flow lanes and reserving them for a respectively smaller number of persons in higher

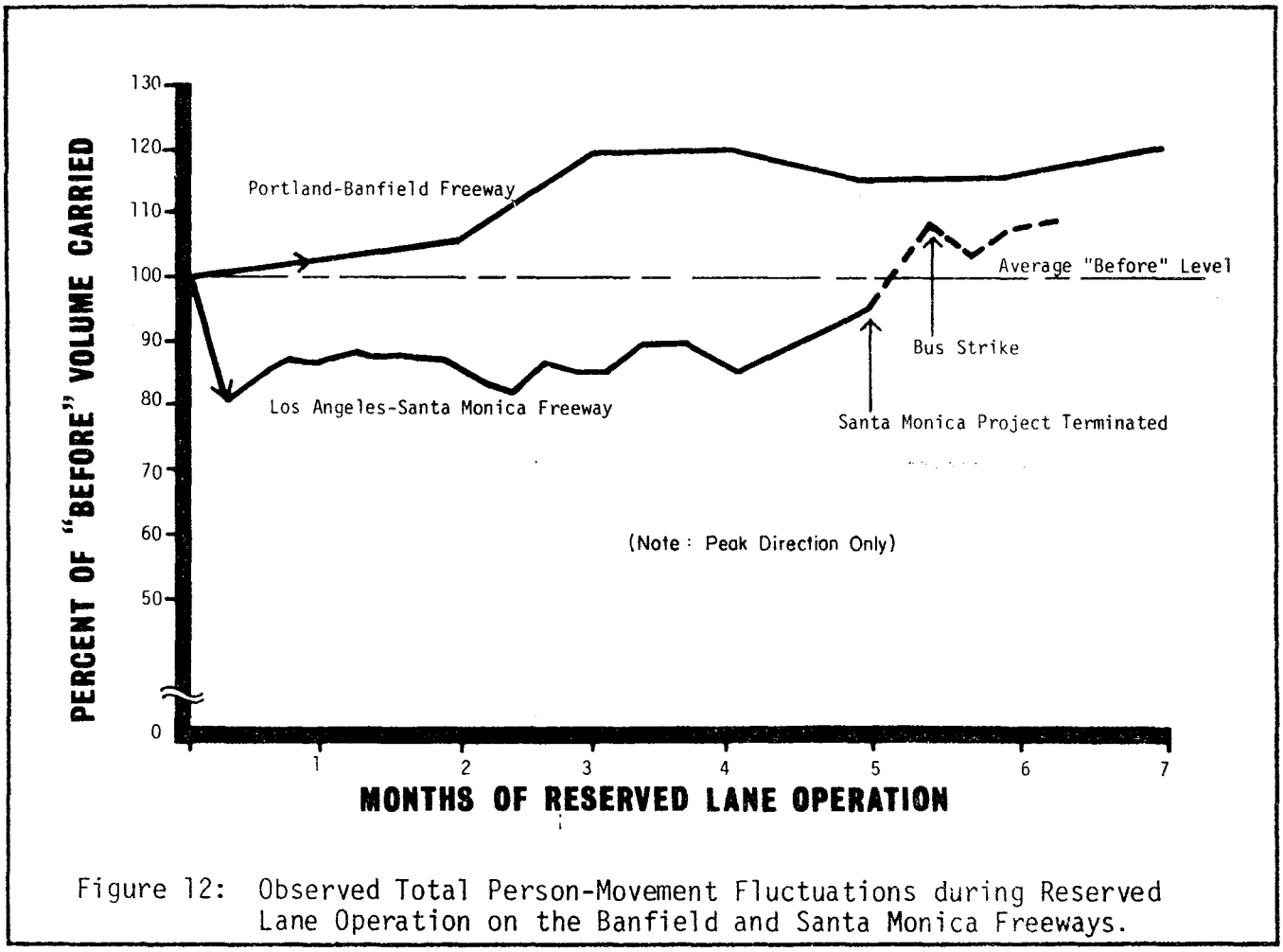

Figure 12: Observed Total Person-Movement Fluctuations during Reserved Lane Operation on the Banfield and Santa Monica Freeways.

Source: References (8), (19).

occupancy vehicles significantly reduced initial freeway movement to 80 percent of its previous levels. Over time, the project's negative effects on person-movement gradually improved to about 95 percent. Once the project was terminated, it is interesting that person-movement actually increased over preproject levels; even a bus strike following project termination did not have a significant effect on total person movement in the peak seven-hour period observed. Preferential entry ramps for buses and 2+ carpools, improvements which could have optimized person movements, probably had little impact on the trend shown as they were operational before, during, and following the reserved lane project.

Bus and Carpool Utilization During Peak Hours

One occurrence expected as a result of establishing preferential freeway lanes is increased vehicular occupancy, derived from increases in the number of carpools and the ridership in buses. As indicated in Tables 2 and 3, not all counts were measured and reported over the same time period; they reflect daily, peak period, or peak hour information. A preferable method would be to compare peak hour counts. Several counts have been adjusted (shown in Appendix C) to arrive at the estimates in Tables 9 and 10.

Carpools showed more significant gains than bus ridership by averaging a 190 percent increase after six months of project operation. Thus, a likely bracket for expected carpool increases could be between 150 to 200 percent during the peak hour.

Changes in bus ridership appeared to vary widely with individual projects. The lowest, Miami, had already experienced a 42 percent daily increase during its interim improvements. Miami opened a preferential bus lane along a city street and installed a park-and ride lot; thus, little additional increase was noted when freeway reserved lanes were opened. Because of the sizeable bus volumes transported along the San Francisco Golden Gate corridor, its 454 additional peak hour trips, the largest gain of any project to date, netted only a 13 percent increase. Los Angeles, on the other hand, increased service manyfold to produce more ridership. Indeed, passenger occupancies on a per-bus basis actually declined during this project.

Effects of Enforcement on Reserved Lane Violators

All projects have experienced the problem of restricted lane violators in varying degrees. Figure 13 (page 45) summarizes the percentages of reserved

Table 9: Estimated Peak-Hour Carpools (3+ Occupants)*

	Before Project Opened	After 4-6 Months	Percent Increase
Portland	58	183	215
Miami	125	330	164
Los Angeles	300	800	167
San Francisco (Richardson Bay)	150	475	217
			AVG 190

*Assumptions used in arriving at some estimates are shown in Appendix C.

Table 10: Estimated Peak-Hour Bus Ridership*

	First Count Available	After 4-6 Months	Percent Increase
Portland	586 (Initially)	643	10
Miami	370 (Before)	400	8
Los Angeles	210 (Before)	650	209
San Francisco (Richardson Bay)	3468 (Before)	3922	13

*Assumptions used in arriving at some estimates are shown in Appendix C.

lane violators over the first months of each project operation. Miami exhibits the highest overall percentage of violators due largely to a lack of enforcement. Both of Portland's morning and afternoon peak periods of operation show staggering increases in violators until enforcement was increased.

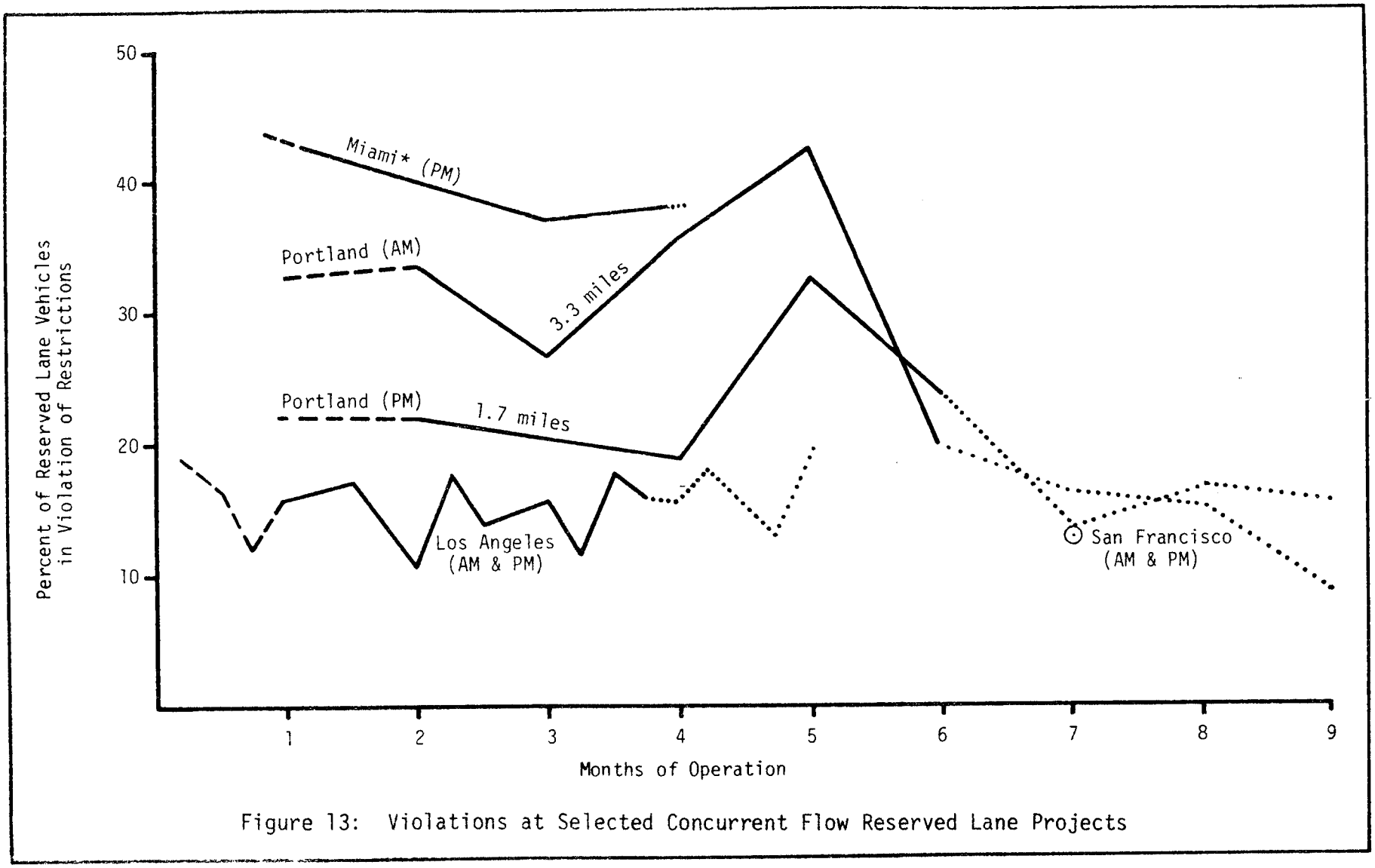

Figure 13: Violations at Selected Concurrent Flow Reserved Lane Projects

Miami and San Francisco defined from first month of shared bus/carpool operation.
- - - Segment averaged for "initial" count in Table 3.
••••• Segment averaged for "after 4-6 months" count in Table 3.

Source: References (2), (8), (13), (18).

After the initial effects of project implementation and increased enforcement were felt, two examples, Los Angeles and Portland, reflect a minimum number of evident violators at between ten and twenty percent of reserved lane traffic. This level appears to exhibit the most optimistic range the concurrent flow concept presently offers after steps have been taken to reduce the number of violators. The degree of enforcement that may be necessary to maintain this level is identified in the following paragraph.

On Portland's Banfield Freeway, during a 2-1/2 month concentrated enforcement campaign, 1647 citations were issued to ineligible vehicles using reserved lanes. It has already been mentioned that saturated patrols, representing a threefold increase in the typical number employed to monitor the freeway, concentrated their enforcement into three days each week; thus, all citations were given in 33 selected days. Using daily averages for the number of violators multiplied by the days of intensive enforcement, a total of 4400 violations were estimated to have occurred on these days. If the number of citations issued, 1647, is divided by the total estimated number of violators, and assuming few violators were cited more than once, as much as 37 percent of all ineligible traffic may have been ticketed during this period. Because no other projects have kept extended records of enforcement accomplishments along with counts on lane usage, it would be difficult to determine what general percentage of violators would have to necessarily be cited before a substantial reduction in violations could be realized in most projects. Nevertheless, this example reflects a sizeable effort on the part of law enforcement officers to track down and stop a significant percentage of the total number of violators, a practice rather difficult in assuring continued concept effectiveness.

Considerations for Reserved Lane Restrictions

As mentioned earlier, if a concurrent flow facility is to be operated, it should provide some advantage to the recipient. This advantage, whether it represents a time savings or a more desirable traffic density, should result from a higher level of service afforded reserved lane users. An improved level of service is expected to stimulate a demand for the facility, thus providing an incentive for individuals to shift to higher occupancy vehicles. The intent of restrictions on lane usage is to protect the level of service offered.

An inherent advantage of concurrent flow lanes often mentioned is the concept's adaptability to shared operation for buses and carpools. This advantage should permit comparatively higher utilization of the facility. The question then arises as to why this advantage is not presently being realized on existing reserved lane projects.

Table 11 shows a distribution of vehicle occupancies prior to reserved lane implementation in Portland, Los Angeles, and Miami. One-occupant vehicles compose about three-fourths of all traffic, while two-occupant vehicles represent about 20 percent. The number of three or more occupant vehicles averages about four percent.

Table 12 provides a distribution of two-hour peak period occupancy percentages collected along thirteen of the more heavily traveled corridors in Dallas and Fort Worth during 1976. While the percentage of single occupant automobiles appears slightly higher, averaging 81 percent, the percentage of 3+ occupant automobiles shows an average of about three percent, reflecting similar proportions evident from other U.S. cities.

Vehicle occupancy counts from these locations highlight the basic problem inherent in using carpools to increase lane utilization. That problem is as

Table 11: Summary of Preferential Project Vehicle Occupancy Percentages

	Percent of 1 Occupant Vehicles	Percent of 2 Occupant Vehicles	Percent of 3+ Occupant Vehicles	Percent Total
FREEWAY OCCUPANCY COUNTS				
Banfield Freeway - Portland (Peak Hours, Nov. - Dec., 1975)	77	21	2	100
Sunset Freeway - Portland (Peak Hours, Mar. - Sept., 1976)	79	19	2	100
Minneapolis Freeway - Portland (Peak Hours, Mar. - Sept., 1976)	73	21	6	100
Santa Monica Freeway - Los Angeles (Peak 7 Hours, March, 1975)	-	-	2	-
North-South Freeway - Miami (Peak Hours, Dec., 1975)	-	20-23	5-7	-
Freeway Averages	76	20	4	100
EFFECTS OF PRIORITY TREATMENT ON FREEWAY VEHICLE OCCUPANCY				
Banfield Freeway - Portland				
Before (Nov. - Dec., 1975)	78	21	2	100
After (Jan. - Sept., 1976)	76	18	6	100
Santa Monica Freeway - Los Angeles				
Before (March, 1975)	-	-	2	-
After (Jun. - July, 1976)	-	-	5-6	-

Source: References (8), (13), (18).

Table 12: Summary of Dallas-Ft. Worth Vehicle Occupancy Percentages*

	Percent of 1 Occupant Vehicles	Percent of 2 Occupant Vehicles	Percent of 3+ Occupant Vehicles	Percent Total
Dallas				
I.H. 35 E (North)	87	11	2	100
I.H. 35 E (South)	80	16	4	100
I.H. 30	80	17	3	100
U.S. 75 (North)	82	15	3	100
U.S. 75 (South)	73	21	6	100
Dallas North Tollway	86	13	1	100
Ft. Worth				
I.H. 35 W	78	18	4	100
I.H. 30	82	16	2	100
U.S. 377	77	18	5	100
U.S. 287	80	17	3	100
S.H. 199	80	17	3	100
S.H. 121	84	13	3	100
Lancaster Blvd.	83	13	4	100
Averages	81	16	3	100

*Percentages based upon peak-flow direction, 7-9 A.M. during 1976.

Source: Reference (25).

follows:

> *If vehicles with two or more occupants are permitted to use the lane, it will immediately become the most congested lane on the freeway. Yet, a restriction of three or more occupants does not yield enough vehicles to adequately utilize the lane.*

Thus, one of the apparent inherent advantages of concurrent flow reserved lanes is largely negated.

Of course, one objective of these projects was to provide an incentive to attract more people into carpools of three or more occupants. The incentive did produce significant results in at least two cases; however, the added carpools were still not enough to keep the lane from appearing underutilized.

Perhaps a more vigorous marketing and public information campaign could convince the public that the measure of effectiveness of a reserved lane should be the number of people it serves rather than the number of vehicles using it. If so, then the need to "fill up" the lane with vehicles might not be so important.

IV. CONCLUSIONS

Priority treatment for high-occupancy vehicles on Texas freeways might be provided by any one of the following five concepts:

1. Exclusive busways (protected by barriers),
2. Reserved lanes-contraflow,
3. Reserved lanes-concurrent flow,
4. Freeway control with priority entry, and
5. Use of service roads.

Because of the intense recent interest nationally in reserved lanes-concurrent flow, this entire report focused on that single concept. The conclusions that can be formulated, based upon the information presented in this report, are summarized in the following paragraphs.

Advantages and Disadvantages

The reserved lane-concurrent flow concept offers the following apparent advantages when compared to other concepts for priority treatment:

1. It is the least costly to implement;
2. It can easily be used by both buses and carpools; and
3. Qualified vehicles can merge into or out of the lane at any location along the freeway.

Because of these apparent advantages, six reserved lane-concurrent flow projects have been implemented in various U.S. cities during the past three years. However, operational experiences from these projects reveal some limitations to these apparent advantages.

First, the anticipated advantage of easy use by carpools as well as buses is limited by the normal distribution of carpool occupants. Only about 4

percent of the vehicles on the freeway contain 3 or more occupants. Another 20 percent contain two occupants. Thus, the vehicle capacity of the reserved lane is still grossly underutilized if the carpool qualifications are set at 3 or more occupants. Yet, the reserved lane could become as congested as other freeway lanes if the carpool qualification level were set at 2 or more occupants. So the apparent advantage of easy carpool use is quite limited.

Second, the ease with which vehicles can merge into and out of the reserved lane leads to an almost insurmountable enforcement problem. Even though the violation rate on the Banfield Freeway in Portland, Oregon was reduced from 40 percent to 10 percent through rigorous enforcement, the level of effort required for this enforcement would probably be considered unacceptable on a long-term basis. Consequently, the anticipated advantage of easy access to the lanes actually is a severe disadvantage for this concept.

Third, the experience with adverse public reaction to the "Diamond Lane" on the Santa Monica Freeway in Los Angeles can be largely attributed to the fact that an existing freeway lane was taken out of general use and reserved for high-occupancy vehicles. This experience suggests that it may only be feasible to implement a reserved lane-concurrent flow project at a time when at least one new lane is added to the freeway. This need for a new lane obviates the apparent advantage of low cost implementation.

Additionally, the increase in accident rates encountered in most of these projects was much more severe than anticipated. Thus, it appears that the accident rate associated with the reserved lane-concurrent flow concept could be considered a disadvantage for that concept vis-a-vis other approaches to priority treatment.

Essential Elements of Implementation

The intent of any priority treatment project is to provide travel advantages to certain vehicles, usually buses and carpools, in order to stimulate a change in travel habits that results in an increased people-moving capacity of an existing freeway. If this goal is to be achieved, then the priority treatment project must provide sufficient travel advantages to attract new users, and it must attain enough public support to enable the project to remain in operation long enough to accomplish its goal. The success of a priority treatment project should be measured in terms of its impact on travel habits--increased bus ridership, increased carpool usage, etc.--and the corresponding increase in freeway productivity.

The reserved lane-concurrent flow concept is one possible approach to priority treatment. The following five elements appear to be essential to the success of any reserved lane-concurrent flow project that might be implemented.

1. The segment of freeway involved must not have any left-hand entrances or exits. The existance of left-hand ramps would necessitate other traffic merging through the reserved lane. This would present severe operational problems.
2. The length of the reserved lane must span the location of normal peak-period freeway congestion. Otherwise, priority vehicles will not receive an adequate travel advantage and they will have difficulty merging into and out of the reserved lane.
3. A reserved lane-concurrent flow project should only be implemented in conjunction with the provision of at least one additional freeway lane. The general public will not accept the tremendous increase in traffic congestion and time delays that

will result from the removal of an existing lane from general use. It will be difficult enough to persuade the general public to respect the restrictions on lane use when it is a new lane.

4. Project implementation should be preceded by a vigorous public information campaign. Hopefully, such a program can minimize the increase in accident rates, and it might even help to minimize violation rates.
5. Project implementation should include a thorough, well-planned enforcement program. Otherwise, the whole concept of a reserved lane may disintegrate due to the number of violators.

The incorporation of all five of these elements in an implementation plan may not insure the success of a reserved lane-concurrent flow project, but the omission of any one of them will almost certainly insure its failure.

Summation

The experience to date with reserved lane-concurrent flow projects is less than encouraging concerning their possible implementation in Texas. Perhaps in a few years the general public will gain an appreciation of the need for reserved lanes serving high-occupancy vehicles. If so, then the lane restrictions will not be so difficult to enforce. Until such time, however, the reserved lane-concurrent flow concept appears to be less attractive than several other approaches to priority treatment for application in Texas.

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APPENDIX A

Selected Time Periods Used in Preparing the Reserved Lane Operation Summary, Table 2

Portland:	(A)	Before Project -	
		Accident Data	- June 1974 - May 1975
		All Others	- November 1975
	(B)	Initially -	
		Violation Rates	- December 1975 - January 1976
		Accidents	- December 1975 - January 1976
		All Others	- February - April 1976
	(C)	After 4-6 Months -	
		Violation Rates	- May - August 1976
		Accidents	- May - June 1976
		All Others	- June - September 1976
Los Angeles:	(A)	Before Project -	
		Counts on all Lanes	- March 1975
		Bus Counts	- March 1976
		Carpool Counts	- May 6, 1975
		Accident Data	- January - February 1976
		Travel Time	- March 1975
	(B)	Initially	- 1-5 Weeks of Operation
	(C)	After 4-6 Months -	- 15-20 Weeks of Operation
		Accidents	- 15-25 Weeks of Operation
	(D)	Arterial volumes extracted only 4th and 13th weeks	
Miami:	(A)	Before Project	- July - December 1975
	(B)	Initially -	
		Bus Ridership	- March 1976
		Violations and Auto Occupancy	- April 1976
		Accidents	- December - January 1975-76
		Vehicle Lane Counts	- April 1976
	(C)	After 4-6 Months -	
		Vehicle Lane Counts, and Violation Rates	- July 1976

Miami:		Accidents	- April - June 1976
		Auto Occupancy	- June - July 1976
		Bus Ridership	- June 1976
San Francisco:	(A)	Before Project	- September - December 1974
	(C)	After 4-6 Months	- January - May 1975 and information from phone conversations

Above specified periods were selected due either to completeness, accuracy, or noted in data.

APPENDIX B

Estimating Average Peak-Hour Carpools and Reserved Lane Mode-Splits for North-South Freeway, Miami

In December 1975, the reserved lanes on Miami's North-South Freeway were opened to three or more occupant carpools. About 40 buses began using the lanes in March, 1975 during each four-hour peak period. It is reasonable to assume that at least half of this number, about twenty buses, operated during the peak hour. Because incomplete data exists during the initial survey period from January to July, 1976, only information for the month of July was used for estimating the following carpool count.

Outbound Reserved Lane Operation

4:30 - 5:30 PM, July, 1976

Total Reserved Lane Vehicles:	571
Violators (Violation rate 38%)	- 217
Estimated Buses	- 20
Remaining Total (Carpools)	334 ∿ 330

APPENDIX C

Estimating Peak Hour Carpools and Bus Ridership for Tables 4 and 5

Because several projects collected vehicular and ridership counts over differing time parameters, the following assumptions were made to adjust some peak period and daily totals to comparable peak hour estimates.

Carpool Counts

Miami

The number of "before" project carpools were averaged from the months of July through November, 1975, prior to official lane opening. During these months, occupancy restrictions were placed upon automobiles using the partially completed lanes. As a result, surveyed counts include a percentage of ineligible vehicles. The actual number of estimated carpools is the difference between the number of violators and total reserved lane counts.

Miami "Before" Evening Peak Hour Reserved Lane Traffic (13)

	Total Vehicles	Violators*	Est. Carpools
July 1975	315	- 176	139
August	300	- 198	102
September	316	- 202	114
October	367	- 235	132
November	389	- 249	140
		AVG	125

*Number of violators calculated from percentages included in Reference (13).

San Francisco

The number of carpools using the Golden Gate corridor is based upon an estimate of 850 peak period carpoolers "before" (3), an assumption that about two-thirds of these carpoolers counted during the three-hour peak period would be considered peak hour commuters, (about 550 carpoolers), and an estimate of 3.7 carpoolers per vehicle in the "after" period on this project (1773 carpool persons/475 carpools). A similar vehicle occupancy is assumed to have prevailed in the "before" period. Thus, about 150 peak hour "before" carpools are estimated.

Los Angeles

When adjusting a daily peak period of seven hours to a single peak hour, the following assumptions were included. 1) Each morning or evening rush period would have included about 50 percent of the daily total. 2) About 40 percent of the volume during each average 3 1/2-hour rush period could have occurred in the peak hour. 3) About 85 percent of the peak hour preferential vehicle flow would have been in the peak direction. (Both reserved lanes in each direction of travel were operational during peak periods.)

Thus from a total of 1,785 daily "before" carpools, a peak hour count might be reasonably estimated at about 300. An "after" count of 4,592 would then be about 780 ∿ 800 during the peak hour.

Bus Ridership Counts

Miami

Daily bus ridership in Miami was adjusted based upon the following two assumptions. 1) Half of the daily total was represented in each peak

four-hour period. 2) At least 50 percent of the peak period bus ridership occurred during the peak hour. From these assumptions the 1,474 daily "before" bus ridership would represent 370 person-trips in the peak hour, and 1,575 "after" daily ridership would reflect 394 ∿ 400 person trips.

Los Angeles

Using the same three assumptions for daily seven-hour peak period bus ridership that were used for carpools, 1,260 "before" bus trips would be 214, or about 210 peak hour. The 3,817 "after" bus trips would then reflect an estimate of about 650 peak hour.