High Occupancy Vehicle Facility Development

Operation and Enforcement

Implementation Package
FHWA-IP-82-1

Volume I

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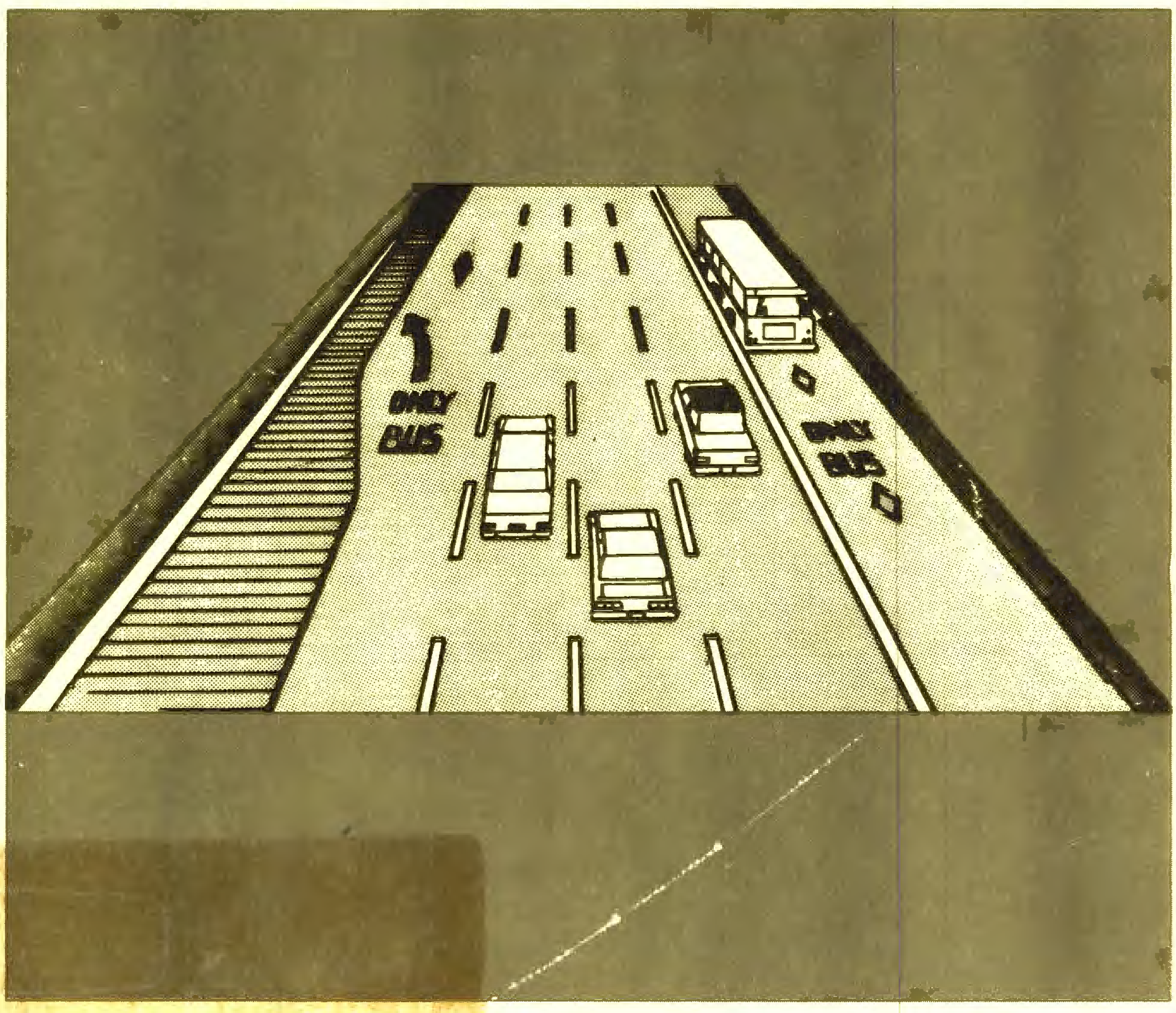

FOREWORD

This textbook was originally written and used as part of a 2-day training course dealing with the design of High Occupancy Vehicle (HOV) facilities. Because of the wealth of information contained in the training textbook, it has been edited and is published herein as a stand alone Implementation Package. It includes types of priority treatments, funding mechanisms, marketing strategy, and evaluation techniques. This book should aid public works officials in the design, installation, enforcement, and maintenance of HOV facilities.

RG Betsold
Director
Office of Development

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16. Abstract

Priority treatment for high occupancy vehicle projects was a direct result of energy shortages and escalating prices. Numerous HOV projects have been implemented, evaluated, and reported. In order to effectively disseminate this information, a report titled "High Occupancy Vehicle Facility Development, Operation, and Enforcement" was developed.

This report provides guidance on the planning, design, operation, and enforcement of HOV Facilities. The report was prepared in two volumes and both volumes are used as textbooks in a two-day training course. Volume I is a stand-alone document that creates an awareness of the need for HOV projects and depicts various HOV treatments. Volume II is a complementary document that provides warrants for selecting potential HOV treatments.

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High Occupancy Vehicle Facility Development

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Volume I

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U.S. Department
of Transportation

Federal Highway Administration

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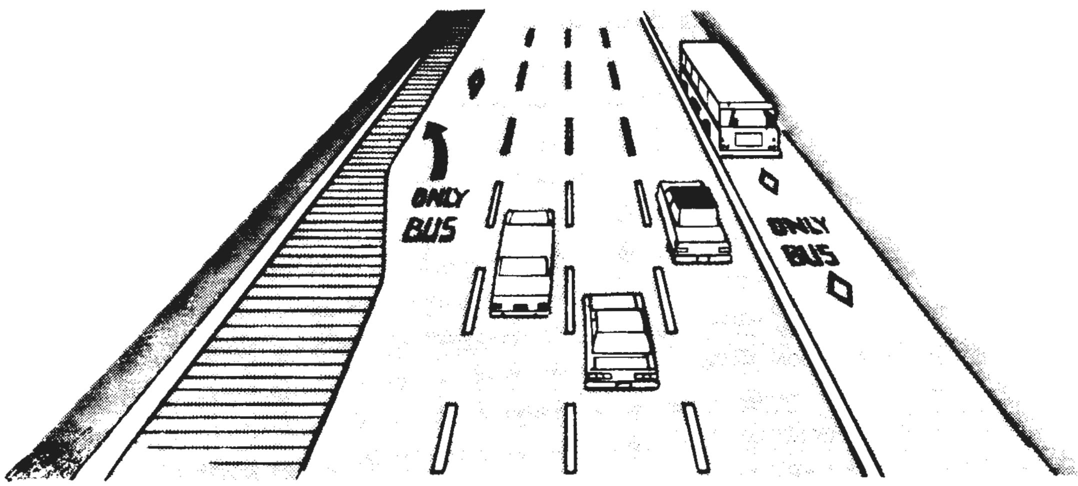
1. INTRODUCTION TO HOV TREATMENTS



I. INTRODUCTION TO HOV PRIORITY TREATMENTS

BACKGROUND

Highway transportation in this country is in the midst of a transition that started in the late 1960's when all levels of government began turning their attention away from major road construction to gaining greater efficiency of existing facilities. This change was reflected by such Federal initiatives as the TOPICS program, the fringe parking program and substantially higher budgets for transit development. The energy crises of 1973-74 and 1979 further accelerated this transition. Energy shortages and higher prices resulted in a search for more efficient means of transportation, and priority treatment for high occupancy vehicles (HOV's) was one of the answers. Many HOV projects were implemented, although often without adequate planning and preparation.

The continuing cost escalation and the predicted shortages with the eventuality of gasoline rationing are beginning to make the American public aware that the energy crisis is real and that driving in the future may at the best be expensive and at the worst be severely curtailed. This transition has been accompanied by significantly increased use of priority HOV facilities and transit modes. Transit usage in 1978 had its highest one year increase in almost 40 years, being up almost 6 percent. Statistics for 1979 and 1980 reveal even larger increases. Meanwhile, carpool ridership on HOV priority treatments that offer significant time advantages are also up significantly.

The impetus for expanding the use of HOV priority treatments in major metropolitan areas seems to be growing in importance. The United States Department of Transportation has given additional emphasis to Transportation System Management (TSM) programs, beginning with Section 142 of the Federal Aid Highway Act of 1970, and continuing with the Clean-Air Act Amendment provisions of 1977 and accompanying Transportation Control Plans (TCP). The re-emerging criticality of the energy supply problem plus fiscal and socio-economic constraints on major additions to the urban highway system combine to make HOV priority treatments increasingly significant during the 1980's and beyond.

The last factor mentioned--constraints in constructing major additions to urban highway capacity--is perhaps the most influential factor.

These constraints are primarily due to escalating construction costs amidst decreasing revenues from traditional sources such as gasoline taxes and highway tolls. Therefore, in urban areas, especially in those where population and travel demand are growing rapidly, it will be essential to maximize the person carrying capacity of the existing highway system in order to accommodate growth in demand while maintaining satisfactory levels of mobility. The encouragement of high occupancy vehicle use is critical to this effort. The recent importance given to HOV priority treatments by the Federal government is summarized in the following excerpt from a joint FHWA/UMTA memorandum to their regional offices, entitled "Improving the Urban Transportation Decision Process" (October 11, 1979):

> "The most practical way for our programs to contribute to energy conservation is for every major urban area to have an effective program for increasing ridesharing and transit patronage. The HOV lane and other types of facilities which give preference to high occupancy use of vehicles must be a priority consideration on every major highway project. Therefore, major new urban highway projects should be approved only after preferential treatment of high occupancy vehicles has been given full consideration. Urban Interstate highways that are in the 1979 ICE and other highways in advanced stages should be reevaluated to determine if priority treatments for HOV could be incorporated. Also, interface with transit lines and routes, including parking, signing and methods to manage traffic, shall be considered in every highway project. These actions must be coupled with steps to attract greater transit patronage and to improve productivity and effectiveness of transit systems through better management."

DEFINITION OF A HIGH OCCUPANCY VEHICLE

A high occupancy vehicle (HOV) can be defined as a vehicle which carries at least a minimum specified number of persons. Often an HOV is defined as a transit vehicle (e.g., bus, trolley) only. However, in many applications the concept of an HOV has been expanded to include carpools or vanpools. A non HOV is any vehicle (e.g., auto, truck, van) which does not carry the minimum specified number of persons.

The legal number of persons which constitutes an HOV varies from project to project. Carpool occupancies typically are either 2, 3 or 4 persons per vehicle with emphasis being placed on setting as high an occupancy criterion as possible. Vanpools typically accommodate 8 to 12 persons per vehicle. Criteria for establishing reasonable HOV occupancy rules are presented in Chapter 5. The power to define an HOV for a given project is vested in the appropriate governmental agency.

OBJECTIVES OF HOV PRIORITY TREATMENTS

Multiple objectives are potentially served by HOV priority treatments. These include the following:

1. Reduce energy consumption by reducing the number of vehicles on the road and by improving overall efficiency of the highway system.

2. Improve air quality by reducing overall vehicle miles of travel and vehicle hours of travel.

3. Increase the person throughput capacity of critically congested highway corridors in order to provide increased accessibility to major activity centers.

4. Reduce total person travel time within a corridor or region.

5. Reduce or defer the need to construct additional highway capacity for general purpose traffic.

6. Improve the efficiency and economy of public transit operations and enhance the schedule reliability of transit service in order to induce mode shift.

TYPES OF PRIORITY TREATMENTS

A wide variety of HOV priority treatments have been used in the United States. These treatments can generally be classified into one or more of the following basic types:

1. <u>Concurrent Flow HOV Lanes (Figure 1-1)</u> - Lanes designated in the normal or with flow direction for HOV's. May include allocating existing lanes (i.e., take-a-lane) or constructing additional lanes (i.e., add-a-lane).

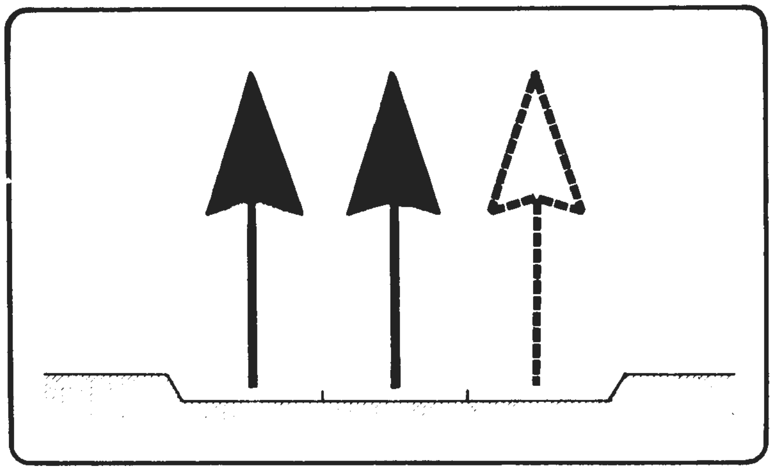


Figure 1-1. Concurrent Flow HOV Lanes

2. <u>Contraflow HOV Lanes (Figure 1-2)</u> - Lanes taken from opposite flow traffic for use by HOV's traveling in the normal or with flow direction.

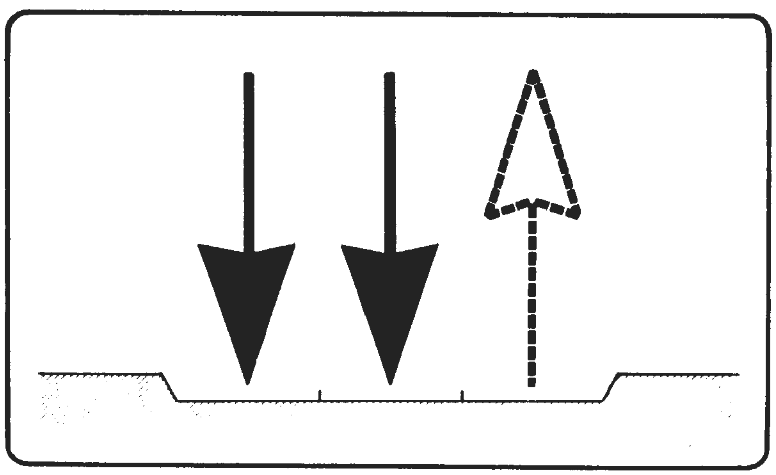


Figure 1-2. Contraflow HOV Lanes

3. Exclusive HOV Roadway (Figure 1-3) - Physically separated HOV lanes or roadway exclusively designated for HOV's.

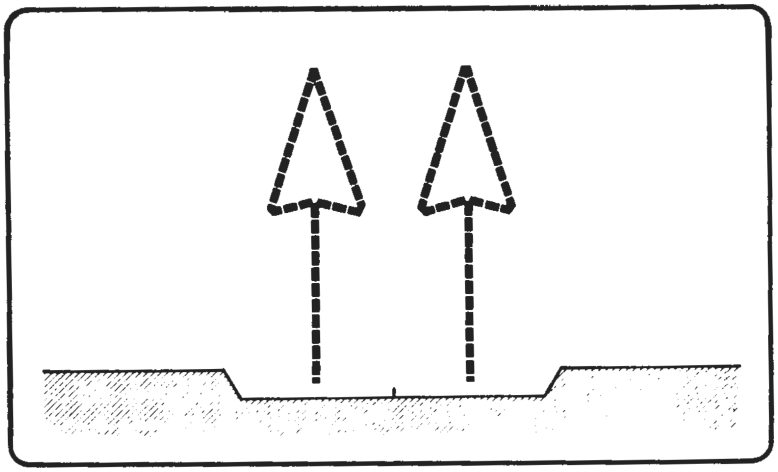


Figure 1-3. Exclusive HOV Roadway

4. HOV Ramp Treatments (Figure 1-4) - Existing or specially constructed ramps designated either for partial (i.e., ramp meter bypass) or exclusive use by HOV's.

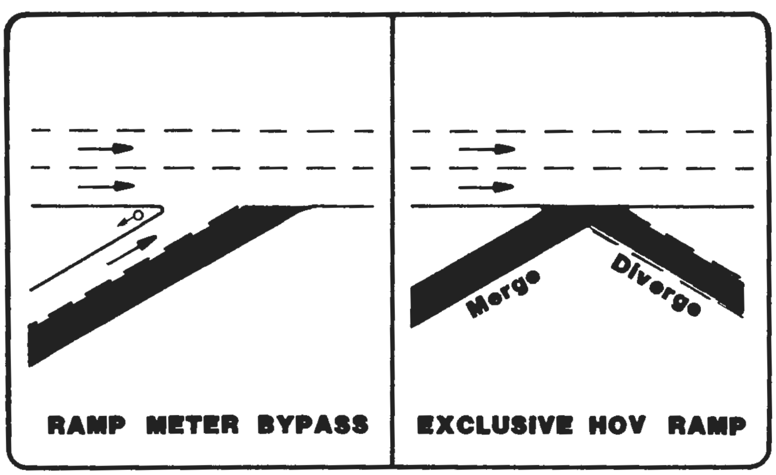


Figure 1-4. HOV Ramp Treatments

5. HOV Signal Priority (Figure 1-5) - Traffic signal changes which provide priority for HOV's. Includes such techniques as signal preemption, separate HOV phases and signal offset adjustments.

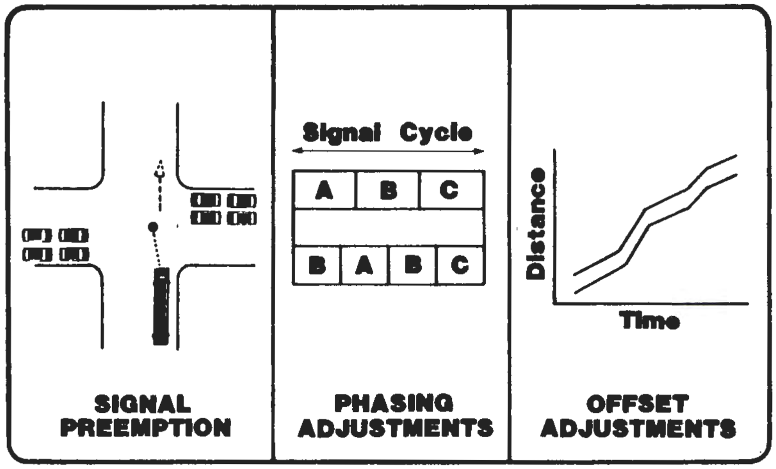


Figure 1-5. HOV Signal Priority

6. Priority Parking (Figure 1-6) - Parking spaces or facilities designated for priority use by HOV's. Includes parking facilities used for transit or carpool staging (i.e., park and ride; park and pool lots).

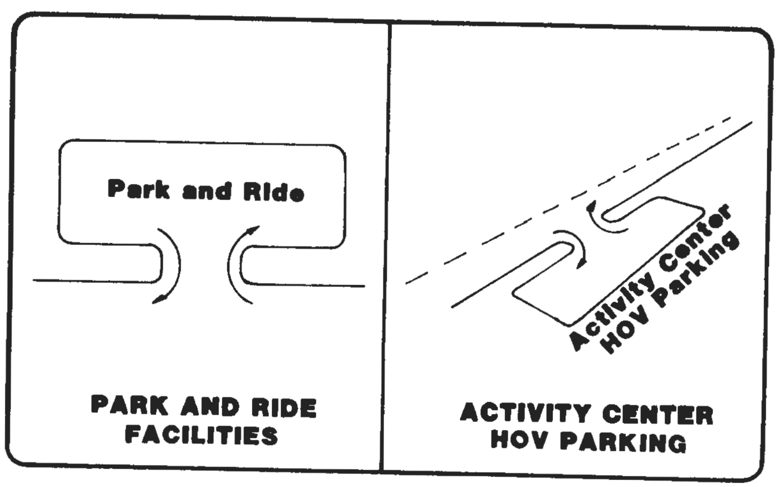


Figure 1-6. Priority Parking

7. Priority Pricing (Figure 1-7) - Reduced prices offered to HOV's. Includes such techniques as reduced tolls and parking charges for HOV's.

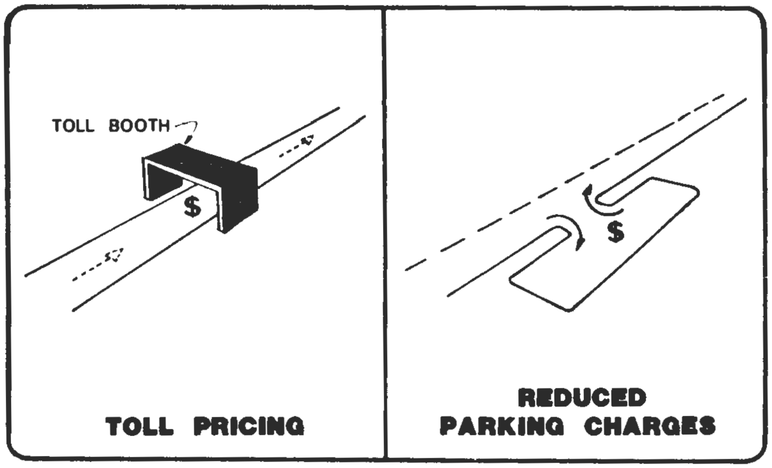


Figure 1-7. Priority Pricing

Each of these HOV priority treatments have been applied on various types of facilities. Three major facility types can be identified:

1. Grade Separated Facilities - Access is limited via ramps. High design speeds are typical. Includes freeways, expressways, and sections of high design surface streets.

2. Surface Streets - Little or no access control is evident. Intersections are at-grade and are controlled by traffic signals or signing. Includes both arterial and activity center streets.

3. Separated Right-of-Way - Right-of-way separated from other roadway facilities. Includes railroad, utility or unconstructed highway rights-of-way.

These classifications of HOV treatments and facility types will be followed throughout the guides.

INTERIM AND PERMANENT HOV TREATMENTS

The different types of HOV priority treatments described in the previous section will either serve an interim or permanent function within the transportation system. This differentiation is important to consider during the planning, design and operation phases of an HOV treatment development.

Interim HOV Treatments

Interim HOV treatments are those which are intended to accommodate HOV's only until a more permanent solution can be implemented. Interim HOV treatments show the following general characteristics:

- Short implementation time;
- Low capital cost;
- Low to moderate capacity to handle HOV's;
- Difficult to create HOV systems.

In addition, interim HOV treatments may exhibit the following aspects:

- High operations and maintenance costs;
- Difficult enforcement;
- Substandard physical design;
- Potential safety problems;
- Controversy.

A tradeoff exists between the ease of implementation of interim HOV treatments and the potential for limitations on design, operations, and enforcement. As a result, controversy with the public and the political sphere may result.

Permanent HOV Treatments

Permanent HOV treatments generally have the following characteristics:

- Longer implementation time;

- Higher capital cost;
- High capacity to handle HOV's;
- HOV systems oriented;
- Lower operations and maintenance costs;
- Easier to enforce;
- Full design standards;
- Good safety characteristics.

Permanent HOV treatments are designed and operated similar to regular transportation facilities. Therefore, most of the deficiencies characteristic of interim HOV treatments are avoided.

The placement of HOV treatment types within the interim or permanent categories offers some new perspectives. Table 1-1 lists each of the seven identified HOV treatment types and the corresponding classification. This table reveals that many HOV treatments may be either interim or permanent, depending upon specific local conditions. For example, HOV ramp meter bypass treatments may be implemented on an interim basis to facilitate HOV movements onto a congested freeway while a permanent in-median HOV facility is being constructed. Conversely, ramp meter bypass treatments may be implemented as a permanent addition to a corridor-wide freeway metering system.

Most permanent HOV treatments could also be implemented on an interim basis; however, interim HOV treatments cannot typically be converted to permanent status without significant design or operational improvements. An example of an interim HOV treatment is a concurrent flow HOV lane. Many times the HOV lane is created by utilizing an existing shoulder or by adding a lane through restriping to narrower lanes. Both situations may compromise design standards and result in operational or enforcement problems. Therefore, the concurrent flow lane serves its purpose on an interim basis, but its limitations will probably prevent its acceptance as a permanent solution to the problem. The same is true of contraflow lanes, where potentially high operations and maintenance costs and unusual traffic operations may not be acceptable on a permanent basis.

Table 1-1. Interim and Permanent HOV Treatments

HOV TREATMENTS	INTERIM	PERMANENT
o Concurrent flow	X	
o Contraflow	X	
o Exclusive roadway		X
o Ramp treatments	X	X
o Signal priority	X	X
o Priority parking	X	X
o Priority pricing	X	X

Many of the specific HOV treatments described in the following sections should be classified as interim HOV treatments, even though they have been or will be in place for several years and may even assume some characteristics of permanent HOV treatments. These differences between interim and permanent HOV treatments should be considered both in the planning and design of HOV treatments.

IMPLEMENTATION EXPERIENCE

Following are brief summaries of the implementation experience with various types of HOV priority treatments:

Grade Separated Facility - Concurrent Flow Lane

A summary of the general characteristics of 13 of these projects is given in Table 1-2. The first project of this type was on the San Francisco-Oakland Bay Bridge where reserved lanes for buses on the approach to the bridge toll plaza were opened in 1970. Priority was extended to carpools in late 1971. This project was a special application of the concept, constituting a "queue jumper" at the toll plaza rather than a long reserved lane section. Eleven additional grade separated concurrent flow lane projects were implemented between 1974 and 1977, with especially significant ones on freeways in San Francisco, Los Angeles, Boston, Portland (Oregon), Miami, and Honolulu. As seen in Table 1-2, these projects include both add-a-lane and take-a-lane configurations. All but one of the projects utilize the inside lane adjacent to the median. Only the SR 520 project designates a right side (shoulder) lane for HOV's.

Surface Street - Concurrent Flow Lane

This treatment is the most widely applied HOV priority project, found in at least thirty American cities. Most applications have occurred along curb lanes of activity center (e.g., CBD) streets using a minimum of signing and marking. Often right-turning non HOV's are also permitted to use the curb lane. Systems of CBD HOV lanes (mostly for buses) have been implemented in Washington, D.C. and in San Francisco.

Implementation of concurrent flow lanes on arterials, as opposed to within activity centers, has been rather limited. The concept is most applicable on congested radial streets carrying traffic to or from the CBD. But in many cities, officials have resisted

Table 1-2. Characteristics of Concurrent Flow HOV Lanes on Grade Separated Facilities

Facility	Year Opened	Length	Lane Configuration	Priority Rule	Hours of Operation	Comments
San Francisco-Oakland Bay Bridge Approach	1970	0.5 mi.	3 lanes taken from 17 at toll plaza. One lane taken from 6 upstream.	Bus only, 1970 3 or more per car, 1971.	6-9 A.M. inbound 2-6 P.M. outbound.	Queue jumper at toll plaza. Free passage through toll plaza without stopping.
San Francisco-US 101	1974	3.8 mi.	1 lane added to 3.	Bus only, 1974. 3 or more per car, 1976.	6-9 A.M. inbound 4-7 P.M. outbound.	Outbound lane is extension of 4 mile bus only contraflow lane. Free tolls on Golden Gate Bridge.
Honolulu-Moanalua	1974	2.7 mi. inbound 1.4 mi. outbound	1 lane added to 2.	4 or more changed to 3 or more.	All day, both directions.	Low bus volumes.
Boston I-93	1974	0.8 mi. inbound	1 lane taken from 3.	3 or more	6:30-9:30 A.M.	Basically a queue jumper at interchange lane changes.
San Diego-Route 163	1975	0.5 mi. outbound from CBD	1 lane taken from 4.	Bus only	3-6 P.M.	Queue jumper upstream of freeway merge area bottleneck. Additional 0.4 mi. on surface street.
Portland-Banfield Freeway	1975	3.3 mi. inbound 1.7 mi. outbound	1 lane added to 2.	3 or more	All day, changed: 6-10 A.M. inbound 3-7 P.M. outbound	Emergency turnouts at 2,000 ft. intervals.

(Ref.38)

Table 1-2. Characteristics of Concurrent Flow HOV Lanes on Grade Separated Facilities (continued)

Facility	Year Opened	Length	Lane Configuration	Priority Rule	Hours of Operation	Comments
San Francisco-I-280	1975	2 mi.	1 lane added to 3.	3 or more.	All day.	Queue jumper at 4 lane to 3 lane drop.
Miami-I-95	1975	7.5 mi.	1 lane added to 3.	3 or more, changed to 2 or more.	7-9 A.M. inbound 4-6 P.M. outbound. Originally 6-10 A.M., 3-7 P.M.	2,200 per park-ride lot at outer end connected by exclusive bus ramp.
New York City Brooklyn Queens Expressway	1976	1.2 mi.	1 lane added to 2.	Bus and taxi.	7-10 A.M.	Queue jumper upstream of freeway merge area.
Los Angeles-Santa Monica Freeway	1976	12.6 mi.	1 lane taken from 4 or 5.	3 or more.	6:30-9:30 A.M. 3-7 P.M.	Extensive priority ramp metering also used. Terminated by court order after 5 months.
New Jersey-I-95, George Washington Bridge Approach	1976	0.25 mi.	1 lane added to right shoulder.	Bus only	Morning Peak	Queue jumper at toll plaza.
Boston-Southeast Expressway	1977	8 mi.	1 lane taken from 3.	3 or more.	6:30-9:30 A.M.	No endorsement till last 2 weeks.
Seattle-SR 520	1973	1.8 mi.	1 lane (right shoulder) added to 2.	3 or more, changed from buses only.	6:30-9:30 A.M.	Crosses 1 on-ramp and 2 off-ramps.

the idea of taking any capacity away from roads which are already overburdened with commuter traffic.

Table 1-3 summarizes the general characteristics of nine selected concurrent flow projects. These include curb lane and inside lane applications using both add-a-lane and take-a-lane strategies. A combination of bus-only and mixed mode operations is presented.

<u>Grade Separated Facility - Contraflow Lane</u>

Only four projects of this type were implemented in the U.S. during the period of 1970 to 1979 (see Table 1-4). One additional contraflow lane was opened in 1979 on a ten mile section of the North Freeway in Houston.

The two projects in the New York area are on short, severely congested sections on the approaches to tunnels into Manhattan. The four-mile long Route 101 contraflow bus lane in the San Francisco area connects with a concurrent flow priority lane open to buses and carpools.

The Southeast Expressway contraflow lanes in Boston were initially operated both inbound in the morning and outbound in the afternoon. The afternoon outbound lane was abandoned after the first year of operation while the morning contraflow lane operation was discontinued in 1977 with initiation of a concurrent flow, take-a-lane project. The new project on Houston's North Freeway is the longest application of contraflow lanes in the United States. This project also features an intermediate crossover point for HOV's along the facility.

<u>Surface Street - Contraflow Lane</u>

Contraflow lanes have been implemented on a large number of surface streets. HOV's usually obtain more significant improvements than on concurrent flow curb lanes because interference with right-turning vehicles is minimized, as is the use of the lane by violators.

Most contraflow applications have been on one-way streets, although a few projects have applied the contraflow concept to two-way surface streets. In particular, the U.S. 1/South Dixie Highway project preempted a median lane from a divided surface street while the Kalanianaole Highway project imposed a reversible 3-1 lane configuration on an undivided

Table 1-3. Characteristics of Concurrent Flow Surface Street HOV Lanes

PROJECT	LENGTH	LANE CONFIGURATION	PRIORITY RULE	PERIODS OF OPERATION	CURRENT STATUS
Arlington Boulevard (Arlington, VA)	4.5 mi (7.5 km)	1 lane (right shoulder) added to 2 (two-way street)	4+ changed from buses only in 1978	AM & PM Peak Periods	Operational
Broadway/Lincoln St. (Denver, CO)	2.5 mi (4.2 km)	1 lane (right curb) taken from 4 or 5 lanes - (one-way pair)	Buses Only	AM & PM Peak Hour	Operational
Lawrence/Larimer Streets (Denver, CO)	0.5 mi (0.8 km)	1 lane (left curb) added to 4 (one-way pair)	3+	AM & PM Peak Hour	Terminated after 10 months (1975)
Kalanianaole Highway (Honolulu, HI)	0.5 mi (0.8 km)	1 lane (next to median) taken from 3.6 lanes total (two-way)	3+	AM Peak Period	Operational
Main Street (Houston, TX)	0.7 mi (1.2 km)	1 lane (right curb) taken from 3 each direction (two-way)	Buses Only	Peak Periods & Midday	Operational
NW 7th Avenue (Miami, FL)	2.7 mi (4.5 km)	1 lane (next to median) taken from 3.6 lanes total (two-way). Connects to contra-flow lane.	Buses Only	AM Peak Period	Terminated 1976
U.S. 1 - South Dixie Highway (Miami, FL)	5.5 mi (9.2 km)	1 lane taken from (next to median) 3.6 lanes total (two-way)	3+; Buses added 1976	AM & PM Peak Periods	Operational
Wilson Boulevard (Arlington, VA)	2.9 mi (4.8 km)	1 lane (right curb) taken from 3-1 reversible street	Buses Only	AM & PM Peak Periods	Terminated 1980
York Road (Baltimore, MD)	7.3 mi (12.2 km)	1 lane (right curb) taken from 2.4 lanes total (two-way)	Buses Only	AM & PM Peak Periods	Terminated 1977

(Ref.38)

Table 1-4. Characteristics of Contraflow HOV Lanes on Grade Separated Facilities

	New Jersey	Boston	New York	Marin County, California	Houston, Texas
Route	I-495 (approach to Lincoln Tunnel)	Southeast Expressway	I-495 Long Island Expressway	U.S. 101	I-45 North Freeway
Length in miles	2.5	8	2	4	9.6
Year started	1971	1972	1972	1972	1979
A.M./P.M.	A.M.	A.M.	A.M.	P.M.	A.M. & P.M.
Remaining traffic lanes	2	2	2	2	3 or 4
Buffer lane	no	no	no	yes	no
Typical bus volumes	500/pk.hr. 900/pk.per.	35/pk.hr. 70/pk.per.	120/pk.hr. 200/pk.per.	70/pk.hr. 150/pk.per.	NA 60/pk.per. (200 vanpools)
Typical passenger volumes	21,000/pk.hr. 35,000/pk.per.	1,400/pk.hr. 3,000/pk.per.	6,000/pk.hr. 10,000/pk.per.	3,000/pk.hr. 6,000/pk.per.	NA 4,500/pk.per.

Source: D. Link, "Freeway Contraflow Bus Lanes: Some Policy and Technical Issues", <u>Traffic Engineering</u>, January 1975. Updated 1980.

facility. The Barbur Boulevard and NW 7th Avenue projects exemplify the use of reversible center lanes for HOV use. Several project characteristics are summarized in Table 1-5.

Grade Separated Facility - Exclusive HOV Roadway

Facilities of this type provide one of the most distinct HOV priority treatments since HOV lanes are physically separated from regular lanes. They are one of the most expensive forms of HOV priority treatment because major new contruction is required but they experience few of the enforcement and safety problems encountered by the non-separated treatments. Separation techniques range from buffer lanes without physical barriers (e.g., a portion of San Bernardino and Route 580 Freeways in California), to full physical barriers (e.g., a portion of San Bernardino Freeway in California and the Shirley Highway in the Washington, D.C. area), to totally preempted facilities (proposed for I-66 in the Washington, D.C. area).

Table 1-6 summarizes the general characteristics of these four projects. Two of the projects, the Shirley Highway and San Bernardino Freeway express lanes, have been highly successful and documentation has been widely published. The I-66 project, scheduled to open in 1983, represents an effort to provide total priority by reserving all peak direction freeway lanes for HOV use.

Surface Street - Exclusive Facility

The creation of exclusive streets for HOV's has become widespread in recent years. The typical application is a transit mall, on which transit vehicles are given exclusive or near exclusive use. Since the late 1960's, over a dozen transit malls within activity centers have been built or are in some state of development in the United States. During the past several years transit malls have been built in Philadelphia, Madison (Wisconsin), and Portland (Oregon), in addition to the widely acclaimed Nicollet Mall that was constructed in Minneapolis in 1967. These projects are summarized in Table 1-7.

An exclusive in-median surface street HOV treatment operates for 1.5 miles (2.5 km) on Canal Street near the New Orleans CBD. The two-lane, two-way facility accommodates buses only.

Table 1-5. Characteristics of Contraflow Surface Street HOV Lanes

PROJECT	LENGTH	LANE CONFIGURATION	PRIORITY RULE	PERIODS OF OPERATION	CURRENT STATUS
Barbur Boulevard (Portland, OR)	1.8 mi. (3.0 km)	Added reversible center lane. 2 remaining lanes each direction.	Buses Only	AM & PM Peak Periods	Operational
College Avenue (Indianapolis, IN)	2.9 mi (4.8 km)	3 remaining lanes (one-way)	Buses Only	24 Hours	Operational
Kalanianaole Highway (Honolulu, HI)	2.0 mi (3.3 km)	Reversible 3-1. 1 remaining lane for off peak flow. Connects to concurrent flow median lane.	3+	AM Peak Period	Operational
Market Street (Harrisburg, PA)	0.2 mi (0.3 km)	3 remaining lanes (one-way)	Buses Only	24 Hours	Operational
NW 7th Avenue (Miami, FL)	7.3 mi (12.2 km)	Reversible center lane. 2 or 3 remaining lanes each direction. Connects to concurrent flow lane.	Buses Only	AM & PM Peak Periods	Terminated 1976
Ponce de Leon/Fernandez Juncos (San Juan, PR)	6.8 mi (11.3 km)	3 remaining lanes (one-way pair)	Buses Only	24 Hour	Operational
U.S. 1 South Dixie Highway (Miami, FL)	5.5 mi (9.2 km)	2 remaining lanes (two-way)	Buses Only	AM & PM Peak Periods	Terminated 1976. Switched to concurrent flow.

(Ref.38)

Table 1-6. Characteristics of Exclusive HOV Roadways on Grade Separated Facilities

Facililty	Year Opened	Length	Lane Configuration	Priority Rule	Hours of Operation	Comments
Washington, D.C.-Shirley Highway (I-395) Express Lanes	1969-partial 1975-final	11 mi.	2 reversible express lanes in median. 3 and 4 unrestricted lanes in each direction.	4 or more per vehicle	11 P.M.-11 A.M. inbound 1 P.M.-8 P.M. outbound	Radial corridor to CBD. Access ramps at 4 locations along route. Major expansion of express bus service.
Los Angeles-San Bernardino Freeway Express Lanes	1973-partial 1974-complete	11 mi.	2 lanes, 1 on left side of 4-lane unrestricted roadway in each direction, separated by buffer lane.	Buses only, changed to 3 or more in October 1976	24 hours	Radial corridor to CBD. Access ramps at 3 locations. 3 bus stations including 1,000 car park-ride at outer terminus.
I-66 Northern Virginia	1983-Expected	9.6 mi.	All peak direction lanes of 4 lane freeway.	4 or more per vehicle.	A.M. & P.M. Peak Periods	Radial corridor to CBD Access Ramps at 4 locations along route
San Francisco-I-580	1977	4 mi.	2 lanes, 1 on left side of 2-lane unrestricted roadway in each direction, separated by buffer lane.	3 or more per vehicle.	24 hours	

(Ref.38)

Table 1-7. Characteristics of Exclusive HOV Roadways on Surface Streets

SITE	NON-TRANSIT USES	BUS VOLUME	PEDESTRIAN VOLUME	TRAFFIC SIGNAL TREATMENT	MOVEMENT OF GOODS	AMENITIES
MINNEAPOLIS – Nicollet Mall	Taxis Emergency vehicles Bicycles	Peak hr.: Before: 20/ea. way After: 60/ea. way	Before: 1,068/block side/hr., 12-hour period After: 1,114/block side/hr., 12-hour period	Re-set for cross traffic flow (computerized traffic control system scheduled).	Alley loading; mall loading by special permit.	Extensive, including electric snow-melting mats, sign ordinance, bus shelters
PHILADELPHIA – Chestnut Street Transitway	Taxis at night, one block only day Emergency vehicles General traffic (1 block only)	Peak hr.: Before: 43 (one way) After: 41/eastbound 11/westbound	After: 3,016/block side/hr., peak periods on major blocks	Bus-triggered mid-block warning light. Signal timings set for expected bus speed. Timings on nearby street reset.	Cross st. loading; on mall by special permit in off-hours	Typical, with mid-block crossing area.
PORTLAND – Fifth & Sixth Streets Mall	General traffic on one lane for 3/4ths of blocks	Peak hr.: Before: 32 6th Ave. 85 5th Ave. Expected After: 207 6th Ave. 211 5th Ave.	Before: 444 6th Ave./ 686 5th Ave./ block side/hr., off-peak periods.	Computer controlled with progression to be adjusted for buses.	Cross st. loading; on mall by special permit in off-hours	Extensive, including bus shelters and concession booths, CRT information display.
MADISON State Street Mall/ Capitol Concourse	General traffic on Capitol Concourse	Peak hr.: Before: 60 (2-way on State St., 1-way on Capitol Square)		On Capitol Square set to make leaving concourse difficult.	Loading on alleys, cross streets, some curbside during restricted hours.	Typical

(Ref.70)

Separated Right-of-Way - Exclusive HOV Roadway

One such project has been implemented. This project, the South PATway in Pittsburgh, was constructed primarily using available trolley right-of-way. The 4.5 mile (7.5 km), two-way bus-only facility jointly shares about half of its length with trolley vehicles, including a refurbished transit tunnel leading to the Pittsburgh CBD. A 7 mile (11 km) East PATway in Pittsburgh, scheduled to open in 1983, is being constructed along unused rail right-of-way. Available right-of-way parallel to I-205 in Portland, Oregon is being constructed as an exclusive HOV facility.

Ramp Meter Bypass Lane

The first ramp meter bypass lane was installed in Los Angeles in 1973. By 1980, the number had grown to over 100 and plans for expansion of the concept call for increasing the number of bypass lanes to 350 by 1983. Implementation of the bus and carpool priority concept in Los Angeles was facilitated by the fact that a large number of entrance ramps already were controlled by metering signals. Also at many of the locations there were two lanes on the approach to the ramp signal so no ramp widening was needed to accommodate the priority vehicle bypass lane.

Minneapolis is the only other city that has made a major commitment to the freeway entrance bypass concept with nine locations implemented in 1974-75 along the I-35W Freeway as part of a freeway corridor surveillance and control project.

Exclusive HOV Ramp

Progress in the implementation of exclusive freeway ramps has been largely limited to special situations. Exclusive ramps have been installed in eight cities. Ramps in New York (I-495), Washington (Shirley Highway), Los Angeles (El Monte Busway), and Miami (I-95) are integral parts of freeway priority lane projects. The Los Angeles and Miami exclusive ramps provide direct connection for HOV's between major park-and-ride lots and the priority lanes.

In Seattle, exclusive ramps in the CBD are provided for buses and carpools entering the mixed-mode reversible center roadway of the I-5 Freeway. In Reston, a Northern Virginia suburb of Washington, D.C., express buses and carpools (allowed 1980) enter and exit the Dulles Airport Access Road on exclusive ramps. A special bus ramp is provided at Chicago's O'Hare Airport which saves buses almost one mile in entering the Kennedy Expressway after circling through the airport to pick up and discharge passengers.

Signal Priority

Implementation of HOV priority signal techniques has not developed as rapidly in the United States as has the implementation of HOV priority lanes. The use of fixed time adjustments (e.g., phasing changes, offset adjustments) to favor HOV's has been virtually non-existent in the U.S., although widespread in Europe. One of the few U.S. locations to have implemented priority fixed time signal plans was in Miami where timing was computed by weighting buses in accordance with estimated passenger loads.

Emphasis in this country has focussed on signal preemption systems, several of which are characterized in Table 1-8. Two of the largest systems implemented to date in Washington, D.C., and Miami were experimental projects which have since been discontinued. Recently, however, implementation of preemption systems seems to be accelerating. Systems in Sacramento, Concord and Santa Cruz, California were made operational in 1976 and 1977. Systems in Dallas, Houston, Memphis, Santa Clara, and Portland (Oregon), are in various stages of development and implementation.

Priority Parking

Priority parking treatments for HOV's have been implemented in various forms in most major cities in this country. Nearly every HOV priority treatment on grade separated facilities has involved the opening of new park and ride lots. Park and ride lots have also been instituted in response to new or expanded express bus services. The growth of carpooling has created a need for park and pool facilities as well. The construction of new parking facilities has been complemented with the use of portions of existing parking lots, such as those at shopping centers, theaters and churches.

Within activity centers, priority parking for HOV's is a relatively new concept. Specially designated close-in spaces for carpools are found at the Pentagon and other government agencies in Washington, D.C. Seattle, Washington and Portland,

Table 1-8. Characteristics of Selected Bus Preemption Signal Systems

Location	Date Implemented	Length	Number of Signals	Priority Technique	Comments
Louisville 2nd & 3rd Street Contra Flow Lanes	1972	4.5 mi.	8	Siganl pre-emption	OPTICOM system. Only at selected intersections along routes
Washington, D.C. Downtown Network	1972	Grid	34 (part of 111 intersection network)	Signal pre-emption	UTCS/BPS computer based control system. FHWA research project. System removed after completion
Miami - NW 7th Avenue	1974	10 mi.	35	Siganl pre-emption and bus priority signal timing	Express buses in median reserved lane. system removed after buses transferred to I-95 freeway priority lane
Sacramento Greenback Lane	1975	3.8	9	Signal pre-emption	OPTICOM system at a series of isolated, full activated signals
Concord, Cal.	1977	3.5	12	Signal pre-emption	OPTICOM system
Houston Westheimer-Richmond Corridor	1982 Installation Planned	?	20	Signal pre-emption	OPTICOM system
Dallas	1978	Grid	46 (part of 62 intersection network)	Signal pre-emption	Computer based systems similar to UTCS/BPS. 38 signals on 3 arterials and 8 signals on freeway frontage road

(Ref.46)

Oregon have initiated special CBD carpool lots. Seattle also restricts certain on-street metered spaces for registered carpools. A priority vanpool (i.e., eight or more persons) parking program was implemented within the San Francisco CBD in 1979. Almost all of these activity center parking projects have also included reduced parking charges for HOV's.

Priority Pricing

Priority pricing strategies directly relevant to HOV's have usually been applied either in the form of reduced roadway tolls or reduced parking charges.

Prime locations for toll collections are across natural boundaries such as a river or a mountain where very few alternative routes exist.

Examples include the Golden Gate Bridge, the San Francisco-Oakland Bay Bridge, and six Hudson River crossings leading into New York City where reduced HOV tolls are collected. Reduced HOV tolls can also be imposed along major radial grade separated facilities which offer large time savings to users. An example is the Connecticut Turnpike which offers carpools cost savings through a maximum of three consecutive toll plazas.

Reduced parking charge strategies are most applicable in activity center locations where general parking rates are high. Government agencies and major employers have taken the lead in promoting reduced HOV parking rates as an incentive for its employees to carpool.

Other HOV related pricing strategies have also been considered in several locations, including elimination of employee parking subsidies, parking tax surcharges, carpool tax incentives, activity center licensing, gasoline taxes, and vehicle purchase or registration taxes. Several of these treatments can be applied on a regional basis.

SUITABILITY OF HOV PRIORITY TREATMENTS

HOV priority treatments are suitable for application over a wide range of urban area sizes, as shown in Figure 1-8. Several applications of HOV treatments such as park and ride facilities and signal priority have been applied in small urban areas with moderate levels of transit service. On the other end of the scale, major HOV lane projects can complement light rail and/or heavy rail systems in accommodating

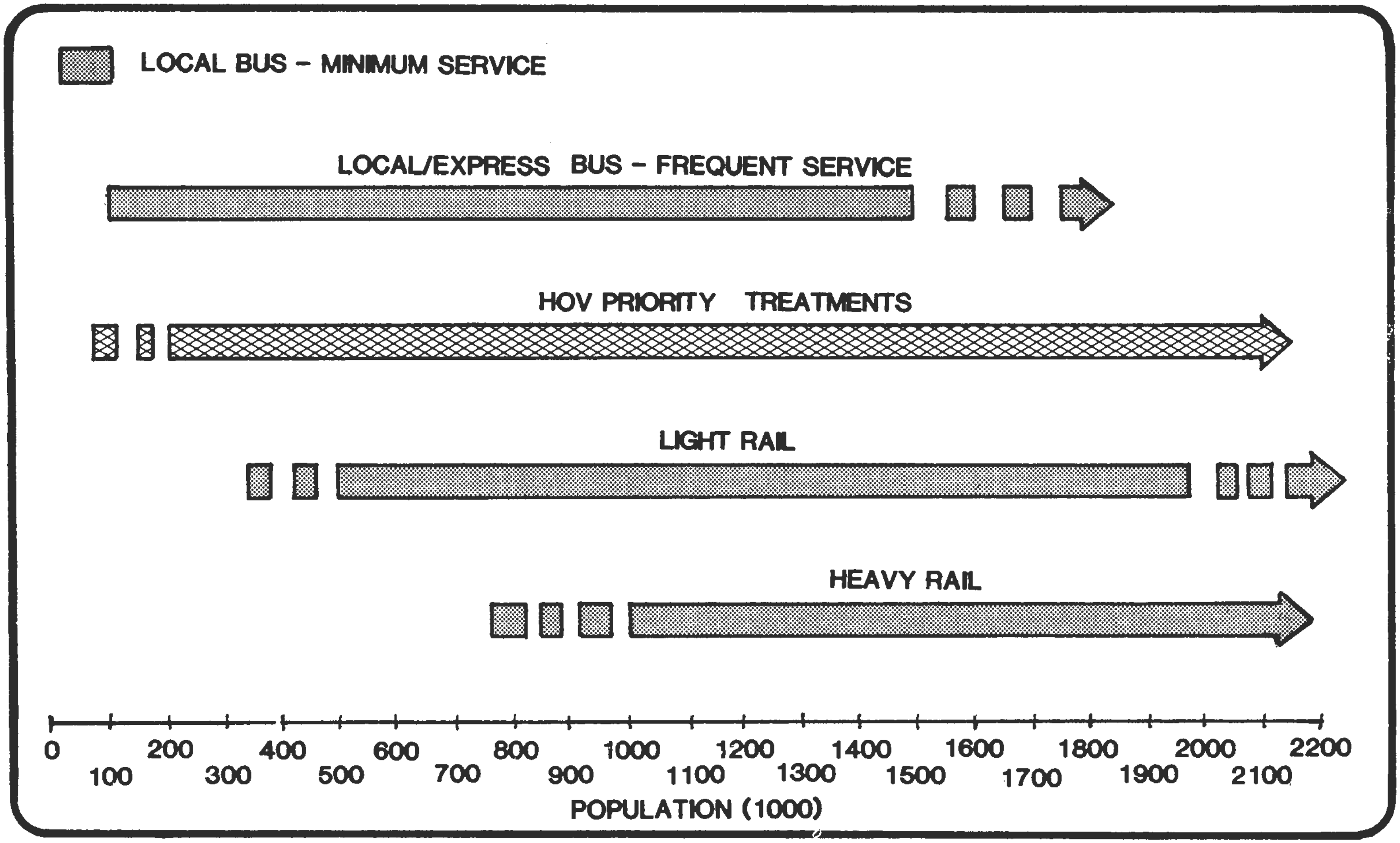


Figure 1-8. Suitability of HOV Treatments

major volumes of persons. HOV treatments which address small area transportation problems can be feasibly applied in many different urban areas.

HOV LEGAL BASIS

The legal basis for instituting and enforcing HOV priority treatments does not seem to present any insurmountable problems. As a general rule, HOV treatments fall within the typical police powers of the state (Ref. 30). Some question still remains as to whether it is necessary to enact special statutes to authorize particular agencies to conduct an HOV project.

An HOV project can be the legal responsibility of the state, county or local government. In most cases, the state exercises the greatest amount of power to carry out an HOV project. Local governments are usually much more legally restricted, but can be specifically authorized by a state legislature to conduct HOV projects. The amount of local authority varies greatly from state to state, depending upon the amount of home rule authorized in the basic law of the state. In strong home-rule states, the traffic ordinances of adjoining local jurisdictions may conflict causing legal disputes to arise regarding the implementation of HOV priority treatments. Table 1-9 depicts the responsibility and legal authority for several HOV priority treatments.

SUMMARY

A high occupancy vehicle (HOV) is a vehicle which carries at least a minimum specified number of persons. It can be a transit vehicle, a carpool or vanpool. The objectives of HOV priority treatments are 1) to induce mode shift, 2) increase person-carrying capacity of highway corridors, 3) reduce total person travel time, 4) reduce or defer the need to construct additional highway capacity, and 5) improve the efficiency and economy of public transit operations.

There is a wide variety of HOV priority treatments. These have been classified into seven basic HOV treatment types which can be applied either on grade separated facilities, surface streets or separated rights-of-way. Many of these treatments are suitable for implementation over a wide range of city sizes and in conjunction with several transportation modes.

Table 1-9. Responsibility and Legal Authority for Selected HOV Projects

	PROJECT	HOV CODE*	RESPONSIBILITY: Legal Responsibility	RESPONSIBILITY: Enforcement Responsibility	LEGAL AUTHORITY: General Legislation	LEGAL AUTHORITY: HOV General Legislation	LEGAL AUTHORITY: Specific Project Legislation
FREEWAY	Shirley Highway - Washington, D.C.	1	state	state		x	
FREEWAY	Interstate 95 - Miami	2	state	state	x		
FREEWAY	Banfield Freeway - Portland	2	state	state		x	
FREEWAY	Route 101 - San Francisco	2	state	state		x	
FREEWAY	Route 101 - San Francisco	3	state	state		x	
FREEWAY	North Central Expressway - Dallas	4	state/city	city		x	
FREEWAY	Interstate 35W - Minneapolis	4	state	state	x		
FREEWAY	Santa Monica Freeway - Los Angeles	4	state	state		x	
FREEWAY	Interstate 5 - Seattle	5	state	state/city	x		
FREEWAY	San Francisco/Oakland Bay Bridge	6	state	state		x	
ARTERIAL	Nicollet Mall - Minneapolis	A	city	city			x
ARTERIAL	Elm/Commerce Streets - Dallas	B	city	city		x	
ARTERIAL	Washington CBD - Washington, D.C.	B	district	district			x
ARTERIAL	US 1/South Dixie - Miami	B	state	city/co.	x		
ARTERIAL	US 1/South Dixie - Miami	C	state	city/co.	x		
ARTERIAL	Marquette/Second Streets - Minneapolis	C	city	city			x
ARTERIAL	Ponce de Leon/Fern. Juncos Aves.-San Juan	C	state	city	x		
ARTERIAL	NW 7th Avenue - Miami	D	state	city/co.	x		
ARTERIAL	NW 7th Avenue - Miami	E	state	city/co.	x		

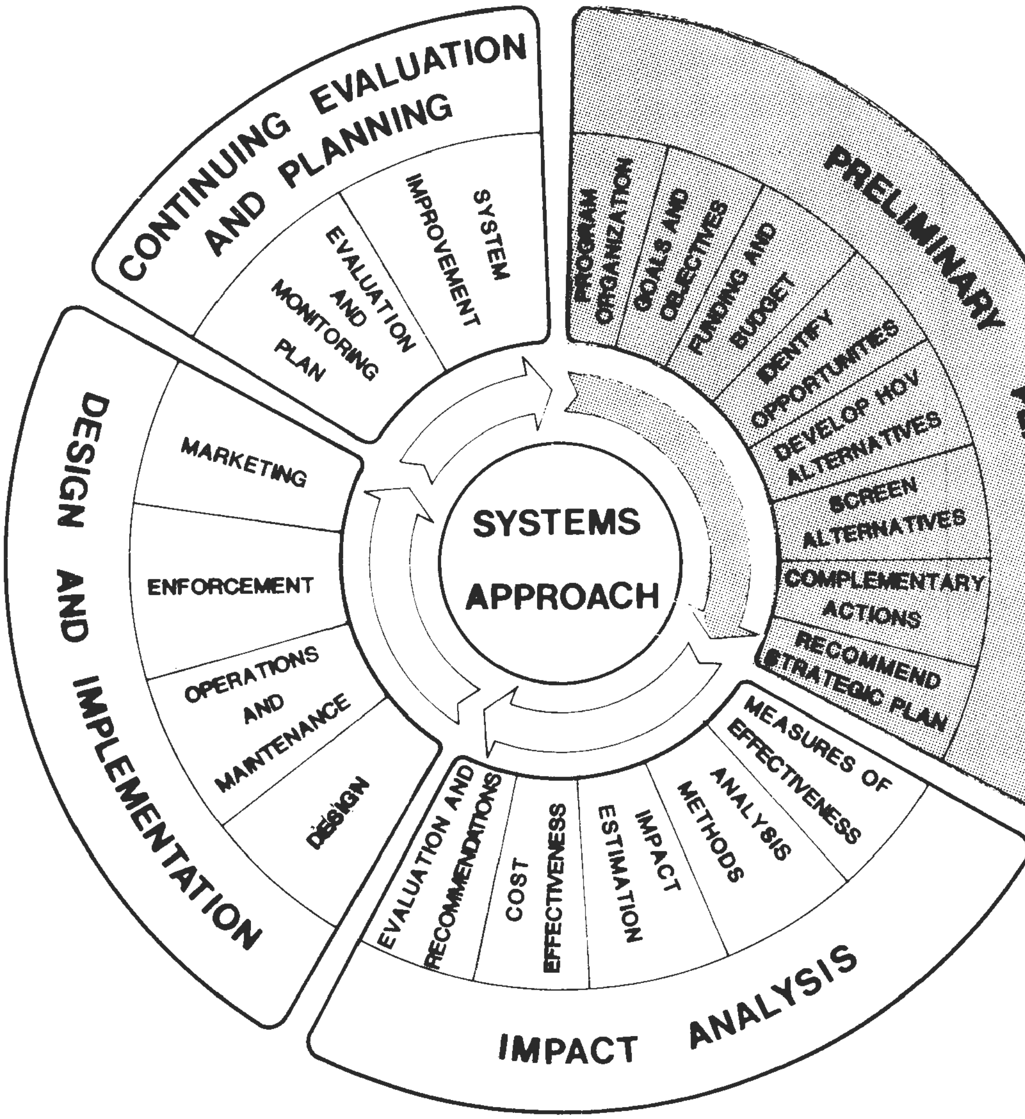
*FREEWAY
1. Separate Roadway
2. Concurrent Lane
3. Contraflow Lane
4. Ramp Metering Bypass
5. Exclusive Ramp/Access
6. Toll Plaza Lane

*ARTERIAL
A. Separate Facility
B. Concurrent Lane
C. Contraflow Lane
D. Reversible Lane
E. Bus Pre-emption

(Ref.30)

As a general rule, HOV treatments fall within the typical police powers of the state. Some question still remains as to whether it is necessary to enact special statutes to authorize particular agencies to conduct HOV projects.

2. PRELIMINARY PLANNING



2. PRELIMINARY PLANNING

INTRODUCTION

Although discussed somewhat independently below, the planning for specific HOV treatments and HOV systems should be done as an integral part of other transportation planning activities in the region. The initial phase of activity is preliminary planning. Preliminary planning for HOV treatments is conducted from an areawide perspective and with an eye toward the intermediate and longer-range applicability and importance of HOV priority treatments in the area. Thus, it may be thought of as the strategic plan development phase.

One of the major purposes of preliminary planning is to develop an overall urban area approach to the application of HOV priority treatment concepts. Of equal pertinence, however, is the determination of the most important first steps (or next steps in the case of a continuing program) to be considered prior to detailed analysis and implementation of HOV priority treatment projects. The product of preliminary planning is a determination of which corridors or subareas should receive the greatest stress and which narrowed-down range of HOV priority alternatives should be seriously considered for these locations.

An approach to preliminary planning is described in this chapter. This approach is structured around a straightforward series of tasks, which parallel the activities of areawide transportation planning. The tasks are as follows:

1. Establish Organizational Responsibilities - This task involves establishing organizational responsibilities for HOV project development within the existing interjurisdictional policy structure. This also includes structuring an approach to community participation specifically for these types of projects.

2. Refine Goals and Objectives - This task requires a full awareness and understanding of broader urban area policy goals and objectives and leads to a specific subset of objectives aimed at providing priority treatment for HOV's.

3. Determine Funding Mechanisms and Budget Constraints - This task will establish which

jurisdictions have the responsibility, willingness and ability to participate in funding the implementation and continuing operation and maintenance of the HOV priority projects within the program.

4. Identify Facility Opportunities - This task will ascertain which corridors, subareas, and point locations which are experiencing congestion problems have the greatest opportunities for successful development of HOV priority treatment projects.

5. Develop HOV Treatment Alternatives - This task specifies, for the most important corridors, subareas, or point locations determined above, the possible types of HOV priority treatments that should be given preliminary consideration.

6. Screen HOV Treatment Alternatives - During this task, the HOV treatment alternatives identified above will undergo a preliminary screening process to be narrowed down to a smaller set of alternatives which are serious contenders for implementation, and which warrant a more detailed analysis along with other (non HOV) transportation alternatives.

7. Consider Complementary Actions - This task establishes potential ways to encourage the expanded utilization of HOV's through instituting or expanding complementary HOV treatments either areawide or within a specific corridor or subarea.

8. Recommend a Strategic Plan - A plan will be formulated in this task which recommends a strategic approach to HOV priority facility development for the urban area. It will recommend immediate pursuit of specific HOV concepts or strategies in selected corridors and subareas during detailed alternatives analysis.

ESTABLISH ORGANIZATIONAL RESPONSIBILITIES

Planning HOV treatments requires an effective program organization. An effective organization includes the proper structuring of policy and technical activities as well as a comprehensive procedure for community participation.

Policy and Technical Activities

Responsibility for planning HOV priority treatment projects may be: (1) assigned to a single existing agency, either as a separate function or as a part of its regular operations; or (2) divided among several existing agencies, such as the local or state highway agencies and an enforcement agency. The agencies most likely to be involved in a project include local and state planning and operating agencies, traffic enforcement agencies, and regional planning organizations with support from Federal agencies. Any regional ridesharing agency should also be an active participant. In all cases, the agency or agencies sponsoring a project will have to determine an appropriate and acceptable mechanism for allocating policy-making responsibilities for project implementation (Ref. 36).

When planning responsibilities are divided among two or more agencies, a means of coordination is essential. In most cases mechanisms for coordination already exist. An interagency team is one approach. The size of the project team should depend on the scope of the preliminary planning effort and the number of jurisdictions involved.

Each participating organization should designate someone to serve as a liaison for the coordination of project activities, if this is not provided for by existing organizational structure. A Program Manager should be appointed by the chief administrative officer(s) to represent top-level concerns and direct the project in a manner which minimizes uncoordinated actions by project team members (Ref: 36).

An ad hoc steering committee formed specifically for providing guidance in HOV aspects of the program can be a useful and more informal method for building cooperation. The committee can provide a forum in which technical and administrative issues are discussed across functional and jurisdictional lines. Such a committee encourages voluntary coordination and informal exchange.

The regional planning organization (i.e., MPO) will usually take the lead in strategic plan development. In addition, the MPO will normally provide the organizational framework for interagency coordination and will ensure that all jurisdictions and functional interests are adequately represented. Finally, the MPO is typically responsible for coordinating the use of Federal funds among the agencies which it serves.

Community Involvement Program

Community involvement should be an integral part of an HOV project from the preliminary planning stage to the evaluation of a project after implemention. The community, both potential users and non-users of an HOV treatment, should have the opportunity early-on to inform planners of their needs and objectives. This involvement will help generate citizen and political understanding and support for potential projects. Community involvement is also a refinement for receipt of Federal funding.

The community involvement program contains two primary activities - identification of interest groups, and the establishment of a community participation mechanism. The major aspects of these activities are described in the following sections. A detailed presentation is given in Reference 36.

Interest Groups and Public Attitudes

HOV priority treatment projects can have high visibility and can often be controversial. As such, they attract the attention of a variety of community interest groups such as:

- Elected or appointed officials;
- Citizen and community organizations;
- Representatives from business, labor, management, and industry;
- Community institutional leaders.

Each of these interest groups should be included in all or some of the HOV planning activities. The manner in which these groups are effectively included in the HOV planning process is determined by various participation mechanisms.

Participation Mechanisms

Community planning participation mechanisms may take several forms depending on the level of involvement. Figure 2-1 shows that at the regional level elected officials or their alternates are the primary participants. Elected or appointed officials must be fully briefed on HOV priority treatment projects as they may well bear the political fallout from angry constituents. Therefore their support is vital and can only be gained if they are fully cognizant of the project (Ref. 36).

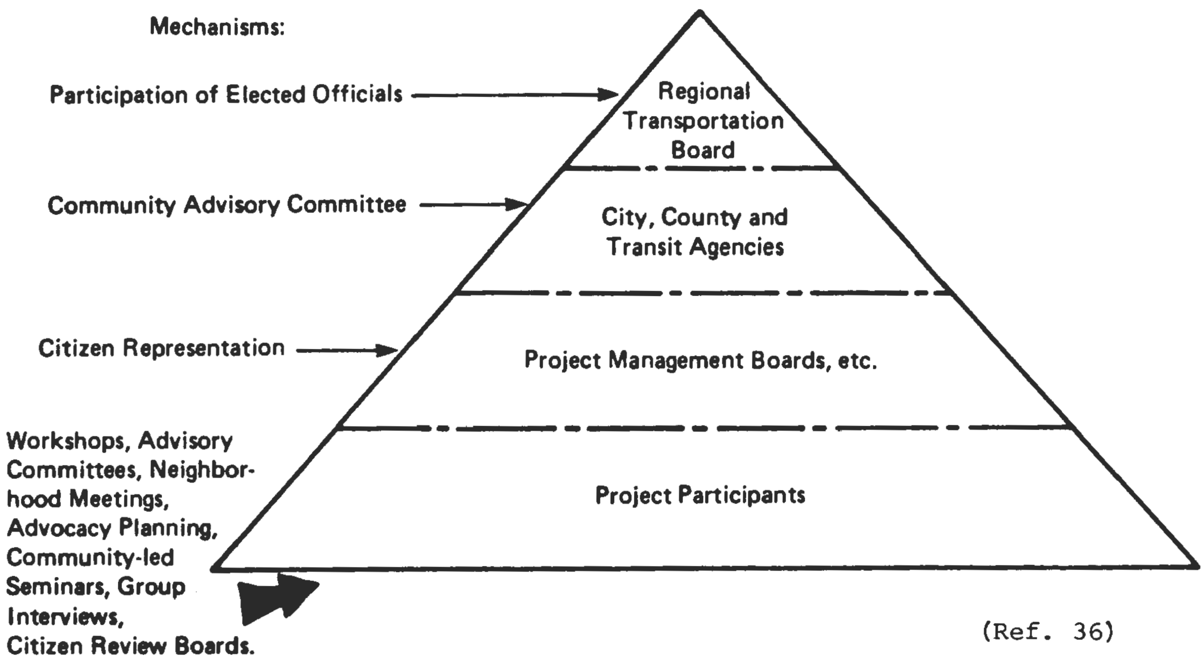


Figure 2-1. Participation in HOV Planning

Private citizen involvement may include some decision-making responsibilities, such as membership on a project management board. Citizen involvement at the neighborhood level is also important in varying capacities. This includes participation in workshops, advisory committees, neighborhood meetings, advocacy planning, community-led seminars, group interviews, and citizen review boards.

Public information meetings during the planning process are highly desirable and often required. Such meetings provide the opportunity for the public to gain an understanding of potential projects and lend its support. They also can result in useful suggestions for fine tuning selected projects prior to and during implementation. Many priority treatment projects will require a formal public hearing process because of the funding involved or the magnitude of the project.

Proper structuring of the community involvement program early in the planning process eases the way to formal interjurisdiction agreements later in HOV project design and implementation. The specifics of interagency agreements are discussed in Chapter 5.

REFINE GOALS AND OBJECTIVES

At the local and regional level, formal goal setting processes have long been part of the transportation planning process. Goals are statements of idealized ends which provide direction. Goal statements usually include terms such as "improve," "maximize," "conserve," etc. Objectives are developed from goals for evaluation purposes. They should be measurable, that is able to be quantified or qualified. Associated with each objective are criteria and related measures of effectiveness (MOE's) which are used to evaluate a project in terms of the degree of objective attainment.

The development of objectives for HOV projects must address two key issues:

1. What are the fundamental transportation/land use goals of the region?; and

2. How does the concept of HOV priority treatments relate, if at all, to these fundamental goals?

Too often specific project objectives are developed independent of the broader policy goals of the region. In fact, they should be refinements of these broader goals and objectives.

General Urban Policies

As part of the process of setting goals and objectives it is of utmost importance for the planning team to help articulate the urban area's general policy toward HOV priority treatments. The present and emerging transportation conditions in different urban areas are highly variable and result in differences in the "climate" for an HOV priority treatment program.

In some small and medium-sized urban areas few opportunities for HOV priority treatments may exist, and they may be a relatively minor ingredient of the total transportation system development policy. In other larger metropolitan areas, however, there may be many opportunities, and high importance may be placed on an aggressive, comprehensive program of HOV priorities as one of the cardinal elements of transportation policy. The policy-makers and technical planning staff both need to forge a clear consensus on the underlying urban area importance of an HOV priority treatment program. To this end, an explicit policy statement should be drafted and agreed upon by all major jurisdictions and functional agencies who are to participate in the HOV priority treatment program. To illustrate possible contrasting policies of different urban areas, three example policy statements are given below.

Example Policy Statement #1 (Low Importance):

"The need for and opportunities to implement HOV priority treatments are very limited in the ____(name)______ urban area. There are no critical corridor transportation service problems that could be substantively influenced by HOV priority treatments. The HOV priority concept should be applied on a limited, specialized, and economic basis, mainly to increase the efficiency of public transit operations in the downtown area and on a few very important line haul routes."

Example Policy Statement #2 (Moderate Importance):

"HOV priority treatments are of emerging and potentially growing importance in the ___(name)_ urban area. Moderate congestion and capacity deficiency problems are apparent in several corridors and these are likely to worsen as population and land-use growth occurs in selected corridors. The HOV priority concept is viewed as an important element of maintaining and expanding transportation service capacity to a vital and thriving central area in a cost-effective manner. A program starting with relatively low-cost pilot projects and aimed at a longer-range broader program of both low-cost and capital-intensive HOV priority treatments should be pursued."

Example Policy Statement #3 (High Importance):

"The _____(name)________ urban area is faced with extreme problems, such as: congestion and capacity deficiency in several major cooridors; decreasing bus service due to congestion; air quality problems; energy supply and price of energy grow worse; and financial resources of the transportation agencies are stretched thin. A HOV priority treatment program is of utmost importance as an essential ingredient of urban area transportation policy.

Aggressive actions to maximize the use of both low-cost and capital-intensive HOV priority treatments should be pursued."

HOV Specific Goals and Objectives

In most cases, regional transportation goals have been established by the State Transportation Agency, the Metropolitan Planning Organization, or other regional agencies. As shown in Table 2-1, each of these transportation goals have associated objectives which cover a full range of situations and problem areas characteristic of urban transportation systems.

HOV project objectives are specific applications or refinements of these more general transportation objectives. Table 2-1 presents a series of HOV project objectives, some or all of which may be suitable for particular HOV planning projects. Table 2-2 presents examples of HOV objectives developed for three HOV projects.

These specific project-level objectives serve a number of useful purposes:

- They allow the project planners to focus their activities;
- They provide the agency and general public with the rationale for the project and hopefully the means by which support can be developed; and
- They establish yardsticks against which the project can be evaluated.

The measures of effectiveness (MOE's) associated with these HOV project objectives are discussed in Chapter 3 - Impact Analysis.

DETERMINE FUNDING MECHANISMS AND BUDGET CONSTRAINTS

Preliminary planning of HOV projects should not be totally constrained by existing funding constraints. It is important to consider HOV priority treatments as part of a regional set of transportation alternatives. Therefore, HOV treatments should be eligible for funding from various regional funding sources, not just from a designated "HOV" fund.

Where moderate or long range implementation times are foreseen, HOV treatments should be identified which

Table 2-1. Goals and Objectives

TRANSPORTATION GOAL	TRANSPORTATION OBJECTIVE	HOV PROJECT OBJECTIVE
1. To maintain and/or improve the quality of transportation services on the existing transportation system.	● To reduce the travel time required for the movement of persons and goods on the existing transportation system. ● To reduce the travel costs required for the movement of persons and goods on the existing transportation system. ● To improve the safety of the existing transportation system. ● To improve the security of the movement of persons and goods on the existing transportation system. ● To improve the comfort and convenience of the existing transportation system. ● To improve the reliability of the movement of persons and goods on the existing transportation system.	● Improve trip time for HOV's. ● Maintain or improve non HOV trip time. ● Increase bus frequency in peak period without lowered occupancies. ● Reduce bus delays. ● Improve bus reliability. ● Improve service for transit dependents. ● Improve transit incentives for newly developed residential areas. ● Reduce occurrence of traffic accidents. ● Reduce injuries and deaths resulting from traffic accidents.
2. To increase the efficiency of the existing transportation system.	● To reduce automobile usage in the immediate future. ● To increase transit patronage in the immediate future. ● To increase pedestrian and bicycle travel in the immediate future. ● To increase the person movement capacity of the existing transportation system to adequately serve demand. ● To increase transportation system productivity.	● Provide an adequate level of enforcement. ● Increase number of carpools. ● Increase average vehicle occupancy. ● Increase transit patronage. ● Increase transit occupancy. ● Improve transit system productivity. ● Increase facility person throughput capacity.
3. To minimize the cost to improve the quality of service on, and efficiency of, the existing transportation system.	● To minimize the capital costs of improving the existing transportation system. ● To minimize the operating costs and deficits of the existing transportation system.	● Reduce the need for alternate facilities to accommodate current or future trip demands. ● Reduce transit operating costs. ● Reduce carpool operating costs.
4. To minimize the undesirable environmental impacts of existing transportation facilities and services.	● To reduce existing transportation system noise and vibration impacts. ● To reduce existing undesirable transportation system air quality impacts. ● To reduce existing transportation system energy consumption.	● Reduce noise and vibration. ● Reduce air pollution. ● Reduce energy consumption.
5. To promote desirable and minimize undesirable social and economic impacts of existing transportation facilities and services.	● To provide adequate service to the transportation disadvantaged and transit dependent. ● To promote desirable and minimize adverse economic impacts due to improvements in the existing transportation system. ● To equitably distribute transportation service and costs. ● To minimize the displacment of residences, businesses, and community facilities due to improvements to the existing transportation system.	● Improve service for the transportation disadvantaged and transit dependent. ● Minimize disruption to goods movement. ● Improve center city environment and economic viability. ● Minimize disruption of access to adjacent businesses and residences.

Table 2-2. Examples of HOV Project Objectives

Shirley Highway (I-395) - Washington, D.C.

Primary objective - Demonstrate to state and local transportation authorities that express bus-on-freeway operations can improve the quality of bus service and lead to an increase in the people moving capability of peak period transportation facilities for an entire urban corridor. Related project objectives were:

- Increase reliability of bus service.
- Reduce travel time for transit and auto commuters.
- Increase coverage by bus routes.
- Increase bus passenger convenience and comfort.
- Increase bus patronage.
- Increase bus's share of corridor commuters.

Secondary objective - Demonstrate that this technology can have a favorable impact on the transportation-related environmental and social conditions with a corridor and on the economic condition of the transit operator. Related project objectives were:

- Reduce peak period auto pollutant emissions.
- Reduce peak period gasoline consumption.
- Increase mobility of the transportation disadvantaged.
- Increase productivity of the bus operator.

I-95/N.W. 7th Avenue - Miami, Florida

- Increase the use of public transit;
- Reduce bus travel time for express buses operating on an arterial street;
- Reduce schedule variability for express buses operating on an arterial street;
- Effect a modal shift from autos to express buses operating on an arterial street; and
- Increase the passenger carrying capability of N.W. 7th Avenue.

Banfield Freeway HOV Lanes - Portland, Oregon

- Assist in implementing the State of Oregon Clean Air Act Implementation Plan, Portland Transportation Control Strategy, by increasing the person per vehicle ratio on the Banfield.
- Provide for carpooling and bus-use incentives in the corridor through use of HOV lanes.
- Reduce traffic congestion on the Banfield Freeway and adjacent arterial streets.
- Provide a safe transportation facility by improving the roadway surface.
- Provide a time and fuel savings to the traveler.
- Provide an interim, low-cost improvement to the Banfield as an expedient, until such time as a major revision can be accomplished.

fill a need in the region. In such cases funding programs and budgets can be changed if there is a demonstrated need.

From a practical standpoint in the short term it is critical to determine potential funding needs, budget constraints and related funding mechanisms for a HOV project during the preliminary planning stage. Knowledge of these factors could possibly affect the selection of specific HOV treatments for implementation. In particular, the availability of Federal funding for reconstruction and other capital improvements may allow certain HOV treatments to be considered which otherwise may have been eliminated due to budget constraints. Federal funding is also available for selected planning activities associated with such projects.

Priority lanes for HOV's can be added to routes on the Federal-aid Primary, Urban and Secondary Systems at the Federal participation level for those systems. The HOV lanes can be added to completed Interstate routes under certain conditions. Supplement 2A discusses the eligibility of Federal-aid highway funds for transportation system management projects, including HOV priority treatments. Various aspects of HOV facility design and construction are eligible for funding. Recent guidelines have broadened the eligibility definition to consider such related costs for signing, leasing of parking spaces for HOV's, bus shelters, and initial costs for enforcement, marketing and evaluation of the projects.

Federal funding mechanisms should be explored in conjunction with existing or planned state and/or local funds. Available local funds may vary considerably between jurisdictions. This availablility is a function of the budget process used in each location as well as the willingness of each jurisdiction to support HOV objectives by financial participation in the projects. Often more complex funding availability situations can arise between states where a proposed HOV treatment crosses state lines.

Timing is another important factor. Since agency budgets are typically prepared annually, the initial funding of HOV projects can vary accordingly. Once a project is implemented, its effectiveness can be heavily determined by the amount of continuing money available for operations, maintenance and enforcement. In some situations, a special budget fund has been established for specific HOV projects.

The early awareness of potential funding difficulties and possible solutions permits sound financial decisions to be made throughout the development process for each HOV project. Funding applications should be submitted early to allow sufficient lead time necessary for the required "paper processing" through the appropriate agencies.

IDENTIFY FACILITY OPPORTUNTITIES

The identification of transportation improvements in a region can include several classes of alternatives. These can be areawide alternatives such as transit service improvements, carpool matching programs, vanpool programs, etc., or they can relate to specific locations or facilities. As shown in Table 2-3, the set of options for specific locations or facilities combines either a Build or No Build decision with or without HOV priority. Within a given corridor or activity center, some or all of these combinations may be feasible. HOV priority treatments must therefore be identified in light of potential non HOV improvements as well as the null, or "no-build" condition.

Table 2-3. Transportation Alternatives

	No Build	Build
Without HOV Priority	Null	Additional facility capacity for all vehicles
With HOV Priority	Existing facility capacity (e.g., take-a-lane, signal priority)	Additional facility capacity for HOV's (e.g., add-a-lane)

In order to fully assess the opportunities for providing HOV priority treatments, both a regional level and facility level analysis should be conducted during preliminary planning. The regional level analysis looks at the region and identifies potential areawide HOV applications and major travel movements within corridors and activity centers. The facility level analysis then focusses on specific facilities which show potential for HOV treatments.

Regional Level Analyses

Regional level analyses of major travel movements should be readily available in most urban areas. The regional transportation planning process (3-C), through its Transportation System Management (TSM) element and the Transportation Improvement Program (T.I.P.), will often have identified these travel movements as well as specific candidate facilities. These pre-existing studies should be supplemented with local knowledge of travel movements within a particular corridor or activity center.

Facility Level Analysis

After a regional level analysis has been performed, the identification of facility level opportunities is possible. Several activities are involved in this procedure as shown in Figure 2-2.

1 - Identify Candidate Facilities

Within each of the major travel movements, specific locations can be identified which exhibit one or more of the following conditions.

- o Radial facilities with recurring congestion due to high traffic volumes;
- o Bottlenecks such as bridges or tunnels that experience congestion;
- o Activity center streets which serve as primary transit routes;
- o Major traffic generators which provide large parking facilities;
- o Congested ramps to/from grade separated facilities;
- o Signalized intersections which show significant

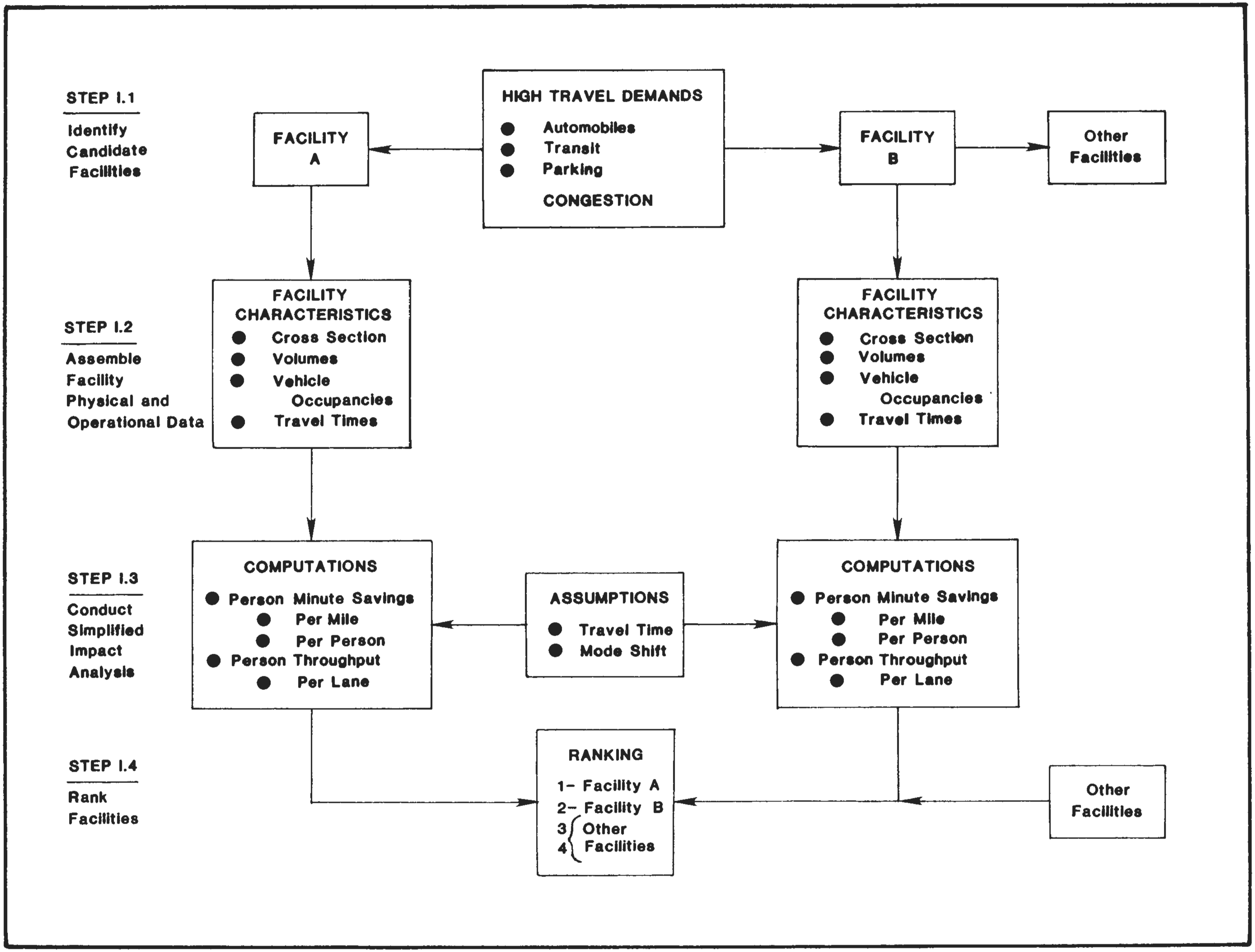


Figure 2-2. Identification of Facility Opportunities

traffic delay.

This analysis should include examination of both extended as well as spot locations of congestion.

2 - Assemble Physical and Operational Data

A limited amount of data collection is required to identify those sites that have the highest HOV treatment potential. This data would include the following:

- Facility length;
- Number of lanes;
- Peak hour or peak period total traffic volumes;
- Peak hour or peak period transit volumes;
- Average vehicle occupancy (transit and auto);
- Typical auto and transit travel times for similar length trips (peak and off-peak);
- Average auto and transit trip speeds (peak and off-peak);
- Delay at signalized intersections.

This data will enable initial impact analyses and facility screening to be conducted. The data will also serve as a good base for identifying alternative HOV treatments for specific facilities.

3 - Conduct Initial Impact Analyses

Once this initial data is assembled, selected analyses can be performed to determine which facilities are most likely to benefit from HOV priority treatment. At this level of analysis, potential person-minute savings and person throughput changes are the most important factors to consider.

Since these analyses will only be used to make relative or order of magnitude comparisons between different facilities, some simplified assumptions can be made for travel time changes and mode shift. For example, it could be assumed that priority treatment would allow HOV's to maintain off-peak travel times throughout the day. Similar assumptions for mode shift can also be made. These assumptions must be consistently applied for all facilities under consideration to provide a basis for comparison.

Using the available travel time and volume data plus the assumptions described above, estimates of person-minute savings and changes in person throughput can be calculated for each facility. The person-minute savings should then be translated into person-minute savings per mile and per person. Similarly, person throughput changes per lane can be computed. These values will allow facilities with varying lengths, width and volumes to be readily compared.

4 - Rank Facilities

Using the results of these initial impact analyses, the candidate facilities can be ranked. In most cases, relative person-minute and person throughput improvements are the most important factors to consider in this facility screening. The use of consistent analysis assumptions permits these comparisons. Other environmental, institutional or cost factors are of lesser importance in this initial identification of candidate facilities. This sketch planning type of analysis can begin to group candidate facilities for further HOV treatment feasibility analyses.

Depending upon the available time frame and/or budget, some or all of the high ranking facilities can then be matched with alternative HOV treatments. This procedure is fully described in the following sections.

DEVELOP HOV TREATMENT ALTERNATIVES

At this point in the planning process, an analysis procedure is used whereby alternative HOV treatments are matched to candidate facilities. The objective of this process is to identify HOV treatment alternatives which could be feasibly implemented on a given candidate facility.

In order to perform this matching procedure, the candidate facility must be classified according to its physical and operational characteristics. Potential HOV treatments are then identified based upon this classification.

A step-by-step procedure is presented for developing potential HOV treatment alternatives on a given facility. As shown in Figure 2-3, the procedure includes four major steps, as follows:

1. Inventory Existing Facility Conditions;

2. Identify "Add-a-Lane" Options;

3. Determine Number of Travel Lanes;

4. Identify HOV Treatment Alternatives.

These steps are discussed below:

1. <u>Inventory Existing Facility Conditions</u>

Before specific HOV treatments can be considered, additional data must be collected for each of the candidate facilities which have been highly ranked. An existing conditions inventory must consider two types of facility characteristics: physical and operational. Much of this data will be readily available from the initial facility ranking analysis. Other data may require additional survey work.

<u>Physical Characteristics</u>

The following facility physical characteristics are used directly in the HOV treatment identification procedure:

- Facility Classification;
- Facility Cross Section;
- Lane Configuration;
- Parking and Loading Zones;
- Right-of-Way Width;
- Median Characteristics.

These characteristics are discussed below:

<u>Facility Classification</u> - The first task is to classify the facility. There are two major classifications used in this procedure.

- <u>Grade Separated Facilities</u> - Access is limited

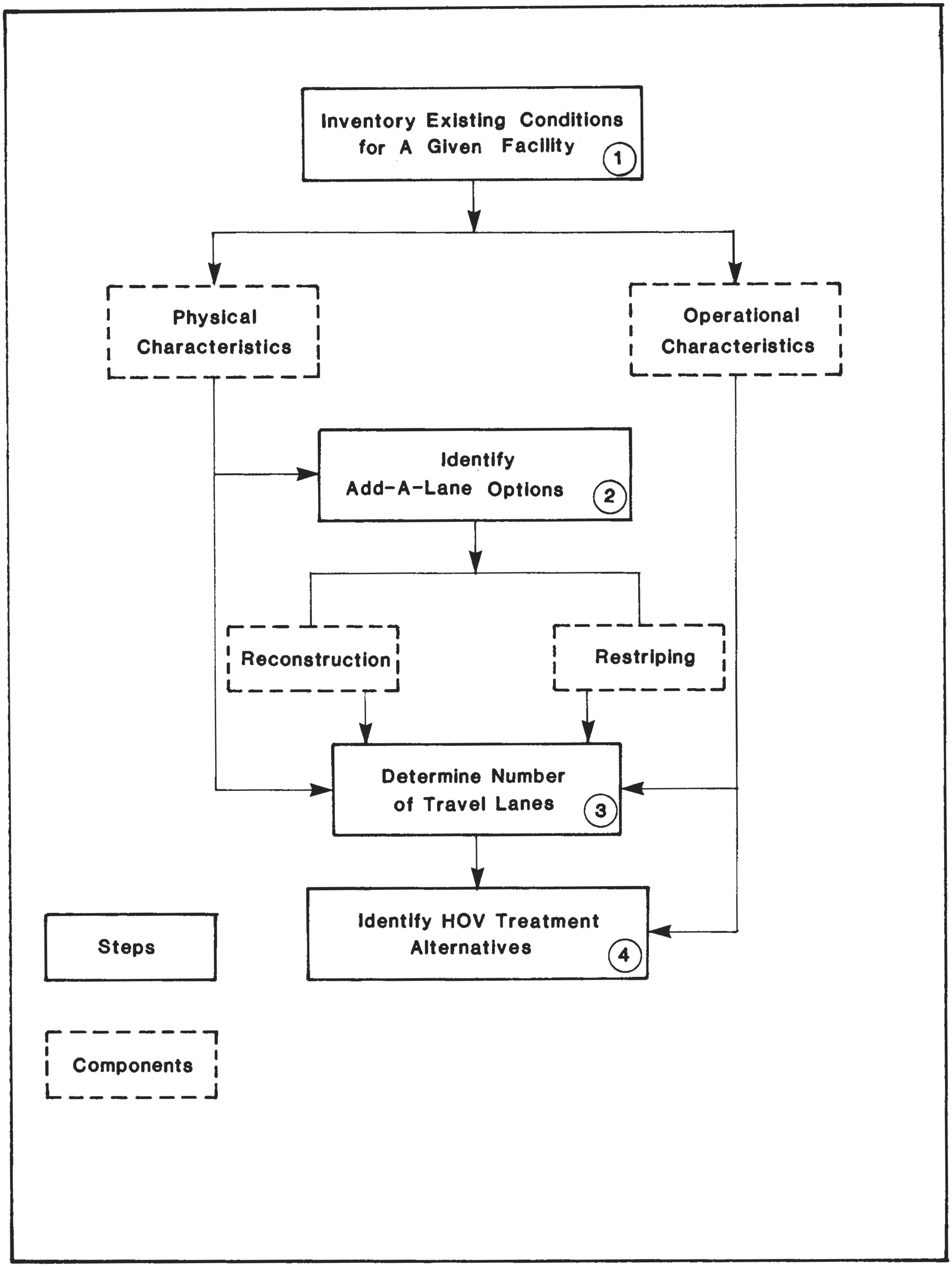


Figure 2-3. Development of HOV Treatment Alternatives

via ramps. High design speeds are typical. Examples include freeways and expressways.

- o Surface Streets - Little or no access control is evident. Intersections are at-grade and are controlled by traffic signals or signing.

Most facilities can be classified into one of these two groupings. However, certain facilities may have unique characteristics which make a single classification impossible. For example, a multi-lane surface street may have a combination of at-grade and grade separated intersections. In such cases, the facility can often be broken into specific segment classifications depending upon each segment's physical and operational characteristics.

Facility Cross Section - The next task is to determine the facility cross sections. The following dimensions should be recorded:

- o Total width, including all shoulder and median widths;
- o Shoulder widths on both sides of roadway;
- o Median width including any inside shoulder width.

The existence of curbs should be noted as well as the type of shoulder construction (i.e., paved or unpaved). Cross sections should be obtained at various locations along the roadway.

Lane Configuration - The lane configuration inventory should include the following data for both intersection and non-intersection cross sections:

- o Number of lanes;
- o Direction of lanes;
- o Orientation of lanes;
- o Lane continuity;
- o Width of lanes.

The intersection data will be especially valuable for considering short congestion bypass HOV treatments.

The number of lanes in a cross section is the total number of lanes available for moving vehicles. This number includes any separate turning lanes, regardless of length. However, it does not include any lanes devoted to parking or other non-moving purposes (i.e., loading or taxi zone). As shown in Figure 2-4, the number of lanes can vary significantly for intersection and non-intersection cross sections.

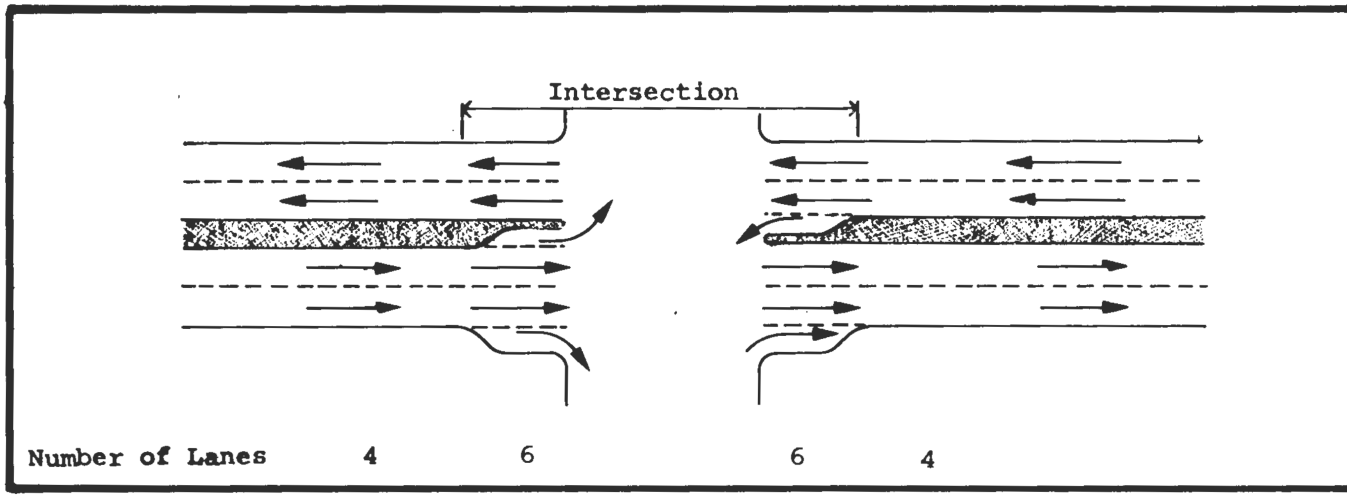


Figure 2-4. Number of Lanes

The direction of lanes describes the direction in which traffic must flow on each lane. One-way versus two-way operations are distinguished. If lanes reverse direction during different times of the day, this designation should be specifically noted.

The orientation of lanes defines the permissible traffic movements in each lane. Certain lanes may be designated as turn-only or through lanes, while other lanes may have optional movements permitted, such as a combined through and left turn lane. Non-intersection segments will generally have through lanes only, while intersections may have a wide variety of lane orientations. Grade separated facilities often have separate lanes designated for ramp movements.

A measurement of lane continuity is also recommended. Figure 2-5 indicates that most roadways are structured around a set of continuous through lanes. These through lanes are combined with various discontinuous lanes, such as turn-only or bypass lanes

(Figure 2-6). Grade separated facilities often add lanes or drop lanes at interchanges. The location and length of continuous and discontinuous lanes should be determined.

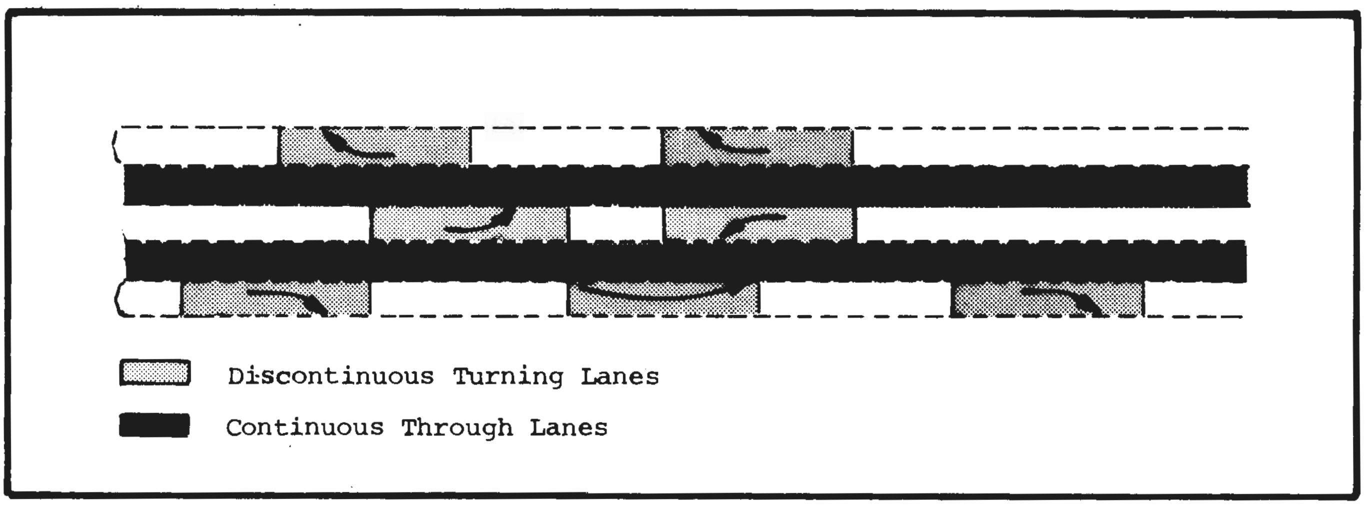


Figure 2-5. Lane Continuity

Finally, the <u>width of each lane</u> should be documented. Particular attention should be paid to changes in lane width within roadway segments.

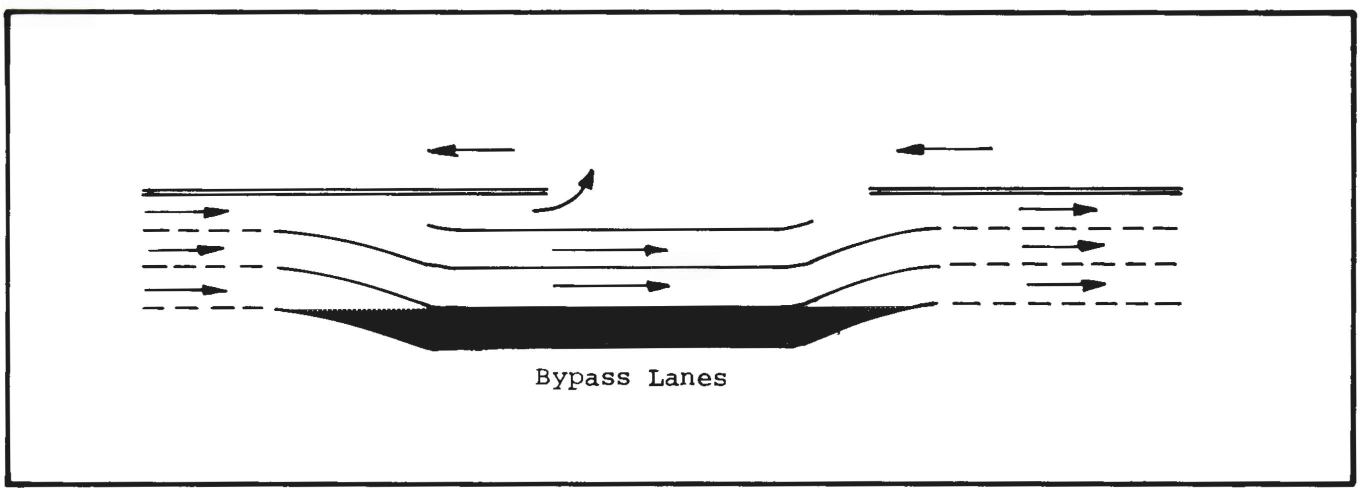


Figure 2-6. Bypass Lane

Parking and Loading Zones - An inventory of parking and loading zones along the facility should be made. The number, location, width, and hours of operation of on-street parking spaces should be determined. Major off-street lots and garages (i.e., greater than 100 spaces) should also be inventoried.

Loading zones include parcel delivery spaces as well as taxi stops. A loading zone inventory should include the location, length, width, and permitted hours of operation of each zone.

Right-of-Way Width - A facility right-of-way inventory should include both continuous and discontinuous sections of right-of-way. Figure 2-7 presents an example where 100 ft (31m) of right-of-way is available in several locations. However, the maximum continuous right-of-way width is only 75 ft (23m). This continuous section represents the "usable" right-of-way for construction of additional lanes. Discontinuous right-of-way width may prove useful for construction of enforcement havens, transit turnouts, or short "queue-jumper" lanes.

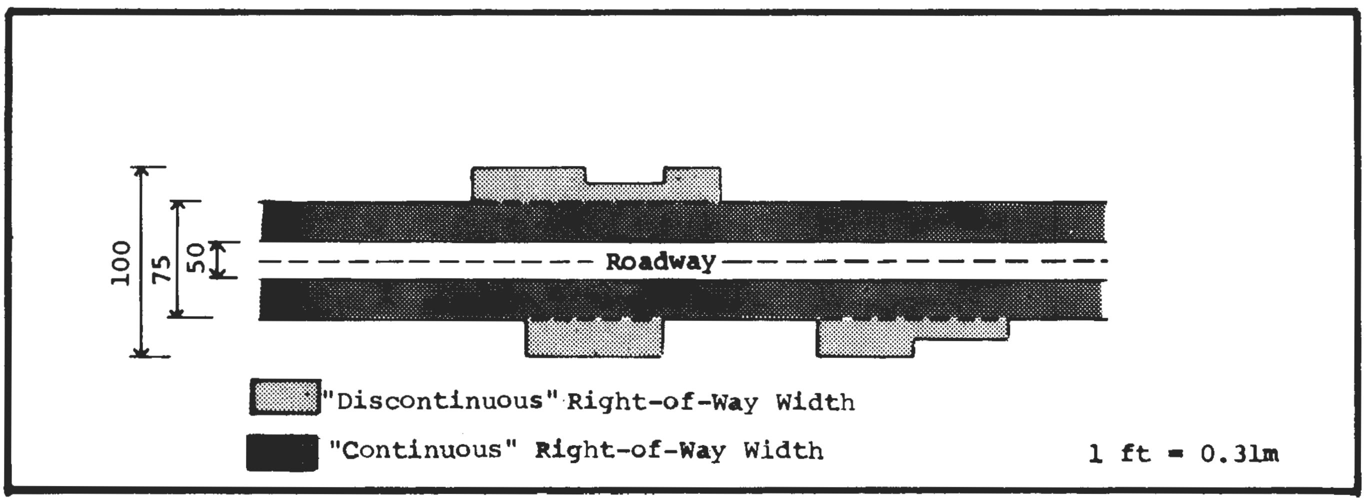


Figure 2-7. Right-of-Way Width

Median Characteristics - An examination of existing median strips should include the following characteristics, as shown in Figure 2-8.

- o Width - Includes the width of any inside shoulder;
- o Type of Construction - Painted, raised curb, grass, gravel (etc.);
- o Median Obstacles - Locations and characteristics of plantings, signs, light poles, bridge piers or other physical obstacles;
- o Vertical Grades - Vertical elevation changes between roadway surfaces;
- o Slopes - Includes the location and slopes of any drainage channels within the median;
- o Crossover Locations - Locations of service or emergency crossovers as well as locations and spacing of turn lanes within the median.

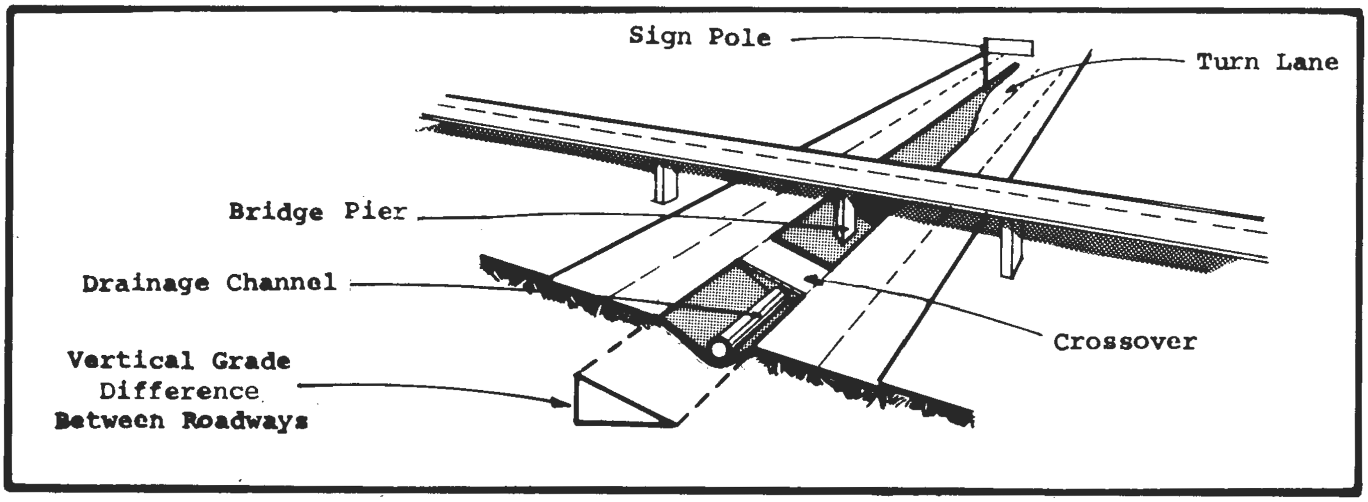


Figure 2-8. Median Characteristics

Additional Physical Data - The following additional physical data may be needed to evaluate specific types of HOV treatments.

- o Spacings of Cross Streets, Traffic Signals, Driveways, and Interchanges - Considers cross streets, traffic signals, and driveways for surface streets; interchanges for grade separated facilities.

- Sidewalk Characteristics - Location of sidewalks within right-of-way and placement of street furniture (e.g., signs, poles, shelters) relative to a curb or shoulder.

- Bus Stop Characteristics - Locations of near, far, or mid-block bus stops; locations of bus turnouts and shelters.

In order to assist in the inventory of existing physical characteristics, a checklist has been prepared (Table 2-4). This checklist can serve as a guide for examining any facility segment.

Operational Characteristics

The second part of the existing conditions inventory considers operational characteristics. The following data are most important:

- Vehicular Volumes;
- Person Volumes;
- Travel Times, Speeds, and Delay;
- Transit Operations;
- Traffic Control Procedures.

These characteristics are discussed below:

Vehicular Volumes - Traffic counting procedures should be used to measure vehicular volumes on several roadway segments. The traffic volumes should, at a minimum, be divided into the following classifications:

- Peak hours;
- Peak periods;
- Daily;
- Intersection turning movements;
- Vehicle classification (autos, trucks, buses, etc.).

Table 2-4. Physical Characteristics Checklist

FACILITY NAME ____________ SEGMENT FROM ____________ TO ____________

Facility Classification: Grade Separated ________ Surface Street ________ Other ________

CHARACTERISTIC	COMPONENTS		SPECIFIC FEATURES	
Cross-Section:	Total Width	________	Linehaul	________
	Shoulder Width(s)	________	Intersections	________
	Median Width	________		
	Curbs	________		
Lane Configuration:	Number of Lanes	________	Linehaul	________
	Direction of Lanes	________	Intersections	________
	Orientation of Lanes	________		
	Continuity of Lanes	________		
	Width of Lanes	________		
Right of Way Width:	Continuous	________		
	Discontinuous	________		
Parking:	Location	________	On-Street	________
	Number of Spaces	________	Off-Street	________
	Width	________		
	Hours of Operation	________		
Street Loading:	Location	________	Goods	________
	Length	________	Taxi	________
	Width	________	Other	________
	Permitted Hours	________		
Medians:	Width	________		
	Type of Construction	________		
	Median Obstacles	________		
	Vertical Grades	________		
	Crossover Locations	________		
	Turn Lane Location	________		
Sidewalks:	Location	________		
	Width	________		
	Street Furniture	________		
Spacings:	Cross Street	________	Surface Streets Only	
	Traffic Signals	________		
	Driveways	________		
	Interchanges	________	Grade Separated Only	
Bus Stops:	Location	________		
	Near, Far, Midblock	________		
	Turnouts	________		
	Shelters	________		

Person Volumes - Person volumes are typically obtained through occupancy counts taken concurrently with vehicular counts. Occupancy surveys stratify the vehicular volume counts according to the number of persons in each vehicle. Typical breakdowns are by 1, 2, 3, or 4 or more persons per vehicle. The same time-of-day tabulations should be prepared as for vehicular volumes.

Travel Times, Speeds, and Delay - Travel time and speed studies are an important element of the data collection activity. The following data should be collected:

- o Travel time and speed profiles between points along the facility for both transit and non-transit vehicles.

- o Delay measurements at intersections and/or congested locations for both transit and non-transit vehicles.

- o Estimates of transit walk times to transit stops, average wait times, transfer times and walk times to destinations.

If possible, these data should be compiled by direction during the same peak and off peak hours as were the vehicle and person count studies.

Transit Operations - An inventory of current transit operational data is important for any consideration of bus priority treatments. The following components should be analyzed:

- o Bus Routes - Those routes operating along or near the facility under investigation.

- o Schedules - The frequency of service and average headways at each transit stop along the facility.

- o Load Factors - Location and magnitude of peak passenger load points for individual routes and also combined for all routes along the facility.

- o Type of Service - Express/local bus mix by route and combined for all routes along the facility.

These transit characteristics should be examined for both peak and off peak periods.

Traffic Control Procedures - An inventory of existing traffic control characteristics should be assembled for surface street HOV treatments. The following data are appropriate:

- o Type of signal controls (e.g., signals, signs);
- o Location and spacing of signals;
- o Treatment of pedestrians (e.g., separate pedestrian signal phases);
- o Traffic signal phasing and interconnection systems.

The traffic control plan should be clearly displayed on a map in order to relate to the physical characteristics of each roadway segment.

Table 2-5 presents a checklist for use in assembling operational data. These data represent those facility operational characteristics which are most useful in the investigation of potential HOV treatments.

Analysis of Existing Conditions

Physical and operational data allow a detailed assessment of existing facility conditions to be made. The analyses which are most pertinent to the evaluation of HOV treatments are the following:

- o Capacity Analysis - Existing levels of service at intersection and non intersection locations should be determined. The effects of lane configuration, vehicle mix, and types of traffic control must be considered.
- o Facility Throughput Analysis - Existing vehicular and person volumes should be compared to the facility type and lane configurations to determine the current rate of vehicular and person throughput (i.e., volume per lane or similar measure). The results of the capacity analyses can provide estimates of maximum facility throughput potential.
- o Travel Time and Delay Analysis - Analyses of the travel time and delay data should include the effects of lane configurations, traffic

Table 2-5. Operational Characteristics Checklist

FACILITY NAME ____________ SEGMENT FROM ____________ TO ____________

Facility Classification: Grade Separated ______ Surface Street ______ Other ______

CHARACTERISTIC	COMPONENTS			SPECIFIC FEATURES
Vehicular Volumes:	Daily		______	By Direction ______
	Peak Period		______	
	Peak Hour		______	
	Turning Movements		______	
	Classification		______	
Person Volumes:	Daily		______	By Direction ______
	Peak Period		______	
	Peak Hour		______	
	Classification		______	
Travel Times, Speed, Delay:	Transit	Non Transit		Peak ______ Off-Peak ______ By Direction ______
Time (Speed) Profiles	______	______		
Delay Measurements	______	______		
Transit Operations:	Route Structure		______	Peak ______ Off- Peak ______
	Schedules		______	
	Load Factors		______	
	Type of Service		______	
Traffic Control Procedures :	Type of Control		______	
	Location & Spacing of Signals		______	
	Pedestrian Treatment		______	
	Timing Procedures		______	

control procedures and vehicular mix of the facility. The causes of delay can often be directly attributable to these factors.

2. Identify "Add-a-Lane" Options

Once the physical and operational characteristics of the existing facility are determined, the next step is to identify any options which may exist to "add-a-lane" to the existing roadway. The analysis includes examinations of different roadway cross sections and/or lane configurations.

The two primary methods for adding lanes are reconstruction or restriping. Reconstruction involves creating additional traffic lanes from available roadway right-of-way. Available right-of-way can include land adjacent to an existing facility, or land within the facility such as a median. The reconstruction of an unimproved roadway shoulder would also fall under this category. Figure 2-9 depicts a reconstruction project involving both a median and an unimproved shoulder.

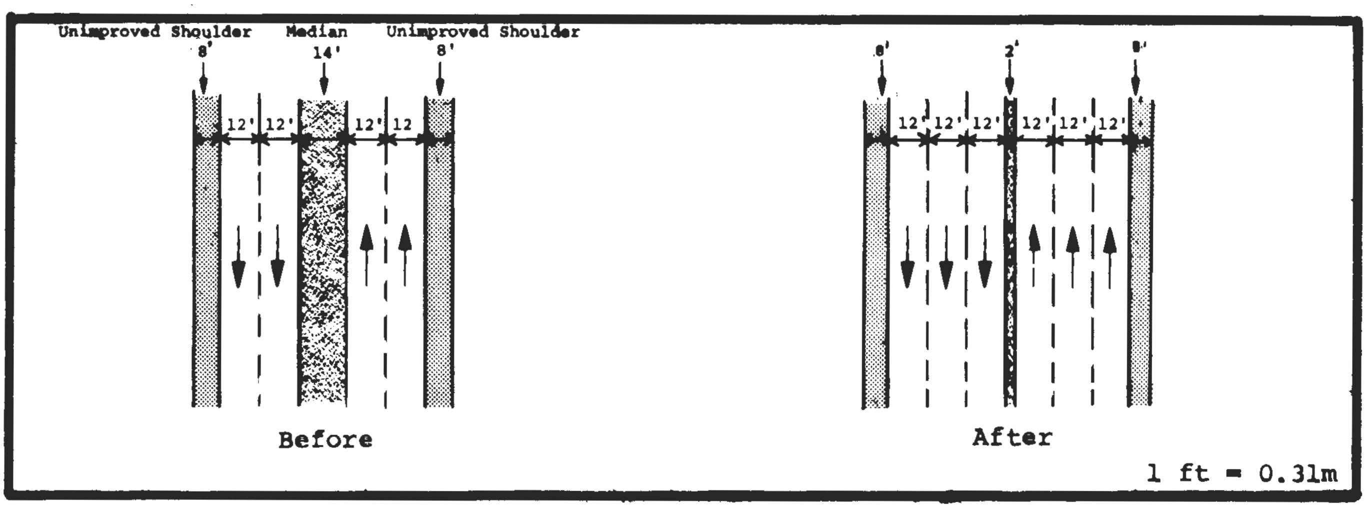


Figure 2-9. Roadway Reconstruction

Restriping involves reallocating the existing paved roadway surface to create different lane configurations. Restriping is typically used to redesignate existing lanes for special uses such as turns only, parking, or reversible lane operations. Restriping can also be used to narrow existing lane widths in order to create enough remaining width for an additional lane. These restriping concepts are illustrated in Figure 2-10.

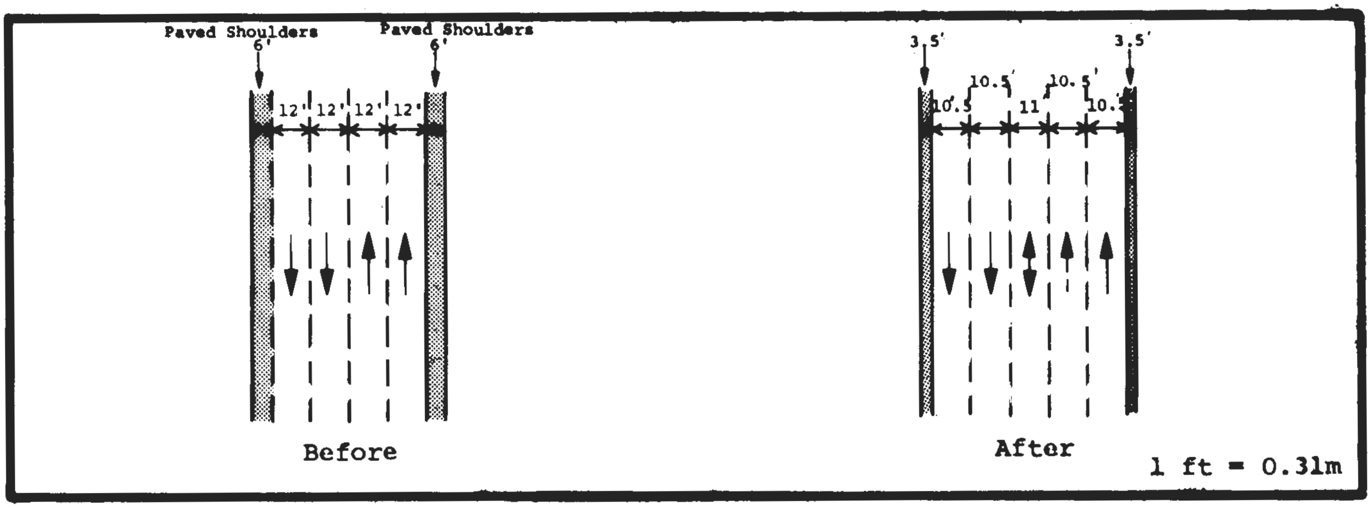


Figure 2-10. Roadway Restriping

Reconstruction and restriping activities can be combined to maximize available right-of-way. For example, a new lane can be created through a combination of median reconstruction and lane restriping. Figure 2-11 depicts a typical situation.

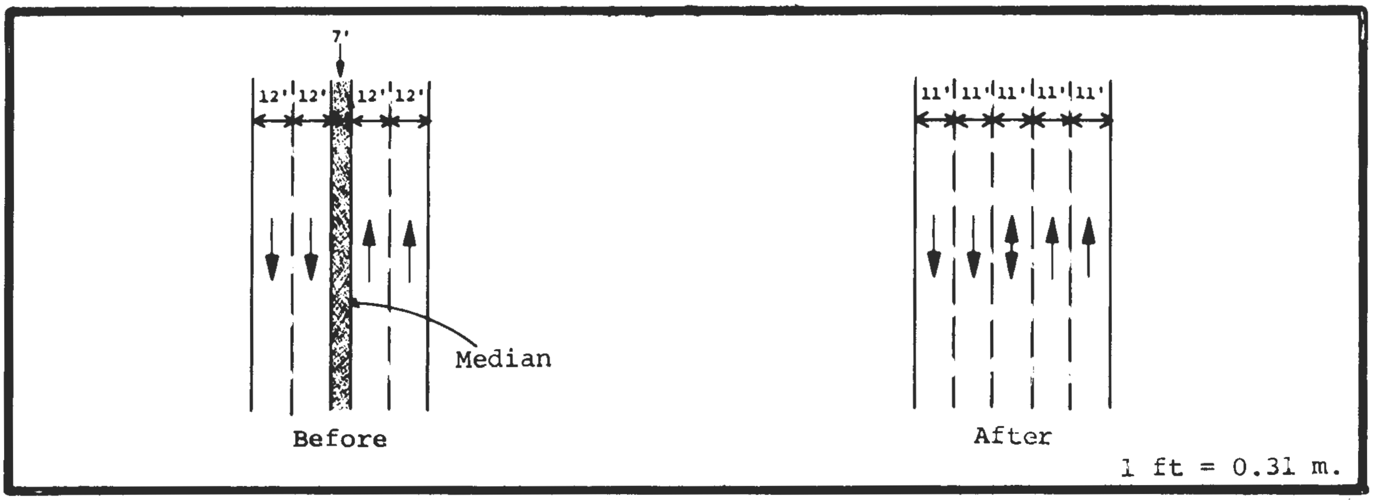


Figure 2-11. Roadway Reconstruction and Restriping

Table 2-6 presents a worksheet for use in examining add-a-lane options for a facility. Each of the options shown to be feasible can then be matched with alternative HOV treatments. This flexibility allows HOV treatments to be examined for both the existing roadway configuration as well as for the different add-a-lane options.

3. Determine Number of Travel Lanes

One of the most important characteristics of a facility is the number of travel lanes available for through moving traffic. Travel lanes often dictate which HOV treatments may be feasible.

The existing conditions inventory provides knowledge of lane widths, lane orientations, lane continuity, lane direction, and the number of lanes devoted to parking and/or loading. The determination of travel lanes considers each of these characteristics as well as any changes due to add-a-lane options.

Table 2-6. Add-A-Lane Option Worksheet

FACILITY: ____________ **SEGMENT FROM** ____________ **TO** ____________

Distance: ____________

Existing Cross Section | **Lane Configuration**

Shoulder Width: ____________

Median Width: ____________

Option 1	**Option 2**
Cross Section **Lane Configuration**	**Cross Section** **Lane Configuration**
Comments:	**Comments:**
Option 3	**Option 4**
Cross Section **Lane Configuration**	**Cross Section** **Lane Configuration**
Comments :	**Comments:**

The number of travel lanes is calculated as follows:

Step 3.1 - Determine the number of continuous lanes available for through, non-turning traffic. This includes any through lanes added due to restriping or recontruction. Continuous lanes can allow turns (e.g., combined through and right turn lane) as long as through traffic is also permitted.

Step 3.2 - Identify existing special use lanes which could be preempted for use by through non-turning traffic. Special use lanes include the following, as shown in Figure 2-12:

- o Separate Turn Lanes;
- o Parking Lanes;
- o Loading or Taxi Zones.

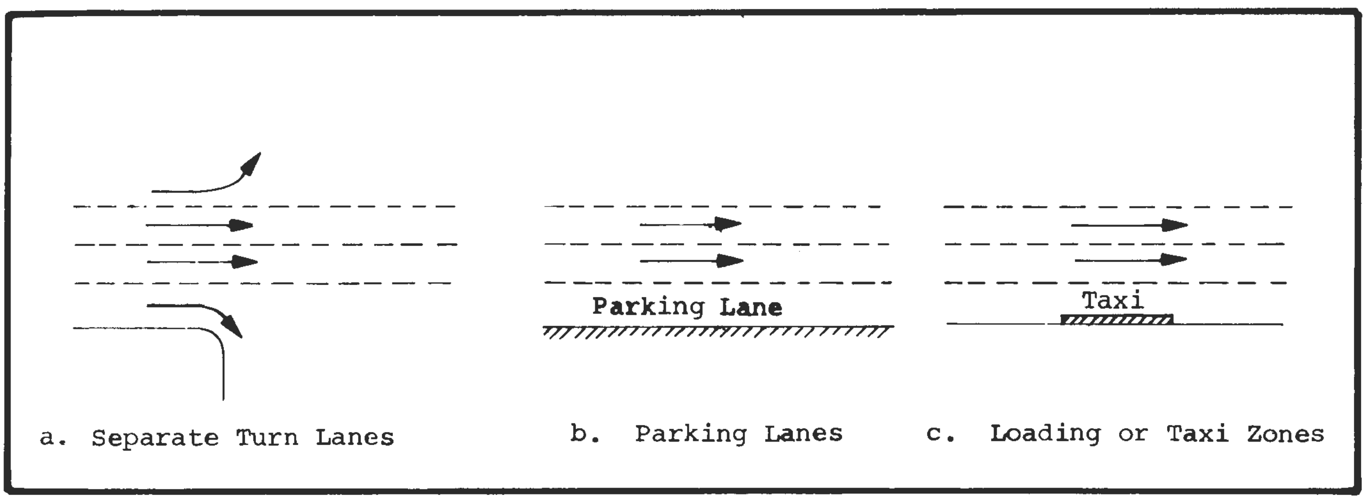


Figure 2-12. Special Use Lanes

Lane continuity and width limitations dictate whether special use lanes can be treated as travel lanes. Most separate turn lanes are not long enough to provide a smooth transition for use by through moving vehicles. Similarly, along a roadway segment parking or loading lanes are often discontinuous.

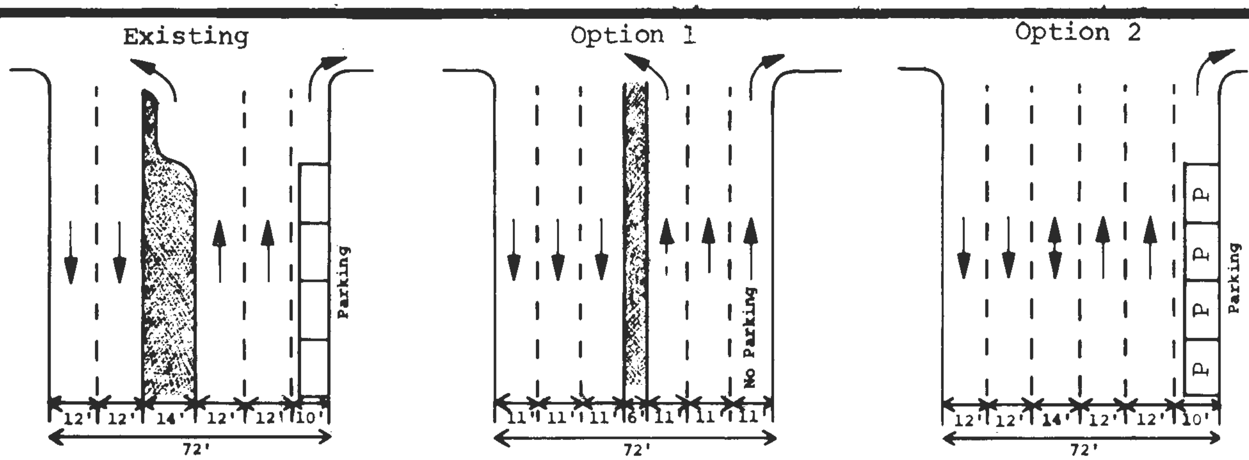
Generally, in order to be considered for use as a travel lane, a special use lane must be situated such that any through moving vehicles using the lane could readily merge back into the continuous through lanes. A common example is a center lane on a two-way street which normally operates as a continuous left-turn only lane. During designated hours, however, left turns could be prohibited in order to allow the center lane to act as a travel lane for through traffic.

The width of a travel lane should be at least 10 feet (3.1m), except under very restricted situations where 9 feet (2.8m) may be acceptable. Oftentimes parking and loading lanes are 8 feet (2.4m) or less in width, which disqualifies their use as travel lanes unless the lanes are widened through reconstruction or restriping.

One potential use of a short special use lane is to act as a bypass or "queue-jumper" of intersection or bottleneck congestion. "Queue-jumper" HOV treatments can be quite effective in selected situations. Therefore, the decision whether to consider a special use lane as a travel lane should be kept flexible pending the investigation of specific HOV treatments.

Step 3.3 - Calculate the total number of available travel lanes. This number is obtained by summing the number of continuous through lanes (Step 3.1) and the number of special use lanes usable as travel lanes (Step 3.2). The number of travel lanes should be computed for both existing conditions and for any add-a-lane options which have been identified. This total number defines the traffic throughput capability of the facility segment. The number of travel lanes calculated using this procedure becomes the input to the identification of alternative HOV treatments.

Figure 2-13 presents an example of travel lane calculations for an existing facility condition and two add-a-lane options. Whereas the total roadway width has not changed in either add-a-lane option, the effective number of travel lanes has changed through reconstruction, restriping, and preemption of special use lanes.



	Existing	Option 1	Option 2
Number of Continuous Lanes	4	5	5
Number of Preempted Lanes	0	1	0
Number of Travel Lanes	4	6	5

Figure 2-13. Travel Lane Calculation

4. Identify HOV Treatment Alternatives

By this time, the physical and operational characteristics of the existing facility and add-a-lane options have been determined. The travel lanes available under each situation have also been calculated. The next step is to match these characteristics with potential HOV treatments.

The matching methodology utilizes a matrix format as displayed in Table 2-7 (also Table A-1 in the Appendix). The COLUMNS of Table 2-7 represent various facility types. Facility type is a composite of roadway classification (i.e., surface street, grade separated, separate right-of-way), lane direction (i.e., one-way, two-way), the existence of a median (i.e., yes, no), and the available number of travel lanes. The ROWS of Table 2-7 are the various HOV treatments.

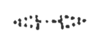
TABLE 2-7
MATRIX OF FACILITY TYPE/HOV TREATMENT COMBINATIONS

HOV TREATMENT \ FACILITY TYPE		GRADE SEPARATED			SURFACE STREETS											SEPARATED RIGHT OF WAY
					ONE-WAY		TWO WAY WITH MEDIAN				TWO WAY WITHOUT MEDIAN					
		4	5	6 +	2	3+	2	3	4	6+	2	3	4	5	6+	
CONCURRENT FLOW	Right Lane	N.A.	Pg. A-21	Pg. A-21	Pg. A-46	Pg. A-46	N.A.	N.A.	Pg. A-46	Pg. A-46	N.A.	Pg. 46	Pg. 46	Pg. 46	Pg.	N.A.
	Inside Lane	N.A.	N.A.	N.A.	N.A.	Pg. A-51	N.A.	N.A.	N.A.	N.A.	N.A.	See Contra Flow Inside Lanes	Pg. A-55	Pg. A-55	Pg. A-55	N.A.
	Left Lane	N.A.	Pg. A-25	Pg. A-25	Pg. A-58	Pg. A-58	N.A.	N.A.	Pg. A-58	Pg. A-58	N.A.	See Contra Flow Inside Lanes	Pg. A-58	See Contra Flow Inside Lanes	Pg. A-58	N.A.
CONTRA FLOW	Right Lane	N.A.	N.A.	N.A.	Pg. A-62	Pg. A-62	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	Inside Lane	N.A.	Pg. A-30	Pg. A-30	N.A.	N.A.	N.A.	N.A.	Pg. A-66	Pg. A-66	N.A.	Pg. A-70	Pg. A-70	Pg. A-70	Pg. A-70	N.A.
	Left Lane	N.A.	N.A.	N.A.	Pg. A-74	Pg. A-74	N.A.	N.A.	Pg. A-74	Pg. A-74	N.A.	Pg. A-74	Pg. A-74	Pg. A-74	Pg. A-74	N.A.
EXCLUSIVE FACILITY	IN Median	N.A.	Pg. A-34	Pg. A-34	N.A.	N.A.	N.A.	Pg. 78	Pg. A-78	Pg. A-78	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	HOV Roadway	Pg. A-38	Pg. A-38	Pg. A-38	Pg. A-82	Pg. A-82	Pg. A-82	Pg. A-82	Pg. A-82	Pg. A-82	Pg. A-82	Pg. A-82	Pg. A-82	Pg. A-82	Pg. A-82	Pg. A-87
Ramp Treatments		Pg. A-42	Pg. A-42	Pg. A-42	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Pg. A-42
Signal Priority		N.A.	N.A.	N.A.	Pg. A-91	Pg. A-91	Pg. A-91	Pg. A-91	Pg. A-91	Pg. A-91	Pg. A-91	Pg. A-91	Pg. A-91	Pg. A-91	Pg. A-91	Pg. A-91
Priority Parking		Pg. A-99	Pg. A-99	Pg. A-99	Pg. A-99	Pg. A-99	Pg. A-99	Pg. A-99	Pg. A-99	Pg. A-99	Pg. A-99	Pg. A-99	Pg. A-99	Pg. A-99	Pg. A-99	Pg. A-99
Pricing Strategies		$ Pg. A-104	$ Pg. A-104	$ Pg. A-104	$ Pg. A-104	$ Pg. A-104	$ Pg. A-104	$ Pg. A-104	$ Pg. A-104	$ Pg. A-104	$ Pg. A-104	$ Pg. A-104	$ Pg. A-104	$ Pg. A-104	$ Pg. A-104	$ Pg. A-104
Summary Index		Pg. A-6	Pg. A-7	Pg. A-8	Pg. A-9	Pg. A-10	Pg. A-11	Pg. A-12	Pg. A-13	Pg. A-14	Pg. A-15	Pg. A-16	Pg. A-17	Pg. A-18	Pg. A-19	Pg. A-20

Several symbols are utilized in Table 2-7, including the following:

 HOV lane

 Non HOV lane

 Reversible HOV lane

 Reversible non HOV lane

 Signal priority

 Priority parking

$ Pricing strategy

N.A. Not applicable

These symbols are also used in subsequent graphics.

A five-step identification process is utilized. This process, diagrammed in Figure 2-14, is described below.

Step 4.1 - Locate the column which corresponds to the type of facility under investigation. The column will be different for existing conditions and add-a-lane options.

Step 4.2 - Scan down the appropriate column to identify the rows (HOV treatments) which are applicable to that facility type. Each combination of facility type and HOV treatment is shown as a cell in the matrix. However, only those cells which represent feasible matches are graphically displayed in the cell. Other facility type/HOV treatment combinations considered to be infeasible due to physical and/or operational constraints are labeled as "Not Applicable" (NA) and are not considered further.

Step 4.3 - Locate the page number references for further investigation. The page number (A) shown at the bottom of the column refers to one of the Tables A-3 through A-16 in the Appendix which provides a more complete index and summary of the alternative HOV treatments for that particular facility type. The page reference (B) shown in each cell refers to the appendix location of a detailed description of that specific HOV treatment/facility type match.

Step 4.4 - Examine the appropriate HOV treatment

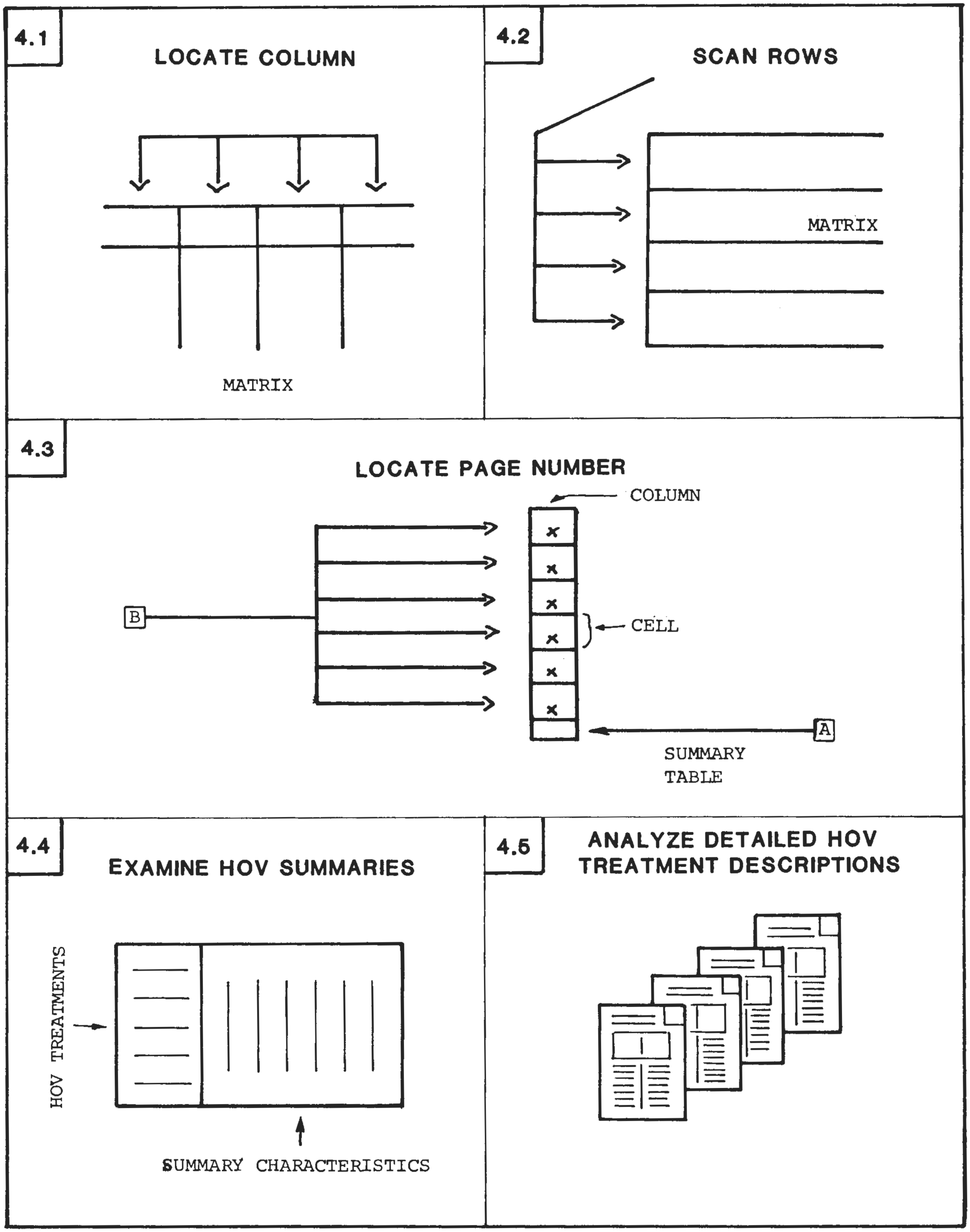


Figure 2-14. Identification of Alternative HOV Treatments

summary table for that facility type. Each of the Tables A-4 through A-18 located in the Appendix presents a summary of HOV treatment characteristics for a specific facility type. These summaries allow general comparisons to be made among various HOV treatments. They also aid in identifying high-potential HOV treatments for more detailed investigation. The definitions of the summary indicators used in these tables are presented in Appendix Table A-3. The page number in the last column of each summary table refers to the location of detailed HOV treatment descriptions within the Appendix. These descriptions are specific to the facility type under investigation and provide the user with a wide range of design, operational, impact, cost, and institutional guidelines.

Step 4.5 - Analyze the detailed HOV treatment descriptions. Detailed descriptions of 20 matches of facility types and HOV treatments are presented in the Appendix. These 20 combinations were formed by aggregating cells of similar characteristics from Table 2-7 (A-1). The cell aggregation was performed to reduce redundancy between similar facility types. As can be seen in Appendix Table A-2, the aggregated cells combine similar facility types (i.e., columns). HOV treatments (i.e., rows) have not been aggregated in order to present the uniqueness of each HOV treatment.

Most of the 20 HOV treatment descriptions are presented in a four to six page standard format. The following aspects are considered:

A. General Applicability
   1) Location
   2) Type of HOV

B. Design
   1) Geometrics
   2) Signing & Marking
   3) Intersection (Surface Street) or Interchange (Grade Separated) Treatment
   4) Signalization
   5) Transition Treatment
   6) Transit Loading Areas

C. Traffic Operations
   1) Vehicular Movements
   2) Safety

D. Operations & Maintenance

   1) Day-to-day Operations
   2) Enforcement

E. Estimated Impacts
   1) Travel Time Changes (HOV's; Non-HOV's)
   2) Mode Shift
   3) Person Throughput

F. Project Cost
   1) Implementation
   2) Operations & Maintenance

G. Institutional Considerations
   1) Legal Concerns
   2) Anticipated Community Reaction
   3) Time to Implement

H. Examples

Each description includes several graphical displays of design and operational features. These graphics in combination with the written guidelines, provide many of the tools necessary to perform preliminary evaluation of alternative HOV treatments.

The guidelines presented in each description must be analyzed with respect to physical and operational data specific to a facility. In particular, a thorough knowledge of the unique operational characteristics of a facility (e.g., volumes, travel times, transit operations) is required to assess the overall magnitude of potential specific HOV treatment impacts. The design guidelines should also be related to the particular physical characteristics of a facility.

Perhaps of most importance, the available project budget and local political atmosphere should be compared to the estimated project costs and institutional considerations outlined in the descriptions. These comparisons between localized conditions and the guidelines presented in these descriptions will help identify those aspects of a specific project which should be more fully investigated during detailed impact analysis.

SCREEN HOV TREATMENT ALTERNATIVES

Once the HOV treatment alternatives have been developed for the facility under investigation, the next task is to perform preliminary screening of these alternatives prior to conducting detailed impact analyses (see Chapter 3). In order to screen the alternatives, two basic questions must be answered.

1) Is a particular HOV treatment feasible or desirable for a given type of facility? That is, how does any HOV treatment alternative compare with the "do-nothing" alternative?

2) How do the attributes of a particular HOV treatment compare with those of other alternative HOV treatments on the same facility type?

In many instances, the answers to these questions will require detailed tradeoffs between design, operational, cost and institutional factors. In other situations, one single physical or operational feature may determine the choice of an HOV treatment.

Some HOV treatments on a given facility are likely to be eliminated from further consideration after reviewing the detailed HOV treatment descriptions. For instance, curb HOV lanes on a roadway segment might be ruled out based on knowledge of particular curb access needs. Similarly, a contraflow HOV lane may be eliminated from consideration because of high off peak volumes (i.e., inability to preempt an off peak direction lane). In all cases, a comparison to the existing, or do-nothing, situation should be made.

This process of elimination often yields two or more remaining HOV treatments which are both physically and operationally feasible. In these situations, some basic comparisons can be made between these remaining HOV treatment alternatives. The set of summary tables A-4 through A-18 compare alternative HOV treatments for a particular facility type according to five criteria--design, cost, effectiveness, traffic operations and enforcement. Although general in structure, these criteria cover several important aspects of an HOV treatment evaluation. Using these tables, candidate HOV treatments can be screened comparing ratings for one or more of these criteria.

Depending upon the goals and objectives of the HOV study, certain criteria may be given greater consideration than others. In one situation, cost may be the most important criterion with effectiveness and traffic operations weighted slightly lower in importance. In this case, the HOV treatments should be ranked first relative to cost but with heavy consideration also given to traffic operations and effectiveness. The two remaining criteria, design and enforcement, while considered of less value in this example, may be the primary criteria for other studies.

The same screening procedure could also be applied to a larger number of criteria. Several of the generalized criteria presented in the summary tables (A-4 through A-18) could be separated into more detailed criteria. For instance, cost could be broken into implementation cost and operating cost. Likewise, traffic operations can be separated into HOV versus non HOV operations. The 25 detailed HOV treatment descriptions provide sufficient information to screen alternatives usinng several levels of criteria.

The preliminary screening of HOV treatment alternatives should be based upon logical assessments of these criteria. Therefore, the use of singular warrants to either justify or eliminate a project from consideration should be avoided. Since no two projects are alike, it is often impossible to provide warrants or minimum "cut-off" levels for project screening. There are several reasons for this: (Ref. 36)

- Generally more than one agency is involved in the planning and operation of an HOV project. As a result, conflicting philosophies often make establishment of warrants impossible.

- Political expediency is often a major reason cited for an HOV project implementation. In such cases, specific warrants are of little value.

- HOV projects are typically implemented to create new demand for HOV usage rather than to accommodate existing demand. However, it is often difficult to estimate the latent demand for HOV projects. As a result, warrants based either on existing or predicted changes may not be good indicators of a potential project's success or failure.

The preliminary screening procedure described above can be used to prepare an orderly set of HOV treatments for detailed impact analysis along with other (non HOV) transportation alternatives. The detailed impact analysis will deal with specific aspects of each high ranking HOV treatment (e.g., design, operations, enforcement, costs, effectiveness) and will further refine the alternatives allowing for the ultimate selection of the best transportation strategy. Methodologies for performing detailed impact analyses of HOV treatment alternatives are presented in Chapter 3.

CONSIDER COMPLEMENTARY ACTIONS

Preliminary screening of HOV treatment alternatives should also consider possible complementary actions. Complementary HOV actions can often produce more significant project impacts than separate HOV treatment applications.

Complementary HOV actions can take several forms. A common case is the combination of a facility specific HOV lane or ramp treatment with a non-facility specific treatment such as a park and ride lot or some form of pricing strategy (e.g., toll pricing). Transit service expansion and/or ridesharing matching and promotion can also be considered. Some of these complementary activities may have been considered earlier in the process on an areawide basis but each should be reconsidered as it relates to the specific facility in question.

Combinations of two or more HOV lane treatments can also be effective in selected circumstances. For instance, a concurrent flow lane and contraflow lane were effectively applied along the same facility segment on U.S. 1 - South Dixie Highway in Miami. Similarly, different HOV lane treatments can often be linked end to end along successive facility segments. One example is in the Shirley Highway Corridor in Washington, D.C., where a surface street concurrent flow lane ties into a separate HOV roadway within the median of a grade separated facility.

Complementary HOV actions are sometimes implemented in successive project stages. Staging of complementary HOV treatments often allows time to gain operating experience with each aspect of the project as well as allow the incremental effects of each successive treatment to be measured.

Oftentimes budget limitations provide the major impetus to implement one portion of a larger HOV treatment project in order to lay the basis for later expansion of the project. On the other hand, staging a project without full complementary treatments (e.g., HOV lane without added express bus service) may create minimal initial benefits and thus doom the project to failure before the succeeding stages can be implemented. In all cases, care must be taken to ensure that the staged complementary treatments do not create confusion among HOV's and non HOV's. Various approaches to combining complementary HOV treatments into HOV systems are discussed further in Chapter 8.

RECOMMEND STRATEGIC PLAN

The final step in the preliminary planning process is the preparation of a recommended strategic plan for HOV priority treatment in the urban area. This strategic plan should be incorporated as part of the overall transportation plan and improvement program. The plan should be subject to review, refinement, and adoption as policy by the participating political jurisdictions and operating agencies. It would contain as essential ingredients the results of each of the preceding steps of the preliminary planning phase. As a minimum, the strategic plan should include:

1. An explicit statement of urban area policy toward HOV priority treatment program development, indicating the degree of importance and scope of the future program.

2. An organizational plan for conducting the subsequent detailed analysis and implementation phases, with particular attention to differences in organizational approach compared with that of the preliminary planning phase.

3. An overall description of the conceptual approach to the HOV priority program indicating: locations to be included; types of HOV priority treatments that appear to be feasible; a rough time schedule for a staged implementation plan; and approximate total financial resources required and available sources.

4. A ranking by corridor and subarea location of HOV priority treatment needs and opportunities and recommendations of the top priority projects, including the short list of possible alternatives for each project.

5. A detailed time schedule and budget for the alternatives analysis phase for the recommended top priority projects.

6. A discussion of the status of and plans for complementary programs to encourage the expanded utilization of high occupancy vehicles (e.g., transit service expansion, park and ride lots, ridesharing matching and promotion,

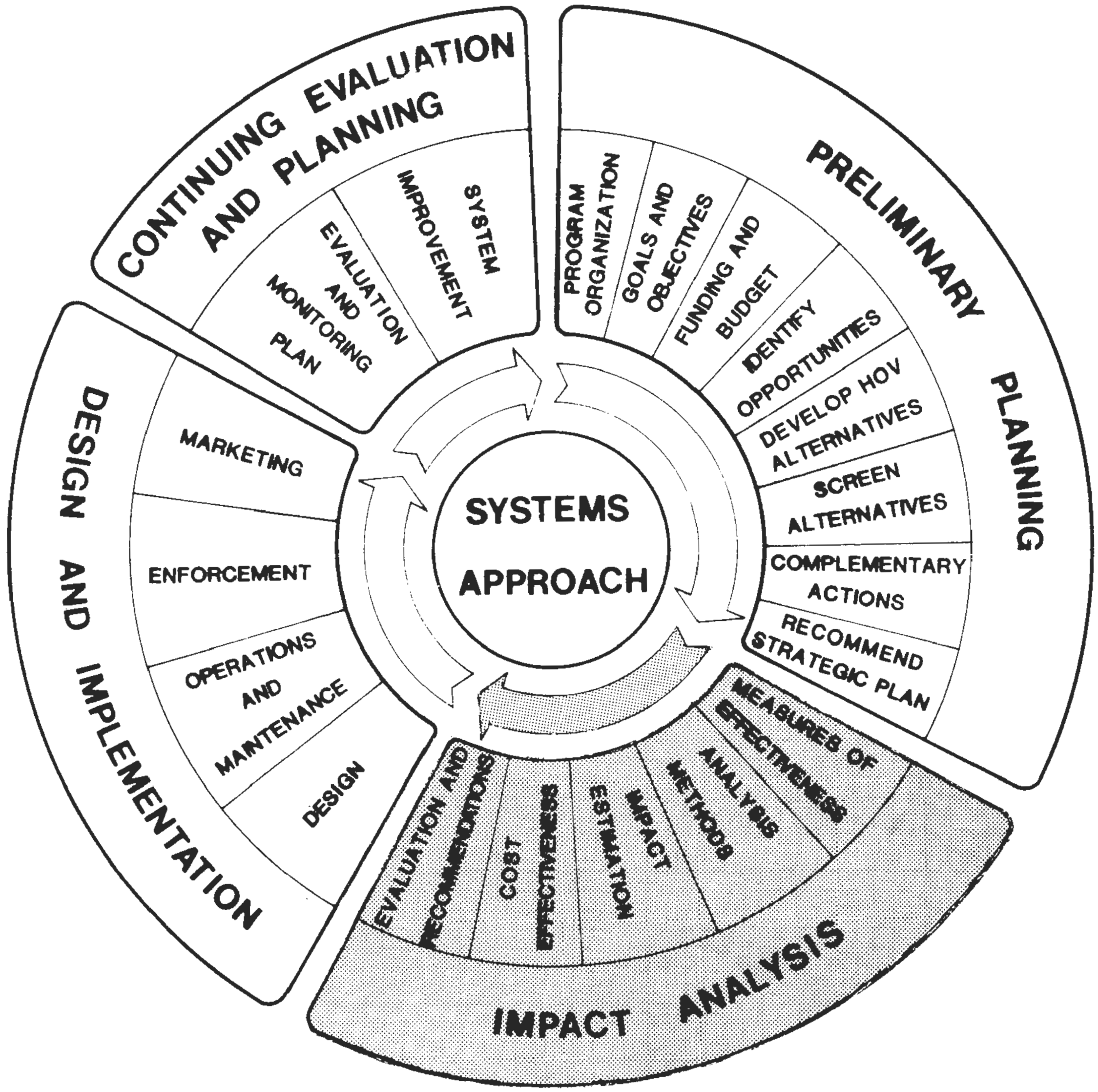
parking management, etc.). Particular emphasis should be given to complementary actions which should be newly instituted or substantively expanded in order to increase the chances of success of the recommended HOV priority treatment program and top priority projects.

SUMMARY

Preliminary planning for HOV priority treatments should be done in conjunction with other transportation planning activities in the region. It should consider an areawide perspective with an eye toward intermediate and longer-range applicability.

Preliminary planning for HOV priority treatments entails the following tasks: 1) establish organizational responsibilities, 2) refine goals and objectives, 3) determine funding mechanisms and budget constraints, 4) identify facility opportunities, 5) develop HOV treatment alternatives, 6) screen HOV treatment alternatives, and 7) consider complementary actions. Finally, a strategic plan should be prepared which combines these elements and incorporates HOV priority treatments into overall transportation plans and improvement programs for the area.

3. IMPACT ANALYSIS



3. IMPACT ANALYSIS

INTRODUCTION

This chapter presents information aimed at helping state and local transportation agencies conduct impact analyses of HOV priority facility alternatives. This is a critical step in the systems approach in that the end product is firm recommendations on specific HOV priority treatments to implement in a given corridor or subarea. The basis for these recommendations is a set of estimates of the impacts of alternative actions. Types of impact estimates that are essential include:

- Travel demand impacts;
- Travel time impacts;
- Energy and emissions impacts;
- Safety impacts;
- Costs;
- Cost-effectiveness.

MEASURES OF EFFECTIVENESS

An important step in the impact analysis process is the selection of the appropriate set of Measures of Effectiveness (MOE's) to use for impact assessment. MOE's are used to determine the quantitative degree to which a particular goal or objective has been attained. MOE's are used as a basis or standard of comparison. Table 3-1 summarizes criteria for selecting proper MOE's.

It is important to differentiate between the impact analysis phase in which MOE's are being estimated (i.e., forecasts are being made) as opposed to the later phase of evaluating implemented actions. It is always important to keep the number of MOE's manageable and non-redundant, but this is particularly so during the impact analysis phase.

Listed below is a relatively short list of what are felt to be the most essential MOE's of concern during impact analysis. Since HOV treatments are primarily applied during peak periods, all of the measures should be estimated for those specific times of day when the HOV priority facility is operational.

Table 3-1. Criteria for Developing MOE's

Relevancy to objectives: Each MOE should have a clear and specific relationship to HOV objectives in order to insure the ability to explain changes in the condition of the transportation system.

Simple and understandable: Within the constraints of required precision and accuracy, each MOE should be simple in application and interpretation.

Quantitative: MOE's should be specified in numerical terms whenever possible.

Measurable: Each MOE should be suitable for application in pre-implementation simulation and evaluation (i.e., have well-defined mathematical properties and be easily modeled) and in post-implementation monitoring (i.e., require simple direct field measurement attainable within reasonable time, cost, and manpower budgets).

Broadly applicable: MOE's which are applicable to many different types of strategies should be used wherever possible.

Responsive: Each MOE should be specified to reflect impacts on the various actor groups taking into account, as appropriate, geographic area and time period of application and influence.

Sensitive: Each MOE should have the capacity to discriminate between relatively small changes in the nature or implementation of a control strategy.

Not redundant: Each MOE should avoid measuring an impact that is sufficiently measured by other MOE's.

Appropriately detailed: MOE's should be formulated at the proper level of detail for the analysis, (e.g., if conceptual-level sketch planning is involved, the appropriate MOE is probably less detailed than one useful for more detailed implementation planning and design).

Travel Demand

- Total person trips (constant across alternatives)
- Total person miles of travel (PMT)
- Total vehicular trips (VT)
- Total vehicle miles of travel (VMT)
- Average vehicle trips per person trip (and its reciprocal, average vehicle occupancy)
- Average vehicle miles per person mile
- Vehicular capacity at critical points (VPH)
- Person movement capacity at critical points (PPH)
- Modal distribution (percent of total person trips by modes)
  - Drive alone
  - Carpool
    - 2
    - 3
    - 4+
  - Vanpool
  - Transit

Travel Time (Efficiency)

- Vehicular travel time
  - Average for HOV's
  - Average for non HOV's
  - Net (weighted average)
  - Total (VHT, vehicle hours of travel)
- Person travel time
  - Average for HOV's
  - Average for non HOV's
  - Net (weighted average)
  - Total (PHT, person hours of travel)
- Vehicle hours per person mile of travel (VHT per PMT)
- Vehicle hours of travel per person trip

Energy and Emissions

- Total fuel consumption (gallons)

- o Total quantity of emissions
  - CO
  - HC
  - NO_x

- o Rates of energy and emissions per PMT and per person trip

Safety

- o Total accidents
- o Total accident rates per mvm
- o Total accident rates per mpm

For the impact analysis stage, estimate rough orders of magnitude change in accident measures.

Cost

- o Equivalent annual marginal outlay for capital cost, operations, and maintenance, and/or
- o Present value of marginal capital, operations and maintenance costs.

ANALYSIS METHODS

Because forecasting the impacts of HOV priority facilities is a relatively new requirement, analytical planning methods (forecasting models) are still undergoing development and refinement. Although such models are of significant value and should be used when substantial capital investments are under consideration, by no means should they be expected to give precise answers. Accordingly, a major part of the impact analysis approach is to forecast impacts on the basis of actual results of comparable projects which have been empirically evaluated.

Special attention should be given to correct establishment of the corridor boundaries within which these analyses are to be made. It is essential that the area of analysis be large enough to encompass all significant marginal impacts of alternatives. A common mistake is analyzing too small a subsystem and thereby overlooking or underestimating some impacts.

Analysis Framework

Figure 3-1 presents a suggested framework for applying impact analysis models to evaluate HOV priority treatment concepts. This framework interactively treats both travel demand and traffic flow. Each proposed HOV priority treatment alternative under consideration is defined. Input data for each is then prepared, specifying highway geometrics, traffic demand levels during peak periods, and traffic control features.

Input data are supplied to a selected traffic flow model which is used to estimate in-vehicle levels of service (i.e., travel time) for competing travel modes (i.e., non-priority auto, priority carpool, and priority bus).

The resulting estimates of in-vehicle travel times of competing modes, along with other estimates or assumptions about out-of-vehicle travel time and cost attributes, are input to a travel demand modeling process. This step estimates the mode shifts and route shifts induced by the HOV travel time advantage provided by an HOV priority treatment.

The resulting traffic demand changes produced by mode shifts and route shifts may be substantial enough to effect changes in traffic flow performance. If significant changes are anticipated, the revised traffic flows are fed back for another pass through the traffic flow and travel demand estimation chain. Usually two iterations of the analysis process are sufficient to close in on the new traffic flow/travel demand equilibrium point.

Analytical Models

Several types of analytical models are available to help estimate impacts of HOV priority treatments. The ones that are the most practical and useful at this time include travel demand models and traffic flow models.

Travel Demand Models

Travel demand models are used for estimating mode shifts induced by HOV priority treatments. Much emphasis in past years has focussed on the use of large scale computer based demand forecasting models, including various UTPS and FHWA PLANPAC computer models. These models are useful for making

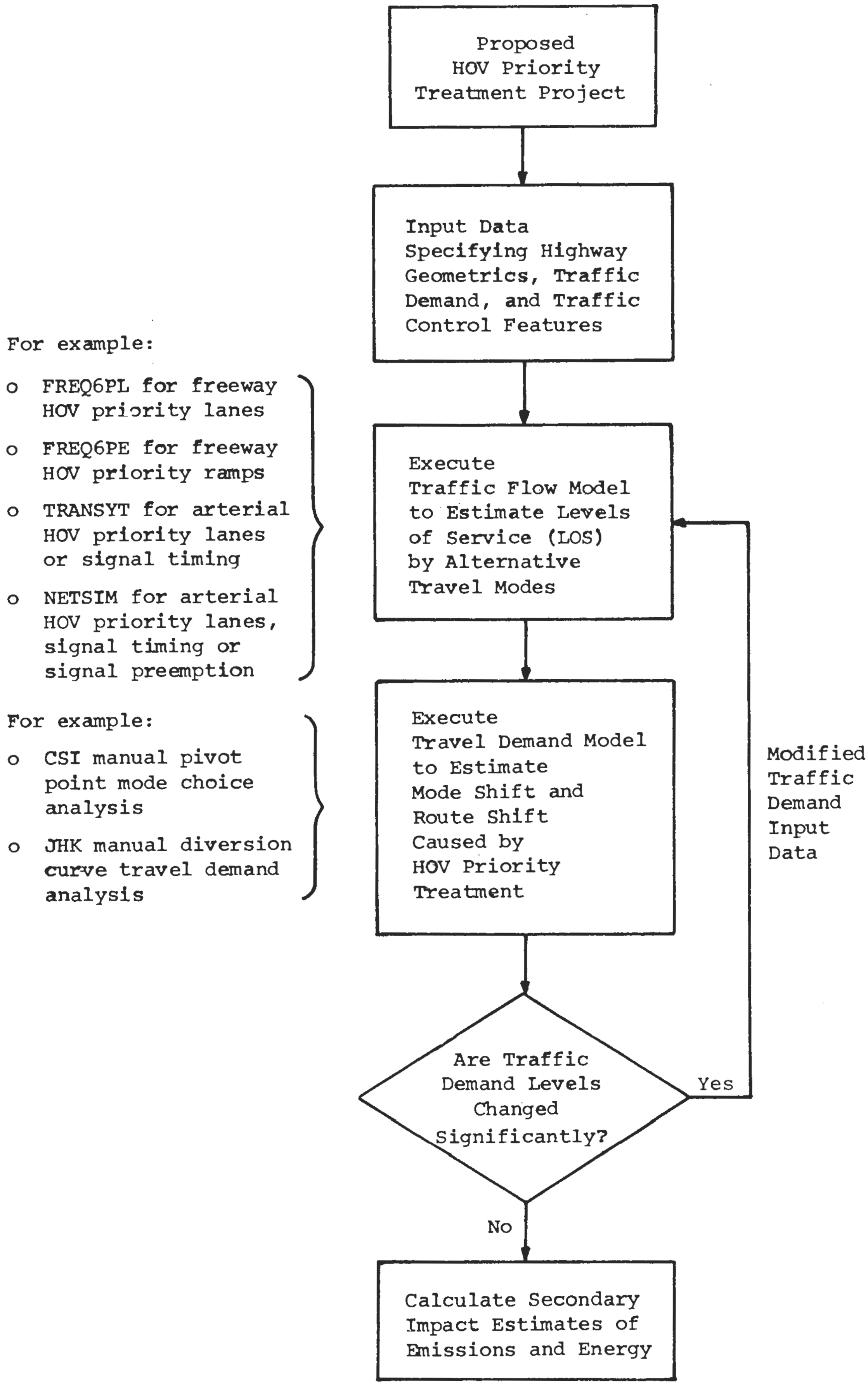


Figure 3-1. Framework for Applying HOV Impact Analysis Models

corridor-level demand forecasts of large HOV lane projects. However, the extensive data requirements of these models, the need for local area calibration, and the relative insensitivity of these models to the types of travel time and cost changes typical of most HOV priority treatment projects has created a recent effort to produce new models. Much of this effort has focussed on the advancement of manual modeling methods.

Reference 10 provides an overview of several of these models. Two of the more promising models, a manual pivot point and a manual diversion curve model, are discussed below.

CSI Pivot Point Mode Choice Model - This model was developed by Cambridge Systematics, Inc. (CSI) for the Department of Energy in 1977 and has been tested and refined in several subsequent efforts. The most recent descriptions and case examples are given in an EPA-sponsored report (Ref. 35).

The pivot point model is an adaptation of the multinomial logit model that predicts changes to existing travel behavior. The input data consist of information on existing travel behavior and changes in transportation level of service characteristics. Using an "incremental" approach in which travel demand coefficients are used to pivot about an existing situation reduces data requirements and eliminates the need for detailed socioeconomic and level of service data for each household or traffic analysis zone.

The methodology consists of the five basic and five supplemental worksheets. Several steps are required prior to using the worksheets:

- First, the user must determine the appropriate geographic scale for analysis: regional, corridor, specific facility, etc.

- Second, the user must decide on the number and characteristics of "market segments" or population subgroups for which separate analyses will be performed. The analysis population can be differentiated into a number of subgroups on the basis of such criteria as geographic location, transit availability, or trip orientation, to more accurately reflect differences in behavior among specific groups or travellers.

- Third, base case modal shares must be estimated for each market segment, taking into account the specific level of service or costs experienced by each of these subgroups. Obviously, the method is much easier to use when these data are readily available.

After these initial three tasks have been performed, the user can begin to apply the work sheets. Required input data consist of the following items:

- Percent of total population analyzed;
- Average annual household income;
- Average number of non-work auto trips daily;
- Base work trip modal shares (drive alone, shared ride and transit);
- Average carpool size;
- Average trip length (for work and non-work trips);
- Average daily vehicle miles of travel (VMT);
- Changes in in-vehicle travel time for each mode;
- Changes in out-of-vehicle travel time (e.g., walk, wait, transfer, pickup, drop-off) for each mode;
- Changes in out-of-pocket travel cost for each mode;
- For the shared-ride mode only, whether or not its usage is subject to employer incentives.

To apply the worksheets, it is necessary to represent the measure under study in terms of changes in travel time and/or cost. For some measures (e.g., transit fare policies), this is straightforward. However, for some measures (e.g., the designation of a priority HOV lane), the planner will be required to estimate the changes in travel time or cost through use of a highway facility operations model or some other procedure.

The pivot-point model can be used to analyze the effects of virtually any measure which could induce changes in work trip mode choice as a result of changes it makes in the travel time or cost associated with a transportation alternative. It can be applied in the analysis of such measures as priority treatment of high-occupancy vehicles, traffic flow improvements, transit fare changes, pricing policies to discourage low occupancy vehicles, and carpool/vanpool incentives. Thus, the method is applicable for at least some aspects of the analysis of all major transportation-air quality measures, given sufficient information on transportation supply conditions (e.g., changes in travel time).

JHK Manual Diversion Curve Travel Demand Model - This model was developed by JHK & Associates in work for the U.S. Department of Transportation and the Virginia Department of Highways and Transportation. Detailed descriptions and an application example is given in Ref. 78.

This model predicts changes in carpool mode share as a function of changes in the level of service for carpools. It is based on the assumptions that current carpools will choose the fastest path and that modal shifts will occur as the relative travel times between carpools and other modes change for any origin-destination combination. Modes considered include bus, single-occupant vehicle, two-occupant vehicle, three-occupant vehicle, four or more occupant vehicle and, when relevant, a rapid rail transit mode can be included.

The manual analysis method includes five basic steps:

1. Define an origin-destination zone system for the corridor being analyzed. Usually a coarse zone system (i.e., few zones) is selected to permit manual calculations.

2. Define the major elements of the highway network in the corridor, specifying the minimum time path for each O-D pair.

3. Develop interzonal (O-D) travel times for each mode for base conditions and for each alternative HOV priority treatment concept.

4. Develop baseline O-D trip tables for each mode. This usually is done by applying factoring procedures to pre-existing O-D survey data to produce trip tables for analysis years.

5. Apply diversion curves to estimate mode shifts resulting from HOV priority treatments.

The results of this analysis are then used to compute corridor changes in VMT and levels of service. The model resembles a manual version of the computer-based UTPS model. In fact, if output from an existing UTPS model (such as O-D trip tables and travel times) is available, this information can be used as input into this model. However, if this information must be compiled manually, then a fair amount of work is required to derive the O-D speeds and travel times (Ref. 10). The model does not have an explicit capability for level of service feedback, although the outputs of the demand forecast can be readily input into available traffic flow models.

The JHK model was applied with good success in estimating changes in the Shirley Highway express lanes which permitted wider use of this facility by four-person carpools. The diversion curves used in the model were developed from mode choice data in the Shirley Highway corridor. Adjustment or refinement of the curves may be appropriate for application of the model in other urban settings.

Traffic Flow Models

Traffic flow models are used to estimate levels of service changes by alternative travel modes. Several models, three of which are described below, have been developed which can estimate a wide variety of traffic flow impacts for specific levels of vehicular demand.

Many of the traffic flow models also have some capability for approximating route shifts and mode shifts. For large-scale project impact analyses, it may be desirable to use both the demand and traffic flow models in the iterative manner displayed in Figure 3-1.

The FREQ Models - The FREQ models are computer tools that simulate traffic flow and traffic control (including HOV priority treatments) along a freeway facility. Several generations of the FREQ model have been developed over the past few years by Adolf D. May and his associates at the University of California, Berkeley. Most recently developed are two versions: FREQ6PL that can evaluate the impacts of HOV priority lanes on freeways and FREQ6PE that is used to evaluate HOV priority entrance ramp strategies. Detailed descriptions of these models are given in References 12 and 25.

FREQ requires a detailed specification of network geometry, origin-destination flows, and freeway operating policies. Input supplied by the user include:

- o Duration of "time-slices" defined to capture the distinct fluctuations of freeway flow--typically 15 minutes each.

- o "Subsections" defined as the distinct segment of the freeway under study. Only one direction of freeway flow is studied at a time, and no more than 40 subsections may be included.

- o For each subsection:
  - Number of lanes
  - Capacity
  - Length
  - Truck percentage
  - A volume delay curve
  - Subsection gradient
  - Subsection surface quality index
  - Ramp capacities

- o Origin-destination volumes for autos and buses (i.e., freeway ramp and mainline O-D's)

- o Miscellaneous run parameters, depending on the exact FREQ version and analysis circumstances.

- o If a parallel arterial is being analyzed:
  - Subsection data for each of its subsections
  - Base case flow on each of its subsections

The FREQ simulates vehicle behavior in each time slice. It first computes the section-by-section flows. Then it analyzes subsection capacities in light of limiting factors such as weaving and merging. Then, given the flows and modified capacities, it computes travel times by subsection, as well as speeds and vehicle densities at points along the freeway using freeway flow theory and queuing theory equations. Finally, it produces fuel consumption and emissions calculations by subsection, and prints the results for each time slice.

The FREQ models can simulate "uncontrolled" freeway operations, non HOV freeway ramp metering systems, HOV priority entry ramp operation, and freeway HOV priority lane strategies. The FREQ6PE model has the facility for calculating a system of optimum ramp metering rates for any given freeway section. Both the FREQ6PE and FREQ6PL models have simple route shift and mode shift algorithms that can be used to predict preliminary impacts of control strategies on these travel demand characteristics. It is recommended for comprehensive impact analysis to incorporate the use of more refined travel demand forecasting models, as discussed previously. The FREQ model is also useful for testing the impact of increased or reduced traffic demand levels and freeway design modifications.

In past applications, FREQ has required extensive data collection and calibration, but these efforts have paid off in a quite accurate and inexpensive analysis tool. A before-and-after analysis of the Santa Monica Diamond Lane in Los Angeles was remarkably close to what actually occurred.

The TRANSYT Model - TRANSYT is a computer model of traffic flow and control in a network of signalized urban arterial streets. It was originally designed as a tool for optimizing traffic signal settings but has also proven to be a useful simulation model for testing various street design and traffic control measures. TRANSYT has the capability to simulate HOV priority lanes and can optimize and evaluate bus priority signal settings (i.e., signal settings based on passenger weighting rather than vehicular flow weighting).

Several versions of the TRANSYT model have been developed by its originator, D.I. Robertson, at the Transport and Road Research Laboratory (TRRL) in England. The most recent TRRL version in TRANSYT7 and TRANSYT8 is expected to be available by 1981. Various adaptations have also been developed by Adolf D. May and his associates at the University of California, Berkeley, including the latest version TRANSYT6C that includes energy and emissions output estimates, as well as route shift and mode shift algorithms (Ref. 24).

The operation of TRANSYT requires a detailed specification of network geometry, link flows, and signalization criteria. More specific input data include the following:

- A node number for each intersection;
- A separate link for each direction of flow feeding into an intersection. More than one link may be required for special lanes, such as for transit priority or for turning movements;

- Saturation flow rates (in vehicles per hour) for each link, based on roadway widths and variables affecting intersection capacity;

- Link travel times for uncongested flow, for both buses and cars;

- Average flows in vehicles per hour for all links;

- Minimum time required for pedestrians to safely cross at each intersection (considering width of intersection and number of pedestrians);

- Existing signalization plan, with cycle lengths, green and yellow times, and coordinated offsets; and

- Other miscellaneous parameters which specify run options, optimization criteria, fuel consumption characteristics, and output formats.

The TRANSYT program has two key sub-models: simulation and optimization. The simulation portion of TRANSYT simply estimates the extent to which platoons are stopped and delayed at each intersection and the resulting total delay in the system, given the fixed characteristics of flow, signal timings, and network geometry. The simulation can depict the consequences of user-specified changes to each of these system features, and is also an essential feature of the optimization process.

The TRANSYT optimizer seeks to minimize stops and delays in the system by selecting the best signal settings for platoons travelling in each direction. It does so by systematically varying the signal timing parameters, including progression and red/green splits, in search of the "global" minimum for a performance index. The performance index is a user specified weighted combination of stops and delays.

While the TRANSYT program can be used to evaluate bus priority signal settings and HOV priority lanes, the program applies to a much broader range of street and intersection-related measures. The basic simulation/optimization model can represent any traffic engineering improvements which affect intersection capacity, including turning lanes, additional signal phases, parking prohibitions, reversible lanes, etc.

In addition, it can reflect changes in exogeneous factors, such as general increase in flow.

The NETSIM Model - The NETSIM network simulation model, developed for the Federal Highway Administration, performs a microscopic simulation of urban traffic flow on an urban street network. It is designed to be applied to the evaluation of alternative network control and traffic management strategies.

The model is based on a microscopic simulation of individual vehicle trajectories as they move through a street network. It has the capacity to treat all major forms of traffic control encountered in the central areas of American cities. The model is designed primarily to test complex network signal control strategies under conditions of heavy traffic flow. It may also be used, however, to address a variety of other simpler problems, including the effectiveness of conventional traffic engineering measures (e.g., parking and turn controls, channelization, one-way street systems, etc.), HOV priority treatments, and a full range of standard fixed-time and vehicle-actuated signal control strategies.

The model is divided into three major components. The components include a processor for data input processing and editing, the main simulator program which actually performs the simulation mathematics, and a post processor of two individual simulation runs.

In order to run the model, an urban street network is first broken down into a set of uni-directional links and nodes. Each link may contain up to five moving lanes. Midblock changes in geometry may be accommodated by breaking a single block down into two or more successive links. Provision is also made for mid-block "source/sink" nodes representing entrances to parking lots, shopping centers or minor streets not represented on the full network.

The movements of traffic traversing the network are simulated in considerable detail. Inputs to the model include the following:

- o A detailed, coded network;
- o Timing plan(s) or signal control algorithms;
- o Average flow rates for each entry link and source/link node;

- o Intra-link target speeds;
- o Intersection discharge rates.

Various types of statistical output are generated by the model. These can include separate statistics for buses or characteristics of bus-only links.

NETSIM differs from TRANSYT primarily in its real-time capabilities for simulating HOV flow on surface streets. The cost of operating NETSIM can increase substantially faster than TRANSYT for large, complex networks.

IMPACT ESTIMATION

As noted previously, the analytical tools may not provide a high degree of precision in estimating HOV priority treatment impacts. Therefore, often the best guide is the prior experience with the various types of HOV treatments. The following sections describe the magnitude and relationships of impacts observed for various types of HOV treatments. Impacts for other HOV treatments may be found in References 30, 31, 38 and 45.

Travel Time and Mode Shift Impacts

Prior to reviewing the travel time and mode shift impacts of specific HOV treatments, it is important to understand some basic relationships. Figure 3-2 depicts a relationship between HOV travel time advantage and shift to HOV's. This curve is nonlinear in that larger travel time advantages (i.e., greater than 1 minute/mile) appear to shift a greater proportion of travelers into HOV's than do smaller time advantages.

Mode shifts and travel time impacts go through an equilibrium-seeking process after an HOV treatment is introduced. Figure 3-3 shows the travel time changes which occur when a take-a-lane type of HOV priority treatment is implemented. Initially, travel time increases substantially for non HOV's, while HOV travel times decrease.

This travel time differential induces people to shift to HOV's and average vehicle occupancy increases. As the volume of HOV's increases and the number of non HOV's decreases, travel times in the HOV lane increase slightly and decrease in the non HOV lanes. This continues until a point of equilibrium is reached, the

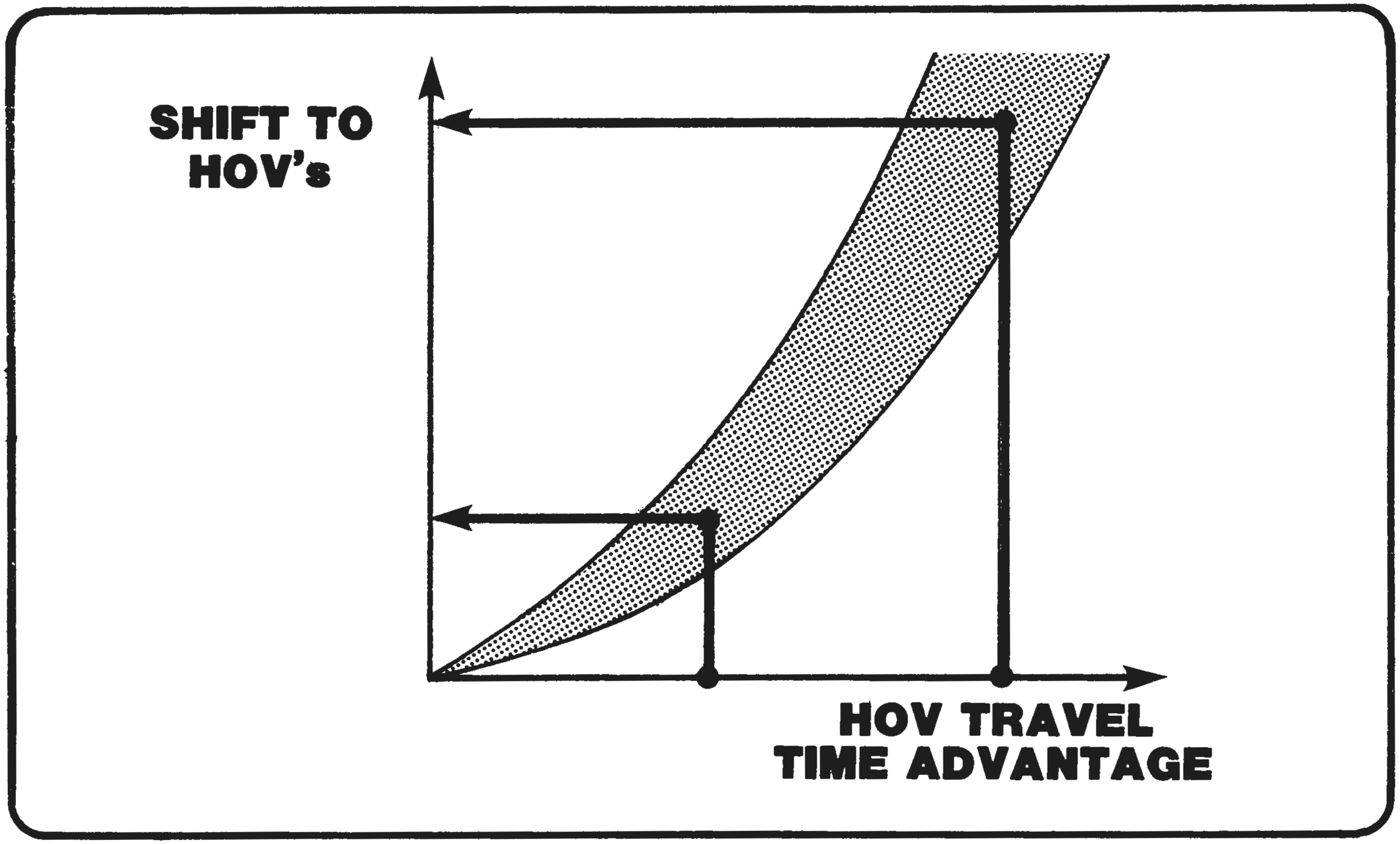


Figure 3-2. Relationship Between HOV Travel Time Advantage and Shift to HOV's

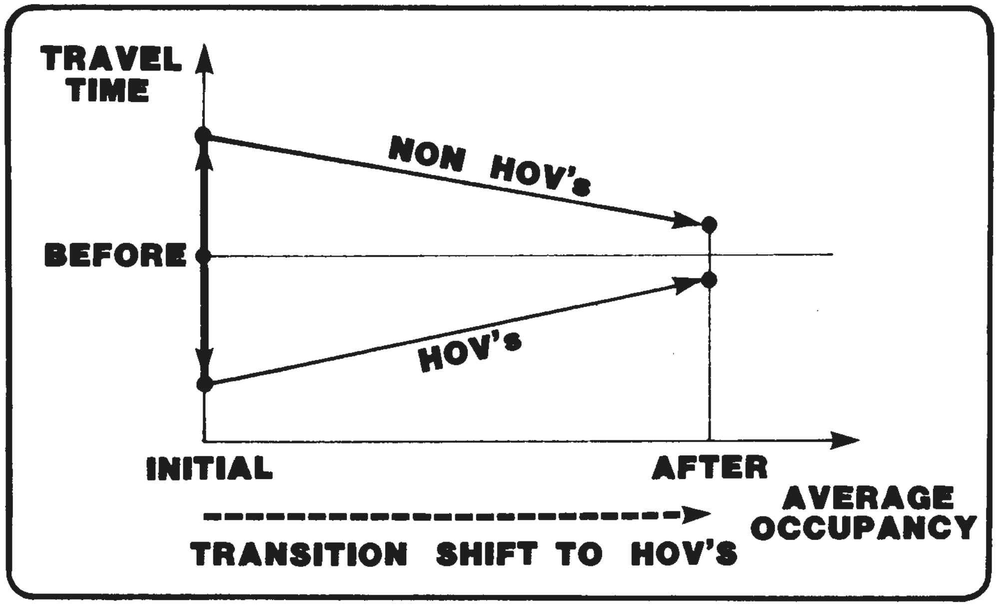


Figure 3-3. Travel Time Impacts of "Take-a-Lane" HOV Treatments

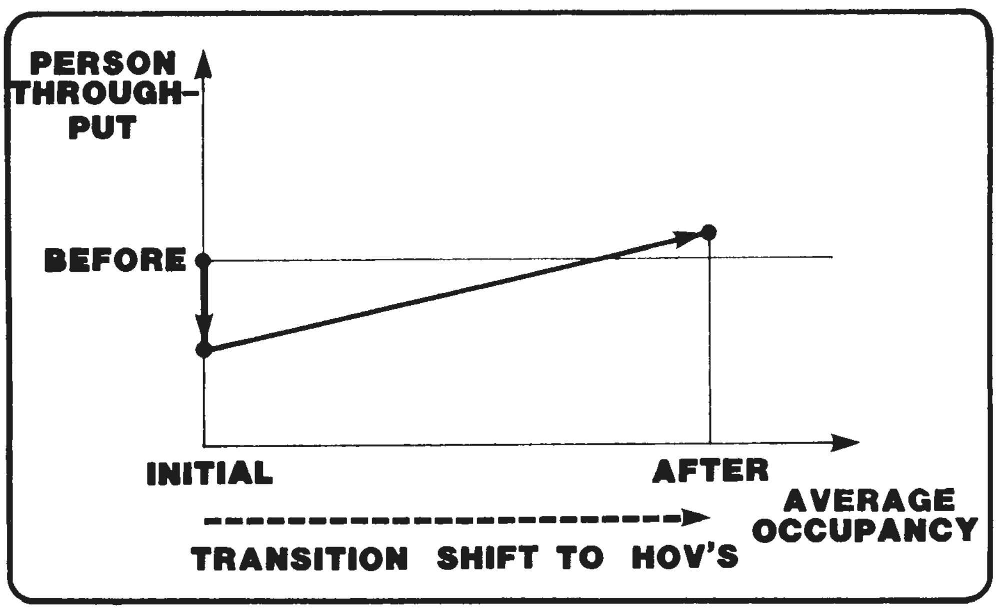


Figure 3-4. Person Throughput Impacts of "Take-a-Lane" HOV Treatments

"After" condition in Figure 3-3.

The mode shift causes a change in person throughput, as indicated in Figure 3-4 for the same take-a-lane treatment. Initially, person throughput will likely drop due to the detrimental effects on the non HOV lanes. However, as the transition shift to HOV's occurs, person throughput begins to increase again, and may surpass the "Before" conditions depending upon the magnitude of shift to HOV's.

The sequence and character of effects is quite different for the add-a-lane types of HOV lane treatments. As shown in Figures 3-5 and 3-6 for travel time and person throughput respectively, both HOV's and non HOV's will generally benefit from this treatment. A travel time equilibrium (Figure 3-5) is reached with a favorable travel time advantage for HOV's, although this differential becomes less as the shift to HOV's continues. Person throughput (Figure 3-6) increases substantially initially due to the added roadway capacity, and then continues to increase as more persons shift to HOV's.

Improved travel time reliability is another typical effect of HOV priority treatments. In comparison with absolute travel time, which indicates the average time required to travel between two points, reliability indicates the range, or standard deviation of travel time which can be expected for a specific trip. Figure 3-7 illustrates that the implementation of an HOV treatment not only reduces the mean, or average, travel time for HOV's but also reduces the standard deviation of the trip time. Travel time reliability is an important factor affecting transit ridership, but it also appears to influence the formation of carpools and vanpools. Unfortunately, only minimal empirical data is available which can fully document the relationship between reliability and HOV mode shift.

To provide a basis for comparing travel time and mode shift impacts, Table 3-2 summarizes the results from a large number of HOV lane projects. Included in the summary table are examples of concurrent flow and contraflow lanes on both grade separated facilities and surface streets, as well as HOV priority ramp treatments.

<u>Grade Separated Facility - Concurrent Flow Lane</u>

For the concurrent flow lanes on grade separated

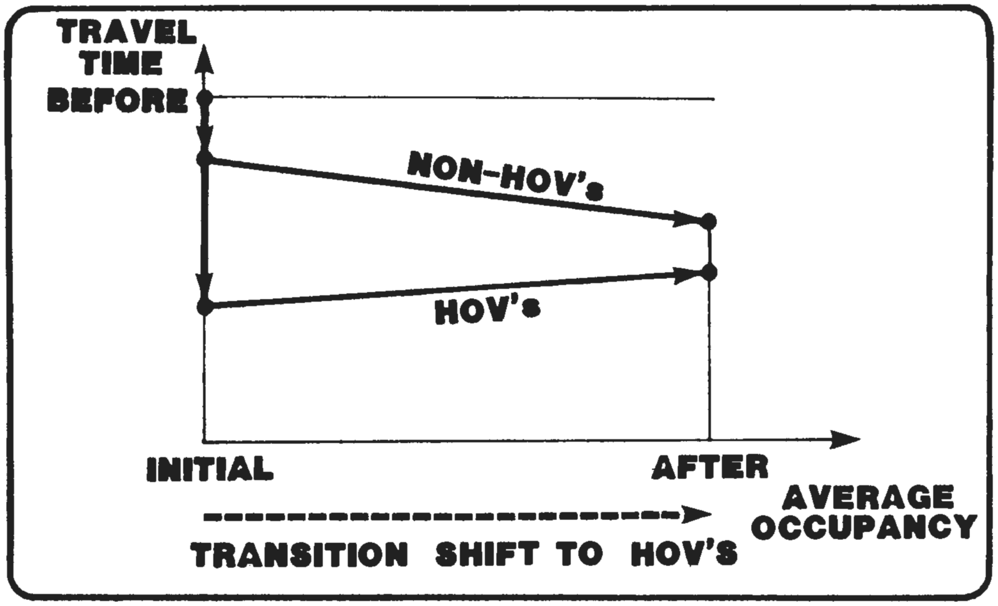


Figure 3-5. Travel Time Impacts of "Add-a-Lane" HOV Treatments

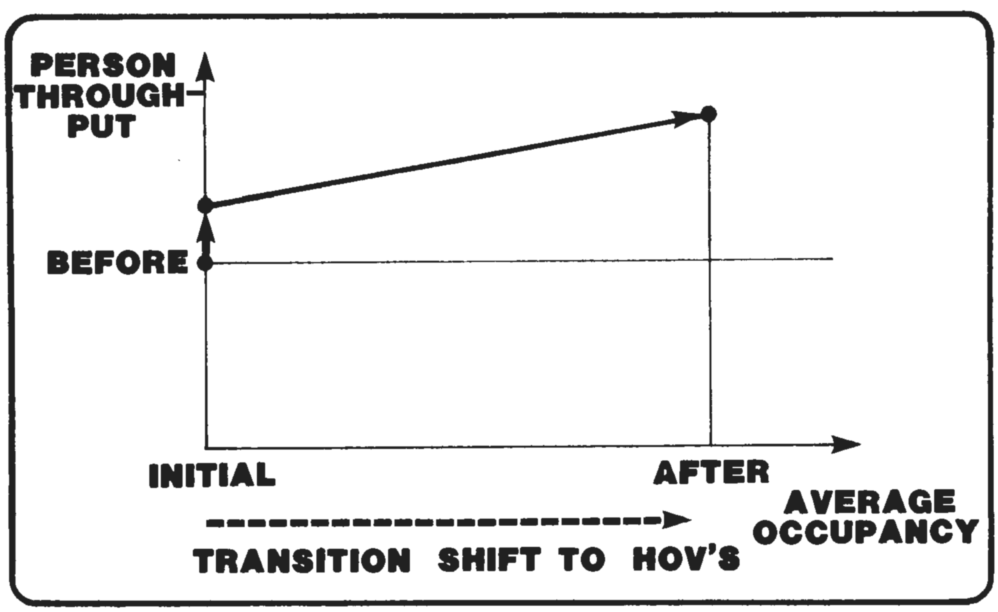


Figure 3-6. Person Throughout Impacts of "Add-a-Lane" HOV Treatments

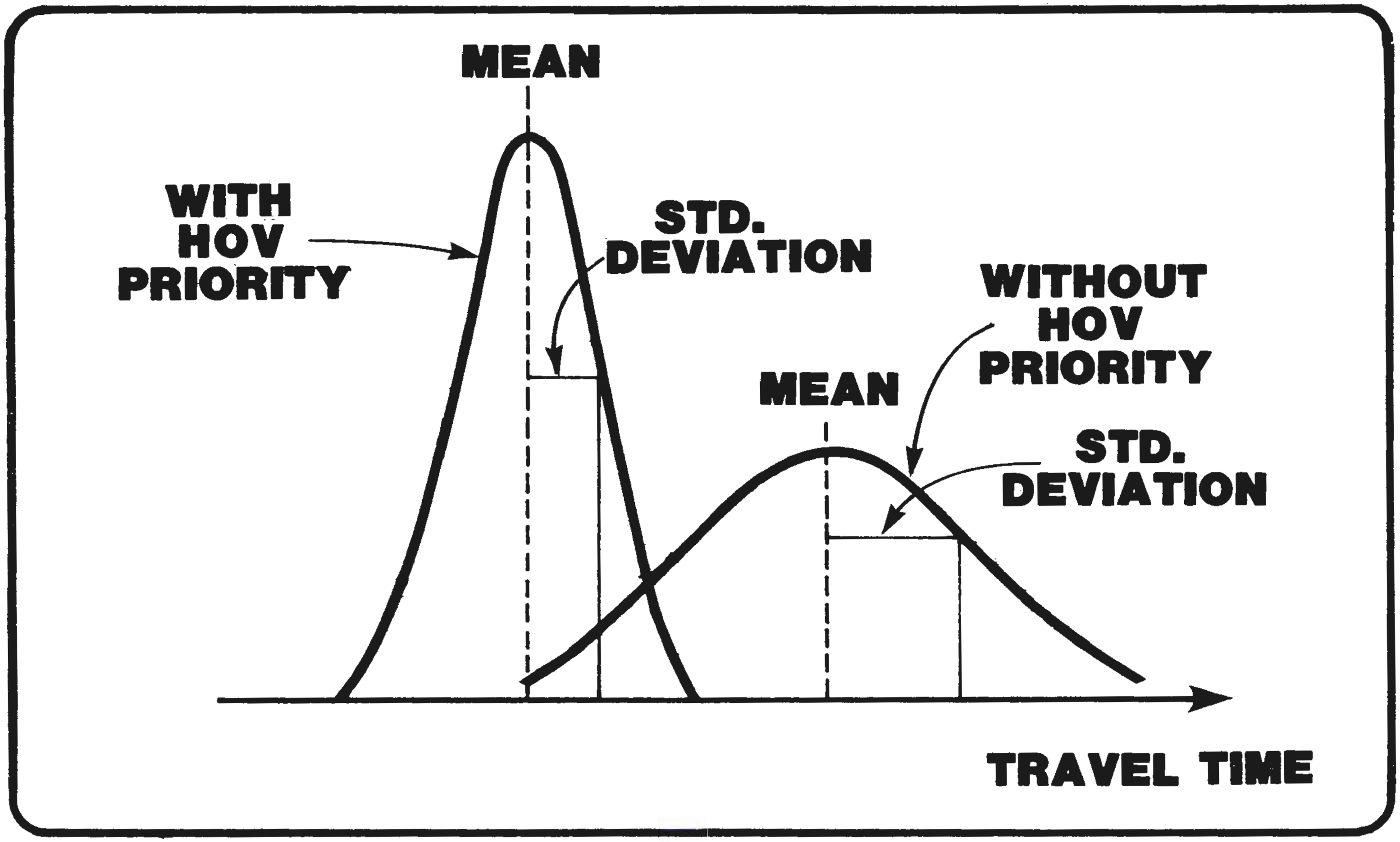


Figure 3-7. Travel Time Reliability

Table 3-2. Travel Time and Mode Shift Impacts of Major HOV Lane Projects

Project	Average Travel Time Savings for HOV's (min.)	Percent Increase in Carpools	Average Car Occupancy Before	Average Car Occupancy After	Percent Increase in Bus Ridership	Reference
GRADE SEPARATED FACILITY-CONCURRENT FLOW						
San Francisco, Oakland Bay Bridge Approach	5	100	1.33	1.43 (+7.5%)	Negligible- (Existing high bus volumes)	(6)
Honolulu-Moanaloa Freeway	3.5 to 6	50	1.70	1.91 (+12.4%)	Negligible- (No charge in bus service. Full loads)	(80)
Boston-Southeast Express-Way						
Pre-Enforcement	5	32	NA	NA	Negligible (No significant service changes)	(95)
During Enforcement	20	70	1.31	1.39 (+6.1%)		
Los Angeles-Santa Monica Freeway	4	65	1.22	1.31 (+7.3%)	225% (Extensive new express bus service)	(52)
Miami-I-95	5	AM 27 avg. 47.5%	1.24	1.25 (+1%)	28% (Express buses moved from 7th Avenue)	(105)
		PM 68	1.31	1.41 (+7.6%)		
Portland-Banfield Freeway	1.5	100+	1.32	1.39 (+5.3%)	100% (Extensive new service and marketing)	(87)
Brooklyn-Queens Expressway	2.5					
Boston-I-93	4 to 10	85	NA	NA	NA	(38)
Seattle-SR520, Evergreen Point Bridge Approach	7	85	NA	NA	20%	(101)
GRADE SEPARATED FACILITY CONTRAFLOW						
New York, I-495 Lincoln Tunnel Approach	4	NA	(Bus Priority Only)		5-10%	(99)
New York, Long Island Expressway	10	NA	"		NA	
San Francisco, U.S. 101	3	NA	"		5-10%	(53)
Houston, North Freeway	18	100+ (vanpool)	NA	NA	400+ (Extensive new express bus service)	

Table 3-2. Travel Time and Mode Shift Impacts of Major HOV Lane Projects (Cont'd.)

Project	Average Travel Time Savings for HOV's (min.)	Percent Increase in Carpools	Average Car Occupancy Before	Average Car Occupancy After	Percent Increase in Bus Ridership	Reference
GRADE SEPARATED FACILITY - EXCLUSIVE IN MEDIAN						
Washington, D.C. - Shirley Highway	10-15	500	1.35	1.87	925% (Extensive bus service	(49,84)
Los Angeles-San Bernardino Express Lanes	5-9	300	1.22	1.54	1,000% (Extensive new express bus service)	(74)
GRADE SEPARATED FACILITY - RAMP TREATMENTS						
Average of 56 Los Angeles Ramps	1-5	35	1.20	1.26 (+5.0%)	NA	(6)
Minneapolis I-35, Grant Street	1	40	(Extensive diversion from other ramps)		NA	(51)
Seattle I-5, Columbia-Cherry	2-4	10	NA	NA	NA	(38)
SURFACE STREET - CONCURRENT FLOW						
Honolulu-Kalanianaole Highway (Includes a contraflow lane section)	2-3	36	1.65	1.79 (+3.5%)	Negligible- (Express bus expansion preceded priority lane)	(79)
Miami-South Dixie Highway (Buses originally in contraflow lane)	6-9	50	1.38	1.60 (+16.0%)	50% (New express bus service)	(92)
Miami-7th Avenue (Also includes bus priority signals)	6		(Bus Priority Only)		42% (New express bus service)	(106)
Denver-Broadway Lincoln	0.5-1.0		(Bus Priority Only)		15-25% (New bus service)	(58,60)
Arlington, VA, Route 50	2.7	100	1.34	1.53 (+14.2%)	+10%	(38)
Arlington, VA, Wilson Blvd. (Includes reversible lanes)	2		(Bus Priority Only)		0	(38)
Baltimore, York Road	-0.7 to +1.5	NA	(Bus Priority Only)		0 to -5	(72)
SURFACE STREET - CONTRAFLOW						
Portland, Barbur Blvd.	1.8-2.3	NA	(Bus Priority Only)		NA	(38)
San Juan, Puerto Rico-Ponce de Leon/ Fernandez Juncos	7-15	NA	(Bus Priority Only)		NA	(63)
Miami-South Dixie Highway	8-9	NA	(Bus Priority Only)		500% (Extensive new express bus service)	(38,92)

facilities, the percent increase in carpools ranged from about 30 to 70 percent. The corresponding percent increases in average automobile occupancy was surprisingly consistent for these projects, averaging about 7 percent for the freeway-related treatments.

Surface Street - Concurrent Flow Lane

Concurrent flow HOV lanes on radial surface streets have exhibited noticeable travel time and mode shift impacts, as shown in Table 3-2. Some of these HOV treatments (e.g., South Dixie Highway and Kalanianaole Highway, which allowed carpools as well as buses) resulted in HOV travel time advantages and mode shifts to HOV's which were similar in order of magnitude to the freeway priority lane projects. Conversely, bus only projects in Baltimore (York Road) and Arlington, Virginia (Wilson Boulevard) produced only minimal improvements for HOV's and resulting congestion to non HOV's. The projects which added new bus service and/or permitted carpools into the HOV lane were generally the most successful in terms of mode shift to HOV's.

For many years, concurrent flow bus lanes have been implemented in major activity centers, especially CBD's. Usually, the right curb lane is designated as a bus lane and often right turns by general traffic and curbside taxi operations are also permitted. As a result, the travel time impacts are typically not very significant.

Table 3-3 lists the characteristics and travel time impacts of a number of priority bus lanes in activity centers. The total time savings for buses are generally lower than those on the grade separated and radial surface street HOV lanes reviewed previously, chiefly because the activity center projects are limited to relatively short sections of street, often under a half-mile. No evidence is available to show that activity center bus lanes have caused significant increases in bus patronage. However, the high bus volumes, worthwhile travel time improvements and improved bus reliability shown are reasons enough for pursuing such projects for the objectives of improving the efficiency of transit operations and the efficiency of activity center curb usage.

Table 3-3. Representative Time Savings on Activity Center Bus Lanes

Location	Length of Bus Lane, Miles	Improvement in Bus Travel Time		Remarks
		Minutes	Minutes per Mile	
Atlanta-Peachtree St.	0.30	0.11	0.4	Discontinued 1962
Baltimore-Paca St.	0.36	AM (0.18) PM 0.57	(0.5) 1.6	
Chicago-Washington St.	0.60	AM 2.0 PM 8.5	3.4 14.1	Median Lane
Newark-Market St.	0.34	1.0	3.3	
New York-5th Avenue	2.50	4.65	3.7	-1.25 mile survey section
New York-Madison Avenue	1.12	4.95	4.0	-1.23 mile survey section
New York-2nd Avenue	1.90	2.30	1.2	
New York-1st Avenue	1.90	2.60	1.4	
San Francisco-O'Farrel St.	0.65	0.70	0.6	-1.20 mile survey section

Source: Adapted from Ref. 48.

Grade Separated Facility - Contraflow Lane

Contraflow lane treatments on grade separated facilities, primarily oriented to buses, have shown travel time savings in the range of 1 to 3 minutes per mile (see Table 3-2). Although mode shift information was generally lacking, increases in person throughput on the order of 5 to 10 percent were noted in New York (I-495) and San Francisco (U.S. 101). The Houston project (North Freeway) has exhibited dramatic increases in both bus and vanpool ridership, almost double the pre-project goal. In all cases, the contraflow lanes carry a high percentage of the total peak direction person throughput (20 to 50 percent).

Surface Street - Contraflow Lane

The time savings potential for buses in surface street contraflow lanes can be highly significant, as shown in Table 3-2. Reliable data is generally not available on resultant increases in bus ridership. The South Dixie Highway project in Miami revealed a substantial increase in ridership. However, the effects of the extensive new bus service using the contraflow lane cannot be isolated.

Grade Separated Facility -
Exclusive In-Median Lanes

For the two best known exclusive in-median HOV lanes on grade separated facilities, the San Bernardino Freeway and the Shirley Highway, peak period travel time savings per HOV averaged 7 minutes and 12.5 minutes respectively. During the height of the peak period, the travel time advantage has been twice or more as great as the indicated peak period average values.

The mode shift to HOV's was markedly higher for the two physically separated exclusive lane projects as might be expected because of the greater travel time advantage, the isolation from disturbances in the adjacent lanes, and the more positive enforceability characteristics of this concept. On the San Bernardino Freeway, 3+ carpools increased by about 300 percent and on the Shirley Highway, where travel time savings for HOV's were greatest, 4+ carpools in the 3.5-hour peak period increased by an extraordinary 500 percent, growing from approximately 700 before implementation in 1973 to more than 4,000 in 1980. Average peak period auto occupancy on the Shirley Highway has increased from 1.35 in 1973 to 1.87 in 1980, a 38.5 percent rise.

Growth in bus ridership ranged from negligible amounts on several projects to a 1,000 percent increase on the San Bernardino Freeway. It is difficult to analyze the causes of the increased bus ridership because of the effect of major expansions of express bus service in nearly all of the corridors. It is certain, however, that the HOV treatment contributed some significant portion of the ridership growth that otherwise would not have occurred. On the San Bernardino Freeway and Shirley Highway Express HOV lanes, approximately half the express lane users are in buses and the other half in carpools. This vividly demonstrates that the productivity of HOV lanes can be greatly increased if carpools, as well as buses, are given priority treatment.

Separate Right-of-Way - Exclusive HOV Roadway

The South PATway (Pittsburgh, Pennsylvania) has exhibited substantial travel time savings on the order of 6 to 10 minutes. Mode shift data was not available; however, the buses on the HOV lanes carry approximately 25 percent of total peak period corridor person throughput in only 2 percent of the total vehicles.

Surface Street - Exclusive HOV Roadway

Transit mall projects in downtown areas have shown negligible bus travel time savings, although bus reliability has improved in most cases. The diversion of non HOV's did not create significant congestion on parallel facilities. Mode shift has not been significant, although transit person movement is generally more heavily concentrated on the exclusive roadway. There is some evidence of increased use by buses during midday hours. In most projects of this type, the major incentives for implementation have been to increase the efficiency of transit operations and to separate the conflicts between buses and autos, rather than just attempt to increase bus ridership.

HOV Ramp Treatments

HOV priority ramp treatments as shown in Table 3-2 have shown significant impacts on carpooling. Ramp meter bypass treatments in Los Angeles have induced carpool increases up to 35 percent based upon travel time savings ranging from 1 to 5 minutes. Substantial diversion of existing carpools to the HOV ramp from adjacent non HOV priority ramps was not able to be isolated. Similar findings were recorded in

Minneapolis. The impacts of exclusive HOV ramps have not been fully documented, although the travel time incentives for HOV's can be dramatic compared to alternate ramp locations.

Signal Priority

Table 3-4 presents impacts of bus priority signal preemption systems installed in four cities. All of these are on fairly long sections of major arterials and two of the projects (Miami and Louisville) are on routes with express bus service. The bus travel time savings produced by signal preemption systems mostly fall in the range of 0.5 to 1.0 minutes per mile. Consequently, worthwhile total time savings can be obtained if the technique is implemented along a long stretch of an arterial.

The Miami results show that the combination of bus priority signals and bus priority lanes result in significantly greater time savings than either technique applied independently. The Miami findings also indicate that bus priority optimization of pretimed signal settings (an action requiring no hardware investments) can produce time savings for buses which are nearly as great as those provided by the more costly signal preemption system. As a general rule, however, bus priority optimized signal settings should be used when bus volumes reach 30 or more per hour, whereas signal preemption is a feasible concept with bus volumes as low as 10 to 15 per hour.

None of the signal priority treatments have exhibited much direct impact on bus ridership. However, improved bus reliability was a major factor in promoting and maintaining ridership. Other potential impacts of the improved travel times include reductions in operating costs due to fewer buses needed to meet a given schedule and due to better fuel efficiency. These benefits are likely to be greatest on long arterials where new express bus service are being introduced.

Priority Parking

The impacts of HOV priority parking projects are more difficult to isolate than those of HOV lane treatments. An easily accessible park and ride lot with good transit service will allow users to complete their trip with minimum delay. Decreases in door-to-door travel time can even occur where HOV's (buses and/or carpools) are given direct access from

Table 3-4. Travel Time Impacts of Selected Bus Priority Signal Preemption Systems

Location	Length	Bus Travel Time Savings	
		Average	Average per Mile
Miami - N.W. 7th Avenue	10 mi.		
Signal Preemption in Mixed Traffic		5 to 8 min.	0.5 - 0.8 min.
Signal Preemption with Median Bus Lane		8 to 9 min.	0.8 - 0.9 min.
Bus Priority Optimized Timing with Bus Lane		6 to 8 min.	0.6 - 0.8 min.
Louisville	4.5 mi.	2 min.	0.4 min.
Sacramento - Greenback Lane	3.8 mi.	WB 0.57 min. EB 2.88 min.	0.15 min. 0.75 min.
Concord, California	3.5 mi.	3 to 4 min.	0.85 - 1.1 min.

1 mi = 1.65 km

Source: Ref. 46

parking facilities to HOV lane treatments. Close-in activity center HOV lots can often decrease walk times to destinations. Designated HOV spaces can also minimize parking space search time.

Existing projects have shown wide variations in HOV parking facility usage depending upon such factors as location, level of transit service, access and amenities. Park and ride lots near major grade separated facilities and those which have added express bus service show the highest usage, often filled to 90 or over 100 percent of lot capacity. The redesignation of existing lots for park and ride lots has generally been less effective.

Activity center lots for HOV's often exhibit capacity usage especially when combined with reduced parking charges. Some desirable HOV lots may need to be restricted to high occupancy vanpools in order to prevent overcrowding by existing and newly formed carpools. On-street metered carpool spaces have also been designated in Portland and Seattle with high utilization by HOV's.

Priority Pricing

Priority pricing strategies have achieved mixed results. Toll pricing impacts have varied widely due to such factors as the characteristics of the toll plaza users and the percentage of total trip cost which the toll reduction represents.

Two applications of reduced HOV toll payments are along the Connecticut Turnpike and across six Hudson River crossings between New York and New Jersey. Both pricing strategies were aimed at carpools, although buses also received some benefit. The impacts of the toll pricing strategies varied from a 150 percent increase in carpooling along some sections of the Connecticut Turnpike to approximately a 5 to 10 percent increase in carpooling on the river crossings. The major reason for this wide range in mode shift is partially explained by the relative market for new carpooling in each location. The New York City carpooling market had only small room for expansion, whereas the market in Connecticut was still growing. As a result, the major effect of the toll pricing strategy in New York was to help maintain existing levels of carpooling while in Connecticut the toll reductions provided a visible incentive for new carpooling.

Activity center reduced parking charges for HOV's have generally been successful in maintaining existing carpools as well as attracting some new carpools, especially where the price reduction represents a significant proportion of daily carpool costs. The most successful applications have included designated HOV parking spaces in addition to the price reductions. Pricing strategies aimed at vanpool parking have been quite successful. One program in San Francisco has been experiencing vanpool increases of 5 to 10 percent a month using reduced parking charges and special vanpool spaces.

Net Vehicle Travel Time Impacts

The foregoing discussions gave the travel time differentials between vehicles using HOV priority lanes and those using regular lanes. However, It is also important to estimate the overall net effect on travel time for all vehicle trips using facilities on which HOV priority treatments have been implemented. Table 3-5 summarizes travel time impacts for add-a-lane and take-a-lane HOV priority lane projects. Changes in travel time in the regular lanes and in the HOV lanes are shown. The overall average travel time changes are computed based on a weighted average, knowing the percent of total vehicles in the HOV and regular lanes.

The averages shown represent general tendencies, or rough orders of magnitude, rather than precise estimates. Even with this caveat, however, the results clearly show the difference in the nature of travel time impacts for projects in which new HOV lanes are added versus those in which existing lanes are taken from general traffic use.

For HOV projects on grade separated facilities in which lanes were added, the overall effect on average vehicular travel time ranged from virtually zero in Portland to a reduction of 4 minutes per vehicle trip in Miami. Assuming an average work trip travel time for vehicles using these add-a-lane freeway facilities of approximately 30 minutes, the average reduction in travel time equals about 6 percent, attributable to the fact that highway capacity was increased.

For the HOV projects on grade separated facilities in which lanes were taken, travel time was significantly increased for regular lane vehicles as well as for the weighted average of all vehicles using the facilities. Average travel time increases for all vehicles ranged from 2.8 minutes to 10.2 minutes on the

Table 3-5. Net Travel Time Impacts on Selected HOV Lane Projects

Project	Average Travel Time, Minutes: Before — Regular Lanes	Average Travel Time, Minutes: After — Regular Lanes	Average Travel Time, Minutes: After — Priority Lanes	Change in Travel Time: Regular Lanes	Change in Travel Time: Priority Lanes	Percent of Total Vehicle Volume: Regular Lanes	Percent of Total Vehicle Volume: Priority Lanes	Overall Change in Peak Period Average Travel Time (Minutes)
LANES ADDED								
Miami - I-95	13.50	9.60	7.90	-3.90	-5.60	95	5	-4.0
Portland - Banfield Fwy.	5.36	5.27	3.88	-0.09	-1.48	95	5	-0.2
Honolulu - Kalanianaole Hwy.	11.00	10.00	7.00	-1.00	-4.00	80	20	-1.6
								Average = -1.9
LANES TAKEN								
Los Angeles - Santa Monica Fwy. AM	15.70	20.20	14.70	+4.50	-1.00	95	5	+4.2
Los Angeles - Santa Monica Fwy. PM	18.40	21.50	15.60	+3.10	-2.80	95	5	+2.8
Boston-Southeast Exp.	28.00	40.00	18.00	+12.00	-10.00	92	8	+10.2
								Average = +5.7
								Avg. (LA only) = +3.5

(Ref.46)

Southeast Expressway in Boston. It should be noted that the Boston HOV rule was enforced for only 2-1/2 weeks and conditions were still in a transitional stage at the time of project termination. It is likely that if the project had been continued, the ultimate equilibrium would have shown less severe average travel time increases.

Because Boston represents a special case it is believed that the Santa Monica Freeway is a better example to use to estimate the "typical" effect of a freeway take-a-lane project. The results indicate a weighted average travel time increase of 3.5 minutes per vehicle. Assuming again an average work trip time of 30 minutes, the travel time <u>increase</u> equals about <u>12 percent</u>, attributable to the fact that vehicular service capacity was reduced.

In theory, physically separated HOV express lanes added to a freeway facility should have an even more positive travel time impact than the unseparated add-a-lane cases. However, the observed average travel times on the San Bernardino Freeway project actually increased slightly as a result of a 25 percent growth in total facility travel demand in the after period and to congestion at the terminal points where express lanes merged back into general traffic. If the physically separated HOV strategy had been tested under conditions of constant person trip demand, net improvements in average vehicular travel time would have resulted. Consider, for example, the following theoretical example of travel time impacts of physically separated HOV express lane projects:

- <u>Before Express Lanes</u>
  - Regular lanes = 30 mph or 2.0 minutes per mile

- <u>After Express Lanes</u>
  - Regular lanes = 50 mph or 1.8 minutes per mile
  - Express HOV lanes = 50 mph or 1.2 minutes per mile
  - Assuming five percent of total vehicles in the express HOV lanes, then average travel time = .95(1.8) + .05(1.2) = 1.77 minutes per mile
  - Reduction in average travel time = 0.23 minutes per mile
  - Reduction for a ten-mile facility = 2.3 minutes
  - Percent reduction for a portal-to-portal

average trip time of 30 minutes = 8 percent

In practice, it is unlikely that person travel demand in corridors where physically separated express lanes are built will be held constant before and after project implementation. Projects of this type are usually pursued in critical corridors where growth trends in traffic demand and congestion require some action to provide expanded person-moving capacity. Both the San Bernardino Freeway and Shirley Highway projects have demonstrated the desirability of building express HOV lanes to accommodate the demand rather than building additional general purpose lanes. It is significant that on the San Bernardino Freeway 25 percent greater person-volumes were served with only a 4 percent increase in average travel time. Even more dramatically, between 1973 and 1979, the person-volumes served on the Shirley Highway have nearly doubled, and these demands have been accommodated with little if any degradation in overall average travel time per vehicle.

In summary, the results of the foregoing analysis indicate the following rough orders of magnitude impacts of grade separated HOV priority treatments on project-level average peak-period work-trip travel times for all vehicles (based on a 30-minute average trip time):

- Lanes taken--12 percent increase in travel time
- Lanes added--six to eight percent reduction in travel time

Net Travel Demand Impacts

The project level impacts on magnitude of travel, total peak period vehicular volumes and passenger volumes for six of the larger scale HOV priority treatment projects are shown in Table 3-6. The data in this table include all modes of travel on these facilities (autos, carpools, and buses) and were used to calculate the ratio of vehicles per person before and after the HOV priority treatments were implemented. The results reveal the reduction in total vehicular volumes past the critical sections of these facilities for a given level of person trip demand.

For the two physically separated HOV express lane facilities (the Shirley Highway and the San Bernardino Freeway), vehicle volumes per person were reduced by 15 percent or more. For the other three HOV priority lane projects shown (Santa Monica Freeway, Miami I-95, and the Kalanianole Highway), vehicle volumes per person were reduced by considerably smalller amounts, averaging approximately 6 percent. The maximum potential short-term reduction in vehicle volumes per person on such facilities appears to be less than 10 percent. The gross percent reductions in vehicle volumes past critical points shown in Table 3-6 are not, however, valid estimates of net reductions in vehicle trips or vehicle miles of travel for persons using these facilities. Vehicle trips and vehicle miles are reduced by somewhat lesser amounts because of a variety of factors, including:

- A portion of the persons shifting to bus make automobile trips to park and ride lots, thereby reducing the apparent gross reduction in vehicle trips and vehicle miles.

- A portion of persons shifting to carpools drive and park at pre-arranged pickup points.

- Carpool trips involve some circuitous travel to pick up passengers, making the trip longer than it would be if the driver traveled alone.

- Some carpools are attracted to the HOV priority facility from more direct, shorter distance routes to their destinations because of the travel time advantage.

All of these factors combine to dilute the apparent gross savings in magnitude of vehicular travel by roughly 35 to 45 percent. For example, in the evaluation of the San Bernardino express lanes, these factors were explicitly accounted for and resulted in an estimated net reduction in vehicle miles of travel of about 10 percent compared with the 15 to 18 percent reduction in vehicles per person traveling on the facility.

Using the above rough order of magnitude estimates, it appears that HOV priority facilities on which express lanes are <u>physically separated</u> from other traffic have the potential to reduce vehicle trips and vehicle miles of travel (for a given person trip demand) by approximately <u>10 percent</u>. On <u>non-physically separated</u> HOV lanes the approximate maximum reduction in vehicle trips and vehicle miles traveled for persons using the project facility is about <u>5 percent</u>. Note that these are <u>project level</u> impacts, not areawide impacts.

Table 3-6. Net Travel Demand Impacts on Selected HOV Lane Projects

Project		Total Vehicles Before	Total Vehicles After	Total Persons Before	Total Persons After	Vehicles Per Person Before	Vehicles Per Person After	Percent Difference
San Bernardino Freeway	AM	27,490	29,232	33,330	43,090	0.825	0.678	-18%
	PM	27,890	28,648	35,360	42,630	0.789	0.672	-15%
Shirley Highway[a]	AM	12,542 (1973)	20,542 (1979)	30,502	59,064	0.411	0.348	-15%
Santa Monica Freeway	AM +PM	113,135	101,678	138,873	136,421	0.815	0.745	-9%
Miami I-95	AM	12,367	15,386	15,856	19,933	0.780	0.772	-1%
	PM	12,117	15,290	16,422	22,338	0.738	0.684	-7%
Kalanianaole Highway	AM	12,020[b]	12,340[b]	19,660[c]	22,050[c]	0.611	0.560	-8%
Boston, Southeast Exp.[d]	AM	14,800	13,900	22,400	21,600	0.661	0.644	-3%

[a]Before data for the Shirley Highway is for 1973, just prior to the time the express lanes were opened for carpoolers. In 1973, express bus volumes during the AM peak period had already grown to 14,000 persons, nearly triple the number in 1971.

[b]Vehicle Miles of Travel

[c]Person Miles of Travel

[d]In Boston, the Southeast Expressway HOV priority rule was enforced for only 2-1/2 weeks before project termination and the shift to carpoolers had not yet reached equilibrium.

(Ref.46)

Energy and Emission Impacts

Fuel consumption and air pollution impacts are dependent on the marginal changes in total trips and vehicle miles of travel, as well as the net travel time impacts on HOV's and non HOV's. Careful trade-off analyses may be made to assess the reductions in vehicle travel resulting from mode shifts against the increases in travel time encountered by non HOV's. The HOV lane projects in which existing road space is reallocated on a priority basis (whether on freeways, freeway ramps, or arterial streets) may result in net increases in vehicular travel time and delay, and consequent increases in emissions and fuel consumption. However, on projects in which lanes are added to existing facilities to accommodate HOV's, or where reversible lanes or contraflow lanes are employed, congestion can be reduced for both HOV's and non HOV's, while at the same time affording travel time advantages for HOV's. In the latter case of added lanes, the fuel conservation and emissions reduction benefits are more certain.

It is important to compute energy and emissions estimates in every total-corridor trip-based framework. By analyzing only the VMT and travel time changes on the facility proper, within the boundaries of the HOV priority treatment, substantial portions of the total VMT reduction impact of a project may be overlooked. Two different quick response analytical methods for assessing travel demand and mode shift impacts, and two models for estimating traffic flow impacts were described previously. These techniques are very useful in performing detailed impact analyses and provide the input for energy and emissions calculations.

The impact of total highway network changes on automobile fuel consumption can be computed by the simple estimating equation: (Ref. 45)

$$\Delta F = 0.0425(\Delta VMT) + 0.60(\Delta VHT)$$

where,

ΔF = change in total fuel consumption, gallons.
ΔVMT = change in total vehicle miles of travel.
ΔVHT = change in total vehicle hours of travel.

Note that both VMT and VHT must be considered in energy analyses. Detailed examples for calculating emissions and fuel consumption as a function of changes in trips, VMT, and average speed or travel time are given in Reference 8. Manual worksheets for performing similar computations are available from EPA.

Safety

The safety impacts of HOV priority facilities are an important concern. The results have been mixed and some projects have caused substantial increases in accident rates.

A comprehensive overview and evaluation of the safety impacts of HOV priority treatments was prepared for FHWA (Ref. 31). The reader is referred to that report for details. The general finding was that the introduction of an HOV project tended to increase accident rates (see Table 3-7). Six projects experienced a statistically significant increase in peak period accident rates, five projects had non-significant increases, one project experienced a statistically significant decrease, and three projects had non-significant decreases. Basing accident rates on person miles improved these impact results somewhat, but not enough to change the general conclusions.

Table 3-8 summarizes peak period safety impacts for the various types of HOV priority treatments. The freeway concurrent flow HOV lanes have produced mixed safety results, with substantial increases in accidents occurring after HOV lane implementation on the Santa Monica Freeway and the U.S. 101 Freeway in San Francisco. In both cases, accident frequency and rate doubled compared with experience prior to HOV lane operation. There has been considerable concern about the potential risks of freeway contraflow lanes due to the high relative speeds between HOV's and oncoming general traffic. Only one project (U.S. 101 in San Francisco) had valid data for comparing before and after peak period accident rates. There was no significant safety impact in the peak directions, but a small increase in accident rates occurred in the off peak directions.

Both of the major physically separated in-median HOV lane projects on grade separated facilities (San Bernardino Freeway and Shirley Highway) have had outstanding safety records. Only about two percent of

Table 3-7. Change in Accident Rates for HOV Priority Treatment Projects

TREATMENT	PEAK PERIOD	ACCIDENT RATE CHANGE FROM BEFORE CONDITION[a]			
		Vehicle-Miles		Person-Miles	
		Increase[b]	Decrease[b]	Increase[b]	Decrease[b]
FREEWAY-RELATED					
• Separate Facility	AM & PM	1 project ns	—	1 project ns	—
• Concurrent Flow Lane	AM & PM	2 **	1 ns	2 **	1 ns
• Contraflow Lane	PM	1 ns	—	1 ns	—
• Toll Plaza Lane	AM	1 ns	—	1 ns	—
• Ramp Metering Bypass	AM or PM	1 **	—	1 **	—
ARTERIAL-RELATED					
• Separate Facility	—	—	—	—	—
• Concurrent Lane (Median)	AM & PM	2 ns/**	1 ns	2 ns	1 ns
• Concurrent Lane (Curb)	—	—	—	—	—
• Contraflow Lane (Median)	AM & PM	2 ns/**	1 ns	1 **	2 ns
• Contraflow Lane (Curb)	AM & PM	1 **	—	1 **	—
• Signal Preemption	AM & PM	—	1 **	—	1 **
TOTALS					
• Significant Change		6	1	5	1
• Non-significant Change		5	3	5	4

a. Some projects do not have comparative before data.

b. Statistical significance of accident rates compared to the before condition:
ns indicates difference is not significant for each project.
**indicates a 95 percent or higher level of significance for each project.

(Ref.31)

Table 3-8. Safety Impacts of HOV Priority Treatment Projects

PROJECT	PEAK PERIOD SAFETY IMPACT
GRADE SEPARATED CONCURRENT FLOW	
Los Angeles - Santa Monica Freeway	Accident rates doubled. Accidents rates in lane next to HOV lane increased sharply.
Boston - Southeast Expressway	No statistically significant change.
Miami - I-95	No statistically significant change. in AM. Accidents reduced by about one-half in PM.
Portland - Banfield Freeway	No statistically significant change. However, peak period accidents tend to cluster in lane next to HOV lane.
San Francisco - U.S. 101	Accidents doubled.
Honolulu - Moanalua Freeway	No significant difference between Moanalua and comparable non-priority freeway.
GRADE SEPARATED CONTRA-FLOW	
San Francisco - U.S. 101	No significant change in peak direction. 30% increase in offpeak direction.
GRADE SEPARATED EXCLUSIVE IN MEDIAN	
Los Angeles - San Bernardino Freeway	No significant change in AM. Small increase in PM. Only 2 percent of total facility accidents occur in HOV lanes.
Washington, D.C. - Shirley Highway	Only 2 percent of total facility accidents in HOV lanes.
FREEWAY RAMP TREATMENTS	
21 Los Angeles ramps	At the total of 21 ramps accidents increased from 2 per year to 17 per year. (i.e. still less than 1 per year per ramp even though the overall rate increased sharply.
SURFACE STREET CONCURRENT FLOW	
Miami - N.W. 7th Avenue	No significant change.
Miami - South Dixie Hwy. (carpools)	Significant increase, 60% in AM, 38% in PM.
Honolulu - Kalanianaole Hwy.	No significant change.
SURFACE STREET CONTRA-FLOW	
Miami - South Dixie Hwy. (Bus Lane)	68% increase.
Puerto Rico - Ponce de Leon/ Fernandez Juncos.	Possible small increase but rates are less than on other non-priority arterials.
SURFACE STREET SIGNAL PREEMPTION	
Miami - N.W. 7th Avenue	70% reduction.

total facility accidents occur on the HOV lanes for these two projects.

On the surface street HOV priority lane projects, the only significant changes in accident rates were on the South Dixie Highway in Miami. Both the concurrent carpool lane and contraflow bus lane operations resulted in significant increases in accident rates.

On balance, peak period safety appears to be degraded somewhat by HOV priority treatments. The safety problems are especially evident for freeway concurrent flow HOV lanes and for HOV entrance ramp bypass lanes. In many instances, however, no significant changes in safety have occurred. When peak period changes were significant, the effect on overall daily accident rates was often very small.

PROJECT COSTS

Implementation and operations costs of priority treatments for high occupancy vehicles are highly variable depending on the type of treatment and the unique design characteristics of an individual project. The following discussion and accompanying tables present costs in terms of 1974-1979 dollars since many project cost items could not be isolated.

Table 3-9 summarizes reported costs of grade separated facility HOV lane projects. Implementation costs depend largely on whether roadway widening to accommodate the priority lanes is necessary.

Concurrent flow HOV priority lane costs, counting only signing, marking, and other control devices, has ranged from $3,700 to $13,000 per mile ($2,240-7,870/km). The Miami I-95 project, at $2.5 million per mile ($1.5M/km), probably provides the most representative example for estimating HOV lane projects that demand major construction efforts (i.e., where lanes are added for substantial distances in both directions of the freeway).

Operating costs on concurrent flow HOV priority lanes are not readily available for most locations, but in three projects they ranged from $28,000 to $194,000 per year. These cost data do not include costs of enforcement which may be substantially higher than normal ongoing enforcement costs. The operating costs in Boston were high because of the daily installation and removal of stanchions separating the HOV lane from other flow. This technique generally has not been used

Table 3-9. Costs of Grade Separated Facility HOV Lane Projects

Project	Capital Cost	Cost Per Mile	Annual Operations and Maintenance Cost
Concurrent Flow			
Boston - Southeast Expressway	$ 91,500	$ 11,400	$194,000
Los Angeles - Santa Monica Freeway	163,000 (signing and marking) 358,000 (marketing)	13,000	Unknown
San Francisco - U.S. 101	25,000 (signing and marking)	7,000	Negligible
Miami - I-95	18,500,000 (including freeway widening but excluding park-ride lot)	2,500,000	88,000
Honolulu - Moanalua Freeway	10,000 (signing and marking)	3,700	Negligible
San Francisco - Oakland Bay Bridge	50,000 (signing and marking) 350,000 (special signal system)		28,000
Portland - Banfield Freeway	2,100,000 (includes freeway widening and other roadway improvements)	780,000	Unknown
Contra-Flow Lanes			
Boston - Southeast Expressway	$ 40,000	$ 5,000	$137,500
I-495 Lincoln Tunnel Approach	700,000	280,000	200,000
New York - Long Island Expressway	44,000	22,000	150,000
San Francisco - U.S. 101	180,000	45,000	60,000
Separated HOV Express Lanes			
Washington D.C. - Shirley Highway	$28,000,000 to 43,000,000 (depending on assumptions)	$2,500,000 to 4,000,000	Unknown
San Bernardino Busway	56,000,000 (including park-ride lot)	5,000,000	Unknown

1974 to 1977 dollars

1 km = 0.6 mi

Source: Frederick A Wagner, "Priority Treatment for High Occupancy Vehicles," Working Paper prepared for Cambridge Systematics, Inc., Cambridge, MA, December, 1978, 52p.

in concurrent flow lanes.

Capital costs of contraflow lanes are similar to costs of concurrent flow take-a-lane projects, ranging from $5,000 to $280,000 per mile ($3,000-$169,000/km). The I-95 Lincoln Tunnel approach contraflow lane was much higher than the others because special access ramps were built and an elaborate surveillance system was installed. Variation in costs are dependent largely on the amount and type of construction needed to provide median crossovers at the terminus of the contraflow lane section. Operating costs for contraflow lanes are higher than for concurrent flow lanes because of the daily installation and removal of stanchions. Operating costs are estimated at $750 to $1,000 per mile per week ($450-$600/km) where stanchions are involved.

Construction of physically separated express lanes, of course, is the most expensive HOV technique, ranging from $2.5 to $5 million per mile ($1.5-3.0M/km). Total costs are sensitive to inclusion of exclusive HOV ramps and to construction of bus stations along the facility. Good data on operating costs are unavailable, but these are likely to be small in comparison with the amortization of capital costs.

Capital costs of HOV lanes on surface arterials are also highly variable. Representative HOV lane costs shown in Table 3-10 range from $9,000 to $136,000 per mile ($5,500-$83,000/km). Construction of exclusive HOV streets such as transit malls may average $1,500 to $3,000 per *foot* ($460-$915/m). Substantive data on operating costs are unavailable.

Bus preemption system costs are probably best estimated by using unit costs for equipping local intersections with special receivers and signal control hardware and installing transmitters on buses. Recent estimates for purchase and installation of OPTICOM signal preemption hardware run at approximately $3,000 per intersection and $1,500 per equipped bus. Where signal preemption for buses has been incorporated in computer controlled signal systems, it is difficult to separate the marginal cost attributable to the bus priority features. However, as more applications of the computer based techniques are developed, standardization of hardware and software may bring marginal unit costs somewhat below those for OPTICOM systems. Implementation of optimized signal timing plans favoring buses requires very little marginal cost compared with non-priority signal timing since no

Table 3-10. Capital Costs of Selected Surface Street HOV Priority Treatments

Project	Capital Cost	Unit Capital Cost
Denver, CO Broadway, Lincoln	$ 71,000	$28,000/mi
Honolulu, HI Kalanianaole Highway	340,000	136,000/mi
Miami, FL N.W. Seventh Avenue	1,350,000 (including signal preemption system)	136,000/mi
Miami, FL South Dixie Highway	500,000	90,000/mi
San Juan, PR Ponce de Leon, Fernandez Juncos	100,000	9,000/mi
Portland, OR Portland Mall	16,000,000	2,730/ft
Philadelphia, PA Chestnut Street Transitway	7,000,000	1,300/ft
Madison, WI State Street Mall	7,800,000	1,150/ft

1974-1978 dollars

Source: Frederick A. Wagner, "Priority Treatment for High Occupancy Vehicles," Working Paper prepared for Cambridge Systematics, Inc., Cambridge, MA, Dec., 1978, 52p.

1 ft. = 0.31m
1 mi. = 1.65km

special hardware installation is required.

Priority parking facilities vary widely in cost. Construction costs can average $1,000 to $2,000 per space for new parking facilities plus costs for any terminal structures. Land acquisition costs depend on location. Existing lots (e.g., shopping centers, churches) can often be leased nominally on a monthly basis. Signing and marketing costs are minimal. Operating and maintenance costs may run $500 to $1,000 per month for cleaning and upkeep of amenities.

Priority pricing strategies are usually quite inexpensive to implement, since construction is typically not required. The largest cost item may become staff time for administering and monitoring the program. Registration of eligible carpools may become necessary to permit reduced tolls or parking fees.

A rough comparison of relative capital and operating costs from several types of HOV treatments is shown in Figure 3-8. This diagram does not reflect actual costs but does offer some basic points for comparison. Many of the HOV treatments exhibit medium levels of relative cost for both capital and operating expenses. Some notable exceptions include contraflow HOV lanes which generally have low capital costs but high operating costs if stanchions are employed. Conversely, exclusive HOV roadways are expensive to construct but have only a moderate operating cost. Capital costs of add-a-lane concurrent flow HOV lanes are higher than for take-a-lane projects, although operating costs are about the same. Ramp treatments, priority parking, and priority pricing strategies often exhibit the lowest relative operating costs.

COST EFFECTIVENESS

In order to illustrate methods and results of the cost-effectiveness of HOV priority treatments, a hypothetical areawide HOV program scenario examined by Peat, Marwick, Mitchell (PMM) is described. PMM relied primarily on a synthesis of information found in the literature on project impacts. They used such findings as a basis for testing the impacts of a series of formal project level and regional scenarios incorporating several types of HOV priority treatments. A highly structured methodology was employed to extrapolate project impacts to areawide impacts. Reference 35 should be consulted for details.

Table 3-11 summarizes the PMM estimates of the

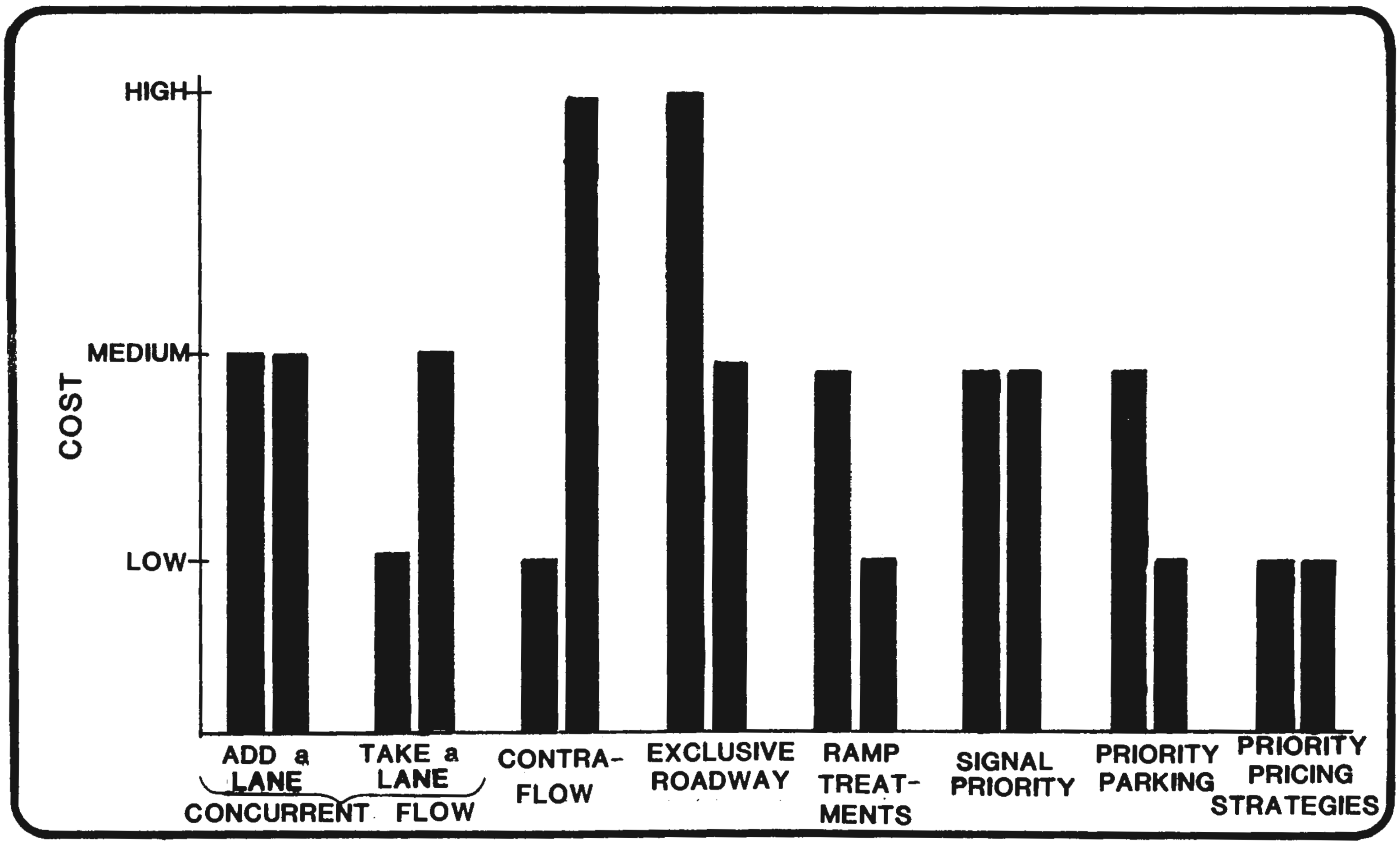


Figure 3-8. Relative Costs of HOV Treatments

Table 3-11. Summary of Project Level, Corridor, and Areawide Impacts of Selected HOV Priority Treatment Scenarios

Project Scenario	Maximum Peak Hour Impacts on Vehicle Volume		Areawide VMT Impacts	
	Project level (Peak Direction)	Corridor Level (Two Directions plus Parallel Arterial)	Percent of Work VMT	Percent of Total VMT
1. Expanded Express Bus in Mixed Freeway Traffic	-3.2%	-1.47%	0.3% (est.)	0.1% (est.)
2. Freeway Reserved Lanes for Buses and Carpools (Plus 1)	-13.7%	-6.30%		
3. Ramp Metering with Bus Bypass Lanes (Plus 1)	-6.7%	-3.06%		
5. Reserved Freeway Bus and Carpool Lanes, Ramp Metering with Bus Bypass Lanes (Plus 1)	-14.6%	-6.98%	-1.5%	-0.44%
7. Contraflow Freeway Bus Lanes and Park Ride Lots (Plus 1)	-8.4%	-3.72%		
9. Reserved Arterial Median Lanes for Express Buses (Plus 1)		-15.47	-1.3%	-0.38%
10. Contraflow Bus Lanes on One-Way Arterials for Local Buses		-4.40%	(Negligible)	

Source: Adapted from Ref.35.

"maximum" impacts of various HOV priority program scenarios. Scenario 5 combines several freeway-oriented HOV priority strategies for an urban area of 1,000,000+ population including:

- o Reserved concurrent flow freeway lanes for buses and carpools (3+ occupants) on 40 miles of radial freeways (lanes taken from existing use);

- o Ramp metering on entrance ramps and bus bypass lanes at 16 of these ramps;

- o Expanded fringe parking facilities (three 500 car park and ride lots per corridor);

- o Doubled the number of peak period express buses or provided a sufficient number for an average bus occupancy of 40 persons at the final equilibrium ridership level, whichever is greater. (Expanded express bus service was incorporated in all the freeway HOV priority lane scenarios and express bus in mixed flow was tested as a separate scenario.)

The estimated areawide impact of this strategy (i.e., Scenario 5) on vehicle miles of travel (VMT) is a reduction of 1.5 percent of work trip VMT and 0.44 percent of daily areawide VMT.

The PMM study also estimated the impact of 72 miles of reserved median lanes on radial arterials, combined with signal preemption, expanded fringe parking, and expanded, reduced-fare express bus service (Scenario 9). The incremental impact of this HOV priority treatment component was estimated to yield an additional reduction of about 1 percent of work trip VMT and about 0.3 percent reduction of daily VMT. These impacts would not be purely additive when combined with the freeway HOV priority strategies, since the radial arterial HOV priority treatments would be competing, in part, for the same new bus riders and carpoolers. The approximate impact of the combined freeway and arterial HOV scenarios would likely fall in the range of 1.5 to 2 percent reduction in work trip VMT.

Table 3-12 presents the cost estimates made by PMM for their freeway HOV priority treatment scenario. This data was refined and extended in two ways:

- o First, the costs of express bus service and

Table 3-12. Summary of Costs of Selected HOV Priority Treatment Scenarios

Cost Element	Capital Cost ($1,000s)	Life (Years)	Annual Capital Cost @ 10% Interest ($1,000s)	Annual Operating Cost ($1,000s)	Total Annual Cost ($1,000s)	Portion of Annual Cost Attributable To:* Expanded Express Bus in Mixed Flow ($1,000s)	Portion of Annual Cost Attributable To:* HOV Priority Treatments ($1,000s)
Reserved Lanes (40 miles, lanes taken)	300	10	49	660	709	--	709
Alternative: Reserved Lanes (40 miles, lanes added)	100,000	30	10,608	660	11,268	--	11,268
Bus Bypass Ramps (16)	1,380	30	146	Negligible	146	--	146
Express Buses	13,662	15	1,796	2,982**	4,778	3,106	1,672
Park-Ride Lots	0/4,860	30	0/516	744	744/1,260	484/819	260/441
Total, Lanes Taken	15,342/20,202		1,991/2,507	4,386	6,377/6,893	3,590/3,925	2,787/2,968
Total, Lanes Added	115,042/119,202		12,550/13,066	4,386	16,936/17,452	3,590/3,925	13,346/13,527

*Assume 65 percent of express bus and park-ride cost are attributable to expanded express bus in mixed flow and 35 percent attributable to extra bus demand induced by HOV priority lanes.

**Assume 42 percent of bus operating costs are recovered by fares.

Source: (Ref. 46)

park and ride lots were adjusted to more accurately reflect the incremental cost of these items associated with the implementation of HOV treatments;

- Second, the PMM estimates assumed that all HOV priority freeway lane treatments were the take-a-lane type. The alternative form of freeway HOV priority treatment in which lanes are added was introduced in the analysis. The add-a-lane HOV priority treatment is much more costly, with construction costs approximating $2.5 million per mile (based on the Miami I-95 project in which one lane was added in each direction of the freeway).

The results indicate that the total annual costs for this type of areawide program of freeway express bus service and HOV priority treatments equals about $7 million when lanes are taken for HOV priority use and about $17 million when new HOV priority lanes are added. Approximately $4 million of these annual costs are attributable to expanded express bus service in mixed flow. Thus, the annual incremental cost of comprehensive freeway HOV priority treatments, as defined in the table, are about $3 million when HOV lanes are taken and about $13 million when HOV lanes are added.

These costs were combined with the PMM impact estimates, and cost-effectiveness indicators were computed. The results are shown in Table 3-13. The incremental costs per VMT reduced because of HOV priority treatments are estimated at $0.08 when HOV lanes are taken, and $0.36 when lanes are added. The combined costs of expanded express bus, park and ride, and HOV priority lanes are estimated at $0.14 per VMT reduced for the take-a-lane case and $0.36 for the add-a-lane case.

The use and interpretation of simple cost/effectiveness indicators such as cost per VMT reduced utilized in this example must be treated with caution. Such indicators should be used for making <u>relative</u> comparisons between alternatives rather than <u>absolute</u> interpretations. HOV priority treatment projects are intended to serve multiple objectives (as discussed in the Preliminary Planning chapter and reflected in the variety of MOE's). Hence, no single cost/effectiveness ratio such as cost per VMT reduced can provide more than a partial perspective on the merits of a project. There is often no substitute for

Table 3-13. Cost-Effectiveness of Selected Areawide HOV Priority Treatment Scenarios

Scenario	Daily VMT Reduction (Thousands)	Annual* VMT Reduction (Millions)		Annual** Cost ($Millions)	Cost per VMT Reduced ($)
Expanded Freeway Express Bus	44	11		3.93	0.36
Expanded Freeway Express Bus Plus HOV Priority Treatments	195	48.75	Take Lanes	6.89	0.14
			Add Lanes	17.45	0.36
Incremental Effect of HOV Priority Treatments	151	37.75	Take Lanes	2.96	0.08
			Add Lanes	13.52	0.36

*Annual VMT Reduction = Daily VMT Reductions x 250.

**Costs in 1976 dollars include annualized capital cost (Interest = 10%) plus annual operating costs.

Note: Costs and impacts based on PM&M analysis for EPA (Ref. 35) with extensions and refinements by Wagner (Ref. 46).

human judgment in assessing a wide array of project impacts--some beneficial and some detrimental--against project costs for the alternatives under consideration.

FORMAL ECONOMIC ANALYSES

Whenever large scale alternatives requiring substantive capital investments are under consideration, formalized economic analysis methodology should be applied. Detailed explanation of economic analysis methodology is far too complex a subject to be covered adequately in this guide. An excellent document for both general and detailed understanding of economic analysis is: A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements, published by AASHTO in 1977.

The AASHTO manual recommends using the net present value approach to analyzing the economic merits of alternative projects. In this approach, the year-by-year time stream of incremental costs and user benefits of a project are needed to calculate the net present value (difference between benefits and costs) "discounted" to the current year. A project is deemed economically justifiable if the present value of all project-related benefits exceed the present value of project-related costs. Similarly, net present values can be used to compare alternative project concepts. But relying solely on net present values will favor the high capital cost alternative if it delivers more absolute dollar benefits than a lower cost project. It is desirable, therefore, to also compute benefit/cost ratios for each alternative (i.e., the ratio of present value of benefits to present value of costs).

A common mistake is analyzing costs and benefits only for a single forecast year (e.g., 1990) rather than developing a yearly time stream of costs and benefits throughout the project life (e.g., 1980 through 1995 for a 15 year project analysis period).

The AASHTO manual recommends using constant dollars (e.g., 1980 dollars) for analysis purposes to avoid the need to speculate about future inflation rates. If constant dollars are used, a four to five percent discount rate should be used as the annual "real" cost of capital (exclusive of inflation).

For major HOV priority treatment projects, attempts should be made to systematically estimate and sum the following categories of benefits:

- o User time savings
  - For all classes of person trips (auto, carpool and transit), and
  - For commercial vehicles

- o Vehicle operations and maintenance cost savings due to
  - Reduced VMT
  - Changed quality of service (i.e., lower average travel time or higher average speed

- o Parking cost savings due to reduced number of vehicular work trips

- o Accident benefits or disbenefits due to
  - Reduced VMT
  - Increased or decreased risk per VMT
  - A single weighted average unit cost per accident should be used instead of attempting to forecast separate changes in property damage, injury and fatal accidents.

Table 3-14 gives a simple example of net present value analysis for two alternative projects. Alternative A has higher capital costs and benefits but lower operations and maintenance costs than alternative B. A ten-year analysis period is used in the example, for the sake of brevity, and a 5 percent discount factor is used. All costs and benefits are stated in year 0 constant dollars. The results of this analysis show that alternative A has a substantially higher net present value but alternative B has a slightly better benefit/cost ratio.

Formal economic analysis, like other elements of impact analysis, do not provide a clearcut choice of the "best" project. A host of other factors including budgetary considerations, public acceptability, institutional feasibility, and so on also have a bearing on final implementation decisions. The various quantitative analyses provide a better perspective and a more systematic framework for the decisionmakers.

EVALUATION AND RECOMMENDATIONS

The final step in the alternatives analysis phase is the final evaluation of the impact estimates as a basis for recommending which alternative to implement. The recommendations should be specific with regard to time schedules and budgets for the design and implementation phases. Also, a clearcut organizational plan for the next steps is needed, spelling out which

Table 3-14. Sample HOV Cost-Effectiveness Analysis

Year	Single Amount Present Worth Factor (@5%)	Alternative A ($Millions)				Alternative B ($Millions)			
		Benefits	Costs	Present Value of Benefits	Present Value of Costs	Benefits	Costs	Present Value of Benefits	Present Value of Costs
0	1.0000	-	50	-	50	-	8	-	8
1	0.9524	10	2	9.5240	1.9048	4	2.5	3.8096	2.3810
2	0.9070	12	2	10.8840	1.8140	5	2.5	4.5350	2.2675
3	0.8638	14	2	12.0932	1.7276	6	2.5	5.1828	2.1595
4	0.8227	16	2	13.1632	1.6454	7	2.5	5.7589	2.0568
5	0.7835	16	2	12.5360	1.5670	7	2.5	5.4845	1.9587
6	0.7462	16	2	11.9392	1.4924	7	2.5	5.2234	1.8655
7	0.7107	16	2	11.3712	1.4214	7	2.5	4.9749	1.7768
8	0.6768	16	2	10.8288	1.3536	7	2.5	4.7376	1.6920
9	0.6446	16	2	10.3136	1.2892	7	2.5	4.5122	1.6115
10	0.6139	16	2	9.8224	1.2278	7	2.5	4.2973	1.5348
			Total	112.48	65.44		Total	48.52	27.30

Alternative A:

Net Present Value = 47.04
(Benefit - Cost)

$$\frac{\text{Benefit}}{\text{Cost}} = 1.72$$

Alternative B:

Net Present Value = 21.22
(Benefit - Cost)

$$\frac{\text{Benefit}}{\text{Cost}} = 1.78$$

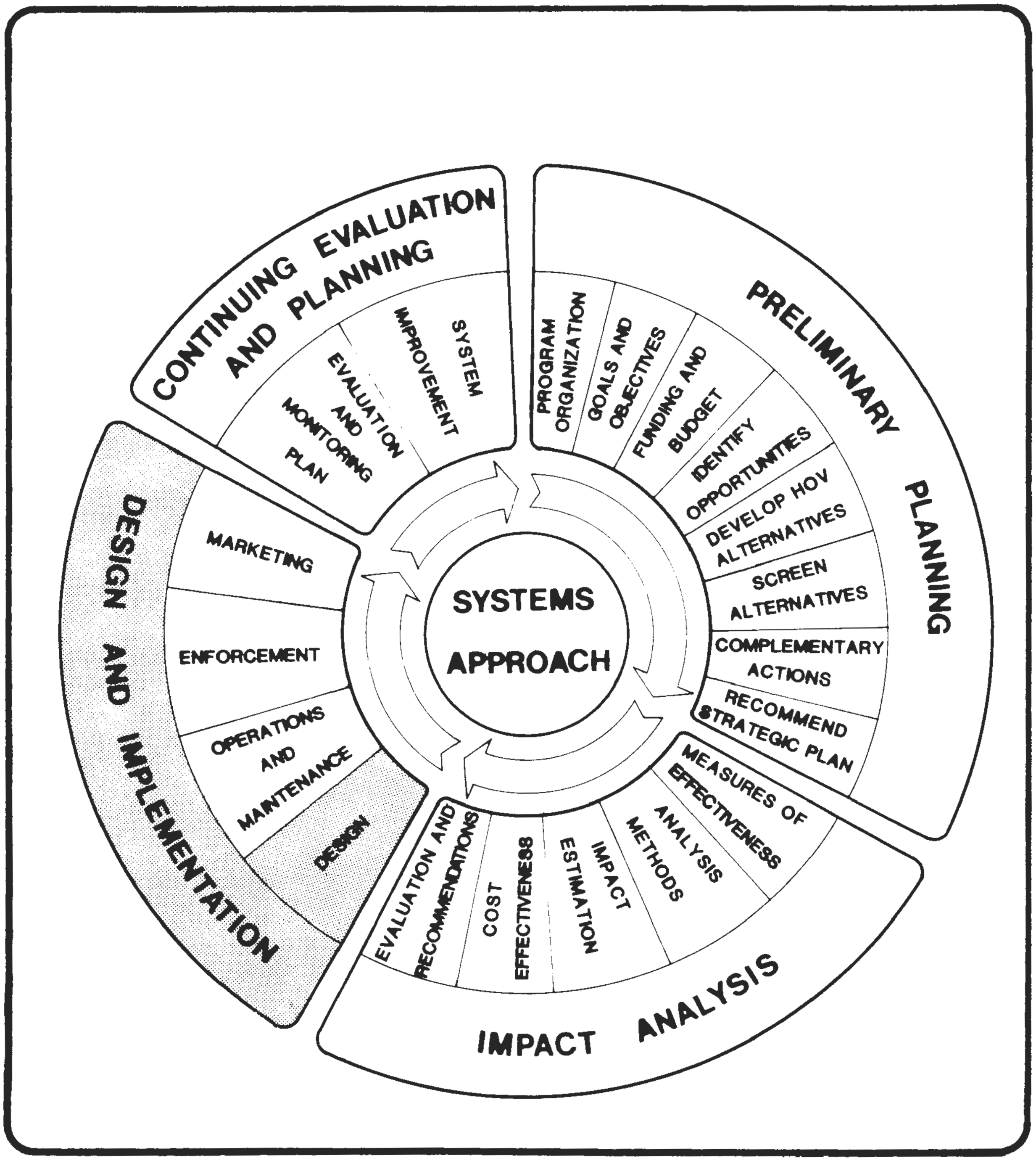
agencies are responsible for various elements of the program. The level of specificity should be adequate to obtain the needed programming and budgeting commitments from the involved governing bodies and operating agencies.

SUMMARY

The analyses of expected impacts of alternative HOV treatments include several types of estimates: travel demand impacts, travel time impacts, energy and emissions impacts, safety impacts and costs. Measures of effectiveness (MOE's) should be carefully selected for use in these analyses. Various analysis methods are available for making impact estimates. However, use of these models must be combined with the forecasting of probable impacts based upon the actual results of comparable projects which have been empirically evaluated.

The results of the impact estimates should be formulated into a cost-effectiveness analysis, whereby the degree of effectiveness of an HOV project is compared to the cost of achieving that level of effectiveness. Care must be taken to utilize formal economic analysis procedures to properly account for comparisons of various time-streams of costs. Finally, the results of these impact analyses should be put into the form of recommendations of a preferred HOV treatment alternative.

4. DESIGN



SYSTEMS APPROACH
PRELIMINARY PLANNING
PROGRAM ORGANIZATION
GOALS AND OBJECTIVES
FUNDING AND BUDGET
IDENTIFY OPPORTUNITIES
DEVELOP HOV ALTERNATIVES
SCREEN ALTERNATIVES
COMPLEMENTARY ACTIONS
RECOMMEND STRATEGIC PLAN
IMPACT ANALYSIS
MEASURES OF EFFECTIVENESS
ANALYSIS METHODS
IMPACT ESTIMATION
COST EFFECTIVENESS
EVALUATION AND RECOMMENDATIONS
DESIGN AND IMPLEMENTATION
DESIGN
OPERATIONS AND MAINTENANCE
ENFORCEMENT
MARKETING
CONTINUING EVALUATION AND PLANNING
EVALUATION AND MONITORING PLAN
SYSTEM IMPROVEMENT

4. DESIGN

INTRODUCTION

The design of HOV treatments can have a major effect on the project's success. Design includes several related topic areas--geometrics, signing and marking, signalization, intersection and/or interchange treatments, transition treatments and transit loading areas.

This chapter focuses on basic design issues. Many of these issues are common to both interim and permanent HOV treatments. Permanent HOV treatments should be designed according to accepted highway and transit design principles. Interim HOV treatments, on the other hand, generally have greater need for employing innovative design methods to adapt existing transportation conditions for HOV use. Examples of HOV designs used on selected grade separated facilities and surface street HOV projects are provided throughout the chapter. AASHTO's Design Guide for High Occupancy Vehicle and Public Transfer Facilities (Ref. 2) provides the most current design guidelines which should be utilized in the field. Other documents (see References 27, 34, 36) also cover specific aspects of HOV treatment design.

DESIGN ISSUES

Geometrics

Current national standards on geometric features for grade separated facilities and surface streets are established by AASHTO's A Policy on Geometric Design of Urban Highways and Arterial Streets (Ref. 3). This document does not present geometric features or standards specifically applicable to a HOV lane, but it does discuss various geometric elements which have relevance to the design of HOV treatments. These include 1) the number of lanes, 2) lane width, 3) curb or shoulder, 4) median, 5) alignment, 6) design speed, 7) sight distance, 8) roadside hazards and 9) pedestrian facilities. Table 4-1 presents the established AASHTO standard for each design element. A section of the policy also presents general geometric guidelines pertaining to reserved bus lanes on surface streets.

Table 4-1. AASHTO Design Standards

GRADE SEPARATED FACILITIES
 	
1. Lane Width: 12 feet
2. Shoulder Widths:
   a. Right: Desired 12 feet; minimum of 10 feet (or 8 feet if low truck volume
   b. Left: 4 to 6 feet minimum for four lanes; 10 feet for six or more lanes
3. Type Shoulder: Paved, flush
4. Medians with Barrier:
   a. Type: Concrete median barrier or steel "W" beam guardrail
   b. Clearance: 6 feet minimum for four lanes; 10 feet minimum for six or more lanes
5. Design Speed: 40 to 70 mph
6. Sight Distance: Varies according to design speed
7. Roadside Obstacles: 30 feet clearance from roadway

SURFACE STREET 1. Lane Width: 12 feet (desirable) 2. Design Speed: 30 to 60 mph 3. Sight Distance: Depends on design speed

(Ref. 31)

Metric Conversion

1 foot = 0.3 meters
1 mile = 1.61 kilometers

Several geometric issues arise with respect to HOV treatments. These issues include the following:

Add-a-Lane Options

The two primary methods for adding lanes are reconstruction or restriping. Reconstruction involves creating additional traffic lanes from existing or newly acquired roadway right-of-way. Right-of-way can include land adjacent to an existing facility, or land within the facility such as a median. The reconstruction of an unimproved roadway shoulder would also fall under this category.

Restriping involves reallocating the existing paved roadway surface to create varying numbers of lanes. Restriping is typically used to redesignate an existing lane for turning, parking, or creating reversible lane operations. Restriping can also be used to reduce existing lane widths or paved shoulders in order to create enough remaining space for an additonal travel lane.

Reconstruction and restriping activities can be combined to maximize the use of available right-of-way. For example, a new lane can be created through a combination of median reconstruction and lane restriping.

Use of Existing Shoulders

The use of existing shoulders for add-a-lane HOV treatments involves several design and cost issues. The use of travel on shoulders may require a change in the geometrics of entrance and exit ramps as well as surface street intersections. A redesignated shoulder lane may also influence the weaving area. If the available weaving distance is too short, the shoulder lane may cause a reduction in capacity and an increase in vehicular conflicts.

Shoulder pavement thickness is often not designed to handle heavy volumes of HOV's, especially buses. As a result, repaving or reconstruction of the shoulder subbase may be required. Attention should also be given to the slope of the shoulder relative to that of the adjacent travel lanes.

Sight distance is often restricted on a shoulder HOV lane. In such cases, HOV speeds may need to be limited or the HOV lane width increased to compensate for this geometric deficiency. Proper geometric design should also be employed at the termination of the shoulder lane. On many grade separated facility projects, a shoulder lane is dropped at an exit ramp. Intersections form the major termination location for shoulder lanes on surface streets. The design should allow HOV's using the shoulder lane to safely transition back into the general use lanes. Other design concerns can involve the removal and adjustments of lane lines, gore markings, and guide signing.

Freeway shoulder modifications are described more completely in Reference 29.

Lane Widths

Although the accepted desirable AASHTO width of a lane is 12 feet (3.7m), some HOV treatments have been implemented on facilities with lane widths of 10 feet (3.1m) or less. However, widths less than 12 feet are not recommended where transit volumes are high.

One design option on limited width facilities is to establish one wide lane (i.e., 12 feet or wider) for HOV's and reduce the width of the other lanes. This design offers more room for HOV movements, especially buses, while creating a more distinct visual impression of the HOV lane.

If lane width adjustments are necessary, old lane lines should be thoroughly eradicated and longitudinal joints should not conflict with lane lines.

Effect of Grades

Roadway grades can affect the performance of an HOV treatment. In particular, fully loaded buses are severely affected on grades steeper than 3 or 4 percent. The ensuing bus speed reduction can adversely impact travel times for carpools under mixed mode operations. Buses may even lose time compared to alternate routes on more level terrain. The use of higher powered vehicles such as over-the-road buses can reduce the effects of grades.

Buffers

Buffers are recommended for separation of HOV and non HOV lanes wherever possible. Buffers strengthen the visual picture of an HOV lane and help improve safety and enforcement. Buffers are particularly beneficial on contraflow treatments where HOV's directly oppose oncoming traffic.

Buffers can vary in width from 1 to 2 feet (0.3 to 0.6m) up to a full lane width. In some instances, stanchions and/or painted chevrons are desirable within the buffer area to discourage violators (Figure 4-1). Permanent buffer areas can also be designed for use as a common shoulder area to accommodate disabled vehicles or enforcement activities (Figure 4-2).

Figure 4-1. Buffer Lane - U.S. 101 (San Francisco Bay Area)

Figure 4-2. Common Shoulder - I-580 (San Francisco Bay Area)

Cross Street Geometrics

Surface street HOV lane treatments can affect cross street geometrics. Curb or median turning radii may need to be increased to allow HOV's, especially buses, to safely enter a contraflow or in-median HOV lane without swerving into adjacent opposing flow lanes. Conversely, curb radii can be decreased to discourage turns from cross streets onto HOV lanes at specified intersections. This design is typically employed along exclusive HOV streets such as transit malls.

The diversion of non HOV traffic away from exclusive HOV streets may create a need to widen certain cross streets in order to handle the additional traffic volume. Upgrading of cross street geometrics may also be necessary where right turn ground loops using cross streets are employed in lieu of left turns at intersections (see Figure 4-13).

Queue-Jumpers

Short bypasses of queued vehicles due to bottleneck situations can often be designed using minimum acceptable geometric standards. Although narrow lane widths and close proximity to roadside obstructions do not provide ideal geometric conditions, the potential HOV travel time benefits of queue-jumpers can help offset disadvantages of geometric deficiencies over short segments.

The queue-jumper is implemented to improve flow past queued vehicles upstream from a bottleneck such as a lane construction or intersection. The queue-jumper lane must be designed to allow the HOV's to enter the lane prior to the major queuing and then reenter the mainstream traffic flow just upstream of the actual bottleneck. This design permits HOV's and non HOV's to merge together more efficiently than if the queue-jumper lane were extended all the way through the bottleneck (Figure 4-3).

Curb Bus Lane Design

Surface street curb lanes which are newly designated as HOV lanes should be inspected for geometric deficiencies. Drainage inlets may need to be resituated or leveled in order to provide a smooth ride for HOV's. Curbside obstacles should be located at least 2 feet (0.6m) from mirrors or other bus appurtances which overhang the curb due to lateral roadway slope or narrow HOV lane.

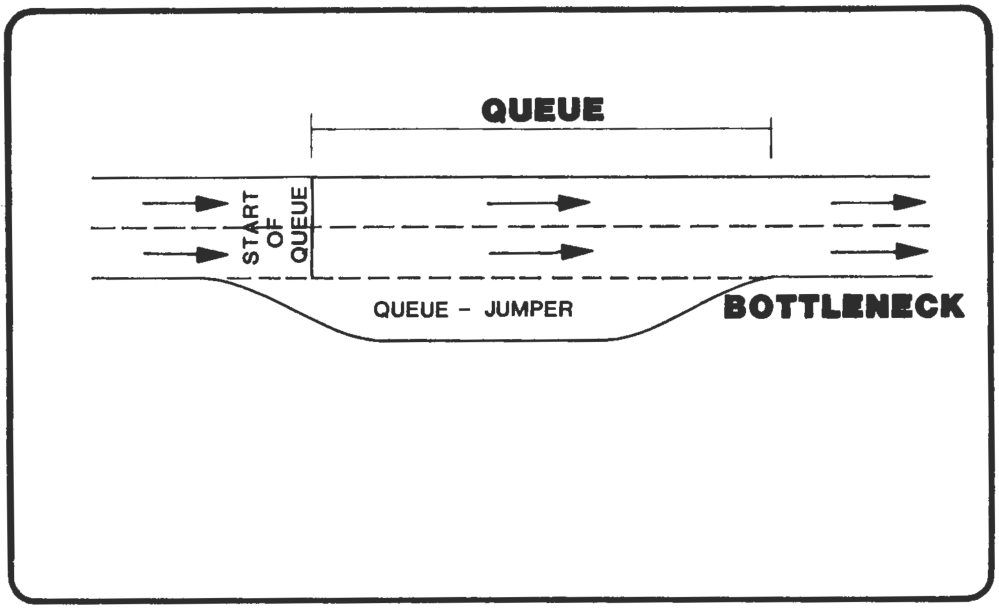


Figure 4-3. Queue-Jumper

HOV Priority Parking Facilities

The geometric design of new HOV priority parking facilities should adhere to accepted parking lot design standards. Internal lot geometrics should minimize walking distances to transit stops, carpool staging areas, or activity center destinations. Maximum walking distances of 500-900 feet (150-275m) are recommended. Sidewalks should be at least 5 feet (1.5m) wide; and at least 12 feet (3.7m) wide adjacent to transit loading zones.

Park and ride lots should be designed for good circulation with adequate self parking and aisles oriented perpendicular to bus boarding areas in order to provide direct pedestrian access to bus loading areas. The bus loading areas should be able to handle more than one bus simultaneously and be wide enough to allow buses to bypass each other without backing up. Buses and auto traffic should be separated wherever possible. Exclusive HOV access ramps and surface street entrances are also desirable (Figure 4-4). A design factor of 70-80 percent should be used to minimize time spent looking for a parking space. A higher factor can be used where additional space exists on adjacent streets or lots.

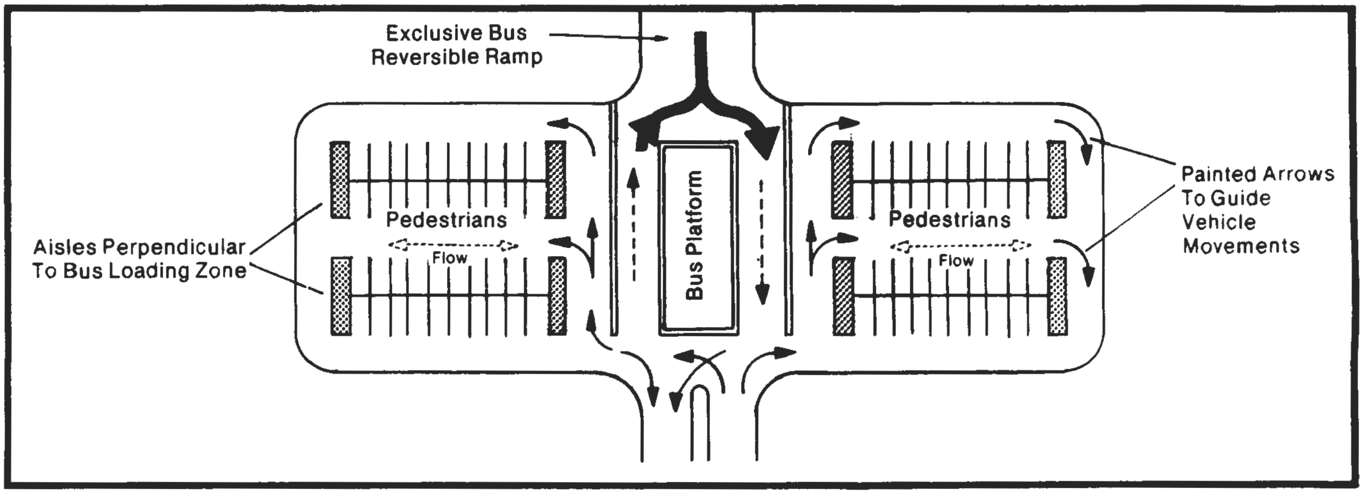


FIGURE 4-4 PARK AND RIDE ORIENTATION

The designation of priority HOV spaces within existing parking facilities often does not require any new design other than restriping of some spaces or, in the case of park and ride lots, designation of areas for bus loadings and maneuvers.

Signing and Marking

Current national standards on signing and marking for freeways and surface streets are established by FHWA's Manual on Uniform Traffic Control Devices (MUTCD) (Ref. 17). The MUTCD has established special pavement markings and signing for preferential lane-use control (Sections 2B-20 and 3B-19). Table 4-2 and Figure 4-5 present the basic MUTCD standards for HOV treatment signing and marking.

Table 4-2. MUTCD Standards

1. Signalization: Lane-use controls on reversible lanes

2. Signing:

	Roadside	Overhead
a. Advanced Warning:	R3-10	R3-13
b. Restricted Lane:	R3-11	R3-14
c. End of HOV Lane:	R3-12	R3-15

3. Lane Demarcation: Solid or skipped white or yellow lines

4. Special Markings: Diamond symbol, spaced frequently enough to be in constant view

5. Delineators: Plastic posts

(Ref.31)

Very few states have established specific guidelines for applying the MUTCD signing and marking standards for HOV projects. One notable exception is California which has distributed typical signing and marking plans for HOV lanes and park and ride lots. These are depicted in Supplement 4B.

Roadside Signing

Roadside signs should be post mounted directly adjacent to HOV treatments. The sign wording must be clear and precise, stating the lane which is restricted, the type of HOV's allowed, and the hours of operation. The sign "size, location and spacing are dependent upon the conditions under which it is used, but should be consistently applied" (Ref. 17). Roadside signs can also be used to convey other HOV information such as occupancy rules and violation fines.

Roadside signing may be less visible to the motorist than overhead signing because of the existence of other signing, storefronts, and other background diversions. On some HOV projects it has been found necessary to install supplemental overhead signing in order to make the HOV signing more visible. Contraflow lane treatments may require additional warning signs

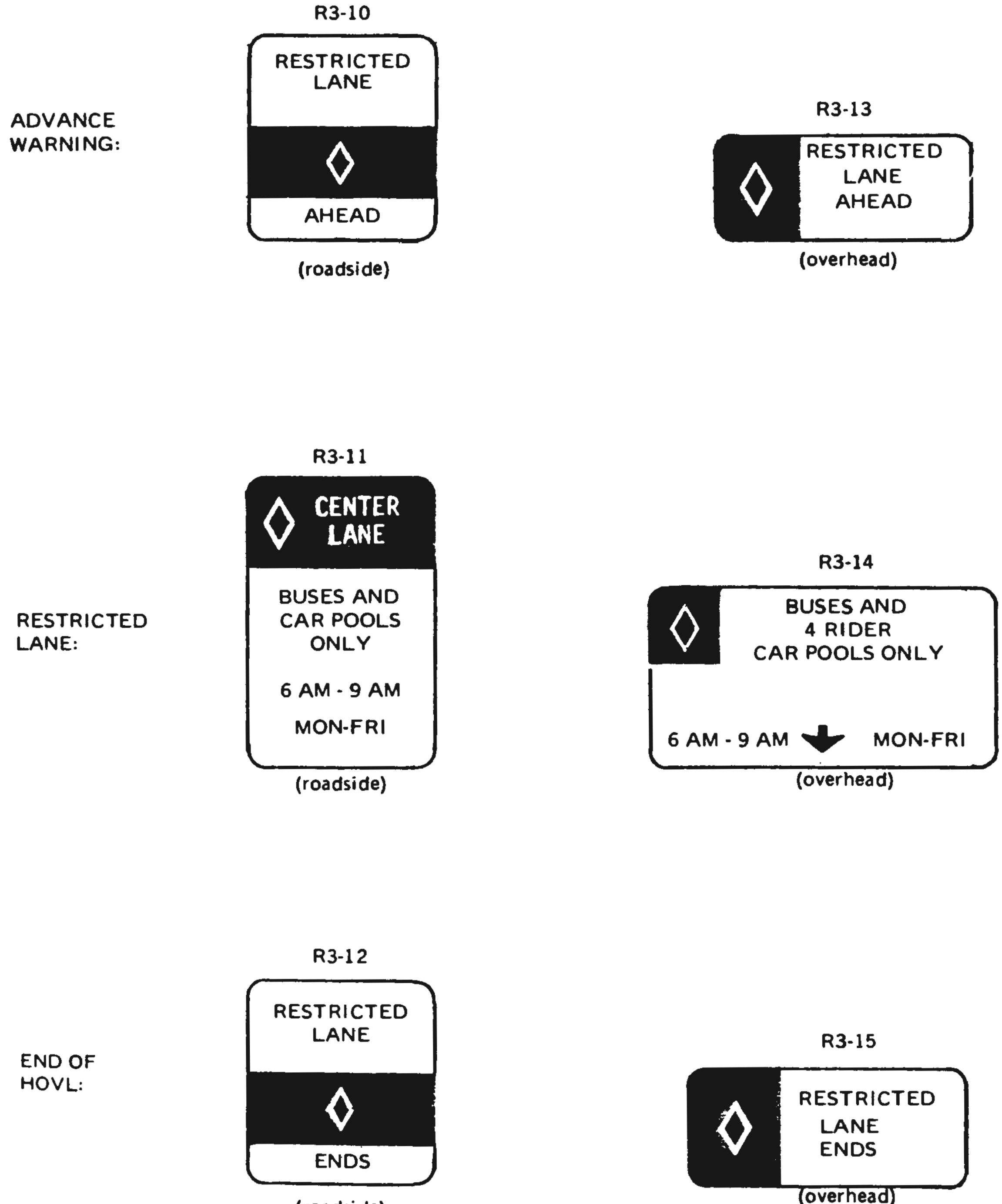


Figure 4-5. MUTCD Signing Standards

Source: Ref.30

for opposing flow traffic. Similarly, a HOV lane on a surface street could have additional signing requirements for turning and parking restrictions in order to improve traffic safety and capacity. In all cases, MUTCD standards should be observed.

Overhead Signing and Signals

Overhead MUTCD signing gives emphasis to an HOV lane restriction, especially in the vicinity of intersections or interchanges. The overhead signs should be placed directly over the HOV lane to provide maximum visibility (Ref. 17).

Overhead MUTCD signs applied on contraflow lane treatments can be equipped with flashers which help warn opposing traffic. Overhead signs can also be used in conjunction with roadside signs along roadway segments.

Reversible lane operations are typical candidates for overhead lane use control signals (MUTCD Sections 4E-8 to 4E-12). Variable message signs (MUTCD Sections 1A-6 and 2A-5) are occasionally used in lieu of standard overhead MUTCD signs. Variable message signs have the advantage that the messages can be changed or blanked-out during hours in which the HOV treatment is not operational. Variable message signs also aid in notifying motorists of downstream accidents or other incidences. Figures 4-6 and 4-7 show examples of lane use control signals and variable message signs.

Park and Ride Signs

MUTCD has established basic signing guidelines for park and ride facilities (described in MUTCD Sections 2D-41, 2E-28 and 2F-20). These guidelines include examples of both roadside and overhead directional signing (Figure 4-8).

The MUTCD presents examples of white-on-green park and ride signing, but recognizes the desirability of designing park and ride signs with appropriate colors and symbols of local transit companies. These park and ride sign guidelines should also be applied to signing for HOV priority parking facilities within activity centers.

Diamond Symbol

MUTCD marking recommendations specifically relating to HOV priority lanes only include the use of

Figure 4-6. Overhead Reversible Arrows (Wilson Blvd.;Arlington, VA)

Figure 4-7. Overhead Electronic Changeable Message Sign
(I-5; Seattle, WA)

D4-2

GUIDE SIGN (EXPRESSWAY)

MUTCD Signs

Figure 4-8. HOV Priority Parking Signing

a diamond symbol. The diamond symbol (Section 3B-19) "shall be formed by white lines at least 6 inches in width, shall be at least 2 1/2 feet in width and 12 feet long and shall be placed coincidentally with the longitudinal center of each restricted lane" (Ref. 17).

The frequency of the diamond marking is a matter of engineering judgment, but the MUTCD suggests an appropriate spacing of 1,000 feet (300m) for freeways and as close as 80 feet (24m) for surface streets. The diamond symbol may be omitted on contraflow or exclusive HOV lane treatments where adequate signing and/or physical barriers or stanchions are used. This is typically the situation on many contraflow treatments and exclusive roadways such as transit malls.

Lane Delineation

There are no specific MUTCD standards pertaining to HOV lane delineation. However, MUTCD standards relating to various types of lane delineation can be partially applied to HOV treatments. The following general guidelines for HOV lane delineations are based upon principles presented in MUTCD Sections 3A-5 through 3A-7 and 3B-1 and 3B-2.

- White Skip Line - Concurrent flow treatment where HOV lane operates only during limited hours.
- White Solid Line - Concurrent flow treatment where HOV lane operates on a 24-hour basis.
- Yellow Skip Line - Center line of two-lane, two-way exclusive HOV roadway where passing is permitted.
- Double Yellow Solid Line - Contraflow treatment where HOV lane operates on a 24-hour basis. Also as center line of two-way exclusive HOV roadway where passing is prohibited.
- Double Yellow Skip Line - Contraflow or reversible flow treatment where HOV lane operates only during limited hours.
- Yellow Solid Line plus Yellow Skip Line - Continuous two-way left turn lane. Also center line of two-way exclusive HOV roadway where passing is prohibited in one direction.

Lane delineation guidelines for specific types of HOV treatments are presented in the appendix.

Stanchions

The use of stanchions can assist in delineating HOV lane treatments. Stanchions come in many forms--rubber cones, plastic posts, or mechanical "pop-up" dividers. Flexible plastic posts placed into holes drilled in the pavement are the most common form of stanchion used on HOV projects.

The MUTCD does not specify standards for use of stanchions on HOV projects. However, MUTCD Sections 3F-2, 6C-3 and 6C-4 present several design and application guidelines relating to the use of stanchions to channelize traffic.

Stanchions placed at 20 to 40 foot (6.1-12.2m) intervals are often used on contraflow projects where separation of opposing traffic flows is critical. This spacing is dependent upon vehicle speed. Some concurrent flow projects (e.g., Kalanianaole Highway-Honolulu; Southeast Expressway-Boston) have also experimented with stanchions in order to discourage weaving into and out of the HOV lane. These spacings tend to be wider (40 to 100 ft; 12.2 to 60.5m). Where possible, the stanchions should be placed within a buffer area in order to create a gap between vehicles and the stanchions. The use of appropriate overhead signing and lane use control signals can minimize the need for stanchion placement.

Word Markings

The use of word markings on the pavement can often clarify an HOV treatment restriction. Words such as "Buses and Carpools Only" in conjunction with the diamond symbol are effective, especially at transition points. Word markings are not suggested on HOV treatments which operate during limited hours unless the designated hours are included in the word message. This minimizes confusion to motorists during hours when the HOV treatment is not in operation. All word markings should be designed in accordance with MUTCD Sections 3A-8 and 3B-17.

Textured Pavements

Textured pavements can be utilized on permanent all-day HOV treatments to provide added visibility to the project. Most applications of textured pavements have been on transit mall projects where the roadway surface is designed to contrast with cross streets and widened sidewalks along the mall. Other applications include median HOV lanes along surface streets, such as exclusive trolley lanes along Judah Street in San Francisco. The textured pavement should be designed to minimize any roughness in the ride for HOV's while at the same time providing a visible disincentive to potential violators.

Intersection/Interchange Treatments

Intersections and interchanges create special design needs for a HOV treatment. One of the major design problems at surface street intersections is how to accommodate turns without adversely affecting HOV flow. On concurrent flow curb lane HOV treatments, the typical design has been to permit non HOV turns from that lane at intersections. MUTCD signing alerts motorists to those locations where joint use by HOV's and turning vehicles is permitted (Figure 4-9). In most cases, right turns are only allowed to enter the HOV lane within say, 100 feet (31m) or one block from an intersection. In practice, the enforcement of these restrictions has been very difficult.

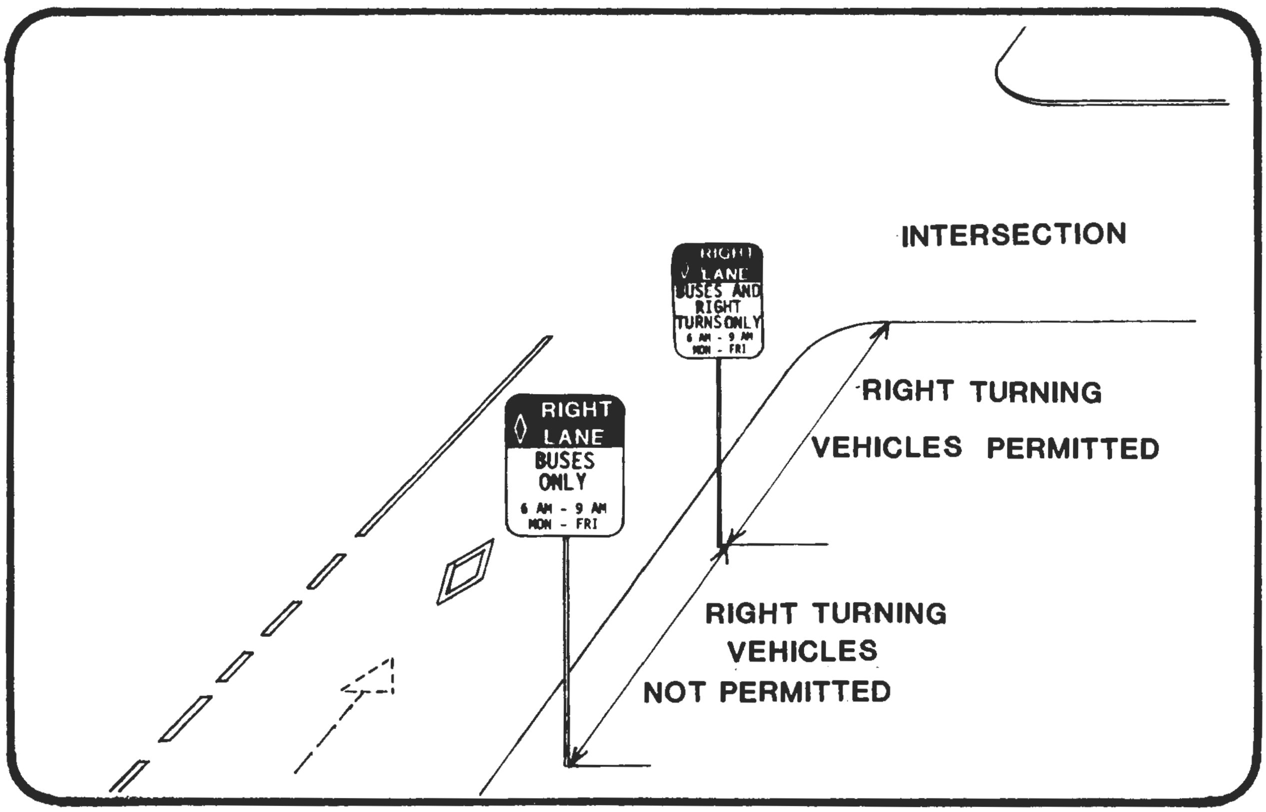


Figure 4-9. Treatment of Right Turns

Left turning restrictions on inside lane concurrent flow and contraflow treatments have been varied. Figure 4-10 displays some typical treatments of left turns, ranging from prohibition of all left turns to joint use of median left turn bays by HOV's and non HOV's. The use of right turn ground loops (Figure 4-11) can accommodate prohibited left turning movements where block sizes are small enough and where diverting traffic around the block will not create adverse neighborhood disruptions. Alternatively, the use of special signal turn phases or setback techniques (see Figure 4-16) can aid HOV's and non HOV's in making turns even at heavily used intersections.

Turns from cross streets may be restricted where such movements would adversely affect HOV movements. In one median HOV lane project, cross street left turns have been limited to signalized intersections where cross street vehicles would not block the HOV lane while awaiting a gap in the traffic flow.

HOV lane treatments on grade separated facilities generally permit ramp access along the project. Most concurrent flow left side HOV lanes and all contraflow HOV lanes are constructed along facility segments which have no left side ramps. On the one hand, this design eliminates direct ramp/HOV lane conflicts; on the other hand, HOV's must often weave across several non HOV lanes to access the ramps. One project (I-95; Miami, FL) provided overhead signing to warn non HOV's of this weaving maneuver.

So far, there has been only one application of a concurrent flow right side lane on a grade separated facility. In this project (SR 520; Seattle, WA) the shoulder HOV lane crosses both on and off ramps with no restrictions on usage of the ramps by non HOV's or HOV's. HOV's are able to safely weave across ramp movements because of good HOV lane visibility and courteous drivers (Figure 4-12).

<u>Transition Treatments</u>

Transition design plays an important role in the effectiveness of an HOV lane treatment. The design of vehicular access is also a major determinant of safety and enforceability.

Transition treatments may consist of various combinations of signing, marking, movable barriers, geometric changes or signalization. MUTCD signs R3-10, and R3-13 (see Figure 4-5) provide warning of the

Left Turn Across Bus Lane
(NW 7th Avenue; Miami, FL)

Figure 4-10. Intersection Left Turn Treatment

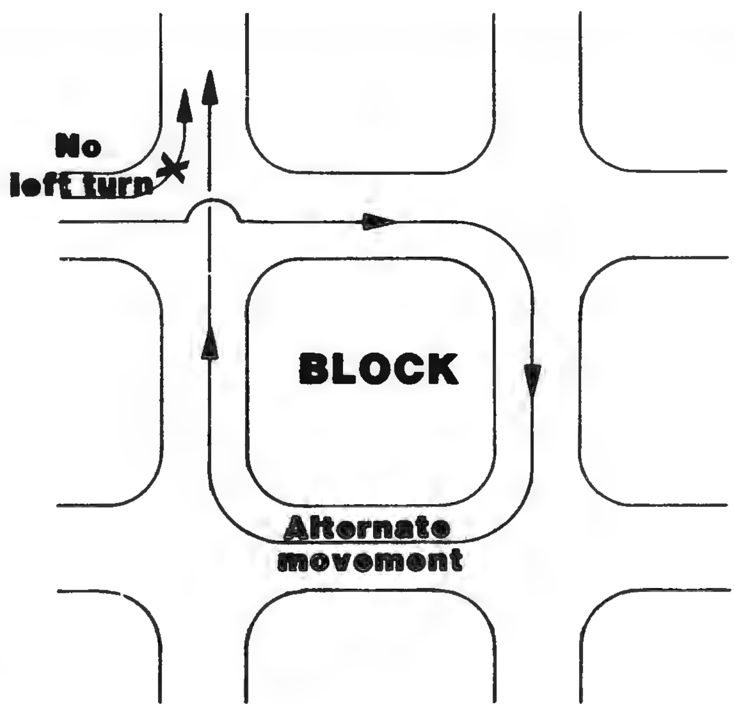


Figure 4-11. Ground Loop

beginning of a HOV lane treatment. The placement of advanced warning signs upstream of an HOV treatment is most critical, since considerable lane changing often occurs in this vicinity. A series of advanced warning signs (e.g., 1 mile, 0.5 mile, 1000 feet, etc.) should be used where possible to allow HOV's and non HOV's to safely move into the appropriate lanes. On surface streets, these signs should be placed at least one block prior to the HOV treatment. Advanced signing on ramps is also recommended where the ramp leads directly to a restricted HOV lane.

Figure 4-12. Interchange Treatment (SR 520; Seattle, WA)

MUTCD signs R3-12 and R3-15 (see Figure 4-5) used at the end of an HOV lane informs HOV's and non HOV's that restrictions are no longer imposed. In many concurrent flow lane treatments, the HOV lane terminates by simply becoming a general use lane. However, in situations where an HOV lane has been added and then dropped, HOV's may be forced to merge back into the general use lanes. This situation can arise on grade separated facilities where a HOV lane has been added between successive entrance and exit ramps. Similarly, on surface streets, removal of parking to accommodate an HOV lane segment can create an add-a-lane then lane drop geometric condition where parking is permitted after the termination of the HOV lane. In such cases, enough advanced warning of HOV lane termination should be given to allow HOV's to safely merge back into adjacent lanes.

Markings can be used to facilitate HOV transitions. In the case of 24-hour HOV lane restrictions, the use of striped or crosshatched pavement markings or arrows can help channelize traffic at the beginning of a HOV lane. Word markings such as "BUS LANE AHEAD" can also be used to highlight the transition. The use of permanently marked transitions is not recommended on limited hour HOV treatments since confusion may occur during hours when the HOV treatment is not in operation.

As an alternative, movable barriers such as stanchions can be placed upstream and downstream of a HOV lane during hours of HOV operation. Stanchions are particularly useful in contraflow lane projects for diverting opposing direction traffic. Stanchion spacings at transition points are usually smaller (e.g., 10 ft; 3.1m or less) than corresponding stanchion spacings along the treatment itself. Figures 4-13 and 4-14 give examples of the use of pavement markings, stanchions and overhead signing for contraflow lane transitions.

In addition to the use of stanchions, some contraflow projects have utilized movable median barriers at crossover points. This practice is not recommended where sufficient median width exists to provide a safe transition using median geometric changes. Where movable barriers are utilized, they should be designed to adequate structural standards to sustain vehicular impacts during hours when the median crossing is closed.

Geometric alterations are occasionally required to

Figure 4-13. Transition on Contraflow Lane
(U.S. 101; San Francisco, CA)

Figure 4-14. Contraflow Transition on Surface Street
(Spring Street; Los Angeles, CA)

accommodate HOV transitions. Exclusive HOV lanes in the median typically involve the redesign and reconstruction of the median while contraflow lanes may require construction of median crossovers. Ramp meter bypass HOV lanes will also require some redesign of ramp geometrics to accommodate HOV/non HOV merges. Crossovers, entrance and exit lane widths and tapers should follow accepted AASHTO design standards (see Ref. 3).

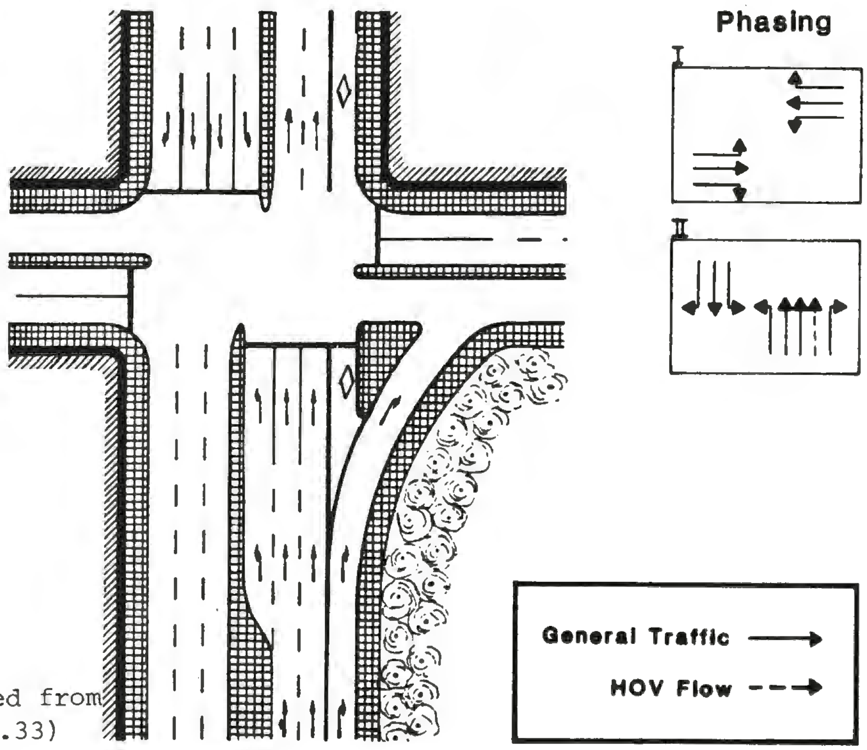
Surface street intersections may require increases in curb or median radii to allow HOV turns. Conversely, curb radii can be decreased to discourage access by non HOV's from designated cross streets. This procedure has been used successfully on transit mall projects where transition to the exclusive roadway is restricted to few locations.

Surface street HOV lanes usually begin and end at intersections. If the HOV lanes start immediately following an intersection, particular care must be exercised to prevent a queue of non HOV's from blocking the intersection. One design for concurrent flow curb lanes, shown in Figure 4-15, shows an HOV lane beginning immediately prior to a channelized intersection in conjunction with a separate right turn lane.

The termination of concurrent flow HOV lanes can occur at an intersection "setback". As shown in Figure 4-16, the HOV lane terminates at a pre-signal. At this point, the pre-signal offers a priority green phase to the HOV lane, allowing HOV's to move forward to any of the approach lanes. Once the HOV's have assumed their positions in the approach lanes, the pre-signal allows the non HOV's to advance. The main signal is then activated to permit the clearance of the approach. Termination of the HOV lane at the pre-signal permits maximum use of the intersection approach capacity, especially where HOV volumes are low. At the same time, a setback can aid turning movements for all vehicles by reducing the weaving of HOV's and non HOV's. The HOV lane can terminate at the setback or begin again after the intersection (Figure 4-16).

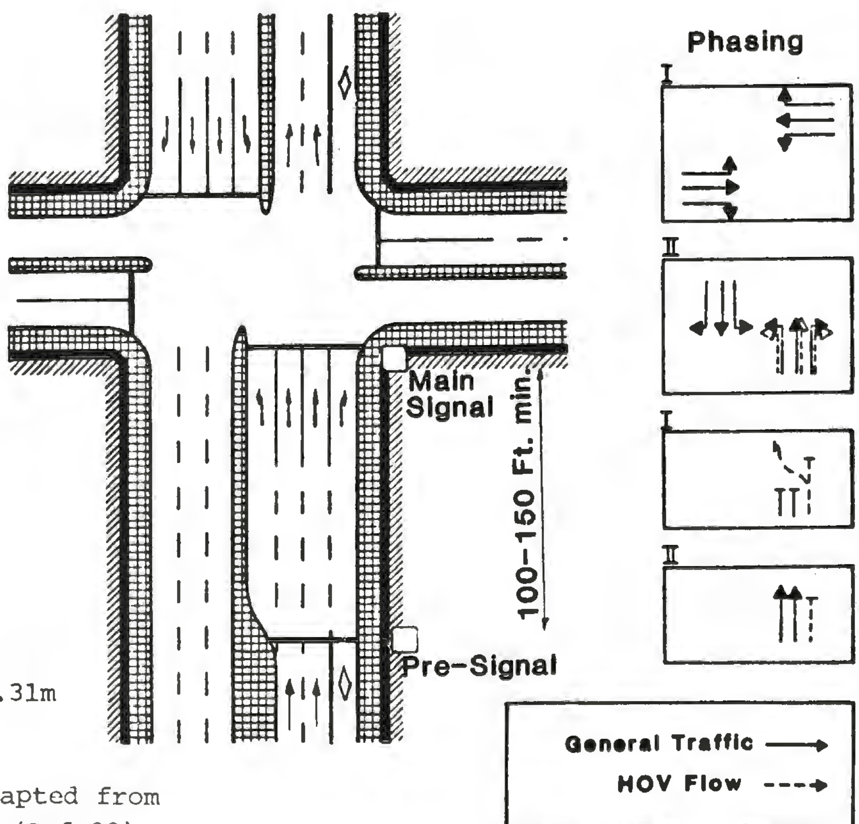
Transitions to one-way surface street contraflow lanes require turns to/from cross streets. Intermediate access should not be permitted.

Transition design is very important in projects which are undergoing staged implementation. In particular, staged HOV lane treatments must be designed



Adapted from
(Ref.33)

Figure 4-15. HOV Lane With Free Right Turn



1 ft = 0.31m

Adapted from
(Ref.33)

Figure 4-16. Setback With HOV Signal Priority to provide safe transitions at the termination point of each project stage. Particular attention should be paid to roadway tangents and traffic characteristics in the vicinity of the proposed transition. Contraflow or physically separated HOV lanes may require interim median crossovers or exclusive ramps to be constructed. In all cases, the project signing and marking must clearly indicate the interim transition points. The lack of suitable interim transition points can influence a decision whether or not to construct a particular project in stages.

Signalization

Signalization can significantly affect HOV treatment effectiveness and safety. Signalization design is most applicable on surface street HOV treatments, although many designs have been expanded to metering systems on grade separated facilities.

In most cases, existing signal heads and controllers will not require replacement as the result of HOV lane treatments. However, some signal heads may need to be moved. This situation will commonly arise where reconstruction or restriping activities shift the position of traffic lanes. Contraflow lane treatments usually require lane control signals located directly above the HOV lane.

Signals may need to be retimed to reflect changing facility speeds as a result of the HOV lane implementation. Contraflow lanes on one-way streets typically require a revision of offsets to accommodate the opposite flow HOV movements. Contraflow lanes on two-way streets follow the same timing plan as for the peak direction general traffic flow.

Signal priority treatments for HOV's range from minor offset and phasing adjustments to more complex signal preemption techniques requiring changes in controller equipment and occasionally on-board bus equipment. The general design applicability of each of these signal priority treatments is shown in Figure 4-17.

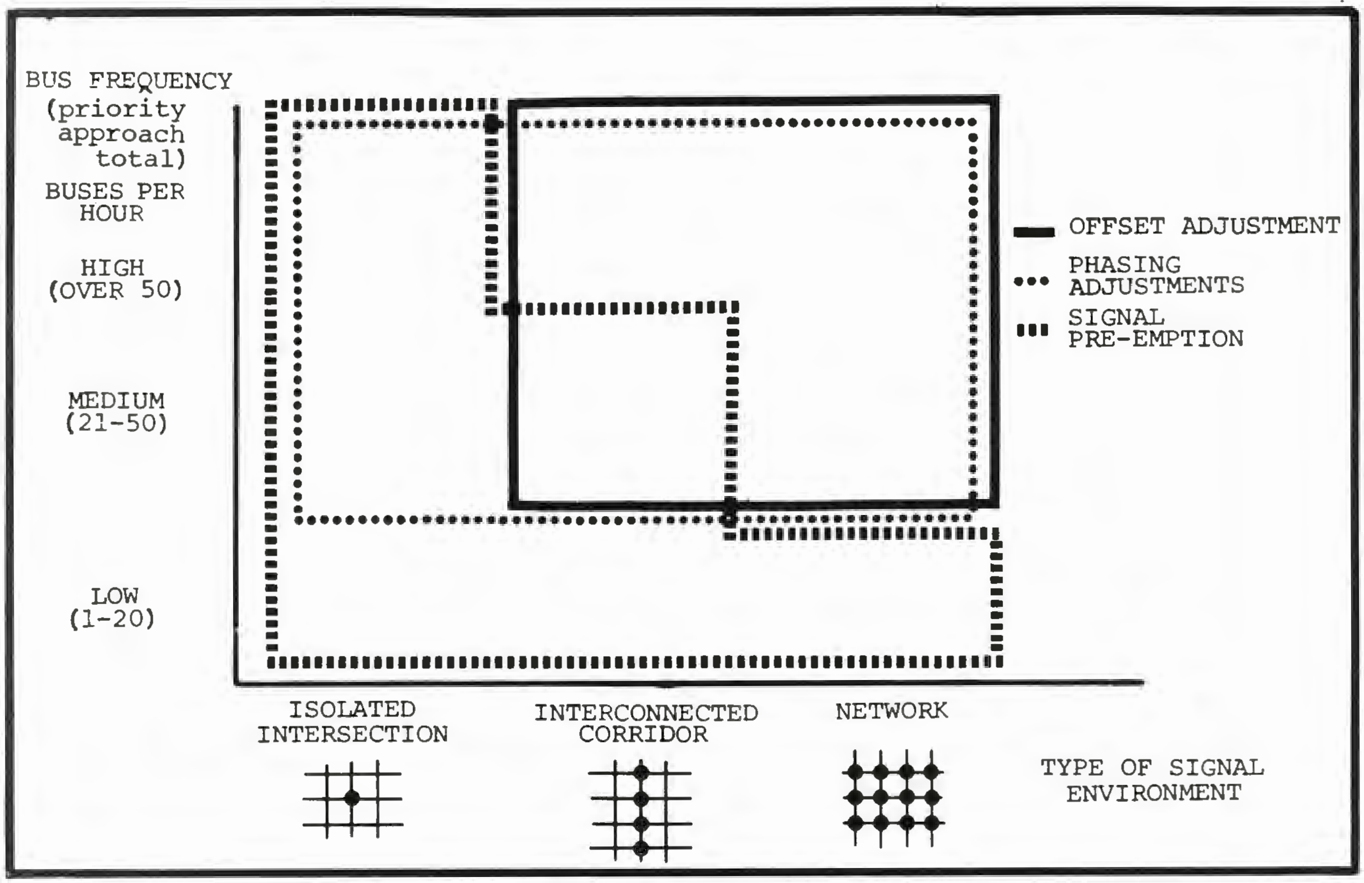


Figure 4-17. Applicability of Signal Priority Treatments

The design of signal priority treatments must consider the following:

- o HOV volumes;
- o Delay to non HOV traffic;
- o Bus stop locations and spacing;
- o Type of signal control;
- o Variance in transit dwell times and run times;
- o Position of the intersection with respect to other signalized intersections.

Special signal phases for HOV's can be inserted into cycles with or without signal preemption. These priority HOV movements may be instituted as part of a "setback" technique (Figure 4-16) or at independently selected locations. Figure 4-18 displays special HOV signal phases which could be applied in conjunction with an HOV lane. Reference 33 depicts these signal priority designs in greater detail.

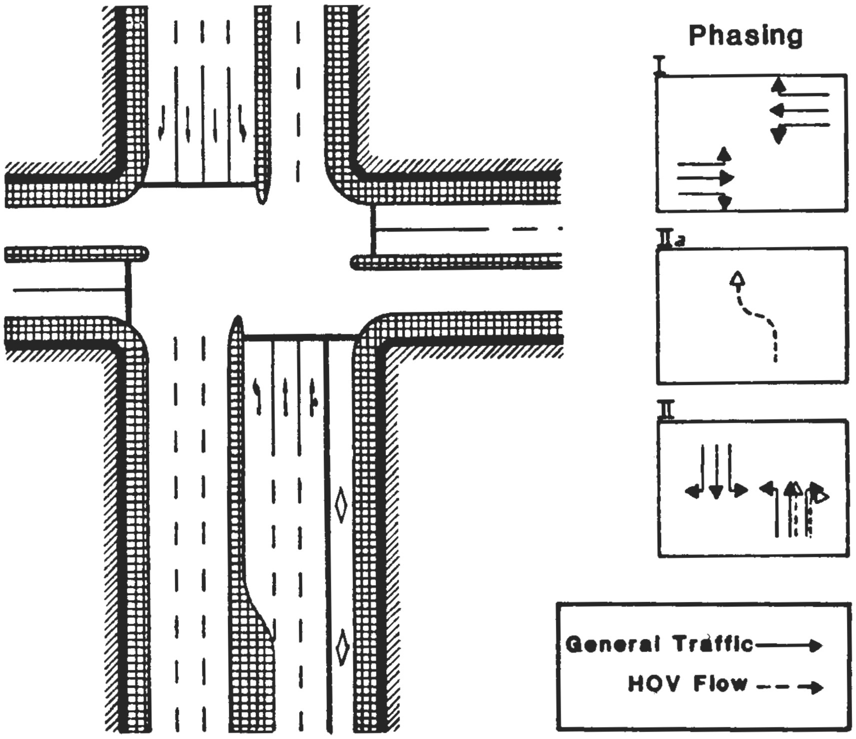
Transit Loading Areas

HOV treatments which include local transit service must consider the provisions for transit loading areas. Transit loading area designs range from traditional designated curb stops with no amenities to off-line transit terminals. The selection of an appropriate design is largely a function of the HOV lane and facility geometrics as well as the level of mixing between the local buses and express buses or carpools.

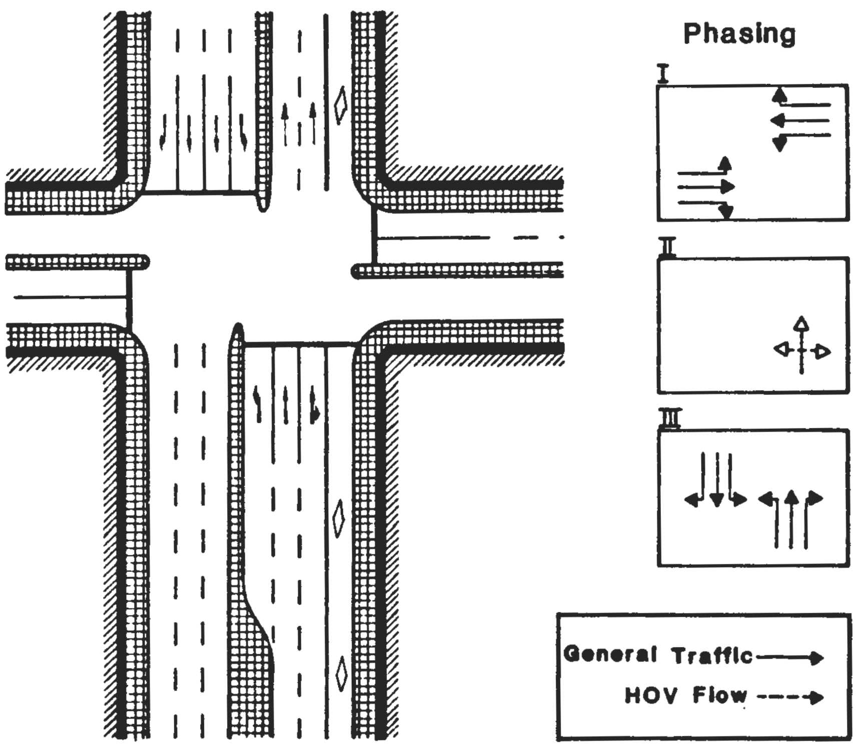
Surface street HOV treatments adjacent to a right side curb typically permit local buses to make loading/unloading stops along the HOV lane. This is the situation on most activity center bus lanes, where the vast majority of buses are operating in a local mode. However, frequent stops can severely increase travel times for any express buses and/or carpools utilizing the lane.

One option is to construct bus turnouts, thus allowing HOV's to bypass stopped buses. As seen in Figure 4-19, bus turnouts can be designed at nearside, midblock, or farside stops. Care must be taken to design enough turnout length (50 feet minimum per bus) to adequately handle the local bus load. The use of bus turnouts can be extended to contraflow or in-median HOV treatments where sufficient median width is available. A minimum of 5 feet (1.6m) should be provided for a passenger loading area in medians. This minimum width must also extend continuously to a crosswalk in order to provide safe movements for passengers. The use of a fence or splashguard is recommended. These same guidelines apply to the design of passenger loading islands constructed along surface streets with no median (Figure 4-20).

Local bus stops have typically not been provided along grade separated facilities due to the high travel speeds and lack of adequate stopping points. However, there have recently been several designs of on-line bus turnouts in the vicinity of interchanges. Ramps also offer good opportunities for local bus stops. Care must be taken to provide adequate acceleration and



Termination of HOV Lane



Continuing HOV Lane

Adapted from (Ref 33)

Figure 4-18. Special HOV Signal Phases

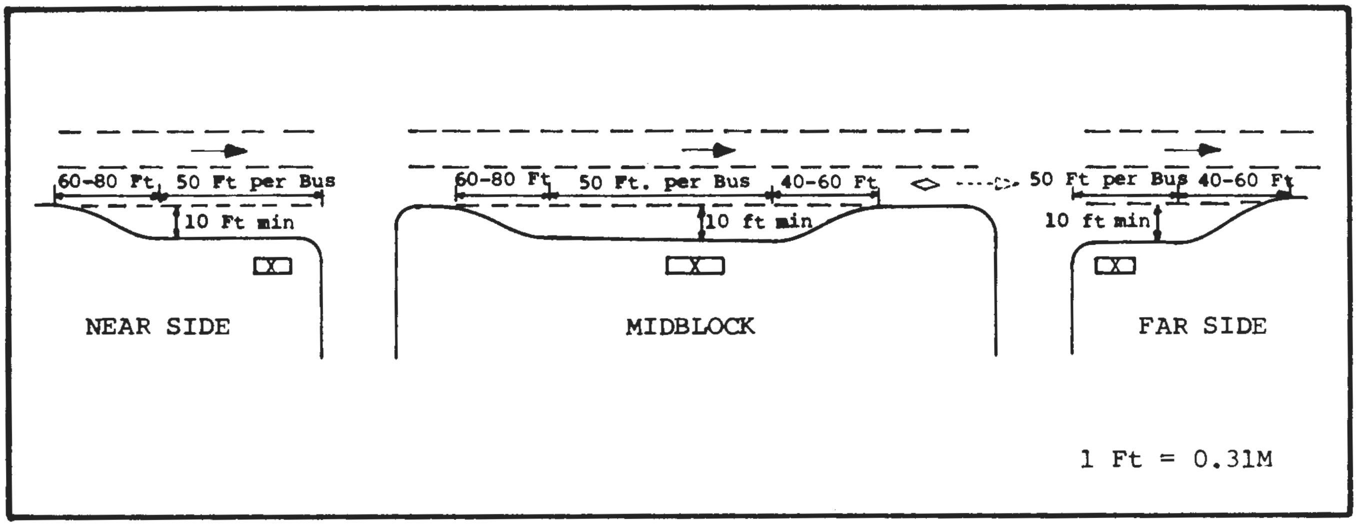


Figure 4-19. Curb Bus Turnouts

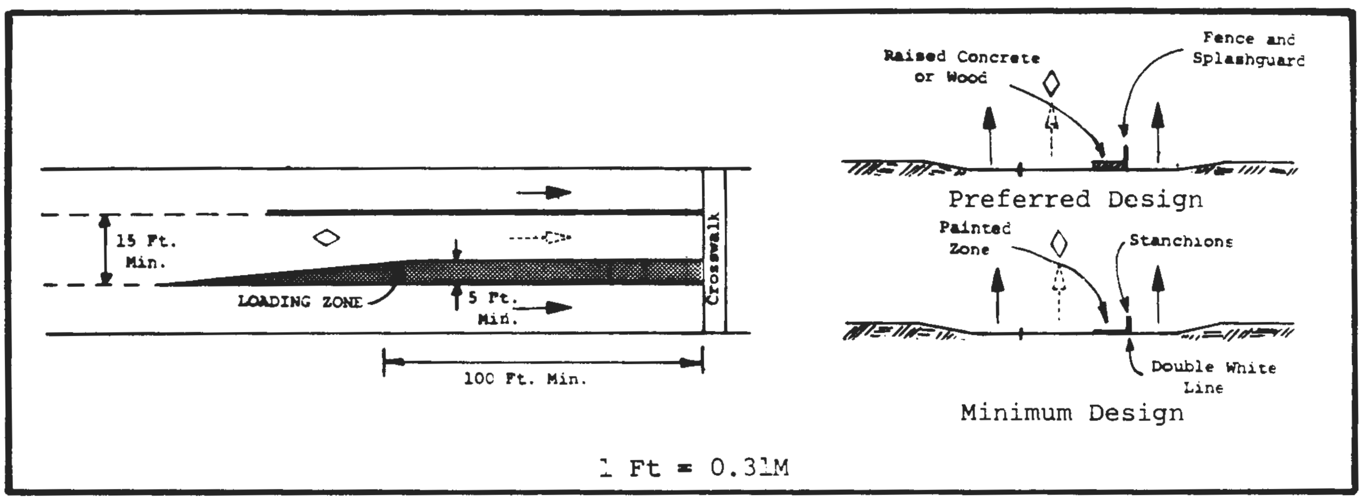


Figure 4-20. Passenger Loading Island

deceleration distances for buses to safely exit and reenter the traffic stream (see Ref. 3).

Off-line transit terminals are usually located at the ends of an HOV treatment in conjunction with park and ride lots. These terminals may be linked to express HOV lane treatments via exclusive HOV ramps, connector streets, or HOV signal priority treatments at terminal access points.

Design for Curb Access

One of the most difficult problems encountered in the design of surface street curb HOV lane treatments is the provision for curb access. Curb access demands are typically found from three sources - parking, goods deliveries, and taxis. There are several design solutions which can be applied to this problem:

- Restrict curb access to designated times (e.g., off-peak hours). This is a solution typically employed on peak period HOV treatments. However, strict enforcement is usually required to remove illegally parked vehicles.

- Utilize cross streets and alleys in lieu of curb access. This solution is most applicable to goods deliveries where parking is preempted on key cross streets and in alleys.

- Provide for curb access adjacent to the HOV lane. This solution solves the problem of illegal parking within the HOV lane, but does not solve the problem of vehicles crossing the HOV lane to gain access to the curb. Several HOV lanes in San Francisco are 17 feet (5.2m) wide in order to accommodate parking and loading.

- Provide a special delivery lane. This is a preferred design where HOV's and curb traffic are separated by a physical barrier. However, this design utilizes considerable street width and may not be a feasible design along high volume streets where an extra lane cannot be taken away.

Design for Safety and Enforcement

The design of HOV treatments significantly affects the safety and enforceability of the project. Two recent studies entitled Safety Evaluation of

Priority Techniques for High Occupancy Vehicles (Ref. 31) and *Enforcement Requirements for High Occupancy Vehicles Facilities* (Ref. 30) recommend several key design features related to safety and enforcement. These recommendations are summarized in the following sections.

General

- Whenever possible, the HOV lane should be an added lane and not be established by the taking of an existing general traffic lane. Oftentimes, this recommendation cannot be followed due to right-of-way, cost or construction schedule considerations.

- AASHTO and MUTCD standards should be used as much as possible. Existing roadway deficiencies should not be exaggerated by the HOV project design. Every effort should be made to maximize the quality of the geometrics including medians and shoulder areas. The traffic control devices should be highly visible and frequently spaced. At decision points (particularly terminals and cross-overs), these devices should be prominent to remove confusion as to proper lane use.

- Lane widths for all lanes should be 12 feet (3.7m) and the HOV lane can even be wider. If lane width adjustments are necessary, old lane lines should be thoroughly eradicated, longitudinal joints should not conflict with lane lines and when this is not possible, resurfacing should be considered. If the HOV lane is newly constructed, the surface of the HOV lane should closely match the existing surface.

Grade Separated Facility - Exclusive In-Median Roadway

- The ideal terminals to and from the separated HOV lanes are exclusive ramps. At the end of the HOV lane, it may be necessary to add a lane or provide an adequate acceleration lane for HOV vehicles merging into the general traffic stream.

- Access locations should be designed to meet the traffic demand but should also be located upstream of bottleneck locations if possible.

- The facility should have full right and left shoulders. Separation should be accomplished by concrete median barriers.

- On partially separated HOV lanes, supplemental signing should be provided at transition points to identify the legal exits from the limited access facility. This is to avoid erratic maneuvers by drivers needing to exit at locations other than the HOV lane terminals.

- On partially separated facilities having a common shoulder, the shoulder should be flush and easily accessible by disabled vehicles. On partially separated facilities having a common shoulder, the shoulder should have chevrons, cross-hatching, word messages and/or safety posts to discourage crossing of this shoulder.

- On reversible in-median HOV roadways, access control must be positive. Use of lane control signals is suggested by the MUTCD and AASHTO but, in addition, gates or barricades should also be provided at the entrances.

Grade Separated Facility - Concurrent Flow Lane

- It is strongly urged that concurrent HOV lanes be "added" to the facility rather than "taken" from existing general use, particularly on heavily congested urban freeways.

- The facility should have median shoulders and refuge areas. These are needed both for public safety and to provide an area for officers to monitor HOV operations effectively.

- Signing and markings should conform to MUTCD standards, and special supplemental signs should be used as needed. If the HOV lane is a continously accessible lane, the lane demarcation between the HOV lane and general lane should be conspicuous white skip lines or raised pavement markers. Where solid lines are used, there should be a left shoulder and/or clear indication that the HOV lane is a traveled lane and that no stopping is allowed.

- The speed differential between the HOV lane and general-use lanes may be controlled if necessary. This can be accomplished by metering general lane traffic at on-ramps, using variable speed control signing on the HOV lane, or a combination of both. Smaller speed differentials may lead to reduced HOV lane effectiveness, however.

- On HOV projects that operate in both directions during the same time period, median barrier cuts should be provided (if there is a median barrier) to enable enforcement activities to be carried out in all the lanes.

<u>Grade Separated Facility - Contraflow Lane</u>

- Full right and left shoulders should be provided for emergency stops in both the contraflow lane (median shoulder) and opposing general traffic (right shoulder) lane(s).

- The ideal terminals to and from the contraflow lane are exclusive ramps or toll booth lanes if the output is to a toll plaza. Where median crossovers are required at the beginning, a short access lane allowing for deceleration should be provided upstream of the crossover. If the ending terminal is not inherently suitable for detaining violators (such as a toll plaza), a refuge area should be provided, preferably in the median.

- A buffer lane should be provided if possible. In all cases, delineation of the HOV lane should include 1) removable safety posts and barricades, 2) variable message signs at access points and/or 3) lane use control signals (red "X" and green arrows) over the contraflow, buffer and adjacent general lanes.

- Where a buffer lane can be provided between the contraflow lane and the general use lanes, overhead lane use control signals are not necessary to designate proper lane use if sufficient physical separation and signing is provided.

- Spacing of lane use control devices should have at least one and preferably more devices in view of opposing traffic. Spacing of delineators should be close enough to discourage lane changes.

- Use of the contraflow lane should be restricted to experienced and trained operators. In addition to transit operators, operators of other vehicles (charter buses, mini-buses, vanpools, taxis and carpools) could be permitted use of the contraflow lane if special licensing requirements are met.

- o It may be desirable to impose additional restrictions on both contraflow lane and/or opposing lane traffic. Reduction of the speed limit and vehicle headways are the most common restrictions, although the effectiveness of the HOV lane may be diminished as a result.

- o Quick-reaction incident detection and removal systems should be incorporated into the project. If possible, median openings should be provided if there is no buffer lane so emergency vehicles can approach in the proper direction; however, these should not be able to be crossed by general traffic nor present a collision hazard themselves.

<u>Grade Separated Facility - Ramp Treatments</u>

- o Ideally, a ramp meter bypass (RMB) HOV lane should be physically separated from the metered lanes(s). This is particularly important at the ramp entry.

- o Where physical separation is not possible on a long ramp with sufficient storage capacity, an RMB lane should begin after the entrance point so there is a single entry lane.

- o Sufficient merging distance should be provided so that HOV's and general traffic can merge together and assume the same speeds prior to merging on the freeway.

- o The intersection with surface streets is of particular concern for HOV ramps. This is especially true if the ramp is reversible. Hazardous maneuvers or conflicts with surface traffic should be minimized by proper geometric design and/or traffic controls.

- o A vantage point should be provided for a stationary officer to monitor the RMB lane out of view of the motorists. Adequate shoulders should be provided for apprehending and ticketing violators.

- The selection of right or left lanes as the HOV lane is important particularly on non-separated RMB ramps. Consideration should be given to ramp access, ramp geometrics, position of signals, vis. a vis. the stopped queue and how the two lanes will merge.

Toll Plazas

- Ideally, the HOV lanes and general lanes should be separated by a physical barrier or raised curb, so long as such a barrier does not pose a safety hazard itself. Otherwise, stanchions delineating the HOV lane should be placed close enough to prevent lane change movements.

- The weaving area at entrance and exit points to the HOV lane should be of sufficient length to minimize conflict. This is especially true where multiple roadways enter and exit the toll facility.

- When possible, special refuge areas or shoulders should be provided adjacent to the HOV lanes. Such areas aid both disabled HOV's and enforcement operations.

- Where the facility is not metered, the capability of informing toll attendants to halt traffic should be included. This would "clear" the downstream roadway allowing police vehicles to pursue violators and, more importantly, allow emergency vehicles to travel unimpeded.

Surface Street - Exclusive HOV Roadway

- Cross streets across the exclusive roadway should be eliminated whenever possible. When the elimination of cross streets is impossible, the turning movements between the exclusive roadway and the cross streets should be restricted. A one-way cross street is preferred to a two-way cross street because of the fewer potential conflicts.

- All appropriate pedestrian controls should be instituted. These include pedestrian crosswalks, pedestrian signals and strict enforcement of "jay-walking."

- It is important that terminal areas and any other access areas be well signed and marked and the traffic appropriately channeled.

Surface Street - Concurrent Flow

- Prohibit taxicabs and other vehicles from stopping in the curb lane to pick up and drop off passengers, or to make deliveries.

- Remove parked vehicles from the curb lane.

- Signing and markings should conform to the MUTCD standards, but special supplemental signs should be used as needed. Stanchions should generally not be used to separate the HOV lane and general travel lanes.

- For inside concurrent flow lanes, prohibit left turns at selected locations, if not at all locations. Closing of non-signalized intersections by cones or other implements should be considered to reduce crossing movements across the HOV lane.

- For a median lane HOV treatment, use of left-turning bays (closed-off due to left turn restriction) have proven to be an effective area for enforcement vantage points and detention areas.

- Enforcement of parking and turning restrictions may require more attention than violations of the HOV lane itself.

- For a curbside lane HOV treatment, locations should be available or provided where officers can apprehend and issue citations to violators without encroaching onto the main roadway. The use of cross streets may be an appropriate detention area.

- For a curbside lane HOV treatment, the signing permitting right turns should specifically state the point at which a right-turning vehicle may enter the priority lane.

- Variable speed control signing on the HOV lane may be used to limit the speed differential between the HOV lane and general-use lanes. However, the effectiveness of the HOV lane may also be reduced.

Surface Street - Contraflow Lane

- Left turns should generally be prohibited along the contraflow lane operation unless separate turn phases are provided. Provide rigorous enforcement of any left-turn prohibition. Reinforce left-turn prohibitions with physical impediments where possible. Enforcement on curb contraflow lanes also needs to focus on parking restrictions.

- Geometric and/or traffic control techniques intended to eliminate or physically impede entering and exiting at intermediate intersections greatly enhances enforcement on contraflow facilities, and should be deployed where possible.

- Overhead lane-use control signals and overhead signs should be used, especially where extensive visual clutter exists lessening the effectiveness of roadside signing.

- The use of temporary traffic control devices, such as cones, gates, and signs on stanchions, can be effective in minimizing illegal turns across the contraflow lanes.

- If possible, curbside contraflow lanes should be wide enough for a bus to safely pass a disabled bus. Wide lanes enhance enforcement by providing 1) an enforcement vantage point, 2) a passing lane for violator apprehension, and 3) a detention/citation area.

- If possible, inside contraflow lanes on two-way streets should have a median from which enforcement officers can monitor the project's operation.

- It may be desirable to impose additional restrictions on both contraflow lane and/or opposing lane traffic. Reduction of the speed limit and vehicle headways are the most common restrictions, although the effectiveness of the HOV lane may be diminished as a result.

Surface Street - Signal Preemption

- Bus speed limits should be strictly enforced if the bus drivers with signal preemption are able to drive faster than the posted speed limit. A lower bus speed should reduce the clustering effect.

- The drivers of the buses utilizing signal preemption should be permanent drivers regularly assigned to these bus trips. A comprehensive driver training program should be conducted.

- The signal preemption strategy and timing package should be carefully designed to provide minimum phase lengths that will insure pedestrian clearance and/or driver expectation intervals.

Legal Concerns

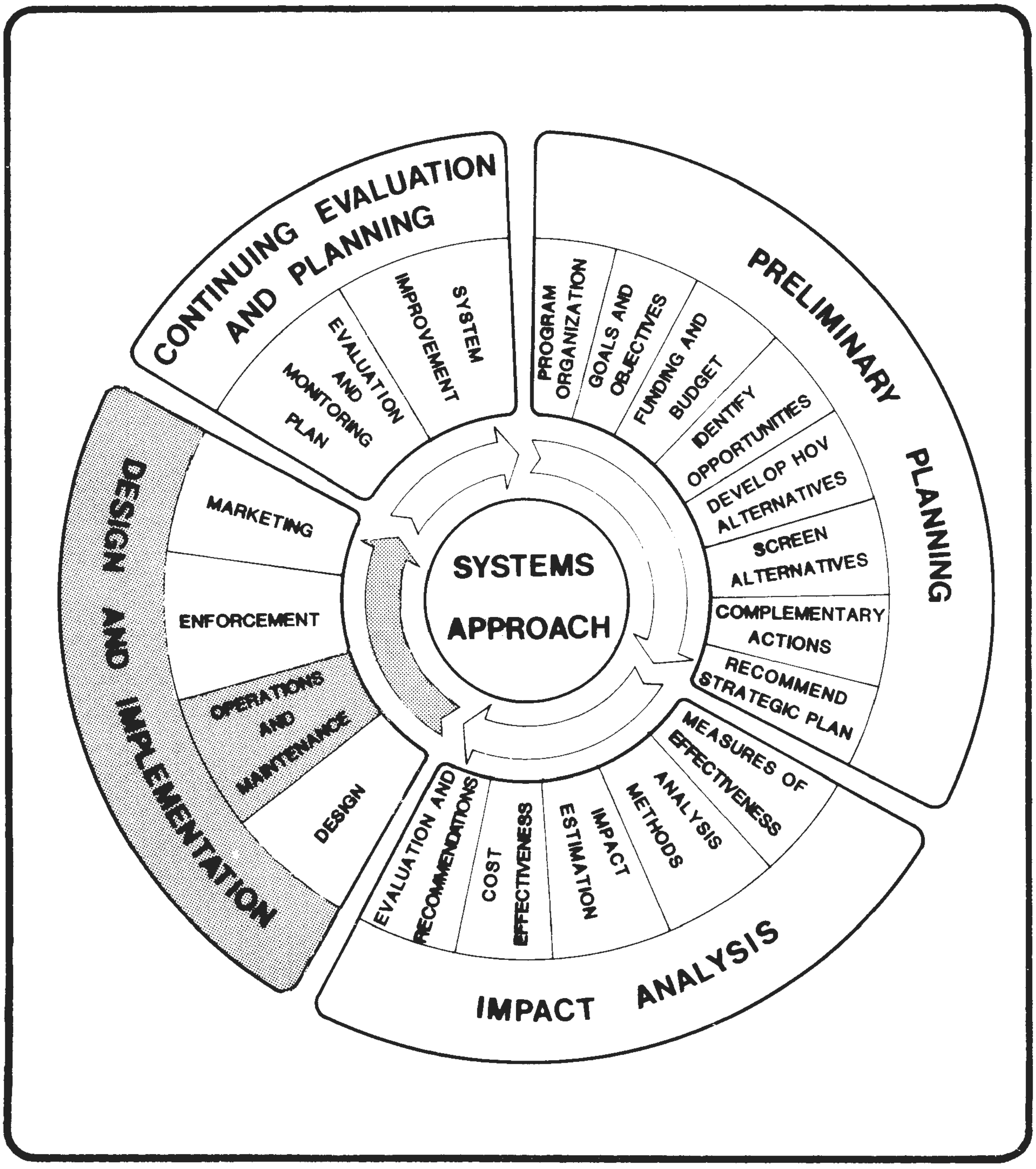
A primary legal issue related to HOV priority treatment design is the potential risk of legal liability faced by an agency when traffic accidents occur. The primary law pertaining to HOV projects would be the "law of negligence". In general, the negligence "cause of action" requires that the plaintiff prove four elements: duty, breach, cause and damage (Reference 31).

Once established, the cause of action can be wholly or partially defeated by the defendent's (e.g., state) proof of certain defenses, such as contributory negligence, assumption of risk and sovereign immunity. Traditionally, in this country, governmental agencies were not held accountable for negligent acts on the theory that the government was immune to suits. However, this theory has broken down to some extent in almost every state. Therefore, thorough examination of specific laws in a particular state and/or local area must be conducted. Reference 31 provides a detailed examination of each of these HOV design legal issues.

SUMMARY

The design of HOV treatments can have a major effect on the project's success. In particular, safety and enforceability are often directly related to the design of an HOV treatment. Design includes the related topic areas of geometrics, signing and marking, signalization, intersection and/or interchange treatments, transition treatments, transit loading areas, and design for curb access. A primary legal issue related to HOV priority treatment design is the potential risk of legal liability faced by an agency when traffic accidents occur.

5. OPERATIONS & MAINTENANCE



5. OPERATIONS AND MAINTENANCE

INTRODUCTION

The operations and maintenance requirements of an HOV treatment should be determined early in the project design process. Operations and maintenance encompasses a wide range of daily and periodic requirements necessary for the efficient and safe functioning of an HOV treatment. These requirements vary considerably by the type of HOV treatment and the specific local, physical and operational setting.

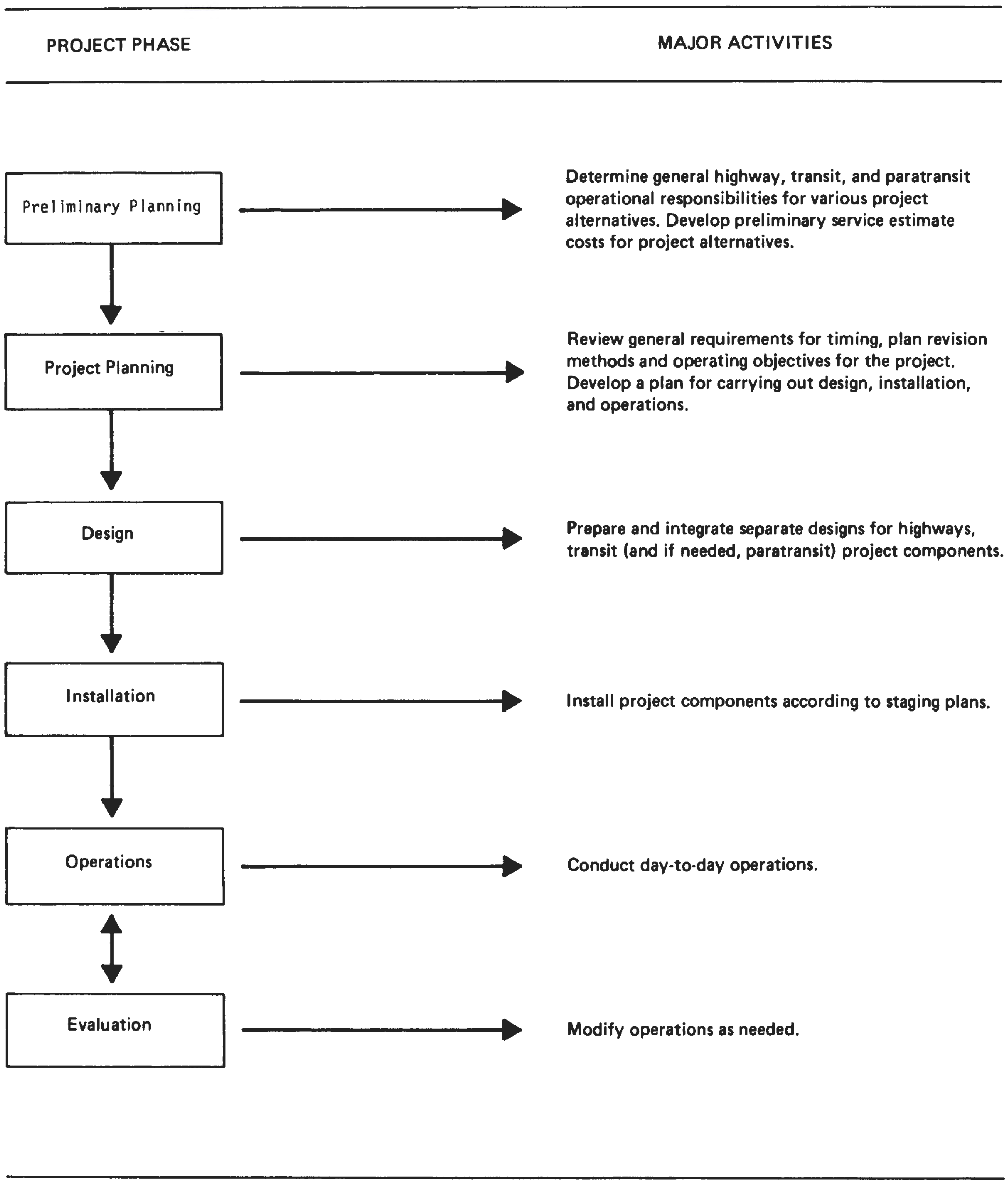
The development of an operations and maintenance plan follows an iterative procedure, as shown in Figure 5-1 (Ref. 36). This figure indicates the need for early definition of project needs as well as a continual monitoring and fine-tuning of procedures once the project is implemented. Chapters 2 and 3 discussed the aspects of operations and maintenance relative to preliminary planning and detailed analysis. This chapter focuses on the design and subsequent implementation of a workable operations and maintenance plan for HOV treatments.

The operations and maintenance plan is usually divided into two components--highway and transit. Each of these elements has specific design requirements which must be considered separately as well as jointly. The major design aspects of these two components are presented in the following sections.

HIGHWAY COMPONENT

The highway operations and maintenance plan details the following aspects of the HOV treatment operation:

- Hours of HOV treatment operation
- Vehicle type criteria
- Occupancy criteria
- Designation of traffic regulations
- Daily operational responsibilities
- Ongoing maintenance responsibilities
- Equipment and personnel needs



(Ref.36)

Figure 5-1. Operations Planning Activities

Each of these project characteristics and requirements must be designed in accordance with existing budget limitations and political atmosphere.

Hours of HOV Treatment Operation

HOV treatments are usually applied during one of three time frames:

- o Peak Hour(s) (e.g., AM and/or PM peak);
- o Daylight Hours (e.g., 6 AM-7 PM);
- o All Day (i.e., 24 hours).

The selection of an appropriate time frame for HOV application is dependent upon expected HOV demand throughout the day, the physical design of the project, and the required level of the project enforcement.

Peak hour(s) HOV treatments typically are implemented along facilities which experience a distinct peaking of traffic volumes and HOV demand during selected hours. Most radially oriented concurrent and contraflow HOV projects fall into this category. In addition, activity center HOV treatments are often limited to peak hours when curb parking can be effectively banned. Most peak hour(s) HOV lanes are not physically separated from non HOV lanes, requiring considerable enforcement which would be expensive to maintain over longer time periods. Priority parking treatments are often restricted to peak periods, after which time remaining lot or curb capacity is made available to any vehicle.

Some HOV treatments are applied during daylight, or working hours only. These treatments are usually located on surface streets within activity centers where transit movements remain high throughout the day. Parking must be prohibited along curb HOV lanes, which can pose an ongoing enforcement problem. Within the San Francisco CBD, extra wide HOV curb lanes permit both off-peak parking and HOV lane operations. The day-long presence of large transit volumes helps discourage violations. In addition, the semipermanence of the HOV lane(s) (e.g., 12 or more hours per day) increases visibility of the HOV restriction.

All day restrictions are common where the HOV lane(s) is physically separated from non HOV flow. In such situations, enforcement is not usually a difficulty. In addition, allowing non HOV's to use physically separated HOV lanes during off peak hours can create a confusing situation, especially at changeover times. The resulting weaving movements can create potentially dangerous conflicts with physical barriers. Exclusive HOV streets (e.g., transit malls) have been restricted at all times to create both a strong visual HOV impression as well as to provide for a more pleasant pedestrian zone.

The use of non-physically separated all-day HOV lane treatments must be restricted to situations where the HOV lane can be permanently signed, marked, and enforced. Contraflow lanes on one-way surface streets are typically marked with solid lines and overhead lane signs to indicate reverse direction flow at all times. Signal priority treatments, priority parking, and pricing strategies are often applied on a 24-hour basis since roadway space is not preempted.

Vehicle Type Criteria

In general, most HOV treatments could be extended to any form of HOV, including transit vehicles, carpools/vanpools, and taxis. However, the type, design, location and operation of an HOV treatment can influence the types of HOV's which can be permitted.

Each type of HOV treatment places different limitations on the selection of appropriate vehicle types. Express HOV lanes on grade separated facilities are prime locations for mixed mode operations since travel speeds of autos and express buses are compatible. Several concurrent flow treatments and exclusive in-median HOV facilities have been extended to use by carpools. Contraflow lanes have typically been restricted to buses, although taxis and vanpools have been permitted on projects in New York and Houston, respectively. Mixed mode ramp treatments are also very common.

Mixed carpool/bus HOV treatments on surface streets have been limited. The presence of slower local buses along curb lane treatments usually discourages carpoolers and even express buses. On the other hand, mixed mode use of inside lane (e.g., next to median) treatments has been successful on South Dixie Highway in Miami. Contraflow HOV lanes on one-way streets have forbidden carpools for safety reasons.

Within activity centers, curb HOV lanes or exclusive transit malls are usually restricted to buses, except where access to off-street parking necessitates allowing other vehicles. Since the travel time savings of these activity center HOV treatments are usually small, there is minimal carpool inducement solely in response to these treatments. However, if combined with radially oriented carpool priority treatments, activity center HOV treatments could logically be extended to carpools.

HOV signal priority treatments have mostly been geared to transit vehicles (e.g., signal preemption). However, such techniques as phasing and offset adjustments can be implemented to benefit carpools as well.

In addition to the type of HOV treatment, other factors should be considered prior to deciding on the correct vehicle mix. In general, the trend has been to allow carpools when the following conditions exist:

- A reserved facility or lane has plenty of excess capacity (i.e., the lane or facility will be otherwise perceived by the public as being greatly underutilized);
- The travel time advantage to buses will not be lost with the addition of carpools;
- Safety will not be jeopardized;
- Adequate enforcement can be accomplished, and;
- There are insufficient buses to make the HOV treatment cost effective.

Carpools have typically not been permitted where bus volumes are high (i.e., greater than 100 per hour). Such volumes have occurred on some contraflow lane projects as well as on bus lanes along major activity center transit routes. Most HOV treatments, however, exhibit low enough transit volumes so that carpools can be permitted without reducing the level of service in the HOV lane.

Occupancy Criteria

The selection of an appropriate number of occupants to define a carpool is a policy issue which should be resolved early in the planning process. From a technical standpoint, the resolution of this issue should be based on project demand for the HOV treatment (Ref. 36). The following criteria should be considered in making this decision:

- o Existing occupancy data;
- o Other projects in area;
- o Travel time savings;
- o Facility capacity;
- o Encouragement of HOV formation.

The existing vehicle occupancies on a facility give a good indication as to the potential for forming additional carpools with a given occupancy. High existing vehicle occupancies (i.e., greater than 1.4) reveal that there already exists a good carpool market which could probably support a higher HOV occupancy rule (e.g., 3+ or 4+). Conversely, low existing vehicle occupancies may necessitate a low occupancy rule (e.g., 2+) in order to be effective.

Other HOV projects in an area set a precedent for any new HOV project. Therefore, wherever possible, a uniformity of HOV occupancy rules should be established to minimize motorist confusion. Uniform occupancy rules are especially important for HOV treatments which are linked together within a corridor or activity center.

Facility capacity and the potential HOV travel time savings should also be considered. As the HOV occupancy rule decreases, the number of eligible HOV's increases. Therefore, a low HOV occupancy rule (e.g., 2+) may cause a congested HOV lane or facility. On the one hand, HOV lane capacity should not be wasted by an overly high occupancy rule; on the other hand, sufficient HOV lane capacity should remain to accommodate growth in HOV usage without adversely affecting travel times. A proposal to drop the Shirley Highway HOV facility occupancy rule from 4+ to 3+ was rejected based upon the expected negative HOV travel time effects of a lower occupancy rule. Subsequent growth in 4+ carpools is itself straining the capacity of the HOV facility.

A major objective of a HOV treatment is encouragement of HOV formation, not merely the accommodation of existing HOV's. Therefore, the HOV occupancy level should be set high enough to provide incentives to shift to a higher occupancy level (e.g., from a 2+ to a 3+ or 4+ carpool). Experience has shown that it is desirable to begin a HOV project with as high an occupancy rule as possible, relaxing the rule to a lower occupancy only if necessary.

Designation of Traffic Regulations

This requirement alerts agencies to the need for identifying traffic regulations or ordinances which must be changed upon implementing the HOV project. These regulations may include the designation of turning or entry restrictions during selected hours in response to the design needs of the HOV treatment (see Physical Design). Reversible lane or contraflow lane projects may require a revised set of operating procedures to be included in existing traffic ordinances.

The revised traffic regulation should be prepared in a clear, concise manner so as to be easily understood by motorists. At the same time, care must be taken to make sure that the regulations are legally valid. Cooperation between the operating agencies, transit agencies and the enforcement agencies is vital to produce a workable set of traffic regulations.

Daily Operational Responsibilities

The daily operational responsibilities of HOV treatments vary according to the type of treatment employed and the physical and operational setting. Several HOV treatments require no daily upkeep. Once the required signing and marking is applied, only periodic maintenance is necessary. This is typically the situation on concurrent flow lane treatments, exclusive HOV roadways and signal priority treatments. Daily cleaning and upkeep of aesthetics (e.g., street furniture, plantings) on surface street exclusive facilities can necessitate more attention.

Manual sign and gate changing can create additional operating responsibilities. These manual operations are usually associated with contraflow lanes or reversible in-median lanes. As exemplified in Figures 5-2 and 5-3, the responsibilities can include opening and closing hinged signs, gates, median barriers or movable roadside signs. Manual sign and gate changing can normally be accomplished with one vehicle and 1 to 2 persons working for 1 hour before and after project operation. During hours of operation, these persons can monitor the project operation and report any accidents or disruptions. The installation of overhead changeable message signs can

(North Freeway; Houston, TX)

Figure 5-2. Gate Closure on Exclusive HOV Ramp

(U.S. 1/South Dixie Highway; Miami,FL)

Figure 5-3. Movable Stanchions and Signs reduce these daily needs, but at an increase in initial capital costs.

Toll pricing and priority parking projects can often be implemented with minimal additional staff time. Regular toll collectors can monitor HOV flow through toll plazas, while periodic inspections of parking facilities can identify problem conditions. Daily or weekly cleaning crews are normally required at park and ride or exclusive activity center parking facilities. Registration of carpools to receive priority pricing or parking privileges may require one additional full time or part time staff person.

The greatest requirement for daily operations occurs where stanchions are placed and removed before and after HOV treatment operating hours (Figure 5-4). For instance, contraflow projects which operate only during peak periods can involve twice-a-day set up and take down operations. A typical stanchion and sign placement operation consists of 4 to 8 persons working for 1 to 2 hours before and after HOV treatment operation. For a project which operates during only one peak period each day, this requirement equates to approximately 20 to 30 daily person hours, or 100 to 150 weekly person hours. In many cases, the number of hours paid to personnel have been greater than the number of hours actually worked due to the need for back-up crews and labor requirements for minimum working time. In addition, changing shift times can create personnel difficulties. This daily effort is compounded where stanchions are placed on both sides of an HOV lane (e.g., Kalanianaole Highway).

Because of the traffic congestion and potential hazards caused during stanchion set-up and take-down procedures, plus the confusion among motorists caused by operation signs which are visible before or after project hours, the trend has been to minimize time by maximizing personnel. However, this also means that equipment needs are maximized, so that two trucks may be required in some situations instead of one, substantially increasing costs.

In most cases, specially equipped trucks (Figure 5-5) must be designed to perform the stanchion placement task. A minimum of one additional vehicle (often obtainable from an existing motor pool) is required to act as lead vehicle in the stanchion placement activity. One project utilizes a total of four trucks operating in tandem to maximize safety for the stanchion placement crew. Supplement 5A provides

(U.S. 101; Marin Co.,CA)

Figure 5-4. Stanchion Placement

(Kalanianaole Highway; Honolulu,HI)

Figure 5-5. Stanchion Placement Truck

an illustration of contraflow lane operational requirements on the North Freeway contraflow lane in Houston, Texas.

An example of problems encountered in the Long Island Expressway Contraflow Lane project is described in the following excerpt (Ref. 15):

> "In the original plan of operation, two men plus a foreman constituted a crew. Two back-up crews were on duty at all times. One of the crews laid the traffic posts, while the other crews handled the signs. At first there were some difficulties in scheduling these crews since the shifts ran from 12:00 to 8:00 and 8:00 to 4:00. This necessitated assigning different crews to the morning duties of placing the posts and putting the signs into position, while a new crew had the responsibility of restoring the roadway to its normal operating condition after 9:30 AM. Negotiations with the representative union resulted in permission for one crew to handle the entire job."

In some cases, the need for laying stanchions has been minimized or eliminated by the installation of overhead changeable message signs and special pavement markings or buffer lanes. However, the added capital cost of installing overhead electronic message signs can offset the daily operating costs of stanchion placement.

Most HOV lane projects will require tow trucks on duty or within easy reach. This requirement is critical on projects where shoulder, buffer lanes or turnouts are not available to store disabled vehicles. Contraflow or physically separated HOV lanes without refuge areas or median breaks can create a situation where HOV's cannot bypass any disabled vehicles. Removal of illegally parked vehicles requires prompt attention on surface street curb lane HOV treatments.

<u>Ongoing Maintenance Responsibilities</u>

Ongoing maintenance consists of fixed signing and marking maintenance as well as upkeep of any electronic changeable message signs or traffic signals. Stanchions used to separate HOV and non HOV flow must be periodically inspected and replaced when necessary. Experience on existing projects has shown that 40 to 50 percent of stanchions need replacement annually. The higher percentage occurs in cold weather climates where the plastic stanchions become brittle. Stanchion holes drilled into the pavement must also be periodically cleaned out. This can become a frequent task where snow and ice often block the holes.

In general, maintenance costs of HOV treatments represent a small proportion of total project costs. Maintenance of signs and/or markings is typically conducted at the same time and within the same budget as other roadway maintenance duties. The level of maintenance for exclusive HOV facilities is similar to maintenance of any other roadway facility. Supplement 5A describes maintenance responsibilities for contraflow lane operations on the North Freeway in Houston, Texas.

TRANSIT COMPONENT

Transit operations are a major component of many HOV projects. A transit operations plan should be prepared which identifies several areas in which a HOV treatment will impact transit services and procedures. An HOV treatment can influence several aspects of transit operations, including transit services, vehicle needs, new construction, and daily operations.

Transit Services

The transit operations plan should first identify the service market along an HOV treatment. Using this market information plus knowledge of existing transit service and the expected benefits of the HOV treatment, an estimate of transit demand for additional transit service can be made. This transit demand should then be translated into a transit service package for implementation in conjunction with the HOV treatment. This package may consist of major service changes or no changes, depending upon the situation. In many cases, the amount of service which can be provided is a function of available vehicles as well as existing budget limitations.

HOV projects are often implemented in conjunction with new or expanded transit services. Radially oriented HOV treatments typically add or consolidate express transit service oriented to activity centers. An extreme example is the Shirley Highway project, which expanded the peak period corridor express bus volume by over 60 vehicles. Most activity center HOV treatments do not induce new transit service but rather focus existing service onto facilities which have the HOV treatments.

The resulting transit service package may include: (Ref. 36)

- o Express and local service routes;
- o Levels of service and schedules;
- o Fare structure, including transfer arrangements;
- o Bus stop locations;
- o Transfer points;
- o Park and ride and terminal facilities; and
- o Passenger amenities, such as special services, vehicle design features, bus stop shelters, distinctive bus stop signs, etc.

For budgetary purposes, standard performance indicators such as revenue passengers, revenue miles, and operating ratio (i.e., revenues/expenses) should be estimated. It is important that any changes in transit service be implemented prior to the opening of any complementary treatment, such as a HOV lane or signal priority. Otherwise, an underutilized HOV treatment may lead to a swift closure.

<u>Transit Vehicle Purchases</u>

The expansion of transit services will usually require additional vehicle allocations. In some cases, project transit requirements can be met from the existing fleet through redeployment and by postponing the sale of vehicles under the transit agency's bus replacement program. If this cannot be done, the transit operations plan should indicate: (Ref. 36)

- o The number and size of vehicles to be purchased;
- o Any special features desired because of the use in project operations;
- o Estimated cost, including delivery and conditioning; and
- o Estimated delivery dates.

In some cases, new express bus service may require purchase of over-the-road vehicles which have higher power and provide greater comfort for commuters. It should be recognized that new transit vehicle deliveries require long lead times (i.e., up to 2 years).

New Transit Construction

New transit related construction may be required to complement service changes. Park and ride facilities are a typical addition to a transit oriented HOV project. Other construction may include additional bus stop signs, shelters, bus turnouts and exclusive bus ramps.

The transit agency, in cooperation with other agencies, should specify the need for any design changes. These needs must then be incorporated into the physical design of the HOV treatment. Finally, the planned transit service changes should reflect the anticipated completion date of key construction activities. In particular, park and ride facilities may require at least twelve months before implementation, considerably longer if Federal funding is sought.

Daily Transit Operational Changes

Daily transit operations may need to be changed to efficiently and safely utilize the HOV treatment. Transit operators should be provided with detailed information and, where possible, a training course covering the operation and rules of the HOV treatment. The information may include the following considerations: (Ref. 36)

- Applicable laws and ordinances;
- Speed limits and following distances;
- Lane operations;
- Special merging and weaving instructions;
- Bus breakdowns;
- Other emergency situations;
- Project map showing access and ramp configurations; and

- o Special gate or ramp operations.

This information is most critical on projects which require unusual lane weaving, turn maneuvers, and/or merging procedures. An example of a bus driver instruction sheet utilized on the Southeast Expressway contraflow lane in Boston is shown in Figure 5-6.

INTERAGENCY AGREEMENTS

HOV priority treatment projects are often viewed as institutionally complex undertakings requiring cooperative participation of several types of public agencies within different jurisdictions as discussed in Chapter 2 - Preliminary Planning. The formation of an ad hoc steering committee was described as a useful method for building cooperation. This cooperation can then ease the way toward formal agreements between agencies.

Long lead times may be required to work out formal interagency agreements on responsibilities for different elements of a project. Substantive differences of opinion, particularly between transportation planning and policy officials and operating agencies (i.e., traffic engineering and police) may be difficult to resolve. Therefore, the ad hoc committee should remain active throughout the life of the project to provide a mechanism for refining and developing additional agreements as necessary.

The lead role in implementing and operating HOV priority treatments naturally belongs to the agency responsible for traffic control and maintenance of the affected roadways or, in the case of treatments involving substantial construction, the agency responsible for design and construction of highways. In many locations, state DOT's have responsibility for operation as well as construction of the urban freeways, whereas municipalities have primary responsibility for the surface street systems. Consequently, lead responsibility for HOV projects will depend on the facility type affected. However, jurisdictional division of highway system responsibilities varies from state to state and sometimes between urban areas in the same state. In strong home-rule states the municipalities are responsible for the operation of both streets and freeways within their boundaries. In such cases, if construction modifications are involved, the state and local agency must share the responsibility for project

Instructions for Bus Lanes

Monday, May 24th, the exclusive bus lane demonstration on the Southeast Expressway between Quincy and Boston starts. Northbound it will be effective from 7 to 9:30 A.M. and Southbound from 4 to 7 P.M. Northbound buses cross into the Southbound roadway at an opening just north of 128 junction (opposite HOJO's) and use the Southbound lane next to the median strip, traveling against the traffic. They re-enter the Northbound lane at another cross-over at the old Berkeley St. off-ramp on the Central Artery.

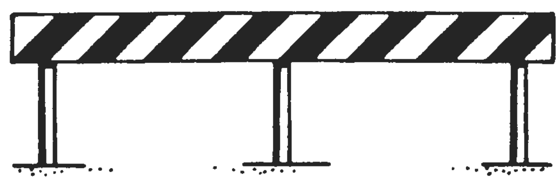
Southbound buses between 4 and 7 P.M. cross into the Northbound roadway at an opening just south of Southampton St., using the lane next to the median strip, traveling against the traffic. Buses will re-enter the Southbound roadway at the cross-over just north of the 128 junction.

There will be constant surveillance at all times by air and ground police to assist in case of problems. Your cooperation is needed for the success of this program.

Heavy duty traffic cones will set off the bus lane from opposing traffic.

Entry to the exclusive bus lane will be indicated by the sign below.

Bus lane will be closed when you see this barrier below at cross-over.



For your driving safety, these operating rules must be strictly observed:

BUS LANE RULES:

1. KEEP 4-WAY EMERGENCY FLASHERS ON.

2. SPEED LIMIT 45 M.P.H. (Maintain at least 400 ft. spacing).

3. NO PASSING (stay in bus lane - don't pass disabled vehicles; police will respond immediately).

4. IF CONE APPEARS IN LANE, DRIVE OVER IT.

5. AFTER EXITING EXCLUSIVE LANE, operator must stay in extreme left lane, next to median strip. Crossing to right will take place after you gain speed and your coach is parallel with traffic.

If you have any problems, questions or comments, please talk to your dispatcher without delay.

Safety *Safety* *Safety*

SOURCE: Massachusetts Department of Public Works.

(Ref.15)

Figure 5-6. Boston Handout to Bus Operators development.

Formal operating agreements allow for documentation of the initial and ongoing roles of the various agencies and jurisdictions involved in the project. These roles must often be specified in writing in order to avoid problems. Typically such agreements include responsibilities for daily operations as well as enforcement (see Chapter 6) and transit service responsibilities. Whenever a project has the potential for becoming controversial, it is imperative that formal agreements be worked out and ratified by the top officials of each participating agency.

Interagency agreements typically cover the equipment, manpower and funding requirements. Often, operations and maintenance are jointly funded and separate funds are used for enforcement.

Transit operators generally are willing to enter into a formal agreement. However, where route changes and/or service level changes are anticipated, the operator may enter into an agreement only if their increased costs are met. For example, in one project the operator insisted on being paid $1.00 per mile for every mile of bus service as well as for all mileage to and from the routes. In another project the operators were unwilling to add the additional service without a guarantee that all other costs would be met.

This financially rooted resistance of transit operators in those cases where loss is a distinct possibility is expected to pose problems for many HOV projects, especially those of smaller size. In some cases it will be necessary to include initial provisions for subsidization into the interagency agreement (Ref. 15).

The I-495 (Lincoln Tunnel) exclusive bus lane project provides an example of an interjurisdictional agreement. The agreement was developed to insure smooth daily operation of the lane through coordination of the three operating and maintenance agencies and the three police units. The operating agreement was entitled <u>Memorandum of Understanding on Operating Responsibilities</u>. It covered the one-year period from December 18, 1970, to December 17, 1971, and arranged tasks as follows: (Ref: 99)

- o The Port Authority, a bistate organization, performed day-to-day operations on the exclusive bus lane, including determination of starting and stopping times, control of changeable signs and signals, placing of traffic posts and handling of traffic stoppages. These tasks were largely carried out by its police, who also performed general patrolling tasks.

- The Port Authority maintained the traffic-control devices especially installed for the bus lane, but there was no change in the normal maintenance responsibilities held by NJDOT, NJTA, and PANYNJ before the project.

- The Port Authority was allowed to make on-the-spot operating decisions where unusual circumstances required them, with any interagency differences resolved later among the parties.

- Insurance coverage varied according to the liability of each agency.

- The New Jersey Department of Transportation reimbursed the Port Authority for two-thirds of the direct cost of operating the bus lane.

- New Jersey State Police assigned to the turnpike screened vehicles at the bus-lane entrance in coordination with the Port Authority police.

A further discussion of the operating plan is taken from Reference 99:

> "There were approximately 25 companies whose buses were to use the exclusive lane. Coordination with the companies was handled through meetings and an exchange of information, facilitated by the already-established contacts of the New Jersey assistant commissioner for public transportation and the Port Authority's terminals department."
>
> "Detailed operating procedures were developed by Lincoln Tunnel staff - primarily by police personnel - with review and concurrence by the project technical committee. The procedures, which are very specific for each step in the opening, operating and closing of the exclusive bus lane (XBL), were revised midway through the project to reduce operating costs with no loss of

efficiency."

> "The plan covers: standard terms for all jurisdictions; the process of deciding whether to operate, made by the Lincoln Tunnel tour commander, considering weather and traffic conditions; specific personnel assignments for patrol, emergency tractors and posting vehicle; step-by-step sequence of operating actions; procedures for every day normal closings and temporary closing and reopening of the lane due to a major stoppage or any other unusual incident."

An example of necessary interjurisdictional agreements on a surface street HOV project is the Kalanianaole Highway in Honolulu, Hawaii. The agreements reached by the respective agencies were in respect to the following situation: (Ref. 80)

> "The Hawaii State DOT is responsible for the construction, operation, and maintenance of all State highways, which includes the Kalanianaole Highway. The City and County DTS, on the other hand, is responsible for the planning, operation, and maintenance of City streets and transit service on Oahu. Therefore, the City DTS is responsible for the express bus service from Hawaii Kai to the CBD and UH. In addition, all the local streets which adjoin Kalanianaole Highway and traffic signals are under the control of the City DTS. Thus, it was necessary to ensure that the maximum level of cooperation and coordination occurred during the implementation of, first, the contra-flow bus lane on Kalanianaole Highway and, then, the opening of it to carpools."

> "Although the Kalanianaole Highway is a State highway, the law enforcement is done by the City and County of Honolulu Police Department. The State of Hawaii does not have a highway patrol and relies upon each of the local jurisdictions to provide law enforcement. The only potential problems occur as a result of the coordination required when State statutes affect the special lane facilities. No such problems have arisen relative to this facility."

A copy of a recent interagency HOV treatment operations and maintenance agreement is shown in Supplement 5B.

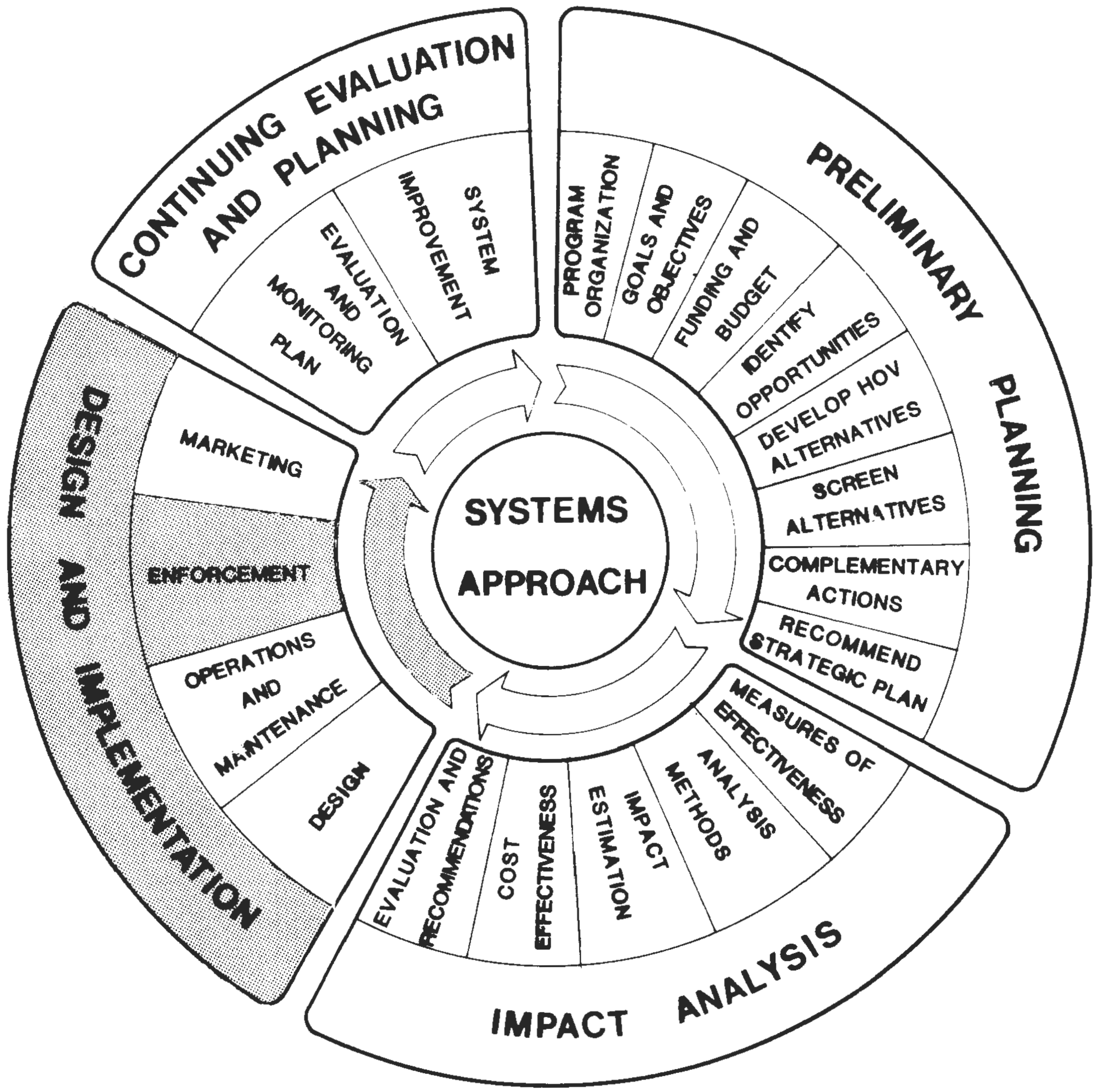
SUMMARY

The operations and maintenance requirements of a HOV priority treatment should be determined early in the project design process. Once a project is implemented, continual monitoring and fine-tuning of procedures is necessary.

An operations and maintenance plan typically consists of two components - highway and transit. The highway component should consider the following aspects of HOV treatment operation: 1) hours of operation, 2) vehicle type criteria, 3) occupancy criteria, 4) designation of traffic regulations, 5) daily operational responsibilities, 6) ongoing maintenance responsibilities, and 7) equipment and personnel needs. The transit component of the plan should consider: 1) transit services, 2) transit vehicle purchases, 3) new transit construction, and 4) daily transit operational changes.

HOV priority treatment projects are often institutionally complex undertakings requiring cooperative participation of several types of public agencies within different jurisdictions. Therefore, interagency agreements covering equipment, manpower and funding requirements are often needed.

6. ENFORCEMENT



6. ENFORCEMENT

INTRODUCTION

This chapter presents several major points regarding enforcement of HOV priority treatments. These enforcement aspects are discussed in greater detail in the accompanying _High Occupancy Vehicle Facility Enforcement Guide_. Much of the information has been condensed from Reference 30, which has been updated to reflect recent project experience.

Objective of Enforcement

The overall objective of HOV enforcement is to maintain the design integrity of allowing only high occupancy vehicles to utilize priority treatments.

Enforcement Process

The steps of enforcement include:

1. Detection of the violator;

2. Apprehension of the violator;

3. Issuance of a citation to the violator; and

4. Resolution of the citation.

Elements of Enforcement

There are a number of interrelated elements which comprise the HOV enforcement program. These elements, which are discussed in the subsequent sections, are: (Ref. 30)

- Objectives of the enforcement program;
- Enforcement strategies;
- Enforcement procedures;
- The priority assigned to the HOV enforcement program;
- Assignment of enforcement personnel;
- Enforcement equipment;
- Enforcement budget and funding.

o Enforcement planning

Integration of Enforcement Program with Other Planning Activities

It is critical that the enforcement program be carefully integrated with other HOV priority treatment planning activities. Enforcement planning should begin as soon as other planning activities.

ENFORCEMENT PLANNING

Enforcement Plan

The most significant factor in achieving a successful enforcement program is the early involvement in the planning process by representatives of the affected enforcement agencies (Ref. 36). The advantages of this center on the following areas:

- o Provision of technical advice
- o Promotion of cooperative relationships
- o Personnel/equipment planning and budgeting

The development of an enforcement plan containing a written set of enforcement procedures is advisable for even minor HOV projects for the following reasons: (Ref. 36)

1. Field officers responsible for the day-to-day enforcement are often not the same officers who have been directly involved in the planning effort.

2. A well-documented, comprehensive enforcement plan may assist in the defense of the project against legal challenges.

3. The enforcement plan lets other project operating personnel know what to expect from enforcement personnel.

4. The activity of developing the plan may in itself highlight previously unanticipated problems which can then be resolved by the project team before project installation. (The manual should also be revised as appropriate once operations have begun.)

A sample enforcement plan outline is presented in Table 6-1.

Goals and Objectives

The setting of realistic goals and objectives is critical to the planning for HOV enforcement activities. Chapter 2 presented several examples of TSM goals and related HOV objectives, many of which are applicable to the development of enforcement strategies. Specific enforcement objectives will vary depending upon the type and location of HOV treatments.

Enforcement Strategies

There are three primary strategies to enforcement. They are: (Ref. 30)

- Routine Enforcement - conducted in concert with normal police officer's duties;

- Special Enforcement - Characterized by continuing, systematic manpower allocations and enforcement tactics specifically dedicated to enforce HOV violations; involves reallocation of existing forces to the HOV effort or assigning additional manpower and equipment during HOV project operating hours (using existing personnel on overtime basis or hiring additional personnel);

- Selective Enforcement - Special tactics are applied periodically to specific problem areas where violations of the HOV facility have been observed. The application of selective enforcement can vary in terms of time, location and level of effort. The personnel is generally made available by a reassignment of manpower from other duties.

Enforcement Procedures

There are several alternative procedures available for conducting HOV enforcement activities. These procedures cover various aspects of surveillance, detection, apprehension and citation of violators. In particular, the use of innovative enforcement procedures has become more widespread.

Table 6-1. Suggested Enforcement Plan Outline[1]

I. DESCRIPTION OF PROJECT

A. Brief statement of objectives of project and purposes of project elements. List participating agencies and outline their responsibilities.

B. Physical Features
1. Cross-sectional diagrams showing lane configuration
2. Map of project area
a. show clearly geographic boundaries and jurisdictional limits if more than one enforcement agency is involved
b. show location of special traffic procedures and/or restrictions (e.g. no left turns or special crossover signals for buses to enter contra-flow lane)

II. SYSTEM OPERATIONS

A. Operating Policies--This section should clearly and concisely deal with operating regulations. These might include:
1. How many vehicle occupants constitute a carpool?
2. What types of vehicles will be granted priority? (municipal buses, inter-city buses, emergency vehicles, taxis, trucks, etc.)
3. Restrictions should be clearly defined, for example, only passenger vehicles having 3 or more occupants will be allowed to use priority lanes.

B. Operating Hours--Specify times of project operation, distinguishing between various elements if necessary. State policy on holidays and define procedures for individual officers to be apprised of special circumstances, for example, "project operates during State holidays, but not on National holidays."

C. Personnel Levels–Briefly specify nature of agreement between enforcement agency and project sponsoring agency.
1. Are there a certain number of officers to be assigned specially to the project or is this to be included in routine patrol duty?
2. If specially assigned, are any officers to remain at particular intersections throughout project hours?
3. If special services such as police helicopters will be used, instruct enforcement personnel on how to contact these services.

III. ENFORCEMENT PROCEDURES
Project sponsors should understand that no matter how specifically procedures are spelled out, individual officers will often have to rely upon their own judgement, particularly in emergencies. However, in order to maximize the effectiveness of those officers, certain guidelines should be established.

A. Routine Enforcement Procedures–Detail specific procedures for enforcement, relating them to various project elements.
1. Violations–Outline general categories of violations to be expected and the penalties for each.

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1. Urban Consortium for Technological Initiatives, A Manual for Planning and Implementing Priority Techniques for High Occupancy Vehicles, Technical Guide. United States Department of Transportation, July 1977.

2. Standard Operating Tactics--This section should cover routine enforcement procedures, such as:
   a. whether violators are to be pulled off the roadway or reports of violators radioed ahead to officers "downstream" (depends on average speed, level of congestion, level of enforcement manpower, etc.)
   b. if project involves priority lanes with special entry/exit points, the role of the officer assigned to each location
   c. special activities related to beginning or ending daily project operations, e.g. special escort for signing crews or "flushing" the lane

B. Procedures for Possible Malfunctions--This section should cover malfunctions of various project elements. Information should include:
1. Bus breakdown
   a. removal of disabled buses (whether next bus should push immobile vehicle to storage area or towing company or emergency crew should be called, phone number (________________)
   b. notification of transit agency (phone number, whether extra bus available)
   c. procedures for transfer of passengers
   d. rerouting of following buses
2. Other vehicle breakdown
   a. removal of disabled vehicle
   b. traffic rerouting
3. Equipment malfunction or damage
   a. list proper agency and phone number for major types of malfunction or damage
   b. list any special interim procedures to be followed until malfunction corrected

C. Emergency Situation Guide
1. List any departures from normal policy for dealing with accidents and other emergencies.
2. Give guidelines for determining if project operations must be temporarily halted due to accident or other emergency.

D. Reporting Procedures--Coordinate with evaluation team to see if special reports are to be filed by enforcement officers regarding accidents, vehicle breakdowns, signal malfunctions or other problems and the subsequent action taken by the officer. Explain the purpose for such reports. If a special form is to be used, it should be developed during the planning phase in conjunction with enforcement officials. Include copy of form and any special instructions in enforcement manual.

E. Special Intersection Considerations--If there are significant changes in operating policy planned for particular intersections (rerouting of traffic due to turn prohibitions, changes in signal operations, etc.) small maps of those intersections indicating the new procedures should be provided.

IV. REFERENCE INFORMATION

Even if phone numbers related to various questions or problems are given elsewhere in the text, it is a good idea to have a special section that can be referred to quickly. It should list the situation, person to be contacted and the phone number. For example:

A. Signal Malfunction
   - Mr. Jones - Traffic Engineering Department
     Phone number:

B. Public Inquiries
   - Ms. Smith - Project Coordinator
     Phone number:

Procedures for Surveillance and Detection (Ref. 30)

The HOV enforcement program may include one or a combination of the following types of patrol:

1. Foot patrol - enforcement personnel travel by foot; generally applicable on HOV projects located in downtown areas.

2. Line patrol - enforcement personnel travel by motor vehicle(s) over a particular roadway section; used more often on freeway facilities.

3. Zone patrol - enforcement personnel travel by motor vehicle(s) over a zone on a particular area (not limited to a roadway section); more often employed on surface street networks.

4. Stationary patrol - enforcement personnel and motor vehicles are deployed in a fixed position at specific locations; most appropriately located at entry/exit points to the HOV lane or locations experiencing a high number of HOV violations.

Procedures for Apprehension and Citation

The enforcement process may include one or more of the following apprehension and citation procedures: (Ref. 30)

1. "Standard" apprehension and citation - involves the pursuit of a violator followed by apprehension and issuance of a citation by a single unit.

2. Stationary apprehension - does not involve pursuit of the violator; involves directing the violator to a refuge area.

3. Signalling or waving-off of a violator - involves using appropriate gestures (waving of the arm, honking the horn) by the officer to the motorist in violation of the HOV restrictions so that he will safely exit the HOV lane; does not involve apprehension or issuance of a citation.

Line and stationary patrols with standard or stationary apprehension and citation methods are the most commonly used enforcement procedures. Two innovative apprehension and citation techniques are the use of mail-out warnings or citations and the use of tandem or team approaches. Both of these procedures are discussed in the following section.

Innovative Enforcement Procedures

In order to overcome some of the difficulties posed by "standard" enforcement processes such as lack of safe and easily accessible refuge areas and absence of a vantage point (see Chapter 4), the use of "innovative" enforcement techniques has become more widespread.

The techniques listed below are innovative in the sense that they are not widely used within the context of current traffic law enforcement practice. The techniques that could benefit HOV enforcement include: (Ref. 30)

1. Use of photographic systems and instrumentation - may be applied to a) detect violating vehicles for subsequent enforcement purposes, b) obtain suitable evidence of a violation, and/or c) study violation patterns. Photographic detection is less conspicuous and disruptive while providing a permanent record of the situation.

2. Mailing of traffic citations - eliminates the pursuit/apprehension process; can reach a large number of violators with a minimal enforcement effort.

3. Remote apprehension - where two or more enforcement personnel work in tandem with each other--one officer detects the violation, another officer downstream apprehends the violator. In some states, the apprehending officer must also be the officer witnessing the violation.

4. Mass screening technique - involves use of a small portable computer which stores license tag information on violating vehicles; could be used for repeated but unapprehended violators.

5. Use of paraprofessionals - utilized primarily for off-line activities such as data base development or for stationary detection and citation activities.

These innovation techniques can be used in conjunction with each other; however, for many HOV projects, changes in law would be necessary prior to their use.

EVALUATION OF ALTERNATIVES

Evaluation of HOV enforcement alternatives involves analyses of expected effectiveness as well as enforcement costs. The following descriptions of various aspects of effectiveness and costs of enforcement techniques should be considered in the development of an enforcement program.

Effectiveness of Enforcement Procedures

HOV enforcement program performance may be examined by 1) the violation and compliance rate, 2) the detection/apprehension/citation efficiency, and 3) the effect on traffic operations and safety.

Violation and Compliance Rate

The violation rate is defined as the percent of the total number of vehicles using the HOV lane which fail to meet eligibility criteria for the HOV lane. A wide range of violation rates have been observed--from 0 percent to over 90 percent. One intent of employing a certain type of enforcement strategy is, in part, to achieve a violation rate that is tolerable to project management, enforcement personnel, motorists, the general public, and state and/or Federal agencies (Ref. 30).

The compliance rate is the percent of the total non HOV traffic which remains in the general use lanes. In general, the compliance rate will decrease as the violation rate increases. A review of compliance rates can often pinpoint situations which an analysis of violation rates only cannot reveal.

Factors which affect violation and compliance rates include: 1) HOV lane signing and marking, 2) bus versus carpool HOV lane restriction, 3) travel time benefits, 4) probability of apprehension, 5) penalty, 6) accessibility to the HOV lane, 7) operating period, 8) occupancy restriction, 9) visibility , and 10) weather conditions.

Figure 6-1 depicts ranges of violation rates observed for several types of HOV treatments. In general, HOV lane treatments which do not provide physical separation between HOV's and non HOV's, such

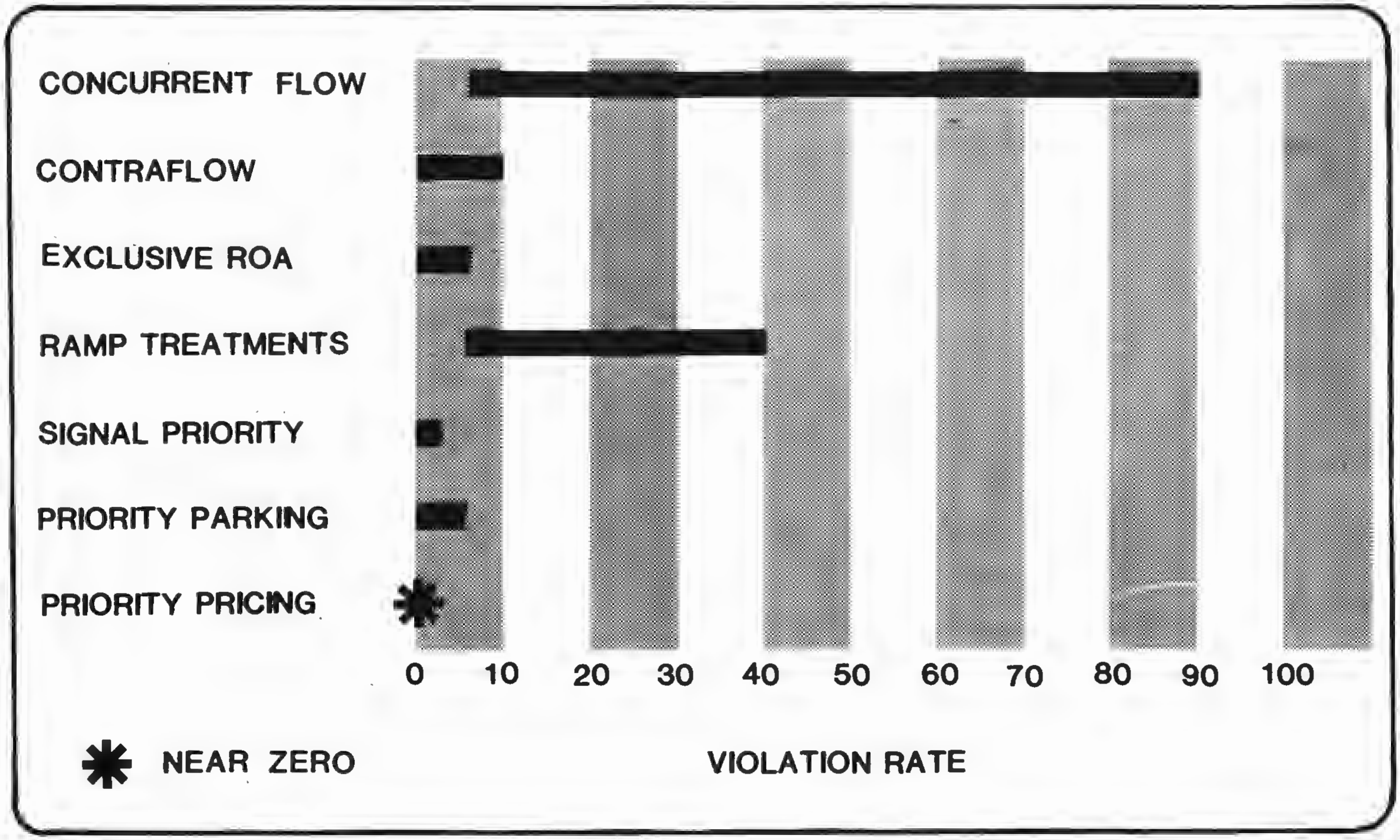


Figure 6-1 Range of Violation Rates

as concurrent flow lanes and various ramp treatments exhibit higher violation rates. In addition, the wide range of violation rates for these projects indicates a much greater sensitivity to the level of enforcement effort which is applied. Physically separated HOV lane treatments and HOV treatments which do not utilize roadway space (e.g., signal priority, priority pricing) are typically much more self-enforcing.

Detection/Apprehension/Citation Efficiency

The time consumed by detection, apprehension, and citation is important. Certain roadway geometrics and operating strategies affect detection, apprehension and citation efficiency. These efficiencies are improved if the roadway and HOV treatment operation contains the following features: (Ref. 30)

1. A safe and easily accessible refuge area(s) bordering the HOV lane in which to cite HOV violators;

2. Existence of a vantage point(s) by which enforcement personnel can observe the HOV lane while keeping, for the most part, out of view of the motorists;

3. A physical barrier between the HOV lane and the general traffic lanes;

4. Existence of a passing zone or area allowing enforcement vehicles to pass other vehicles in the HOV lane.

Traffic Operations and Safety

Enforcement of HOV projects may disrupt traffic flow. The degree to which enforcement can disrupt traffic operations is primarily a function of the project geometry and the enforcement procedure (Ref. 30).

Many traffic flow problems are directly associated with apprehension procedures resulting in hazardous weaving maneuvers performed by the enforcement vehicle alone or the enforcement/violator tandem. This problem is made more serious by the lack of an easily accessible refuge area; by the existence of a speed differential between the HOV lane and general use lanes; and by gap density or gap distribution.

One an HOV violator is escorted to a refuge area, the enforcement effort can be indirectly involved in contributing to traffic accidents through "rubber-necking", which is associated with the curiosity of motorists.

Enforcement Costs

Enforcement costs are primarily attributed to the number of personnel assigned to the project. Other direct costs include equipment such as patrol cars, motorcycles and/or photographic instrumentation. Existing HOV projects have a range in enforcement costs from $20,000-$30,000 per person-year, including some vehicle expenses.

Enforcement Personnel and Equipment

The level of enforcement effort is dependent on 1) project objectives, 2) project length, 3) project operation, 4) project restrictions, 5) enforcement strategy, and 6) availability of enforcement personnel and funds (Ref. 30). The number of personnel assigned to cover HOV enforcement activities can vary widely between very similar projects.

In most cases existing vehicles (e.g., sedans, motorcycles) have been used for enforcement of HOV treatments. The use of photographic instruments will result in added capital and operational expenses, but reduced personnel requirements.

Secondary Enforcement Costs

In addition to the direct costs of HOV enforcement, there can be potential secondary costs such as those caused by diversion of non HOV's to main or secondary arterials. Additional costs may also be incurred by the courts, Department of Motor Vehicles and other elements of the enforcement system (Ref. 30).

Enforcement Budget and Funding

Generally, HOV enforcement programs are funded through the enforcement agency's existing budget. HOV enforcement is usually not a top priority of enforcement agencies. The funding available will limit the type of enforcement employed.

DESIGN AND IMPLEMENTATION

The design of a HOV treatment can significantly influence the types of enforcement procedures which are both feasible and effective. The implementation and daily functioning of enforcement activities must then relate to these design considerations with close coordination with other implementing and operating agencies.

Physical Design Considerations

The detection, apprehension and citation efficiency of an HOV enforcement program can be adversely affected by the absence of certain roadway features. Those geometric deficiencies can also affect the safety and traffic operational features of the highway. (See Chapter 4.) These problems include: (Ref. 30)

- Lack of a safe and easily accessible refuge area which can be used to apprehend and cite HOV violators;
- Absence of any vantage point by which an enforcement officer can observe the HOV facility while keeping out of view;
- The HOV lane not being physically separated by barriers, traffic posts or other implements from the general traffic lanes;
- Lack of passing capability for enforcement vehicles which makes apprehension maneuvers difficult.

Operational Considerations

On HOV systems where carpools are permitted, the determination of the number of occupants in a vehicle is made difficult by 1) young children, 2) vans, mobil homes, etc. 3) mirrored glass, 4) hours of darkness, and 5) inclement weather.

Most HOV projects are designed to obtain a speed differential between the HOV lane and the general traffic lanes. This circumstance presents a significant safety concern for all traffic entering and exiting the HOV lane, but it may be especially hazardous for police officers during pursuit and apprehension of HOV violators. This problem is especially acute when 1) there is no refuge area next to the HOV lane and 2) the HOV lane and general lanes are not physically divided.

Enforcement visibility can also create operational concerns. Although high visibility can have a deterring effect upon violations, it can also result in HOV violators abruptly exiting the HOV lane to avoid apprehension. In other cases, "rubber-necking" by passing motorists watching enforcement activities can create a "shock-wave" effect on traffic flow.

Certain HOV restrictions require judgement decisions on the part of the enforcement personnel. The primary judgement situation faced by enforcement personnel focuses on curb HOV lanes and the use of the HOV lane by right-turning vehicles. The judgement decision is "at what point can a right-turning vehicle enter the lane?" These decisions are especially difficult where the HOV lane regulations are not very specific (Ref. 30).

Implementation

Key areas of interest in the implementation of an HOV enforcement program include a public information program, the development of interjurisdictional agreements, and the establishment of initial enforcement needs. The implementation plan should also specify procedures for evaluation and potential revisions of the initial enforcement activities and the subsequent establishment of an ongoing enforcement program.

Public Information Program

Public awareness is essential to any new enforcement program. (See Chapter 7.) If the public is made to understand the HOV operating strategy and its restrictions, the tendency to violate may be reduced.

The primary message that should be transmitted with respect to HOV enforcement education should be a simple statement of: 1) what the law states and what is prohibited, 2) what will be done if a violation of that law occurs, and 3) what the consequences are if a violator is apprehended or cited (Ref. 30).

Interagency Agreement

An interagency approach involving two or more enforcement agencies is sometimes used because 1) the HOV facility crosses two or more jurisdictions or 2) more than one level of government (city, county, and state) is involved in the HOV project and a sense of cooperation and participation exists. The interagency approach can distribute costs and responsibilities of an extensive enforcement program among several agencies and thereby lessen the manpower and cost impacts on any one agency (Ref. 30).

Initial Enforcement Effort

The experience of previous HOV projects has shown clearly that it is better to have strict enforcement at the outset of project operations than to under-enforce. If there is concern that the public may need time to become accustomed to project operations, then violators should be issued warnings for a short period.

The strict enforcement effort should continue for one to two months depending upon the type of HOV treatment, the number of intermediate access points, the "innovativeness" of the HOV treatment, and the degree to which standardized and frequent HOV signing and marking is utilized.

Following the strict enforcement period, the enforcement effort can decrease to a more steady condition after six to twelve months. Figure 6-2 depicts the relationship between enforcement effort (i.e., monthly citations issued) and the level of violations for several months after the opening of the Banfield HOV lanes (Portland, OR). Note that the level of enforcement effort varied considerably from month to month even after a "steady state" condition was achieved.

Evaluation of Enforcement Program

Specific areas relating to HOV treatment enforcement operations should be quantified within the project evaluation. These areas include the following:

1. The relationship between the number of citations issued and the number of violations occurring,

2. The interrelationships between the violation rate, compliance rate, apprehension rate and the travel time savings of the HOV lane, and

3. The changes in the violation rate and the compliance rate due to changes in the quantitative, qualitative or substantive aspects of the enforcement program.

Based on these ongoing analyses, it may be possible to reduce the initial enforcement level of

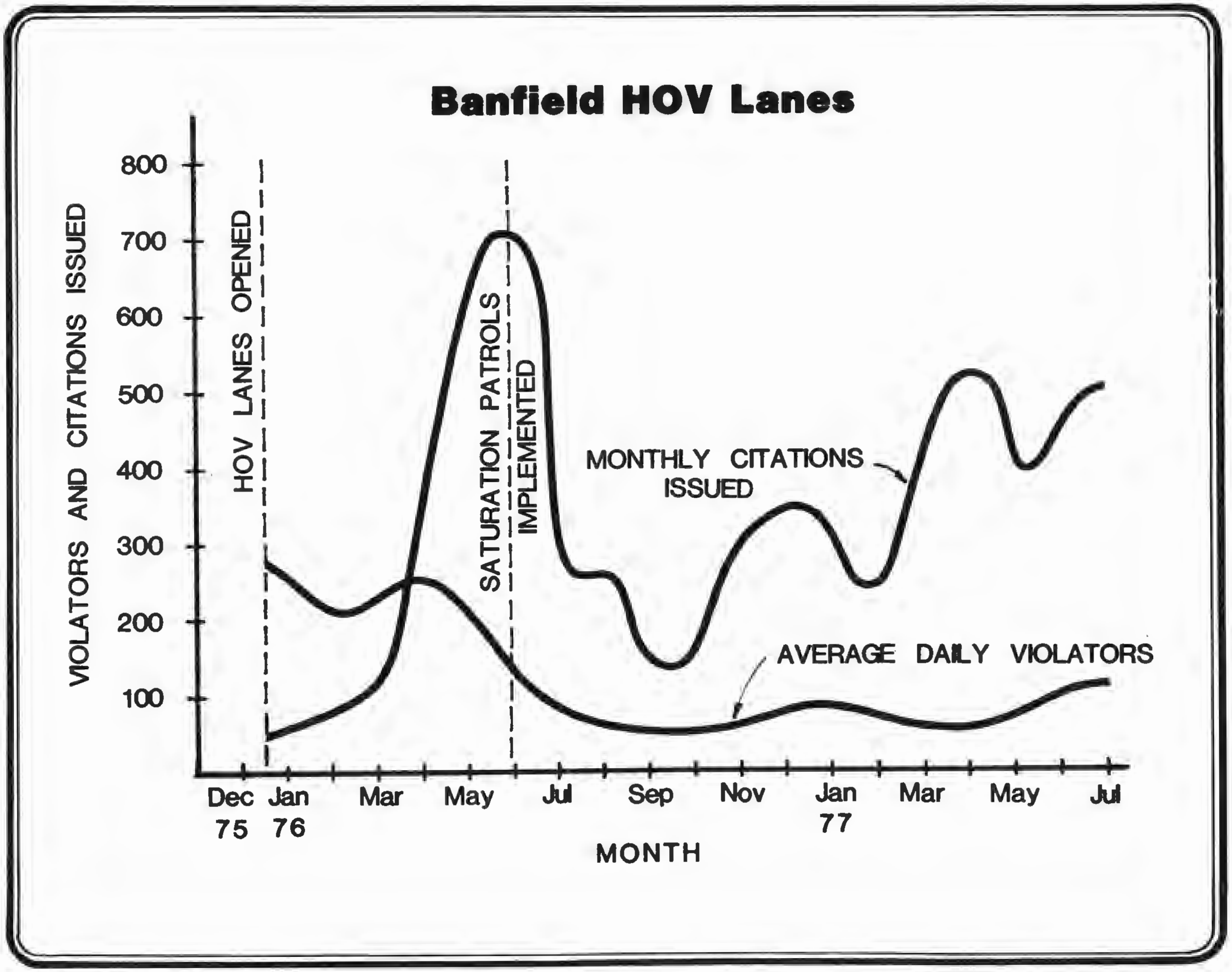


Figure 6-2 Relationship Between Enforcement Effort and Level of Violations (Banfield Freeway; Portland, OR)

effort without compromising HOV lane operations and enforcement objectives (Ref. 30).

Ongoing Enforcement Program

After the initial implementation of enforcement activities and subsequent revisions based upon ongoing evaluation, a more regular ongoing enforcement program can be established. In most cases, the ongoing enforcement program will combine various combinations of routine, special and selective enforcement strategies using different types of patrol.

LEGAL ISSUES

Enforcement of HOV treatments often requires a close look at the particular local legal environment. For many HOV treatments, changes in law are necessary prior to implementation of enforcement procedures.

Legal Concepts

There are four major legal concepts relevant to HOV treatment enforcement. They are as follows: (Ref. 30)

Prima Facie Evidence

This is legal evidence adequate to establish a fact or raise a presumption of fact unless refuted. For a.. HOV project a potential area of prima facie evidence could be that the registered owner of a vehicle violating the HOV facility is the same person driving the vehicle at the time of the violation.

Presumption Clause

This refers to the legal wording in a legislative statute or ordinance whereby prima facie evidence is legally accepted. Presumptive evidence and prima facie evidence are synonymous terms that are used interchangeably.

Decriminalization

A legislature may reduce traffic violations and/or safety equipment violations from criminal offenses to civil (non-criminal) offenses or it may remove jail as a sanction for such offenses. This process is called "decriminalization."

Equal Protection

Equal protection under the Fourteenth Amendment assures that no person or class of persons shall be denied the same protection of the laws which is enjoyed by other persons or other classes in like circumstances. Equal protection does allow for "reasonable classifications" of persons or classes to be made for nonarbitrary legal purposes (e.g., definition of a carpool occupancy rule).

The following legal issues include aspects of each of these legal concepts:

Legal Issues

Several key legal issues have been identified in relation to HOV treatment enforcement. The research conducted in Reference 30 has listed the following issues:

1. Can photographic evidence be made to be admissable in traffic court through legislative action?

2. If instrumentation is used in the enforcement operations, what type and amount of instrument certification would be required?

3. Can the minimum number of occupants required for the utilization of an HOV lane be related to their visibility without being successfully challenged on the basis of age discrimination (i.e., small children) or other grounds?

4. Can citations be mailed out to the owner of a vehicle for a moving violation without the driver's identification being confirmed?

5. Can a non-witnessing officer cite a violator of a HOV facility?

6. Do the legislative requirements for effective HOV lane enforcement require the allocation of powers to the enforcement agency which can then be abused? What can be done to minimize this possibility?

Each of these issues must be researched thoroughly with respect to state and local law before any HOV treatment is implemented.

Implications of Legal Review

The legal review of potential HOV treatment enforcement procedures can pervade the entire enforcement planning process. The time requirements for instituting any necessary legislative changes should be incorporated into the evaluation of enforcement alternatives, since the timetable for making such legislative changes may be greater than the time required for project implementation (Ref. 30). Similarly, legal reviews and resulting time delays can be expensive to an agency, especially where innovative procedures are suggested. Such costs must be built-in to the implementation budget for the enforcement program.

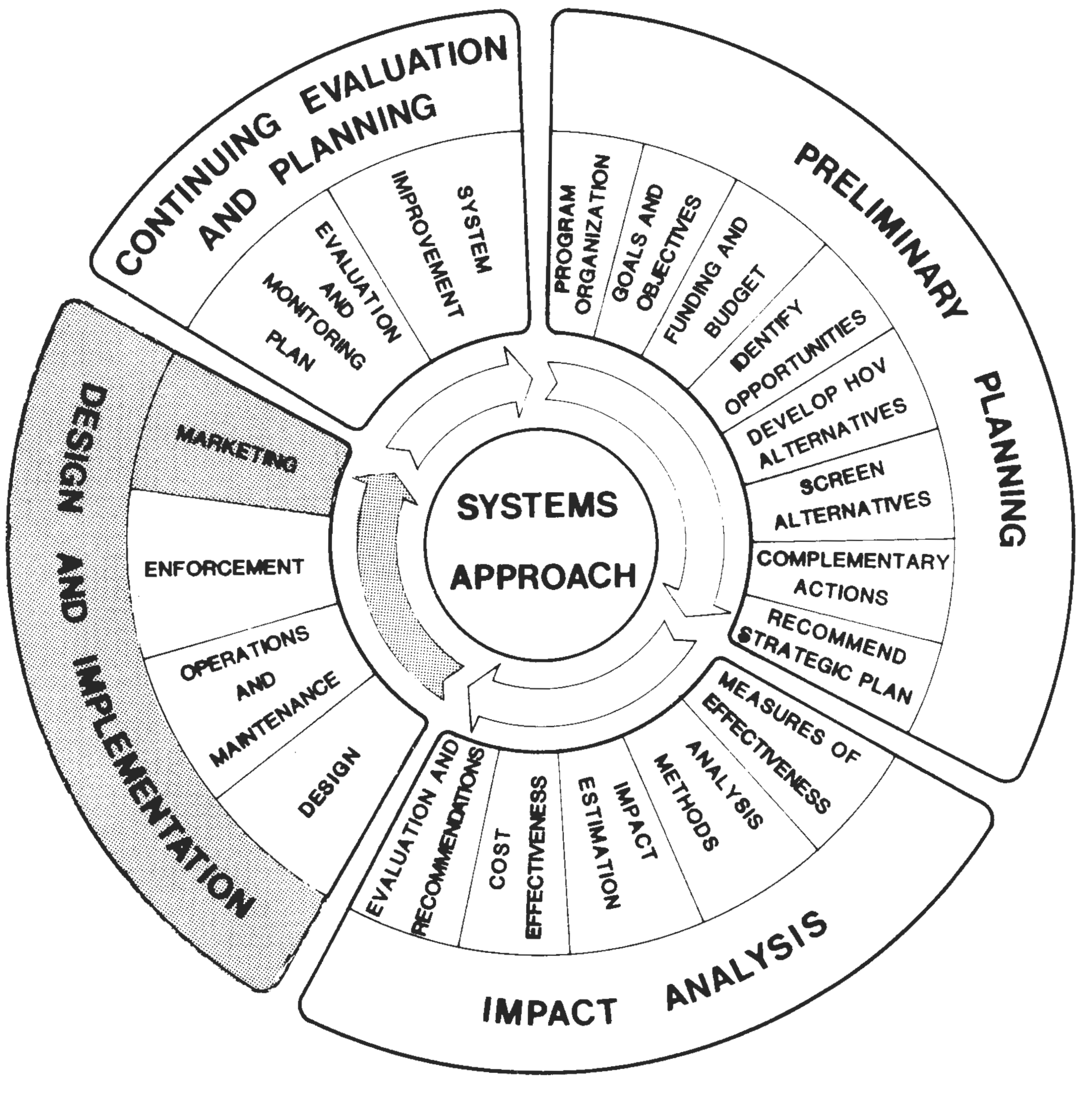
SUMMARY

Enforcement plays an important role in determining the success or failure of an HOV priority treatment. HOV treatment enforcement activities utilize alternative methods for detecting, apprehending and citing violators.

Enforcement elements include various strategies and procedures for meeting the objectives of the enforcement program. These require different levels of personnel equipment and resulting funding allocations.

Enforcement is directly tied to the physical and operational design of the HOV treatment. Therefore, safety, as well as other measures of efficiency, such as the violation and compliance rate, form the basis of enforcement evaluation. Various legal issues relating to standard and innovative enforcement activities must also be considered in the development of an enforcement plan. These aspects of HOV treatment enforcement are presented in greater detail in the accompanying High Occupancy Vehicle Facility Enforcement Guide.

7. MARKETING


SYSTEMS APPROACH
PRELIMINARY PLANNING
PROGRAM ORGANIZATION
GOALS AND OBJECTIVES
FUNDING AND BUDGET
IDENTIFY OPPORTUNITIES
DEVELOP HOV ALTERNATIVES
SCREEN ALTERNATIVES
COMPLEMENTARY ACTIONS
RECOMMEND STRATEGIC PLAN
IMPACT ANALYSIS
MEASURES OF EFFECTIVENESS
ANALYSIS METHODS
IMPACT ESTIMATION
COST EFFECTIVENESS
EVALUATION AND RECOMMENDATIONS
DESIGN AND IMPLEMENTATION
DESIGN
OPERATIONS AND MAINTENANCE
ENFORCEMENT
MARKETING
CONTINUING EVALUATION AND PLANNING
EVALUATION AND MONITORING PLAN
SYSTEM IMPROVEMENT

7. MARKETING PLAN

INTRODUCTION

The purpose of HOV project marketing is to develop public understanding of the project and then to encourage persons to utilize the HOV treatment.

A marketing plan comprises five basic elements: 1) Marketing Strategy, 2) Information Dissemination, 3) Marketing Schedule, 4) Marketing Document, and 5) Monitoring and Evaluation. The basics of the first four elements are presented in this chapter and are described in more detail in References 36 and 105. The fifth element, monitoring and evaluation, is presented in Chapter 8.

The UMTA marketing handbook identifies various benefits which can be derived from a marketing plan, including the following: (Ref. 36)

- o The marketing unit can coordinate, focus, and set priorities for each of its activities through the plan;
- o The plan can provide the marketing unit with an excellent means of communicating its analyses, goals, strategies, and resource requirements to top management;
- o The plan, upon approval, can become the formal management tool for marketing management (i.e., the program can be directly translated to an implementation or action plan); and
- o The plan can serve as the basis upon which the performance of the marketing unit is evaluated.

MARKETING STRATEGY

Development of a marketing strategy should be the first step in preparing a marketing plan. This strategy should include the following: (Ref. 36)

- o Identify the target markets (audiences) upon which to focus the marketing activities;
- o Conduct market research for developing project services. This effort entails gathering information needed to identify the travel needs and demographic characteristics of the target user group(s) of the project. This task should

be performed prior to defining the user services.

- Develop advertising and promotional activities to inform the public about:

  - The objectives of a project and its context within regional transportation plans and programs;

  - The location of project facilities;

  - How to use the project facilities (e.g., what constitutes a legal carpool, what lanes to use, turning or access restricted locations);

  - The operating hours of project facilities;

  - Who or what agency to contact in the event of questions concerning the project; and

  - What new traffic regulations will be enacted.

- Develop an information dissemination program to effectively distribute the advertising and promotional material;

- Develop a customers service mechanism whereby project users will be able to request information concerning project services and facilities;

- Make provisions for evaluation of marketing efforts before and after the project is implemented.

The development of a marketing strategy should follow a logical pattern. For instance, identifying the target market(s) and conducting the related market research precedes the development and dissemination of any advertising and/or promotional materials.

The marketing strategy should focus on potential HOV treatment users in addition to existing transit and/or carpool riders. For mixed mode projects, it is important that the market strategy give attention to both transit and carpool riders. At the same time, however, the marketing strategy should not encourage carpooling at the expense of transit ridership. The advent of ridesharing agencies in many urban areas has produced excellent sources of information on potential users of an HOV project.

INFORMATION DISSEMINATION

The following list presents several media which are often used to disseminate HOV project information:

- Press releases;
- Public service announcements;
- Advertising in and on buses;
- Handout brochures for
  - employees working in areas to be affected by the project;
  - transit riders that will be affected by the project;
- Mailouts to residents in communities that might be served by the facility;
- Radio traffic reports;
- Traffic information systems;
- Posters at public places;
- Roadside billboards.

Making presentations to special interest organizations (PTA groups, Chambers of Commerce, downtown business groups, etc.) can also be an effective means of disseminating information, with the added benefit of obtaining immediate feedback. A speaker's bureau can be formed which can quickly respond to speaking requests.

Well informed and supportive public officials are invaluable to any HOV project. Therefore, special efforts should be made to keep these persons informed and well versed in the importance of the project and how it is to operate (Ref. 36).

MARKETING SCHEDULE

The marketing plan for an HOV project should be prepared as soon as a project is approved for implementation. However, the dissemination of advertising and promotional information should not intensify too early or it will soon be forgotten and not achieve the total desired effect (Ref. 36).

Figure 7.1 depicts a basic marketing schedule and relative level of marketing effort for the immediate periods before and after the start of a HOV project. Approximately one month before the scheduled opening, detailed project information should begin to be provided to the media. The information program should intensify with the maximum effort made in the last week prior to opening. Opening day should preferably be on a Monday and desirably not in the period immediately before a holiday.

Intense marketing efforts should continue once the project is underway for a period of about three months. After that time, lower level but steady marketing efforts should continue. At the same time, post installation marketing data (e.g., surveys, customer service requests, etc.) should be collected and analyzed. HOV project services can then be tailored as indicated by the data analysis.

Table 7-1 presents the initial marketing schedule developed for the Santa Monica Diamond Lane project. Although this schedule was very detailed, it still required alterations throughout the project's life, especially in light of the immediate unfavorable reaction to the HOV lane. Revised marketing efforts included a speaker program, quick response to editorial or press coverage, and an expanded downtown information program.

MARKETING DOCUMENT

A formal document outlining the marketing plan should be prepared when the design of the HOV project facilities and services is completed and approved by decision makers. Table 7-2 shows the possible contents of a marketing plan for a complex project.

Since no two projects are alike, the level of effort applied to preparing such a document will vary significantly with the type and complexity of a project. For example, a project consisting only of a reserved concurrent flow curb lane along a short street section in an urban center will not require the marketing effort of a contraflow freeway project supplemented with carpool staging areas, park and ride lots, and new bus services (Ref. 36).

The marketing document should be updated

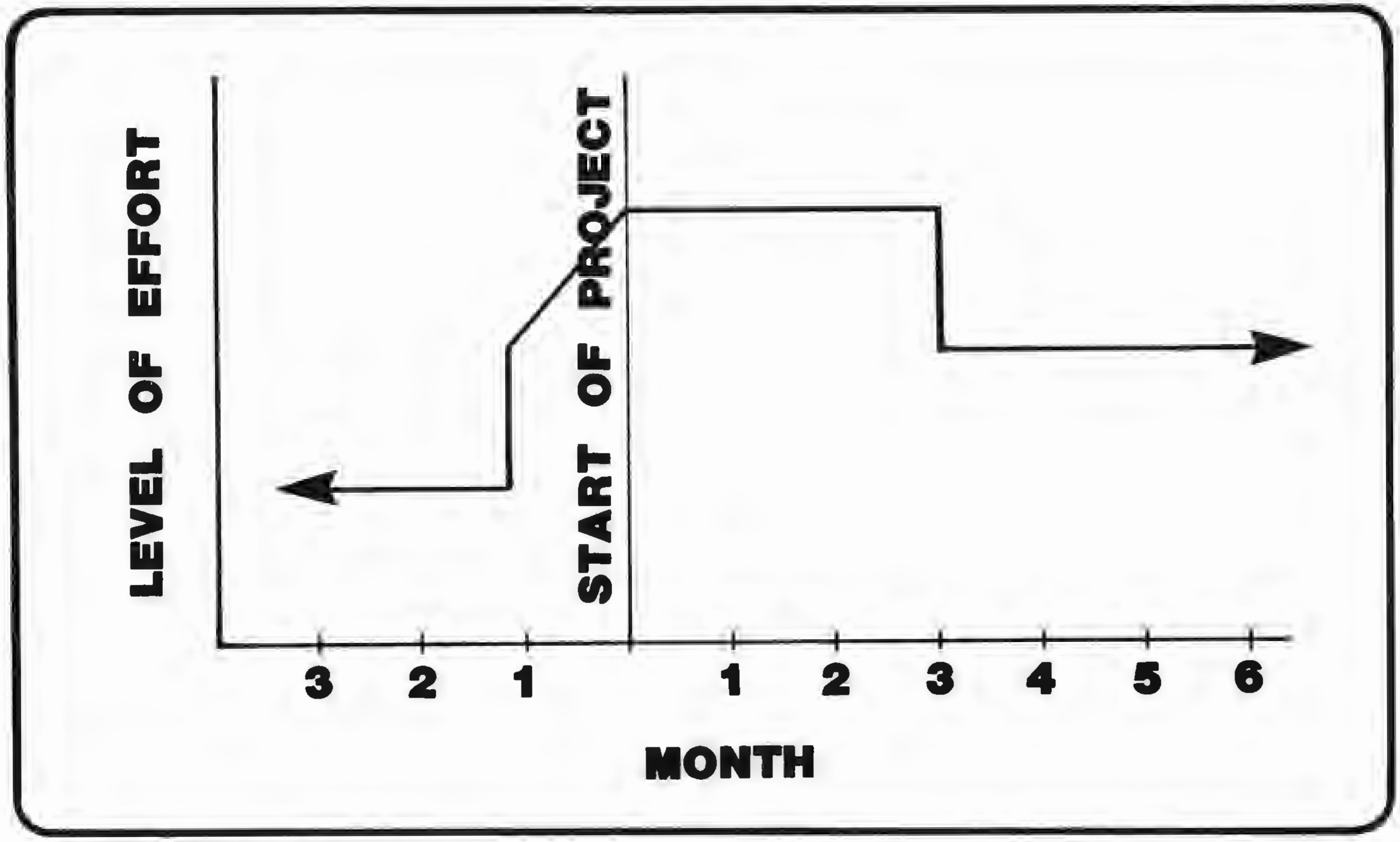


Figure 7-1. Basic Marketing Schedule

Table 7-1. Santa Monica Freeway Diamong Lane Project Marketing Schedule

				MARCH (Opening Day)				
1. Handout CALTRANS Brochure (freeway on-ramps)	******	******	***					↙Began mid-February
2. Freeway Changeable Message Signs (CALTRANS)	******	******	******	******	******	******	***	(Indefinite)
3. Information Booths (RTD)	******	******	******	******	******	******	***	
4. Technical Press Briefing (RTD)	*							
5. CALTRANS Radio Spots		*	******	******	*			
6. Billboards (RTD)				******	******	******	***	(to 4-30)
7. CALTRANS News Advertising		oT	o					
8. RTD News Advertising	o TW	TW o	TW To			TW		
9. SMMBL News Advertising			o o TW	o o	o	o	o o	(to 4-1)
10. Bus Cards (SMMBL)				******	******	******	***	(Indefinite)
11. Bus Cards (RTD)			*	******	******	******	***	
12. Public Service Announcement				******	******	******	***	(to 4-30)
13. Community Relations (non-users)			*	******	******	******	***	(Indefinite)
14. Telephone Information Center	******	******	******	******	******	******	***	(to 4-1)
15. News Releases (CALTRANS)	*		*					
16. News Releases (RTD)			***					
17. News Releases (SMMBL)			***					

o = Santa Monica Outlook
T = LA Times
TW = LA Times -Western Edition

(Ref.52)

Table 7-2. Suggested HOV Marketing Plan Outline
(Source: Ref. 36)

- OBJECTIVES

  These are based on project objectives and should be quantified, time specific and attainable. (e.g. provide carpool matching, bus route schedules and fare information in 50 percent of the retail businesses in the market areas served by the project by Sept. 30, 1977.)

- SUMMARY OF MARKET RESEARCH FINDINGS

  - who the users are (e.g. choice vs. transit dependent)
  - where they are located
  - what their travel needs are
  - data sources used (e.g., origin-destination surveys of market audience; census or other socio-economic data sources; on board transit surveys; and attitude surveys of market audience.

- ALLOCATION OF RESPONSIBILITIES

  - determining who or what agency will coordinate the traffic/bus/carpool public education efforts.
  - determining whether or not buses and carpools should be marketed together. In the past buses and carpools have been viewed as competitive. However, there are four compelling reasons why buses and carpools might be marketed together for priority treatment projects:

    1) Both modes contribute to the attainment of air quality and energy conservation goals.

    2) Carpools are more cost effective at serving low density areas than buses.

    3) Bus service can complement and add more flexibility to carpooling as an alternative when carpoolers must work late or a regular driver is unavailable.

    4) Carpooling can be an incremental step to regular transit usage.

Some of the individual elements of the project marketing plan will relate only to carpools or only to transit, and these should be assigned to the appropriate agency. However, in the view of the public, a priority treatment project which features both carpools and transit is still a single project. Advertising and promotion efforts to make the public aware of the project and its goals should be appropriately coordinated. Fig. 7-7 shows a marketing brochure developed for the Portland Banfield project which markets buses and carpools together.

- SUMMARY OF THE BUDGET AND SOURCES OF FUNDS OR FREE SERVICES

  - How much should be spent. This can be done by three methods:

    1) subjective budgeting based on management judgment

    2) percent of sales budgeting based on a percent of fare box revenues (service firms average 2 to 4 percent, while manufacturers average 10 to 20 percent of marketing budget to sales)

    3) task budgeting (the approach recommended by UMTA) which is done by estimating the resources needed to meet each objective

    Even if the over-all marketing budget is determined by one of the first two means, a marketing plan budget for priority treatment projects is quite amenable to task budgeting. The marketing objectives of a particular priority treatment project should be quite specific and measurable. Marketing professionals in the transit and carpool agencies should be asked to provide estimates of the resources required to meet those objectives.

  - Private sources (e.g. downtown businessmen, other local interests)

  - Public sources (e.g. Federal, state and local sources)

  - Media public service obligations for public education and marketing*

---

*There is free public service announcement time, subject to Federal Communications Commission regulations, which radio and television stations must allocate to qualified public agencies. This should be thoroughly explored for priority treatment projects since it may reduce the costs of the marketing and public education effort substantially.

- •• Press releases.

- A CONTINUING MECHANISM FOR MEDIA RELATIONS

  The media--which may include newspapers, radio and television--are the primary vehicles of public education and may have a significant impact on the public acceptability of projects. If a project is good the media can serve to generate support for it. Vice versa, if a project is bad, or perceived as bad, then the media can serve to stimulate public outcry against a project. The best way to deal with the media is to develop an open and positive relationship with its representatives. Keep the media well informed of all noteworthy project developments, including the bad news, if there is any. If this is done well, things should work out in the best interests of the public.

- PRE-INSTALLATION ACTION PLAN

  - a description of the specific public education and marketing actions by agency and the timing of each activity.

- CONTINUING POST-INSTALLATION ACTION PLAN

  - a description of the continuing public education and marketing activities.

  - a description of the mechanism for answering public questions on facilities and services and requests for changes in facilities and service.

  - a description of marketing and public education evaluation procedures not covered in the project "Evaluation Plan".

periodically to reflect changing project conditions. This updating is particularly important for staged HOV projects such as when a HOV lane is extended or when the vehicle type or occupancy rules change.

Specific Project Examples of Advertising, Promotions and Information Dissemination Techniques

1) The Banfield HOV lane project in Portland, Oregon: (Ref. 87)

   - News conferences
   - Periodic use of major local media to inform and educate the public
   - Distribution of informational brochures to Banfield users to promote bus-use, carpooling, and operational safety
   - Distribution of posters for employee bulletin boards, public buildings, and markets
   - Encouragement of feature stories by local media
   - The erection of 22 informational billboards at strategic locations along the feeder streets
   - Slide presentations and discussions with central business district employers, designed to encourage commuter use of buses and carpools.

Examples of these items are shown in Figures 7-2 through 7-8.

2) The U.S. 1/South Dixie Highway "Blue Dash" project in Miami, Florida: (Ref. 36)

   - Because of the novelty of this type of improvement in the Miami area, there was extensive media coverage both before the project opened and during the first week of operations. The day before the demonstration began, a full-page advertisement in the newspaper gave information about bus routes, location of park and ride lots, road configuration and a complete schedule. This same information was contained in flyers mailed to residents of the target market area shortly before project operation began. Schedules were also placed in major buildings in the three

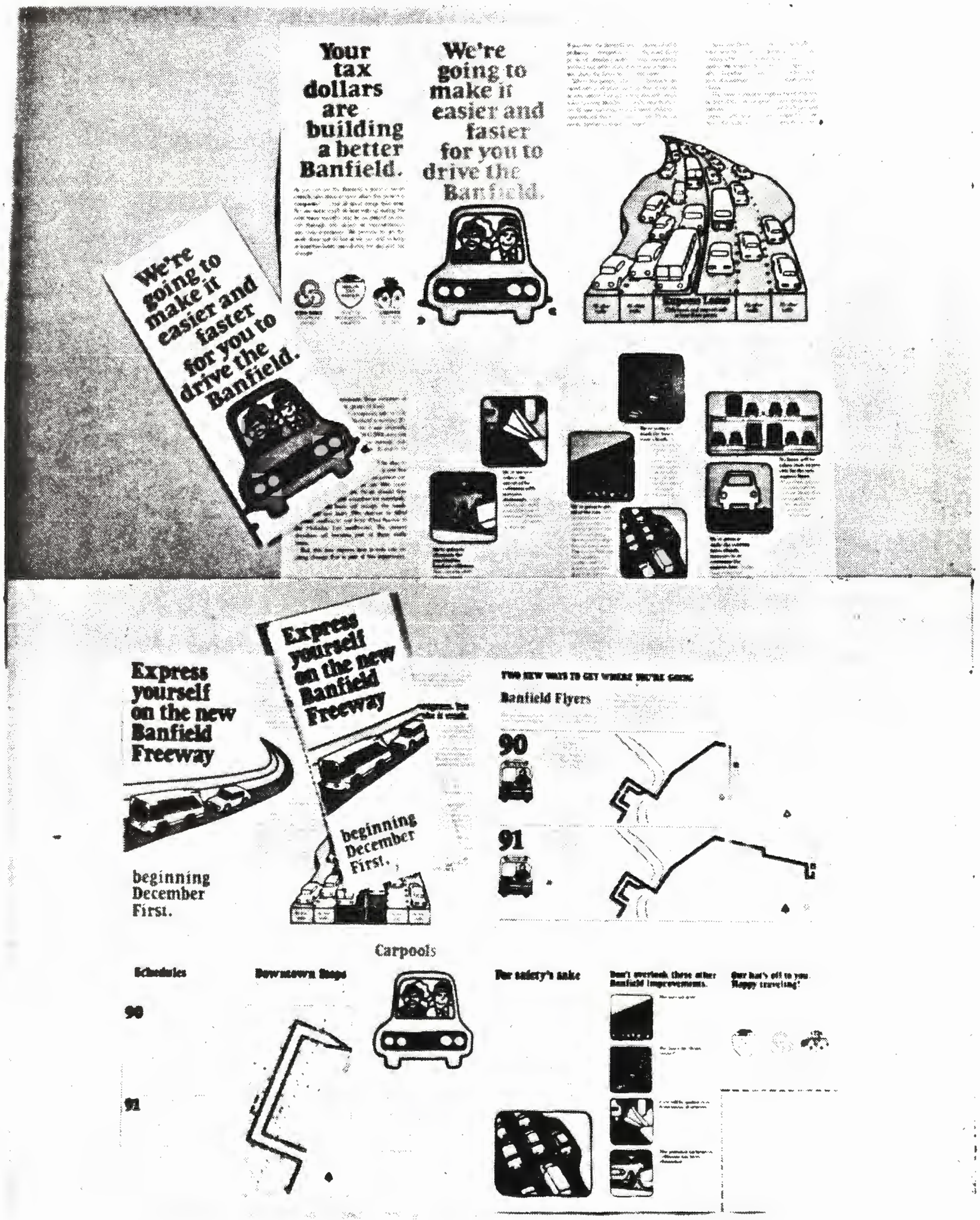


Figure 7-2. Informational Brochures

(Ref.87)

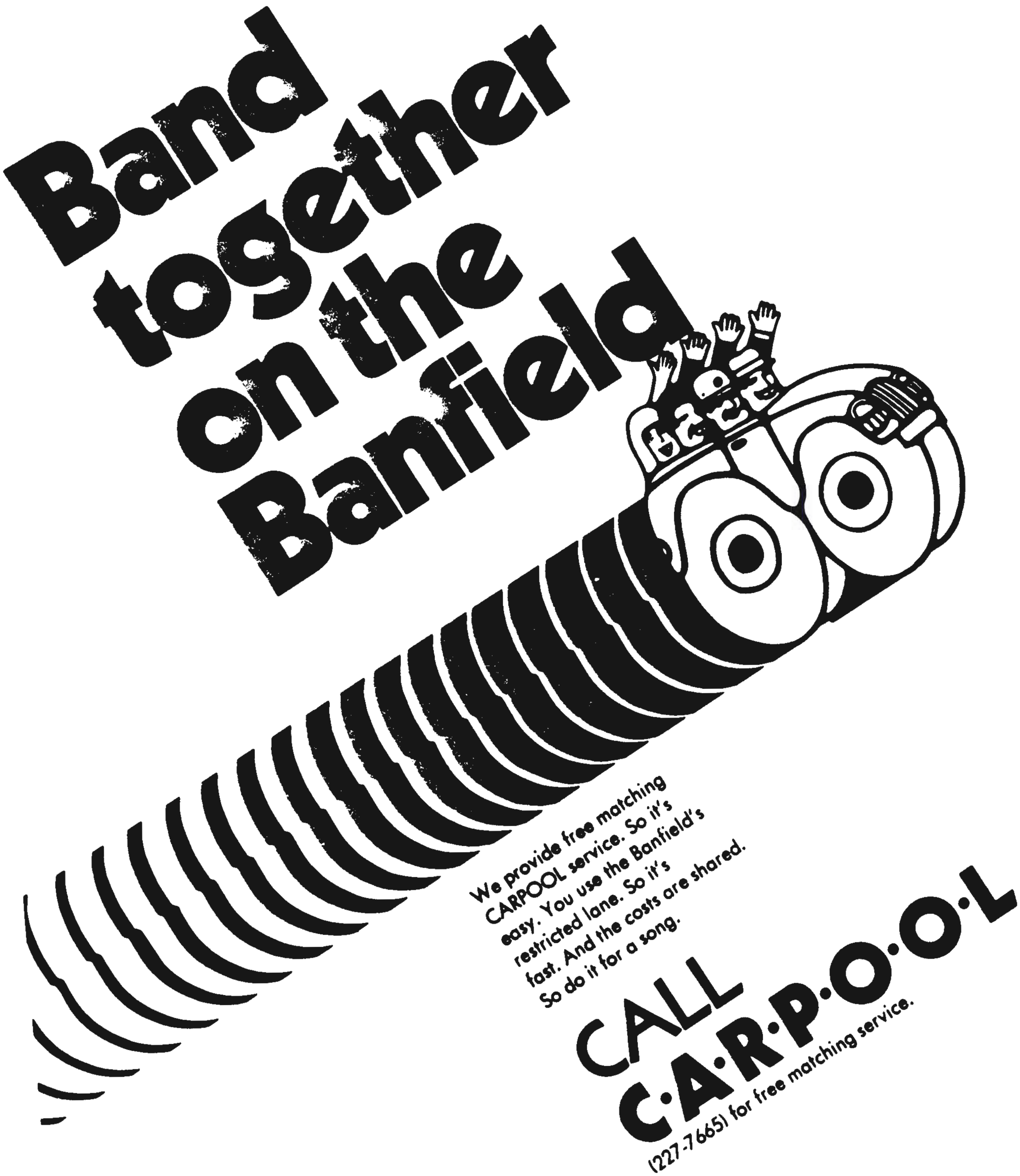


Figure 7-3. Promotional Poster

(Ref.87)

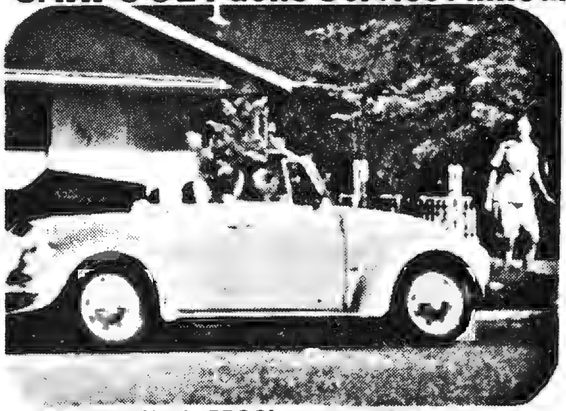
Figure 7-4. Promotional Billboard

Figure 7-5. Banfield Flyer Ad

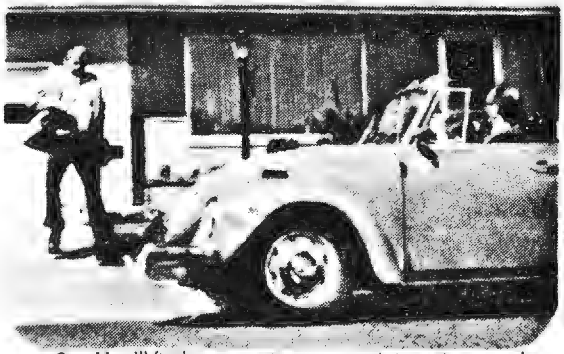
(Ref.87)

CARPOOL Public Service Announcement: 30 second TV

TRI-MET



1. ANNCR: CARPOOLing is more than saving money and energy.

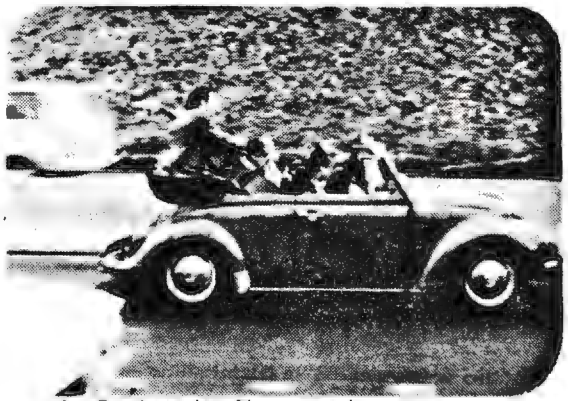


2. You'll find you meet some very interesting people.

3. People who make beautiful music together.

4. JINGLE: Travelin' in and town.

5. Savin on cash and fuel.



6. Band together. It's easy goin'

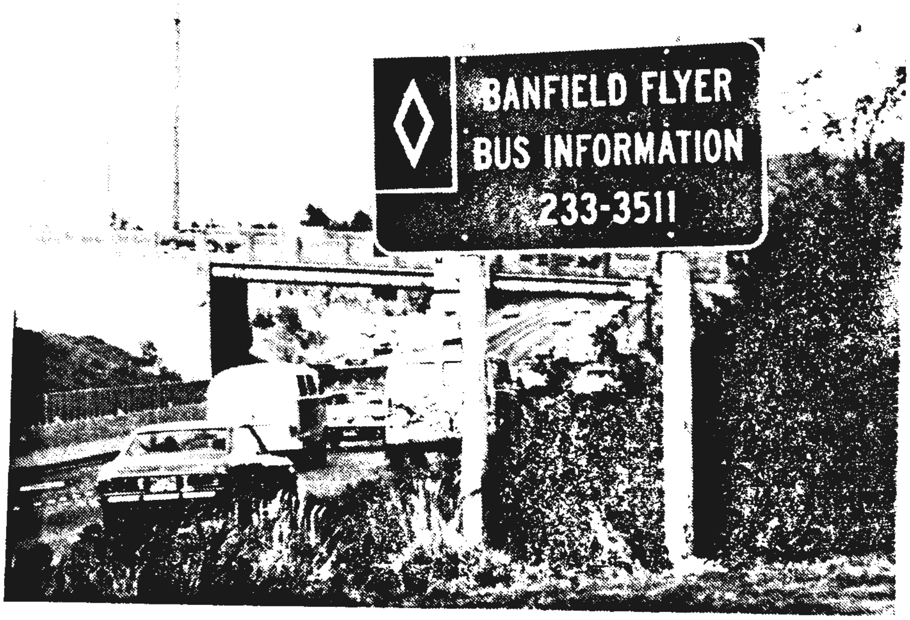
7. When you tune in with CARPOOL. CARPOOLing's swell.

8. Just Dial C-A-R-P-O-O-L. ANNCR: Band together. Dial CARPOOL.

Figure 7-6. 30-Second TV Spot

(Ref.87)

Westbound at Approximately N.E. 16th Avenue



East at Approximately N.E. 58th Avenue

Figure 7-7. Promotional Signs on Freeway

(Ref.87)

Your tax dollars are building a better Banfield.

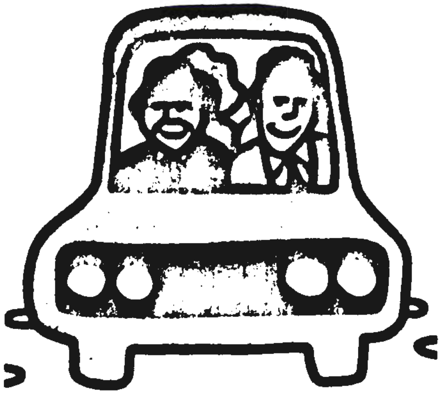
As you can see, the Banfield is going to be an entirely new place to drive when this project is completed . . . but all good things take time. So, we hope you'll all bear with us during the next three months and be as patient as you can through any delays or inconveniences you may experience. We promise to get the work done just as fast as we can and to keep at least two lanes open during the day and one at night.

TRI-MET
TELEPHONE
233-3511

OREGON STATE HIGHWAY
OFFICE OF METROPOLITAN ENGINEER

CAR POOL
TELEPHONE
227 7665

We're going to make it easier and faster for you to drive the Banfield.



If you drive the Banfield, you're aware of all its problems . . . congestion, ruts in the road, deep pools of standing water during rainstorms, washed out white lines that make it hard to see where the lanes are . . . and more.

When the people who plan freeways are faced with a situation such as this, there are several options. Doing nothing obviously would solve nothing. Building a totally new freeway would take too long to implement. Adding a conventional third lane would only fill to capacity, further increasing congestion.

Since the Banfield has been scheduled for total resurfacing, we've decided to take advantage of this construction to exercise another option. We're going to conduct an experiment which hopefully will solve many of the problems at a relatively low cost in a short amount of time.

The most noticeable improvement that will be part of the new program is an experimental express lane, reserved exclusively for buses and carpools with at least three people to a car. Since the express lanes will operate all day, ▶

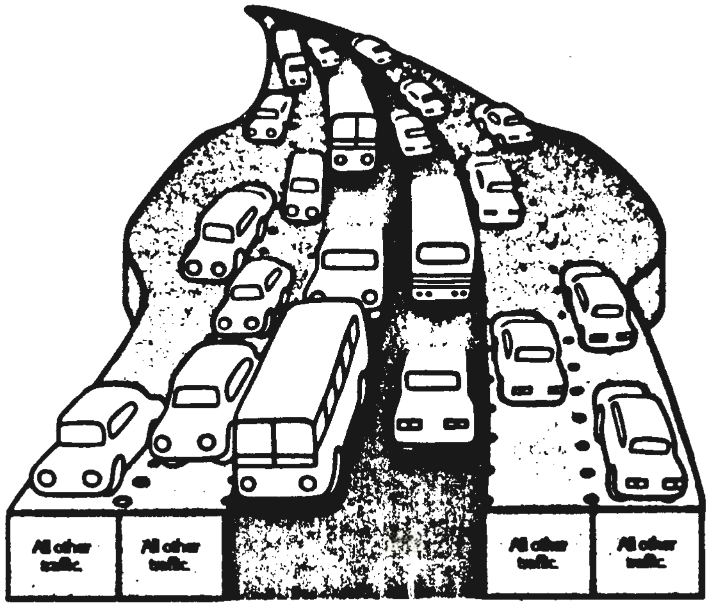


Figure 7-8. Portland-Banfield Marketing Brochure

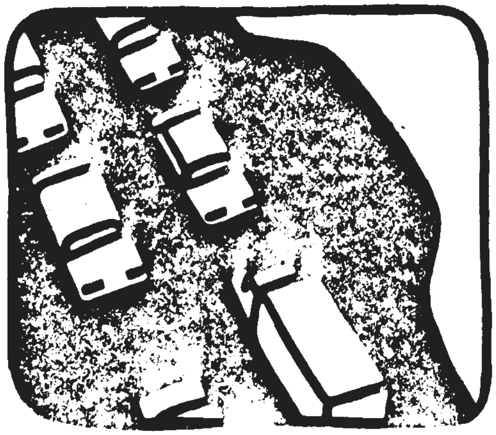
(Ref. 87)

For safety's sake

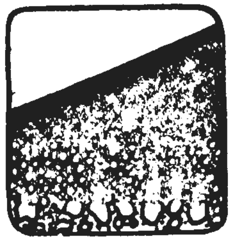
The restricted lanes can help everyone move more easily on the Banfield. By putting express buses and carpools in one lane, the other two lanes will also be less crowded for regular bus lines and those who simply can't ride the bus or carpool.

For this reason, it is to everyone's benefit to allow people to move across traffic to enter and exit from the special lane. Since traffic in the express lane may also be moving faster, drivers should be extremely careful when getting into or out of the lane.

Another important point about safety: Since we've eliminated the shoulder, please make sure your car is in good operating condition before you enter the freeway. It is impossible to always predict when you are going to have car problems, but a properly maintained car is much less likely to break down. If you do have trouble, emergency turnouts have been provided approximately every 2,000 feet and special phones are being installed with a direct line to the state police. Since the police will be patrolling the Banfield more frequently, it shouldn't take long to get assistance to you.

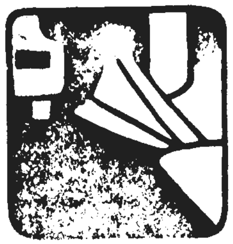


Don't overlook these other Banfield Improvements.

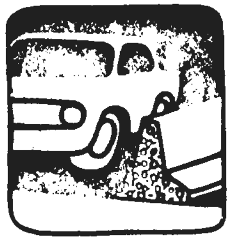


The ruts are gone. The Highway Division has applied a quieter, new resurfacing material which is also more porous, allowing the rain to run through it and away. This will eliminate dangerous puddles and night-time glare from standing water.

The lanes are clearly marked. White lines wear off easily, so new reflector buttons have been installed to clearly light the way. They also help keep you alert because they make a noise when you drive across them. The restricted lanes will be identified by a white diamond painted on the roadway.



Cars will be guided away from bridge abutments. Safety barriers now extend around the base of all overpasses shielding you from would-be obstacles.



The potential for head-on collisions has been eliminated. New concrete safety dividers have been placed between the east and west bound lanes to keep everyone on their side of the freeway.

Our hat's off to you. Happy traveling!

Thank you for your patience while the new Banfield was being completed. We hope you'll now be able to get where you want to go more easily and with greater safety.

OREGON STATE HIGHWAY

State Highway Division
238-8226

Tri-Met
233-3511

CARPOOL
227-7665

I would like to be included in CARPOOL's free matching service:

Mail to: CARPOOL
520 S.W. Yamhill
Portland, Oregon 97204

Name ____________

Home Address ____________

Work Address ____________

Phone: Work ____________ Home ____________

Hours you work: From ______ AM/PM to ______ AM/PM

I will: Ride only ___ Drive only ___ Do either ___

Figure 7-8. Portland-Banfield Marketing Brochure (continued) employment centers served by the buses.

- As part of the marketing strategy, a special identity for the six bus routes utilizing the contraflow lane was created by designating the entire service with a distinctive name--the Blue Dash--and logo. (Differentiation between routes was made by the conventional route number-destination method.)

- In addition to the public information program detailed above, marketing efforts consisted mainly of carefully monitoring ridership by route and run, travel times, a special Blue Dash on-board ridership survey and a County-wide on-board transit survey two months after project commencement.

- Routes and schedules were adjusted on the basis of this information. The original marketing decisions on level of service were based on the philosophy of making the service as attractive as possible, offering two to seven minute headways in the peak hours. Service was cut later as patronage stabilized and low-occupancy runs could be identified.

3) The <u>New Jersey Turnpike's Exclusive Bus Lane</u>: (Ref. 99)

- A comprehensive public information program was developed and carried out jointly by the participating agencies. News releases were issued at various times within the ten-week period preceding the bus-lane opening. These releases generated considerable coverage by the media. Climaxing these efforts, a preview of bus-lane operations for press and public officials was conducted on the day before opening day. Press releases were also distributed several times during the project. Supplementing the general press releases, specific bus-lane advisory material was distributed to motorists, bus drivers and bus passengers.

- Two separate handouts were distributed to motorists at the Lincoln Tunnel and Turnpike toll plazas to inform them of the upcoming operation and to encourage switching to bus transit for their commuting trip. The first flyer was distributed about two weeks before the beginning of operations on December 18, while the second was timed several days in advance of the bus-lane opening. Samples of the cards handed out are in Figure 7-9. These cards were multicolored 4 inch by 11 inch handouts and are shown in reduced black and white form. Two weeks before the bus lane opened a single sided blue-on-white card (top) was distributed to give motorists a general description of the project. Later a two-sided folded card (bottom) provided motorists a detailed description of the operation of the new overhead traffic signals.

- Special efforts went into the bus driver information program, since much of the success of the bus lane depended upon their positive participation. This was part of an intensive bus driver-bus company orientation. Distributed by the bus companies several weeks before operations began, the bus driver handout explained the project, told what signals and signs to look for and indicated the bus-lane "rules." A map of the project was included on the reverse side of the card. In addition, a large version of the bus-lane map was posted in each bus garage. On this map, the approach roads to the bus lane were shown with bold red lines and arrows.

- The bus passengers were informed about the upcoming bus-lane operation through extensive advance press coverage. Also, the Port Authority Bus Terminal staff devoted an issue of the bulletin, Terminal Topics, to the lane. The issue was distributed in the terminal the evening before opening day for maximum interest.

SUMMARY

The purpose of project marketing is to develop public understanding of the project and then to encourage persons to utilize the HOV treatment. A marketing plan should be developed which comprises several elements including a marketing strategy, information dissemination, the preparation of a marketing document and scheduling of marketing activities including ongoing evaluation efforts. The marketing strategy should include: 1) identifying the target markets, 2) conducting market research, 3) developing advertising and promotional activities, 4)

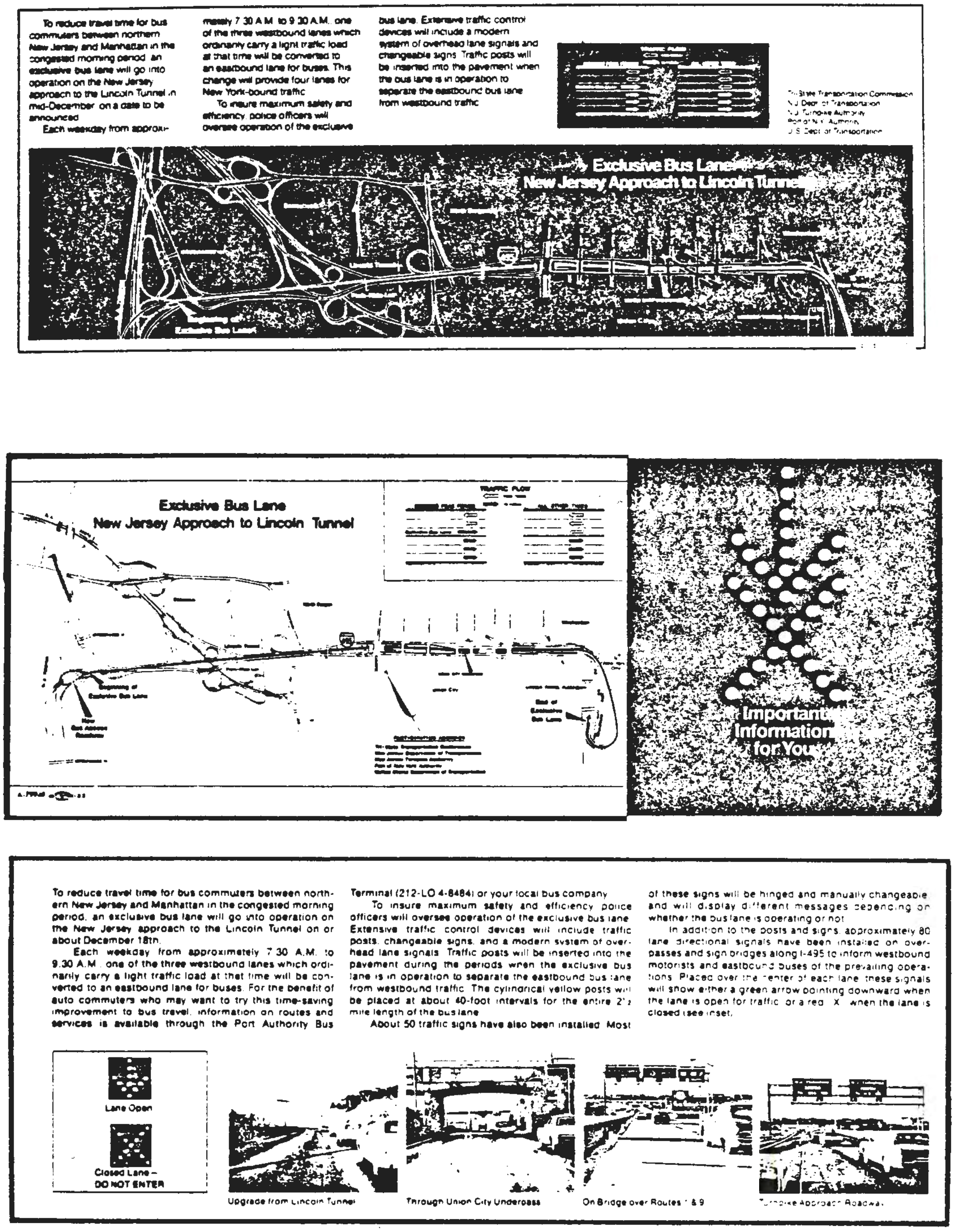
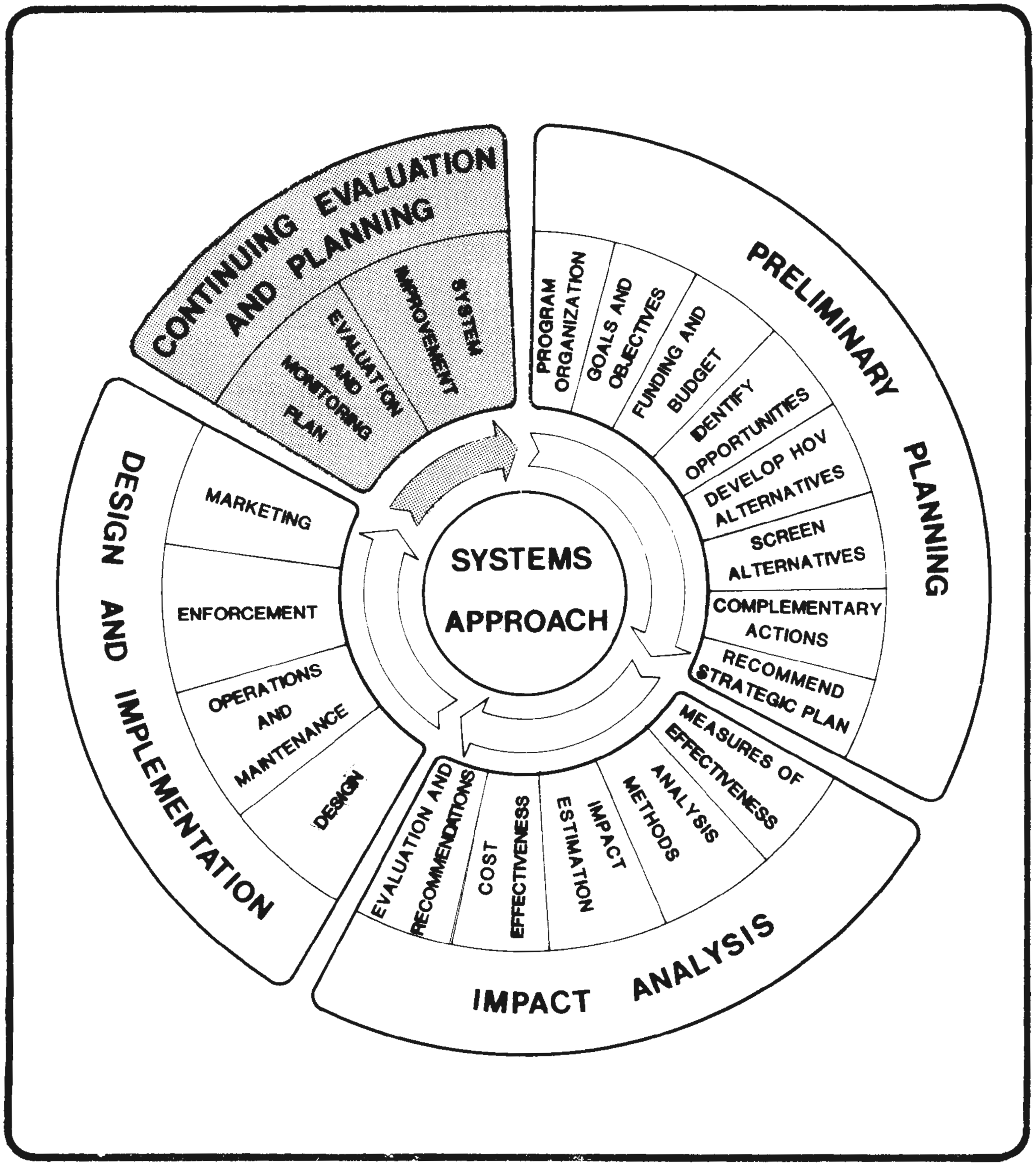


Figure 7-9. Instruction Guide for Motorists

(Ref.99)

developing an information dissemination program, and 5) developing a customers service mechanism. Information dissemination can be conducted through press releases, public service announcements, advertising in and on buses, handouts, mailouts, radio traffic reports, traffic information systems, posters, billboards and presentations. A marketing document outlining the marketing plan should be prepared and a marketing schedule developed which would outline when all of the above activities should be carried out.

8. CONTINUING EVALUATION & PLANNING



8. CONTINUING EVALUATION AND PLANNING

INTRODUCTION

Planning and evaluation activities do not stop once a HOV project is implemented. In addition to daily operational, maintenance and enforcement requirements, there is a continuing need to evaluate the project. Evaluation is important in order to: (Ref. 36)

1. Assess the Project - A careful evaluation is the only sure method of determining whether or not the project meets its stated objectives. Public officials need information upon which to base a decision of whether or not to continue the project. Because such projects entail giving priority to a certain class of users, there are often criticisms from other users of the project facility who are not given priority. A good evaluation will enable transportation officials to assess those criticisms intelligently, and either refute the objections, dismiss them, modify the project, or cancel it.

2. "Fine-tune" the Project - The data gathered for the evaluation can be valuable indicators of adjustments that need to be made in ongoing project operations. There may be a number of options available to the project planner during project design, including changes to service levels (e.g., bus headways, feeder bus vs. park and ride), physical configurations (e.g., lane separators vs. overhead signing), and user definition (e.g., how many people constitute a carpool?). When more than one option seems possible, a staged implementation, with careful assessments of each phase, can make "fine-tuning" the project an easier task.

3. Document the Project - Good documentation of new projects (successes and failures), properly disseminated, will enable each succeeding project to profit by the experience of others. Hopefully, the end result will be reduced implementation and operating costs with increased effectiveness for later applications. In addition, more precise design standards, warrants and justifications can only be developed through assessment of projects that have already been implemented.

Perhaps most importantly, the evaluation findings of a project can be a major input into the ongoing transportation system improvement program and development of HOV systems.

EVALUATION AND MONITORING PLAN

The evaluation of a HOV project proceeds through several stages. As discussed in Chapters 2 and 3, the foundation for an evaluation plan is a detailed set of HOV project objectives related to more general transportation goals and objectives. Each objective has associated measures of effectiveness (MOE's) which are the basis for assessing the quantitative and qualitative impacts of a project.

Data Collection Activities

Once the objectives and criteria are specified, an ongoing data collection plan should be prepared. One of the most important features of this plan is a proposed data collection timetable which specifies when types of data should be collected. This timetable can also specify each agency's responsibility for various data collection and evaluation activities.

The following information should be provided for each impact area: (Ref. 36)

- What data is to be collected;
- Why this data is necessary (sample size);
- Specific procedures to be followed;
- Agency responsibility (estimate person-hours required);
- When data is to be collected;
- Duration and frequency of data collection; and
- Estimated cost of each work item.

This information is important for both "before" and "after" data collection. The relative amount, frequency and time frame for collecting "before" and "after" data is depicted in Figure 8-1.

"Before" Data

The evaluation plan should specify the collection of "before" data on the facility. As shown in Figure 8-1, the "before" data effort begins with the collection of key pieces of data on a regular, but

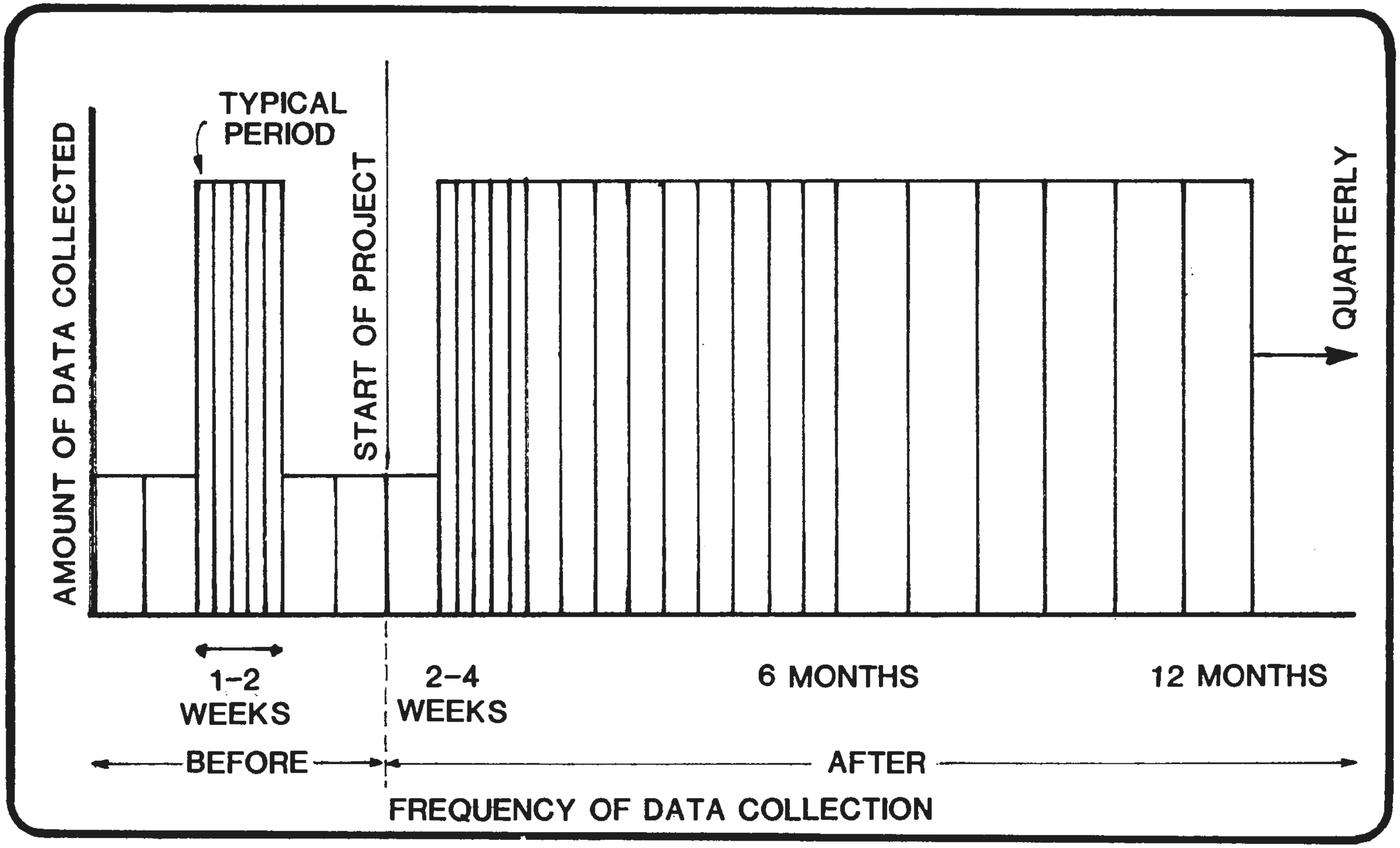


Figure 8-1. Data Collection Activities

generally low level basis. This data would typically include primary operational characteristics such as peak hour and daily vehicular volumes, occupancy counts and transit load factors.

The intense "before" data should be collected for a one to two week period immediately before the project is implemented, provided that period is typical of the conditions which would be encountered after the project is opened. For example, the "before" period should not be during the summer if the project is to be initiated after Labor Day. In this situation, the "before" data collection would be best scheduled for late Spring prior to the closing of school. The intense "before" data collection should include a wider variety of operational characteristics (see Chapter 2) and should be collected much more frequently during this time. Daily data collection permits the most comprehensive analysis of expected data variations. Following this intense data collection period, routine data should continue to be assembled until the project is implemented.

"After" Data

The project monitoring program "after" the project is opened should include both routine visual observation as well as the collection of specific data. Visual observations should begin as soon as the project is opened. Trained traffic operations personnel should be available at all times during the first several days to observe the manner in which the project operates and to make whatever field adjustments may be necessary. After this initial time period, field observations can be reduced to periodic visits of decreasing frequency.

The collection of specific "after" data should be limited at the outset of the project, since it will require several days for travel patterns to begin to adjust themselves. Data collected during the first week of the project is of historical interest and has media value but is of little real significance. As a result, the intense "after" data collection effort should be made during the period two to four weeks after project initiation, as shown in Figure 8-1. This data should be commensurate with the data collected during the intense "before" period, both in quantity, type and frequency of collection (i.e., both on a daily basis). The intense "after" data collection should continue for around a month until conditions begin to show some stabilization.

Following this period, the frequency (but not amount) of data collection can be gradually reduced to weekly and then monthly intervals. Some projects may have data available on a more frequent basis. Projects involving transit will often have daily ridership statistics available from the transit authority. However, it is not necessary that data be collected that often for evaluation purposes. The frequency of data collection and project monitoring can decrease as the project operation becomes routine. After the first year of operation, quarterly information should be sufficient.

The evaluation and monitoring activities must be performed within a budget. An evaluation budget should be adequate to permit a comprehensive analysis of MOE's related to important project objectives. Each type of project will have a different focus requiring different levels of evaluation. For example, the evaluation effort for one bus and carpool bypass ramp might have a considerably narrower focus than a concurrent flow exclusive lane for carpools and buses coupled with an area-wide carpool matching program. Similarly, innovative HOV treatment projects may justify larger evaluation and monitoring expenditures than more standard HOV projects (Ref. 40).

An example of an extensive evaluation program is one conducted on the Banfield Freeway project. In this project, an extensive two-year monitoring program evaluated the operational effectiveness of the HOV lanes in meeting the project objectives. The program was functionally divided into two parts--air monitoring and traffic monitoring.

The air monitoring program included sampling of carbon monoxide, lead, nitrogen oxides and wind speed and direction. The traffic monitoring program included: (Ref. 18)

- o Periodic traffic counts on all freeway ramps on the project;
- o A continual traffic count of all traffic at the western terminus of the project (CBD);
- o Periodic traffic counts on arterial streets paralleling the Banfield;
- o Periodic lane and vehicle occupancy counts at two selected locations on the Banfield; and

- Periodic traffic speed monitoring on both the freeway and arterial streets, through the use of floater cars.

The program included monitoring of bus ridership, carpool occupancies, bus travel time, and traffic accidents on the freeway.

Public Attitudes

One of the most important criteria in calculating the success or failure of a HOV project is the attitude of the public toward the project. Although much of the evaluation plan typically focusses on physical measurements (e.g., travel time and volume changes), public attitudes, both positive and negative, often play a more important role in the project evaluation.

A typical method for obtaining public attitudes is through a survey. Surveys come in many forms--telephone surveys, mail-out surveys, with hand-out surveys being the most common. Figures 8-2 and 8-3 present examples of a hand-out survey (Connecticut Turnpike) and a mail-out survey (San Bernardino Busway). Surveys must be carefully designed to avoid biases in sample selection and survey responses. In particular, both users and non-users of the HOV treatment should be sampled.

Other formalized methods of obtaining public reactions to a project range from logging of pro and con telephone calls or letters received by an agency to holding a public hearing(s) on the subject. In order to obtain an accurate measurement of public reaction, the evaluation activities should preferably include a variety of these data collection techniques.

Special evaluation care must be exercised on projects which appear to generate considerable negative reaction. Oftentimes negative comments tend to overshadow positive reactions, especially within the media (e.g., newspapers, radios, TV). In such situations, the use of multiple surveys and other evaluation procedures can help either to verify or to balance out the negative reactions.

Evaluation Report

Once the evaluation has been completed, the findings should be documented in a report. Many HOV projects in the past have failed to produce any sort of

CONNECTICUT TURNPIKE CARPOOL COMMUTATION SURVEY

FOR OFFICIAL USE ONLY

1. Where did your trip start? (For example if you are coming from your home, fill in the TOWN and nearest STREET, INTERSECTION of your residence) ______ 1

2. What is the destination of your trip? (For example if you are going to work, fill in the name and address of your employer) ______ 7

3. What is the purpose of this trip? 14
   a.______work b.______school c.______other(specify)______

4. How many times per week do you pass through THIS toll station? 16
   ______Number per week

5. How did you make this trip prior to the March 15, 1974 reduction in the cost of the toll tickets for carpools?
   a. Carpool—three or more persons (including Driver)______ 19
   b. Carpool—two persons or more (inc. driver)______ 21
   c. Drove alone ______ 23
   d. Bus ______ 25
   e. Other (specify) ______ 27
   f. Did not make this trip ______ 29

6. Which of the following factors were important in your decision to join this carpool? (Check only one answer on each line).

	Major Factor	Minor Factor	Not a Factor	
a. The high cost of operating an auto	____	____	____	31
b. The high cost of parking at destination	____	____	____	33
c. Difficulty in obtaining sufficient gas	____	____	____	35
d. High price of gasoline	____	____	____	37
e. Reduced toll rates for carpools	____	____	____	39
f. Conservation of energy	____	____	____	41
g. Environmental Considerations	____	____	____	43
h. Other (specify)	____	____	____	45

7. Prior to purchasing the carpool toll tickets, how did you pay the tolls?
   a. Regular commuter ticket______ 47
   b. Cash (25¢) ______ 49
   c. Used Merritt Pkwy. ______ 51
   d. Did not use toll route ______ 53

8. Comments______ 54

(Ref. 93)

Figure 8-2. Sample Survey Questionnaire

SAN BERNARDINO FREEWAY BUSWAY
CARPOOL USER SURVEY

Dear Carpooler:

If you or anyone in your household participated in a carpool on the San Bernardino Freeway Busway on April 26, 1977, it would be appreciated if the driver would answer the questions on the reverse side. The information supplied will remain confidential.

Your answers to this questionnaire will help us evaluate the extent to which the San Bernardino Freeway Busway is meeting the transportation needs of the area. This survey is a cooperative effort of the California Department of Transportation (Caltrans), the Southern California Association of Governments (SCAG), the Southern California Rapid Transit District (SCRTD), and the City of Los Angeles.

Figure A-1a.
Mailed Carpool Questionnaire – Side 1

Thank you for your cooperation. Please fold, staple and mail (no stamp required)

FIRST CLASS
PERMIT No. 41955
Los Angeles, Calif.

BUSINESS REPLY MAIL
No Postage Stamp Necessary if Mailed in the United States

Postage will be paid by —

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
FREEWAY OPERATION BRANCH
DISTRICT 7
BOX 2304, TERMINAL ANNEX
LOS ANGELES, CALIFORNIA 90051

1208

SAN BERNARDINO FREEWAY BUSWAY

CARPOOL USER SURVEY

1. Check the days that your carpool usually travels on the busway:
   __M __Tu __W __Th __F __Less than once a week
2. When was this carpool formed? _____ (month) _____ (year)
3. Do you believe this carpool would have been formed if the busway had not opened to carpools? ____Yes ____No
4. How many members are in this carpool (including yourself)? _________
   How many of the members never drive for the carpool?________
5. Before this carpool was formed, how many of its members, including yourself: (indicate number below)
   _____ used a different carpool?
   _____ drove alone?
   _____ rode a bus? -- what route no.(s): ______, ______, ______
   _____ used other means? -- please specify: __________________
   _____ did not make this trip?
6. What is your carpool destination (nearest major street intersection)?
   __________________ & __________________
   City or community: __________________
7. If you drove alone, how many miles long would your daily round trip be?
   ______ miles.
8. On the days you drive, how many miles longer is your round trip as a result of your participation in this carpool: ______ miles
9. Is your car driven by other members of your household when it is not used in your carpool? _____ Yes _____ No
   If yes, approximately how many miles is it driven per day? _____miles
10. How many vehicles excluding the pool car are used on a typical day by members of the carpool to reach the pickup point(s)?
    ______ vehicles

We would appreciate your additional comments:

Figure A-1b.
Mailed Carpool Questionnaire – Side 2.

THANK YOU

(Ref.74)

Figure 8-3. San Bernardino Freeway Busway Carpool User Survey report which could aid in implementing a similar project elsewhere. The report does not need to be lengthy, but it should present the key findings of the evaluation. These should include tabular and/or graphical displays of "before" and "after" conditions on the facility. It should also present a discussion of significant planning, design, operational, enforcement, marketing, and institutional factors which affected the success or failure of the project. Finally, enough copies of the report should be produced to allow for reasonable dissemination of the document. The bibliography in this guide contains references to a wide variety of HOV treatment evaluation reports.

SYSTEM IMPROVEMENT AND EXPANSION

Evaluation activities produce an assessment of a project's performance. In addition, these evaluations have hopefully provided insight as to how the project could be improved or expanded. This insight can then be transmitted into the planning, design and implementation of other HOV treatments.

As the number of HOV treatments subsequently grows within a corridor or region, there exists a stronger need to consider how these treatments can and should relate to one another. The planning and selection procedure must now compare sets of complementary HOV treatments instead of individual projects. This systems approach to HOV planning can be incorporated into a systemwide TSM planning process. Supplement 8A describes the concept of an HOV system using the case example of the Washington, D.C. region.

HOV Systems

Each of the HOV treatments presented in the preceding chapter is applicable in different physical and operational settings. Separately, many of these treatments may have minimal impact on existing travel patterns and mode usage. However, by integrating several HOV projects into a comprehensive priority scheme, the effects may be considerably greater.

This section develops the concept of a comprehensive system of HOV priority treatments. A framework is presented for investigating various combinations of HOV treatments keeping in mind specific physical and operational constraints. Once these constraints are met, a HOV system can be developed which combines the most feasible HOV treatments in a cost-effective manner.

Definition of an HOV System

A HOV system can be defined as a continuous and efficient combination of HOV treatments within an activity center, corridor, or region designed to serve the origin-destination needs of tripmakers. As indicated in the definition, an HOV system has two desirable characteristics--continuity and efficiency.

Continuity - Continuity within a HOV system is important. On a corridor level, the emphasis is on providing continuous HOV treatments from a point where congestion begins penetrating all the way into and within an activity center. Within an activity center, continuity defines a network of HOV treatments along major intersecting streets following major HOV travel movements. On a regional basis, continuity defines a series of interconnected corridor and activity center HOV systems.

It is important to consider that HOV treatments do not have to be physically continuous to classify as a HOV system. A series of short "queue-jumper" HOV treatments bypassing congested locations along a facility (e.g., intersections or interchanges) can often be as effective as a physically connected series of HOV lanes, and at much less cost.

Efficiency - In order to be efficient, a HOV system must be directly tied to major travel movements between origin-destination pairs. Therefore, interconnected HOV treatments should follow logical travel patterns using the most direct routes available.

Together, continuity and efficiency describe the way in which a HOV system can be most effective. Continuity defines the need for connecting various HOV treatments, while efficiency states that HOV treatments should be combined following direct routes along major origin-destination travel movements. In some situations, it may be more desirable to design discontinuous segments of efficient HOV priority treatments rather than design a series of continuous, but inefficient HOV treatments.

HOV System Components

Before a HOV system can be developed, the components must be defined. A HOV system is composed of facility specific and non-facility specific HOV treatments.

Facility Specific Treatments - Facility specific HOV treatments are those which are applicable only on certain types of facilities. HOV priority lane and HOV ramp treatments fall under this category.

Non-Facility Specific Treatments - Non-facility specific HOV treatments can be readily applied to most or all facility types. Typical non-facility specific HOV treatments include signal priority, priority parking, and priority pricing strategies. Other examples include regionwide ridesharing programs, areawide tax incentives, or parking tax surcharges.

A. HOV system combines facility and non-facility specific treatments in a cost-effective manner. The principles of efficiency and continuity help determine the manner in which these treatments should be combined.

Combination Techniques

In general, there are two techniques which can be considered for combining HOV treatments into a system.

Sequential Technique - The objective of the sequential technique is to link various HOV treatments end to end along a single facility or along a series of connected facilities. A common example of this technique is a HOV treatment on a radial freeway linking up with surface street HOV projects which in turn feed into a series of activity center HOV treatments. Alternatively, different types of HOV treatments may be linked along a facility segment which has changing physical and/or operational characteristics. Figures 8-4 and 8-5 describe various sequential combinations.

Simultaneous Technique - The simultaneous technique considers which HOV treatments can be jointly implemented along the same facility segment. As an example, a multi-lane two-way surface street with a median might accommodate both a concurrent flow curb HOV lane for local buses and a contraflow or concurrent flow inside lane for express buses. Figures 8-6 and 8-7 depict these and other simultaneous strategies.

Application of Techniques

Both facility specific and non-facility specific treatments can be applied in a simultaneous or sequential manner. Because non-facility specific treatments generally do not require any physical roadway space, these strategies lend themselves to simultaneous applications with other HOV treatments.

Facility specific treatments are most readily applied sequentially with one another, although some simultaneous applications are possible.

The physical and operational compatibility of different HOV treatments is an important consideration in the application of these techniques. Compatibility is most significant for simultaneous applications where potential HOV treatments may compete for the same roadway space or require incompatible traffic operations. Sequential applications of HOV treatments are usually more compatible, but consideration must still be given to how particular treatments can be linked together given physical and operational constraints.

Several examples of potential HOV treatment combinations are depicted in Figures 8-4 through 8-7. These include sequential and simultaneous applications on grade separated facilities and surface streets.

<u>Sequential Applications on Surface Streets (Figure 8-4)</u> - Several types of surface street HOV treatments can be linked together to provide continuous priority to HOV's. Combinations of HOV lanes and non-facility specific treatments such as signal priority, parking or pricing strategies are relatively easy to produce. Conversely, linking two or more different types of HOV lanes can be more difficult due to possible physical and operational constraints at transition points.

Parking and pricing strategies along surface streets are often implemented at the beginning and end of a system of HOV treatments (Figure 8-4A). Signal priority treatments can be implemented along almost any signalized roadway segment. One sequential application of signal priority treatments is to aid HOV's in diverting from priority treatments on one facility to those on an adjacent facility. Signal priority treatments can also aid HOV movements to and from priority parking facilities (Figure 8-4B).

HOV lane treatments can be linked along successive segments of the same facility which have different physical and operational characteristics. For example, a two-way surface street may have some segments with medians and some without medians. Contraflow lanes may be most appropriate on the median segments, while concurrent flow lanes may be the most feasible on the non-median segments. These two HOV treatments can then be possibly linked by providing a transition from the contraflow lane to the concurrent flow lane (Figure 8-4C).

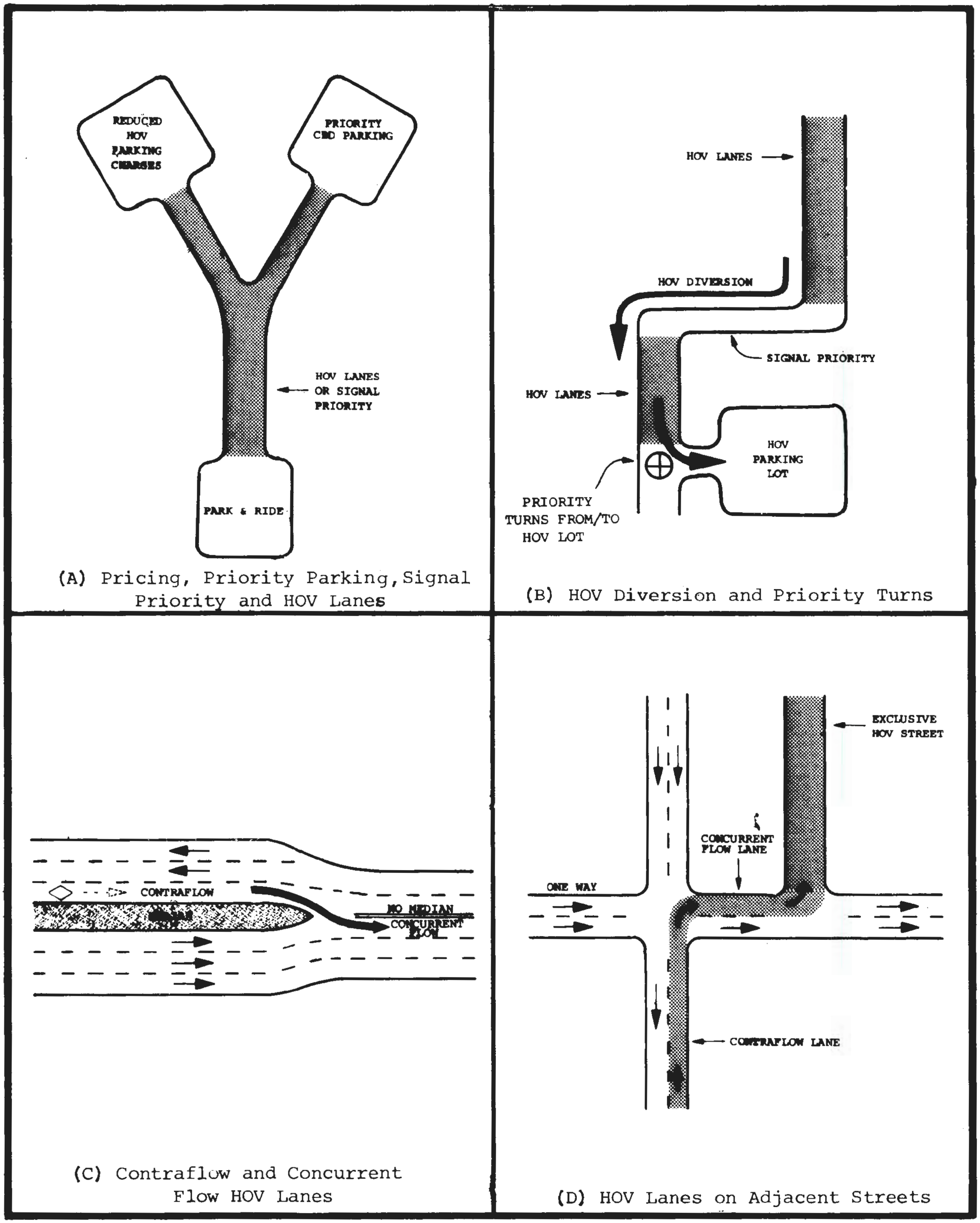


Figure 8-4. Conceptual Sequential HOV Treatments on Surface Streets

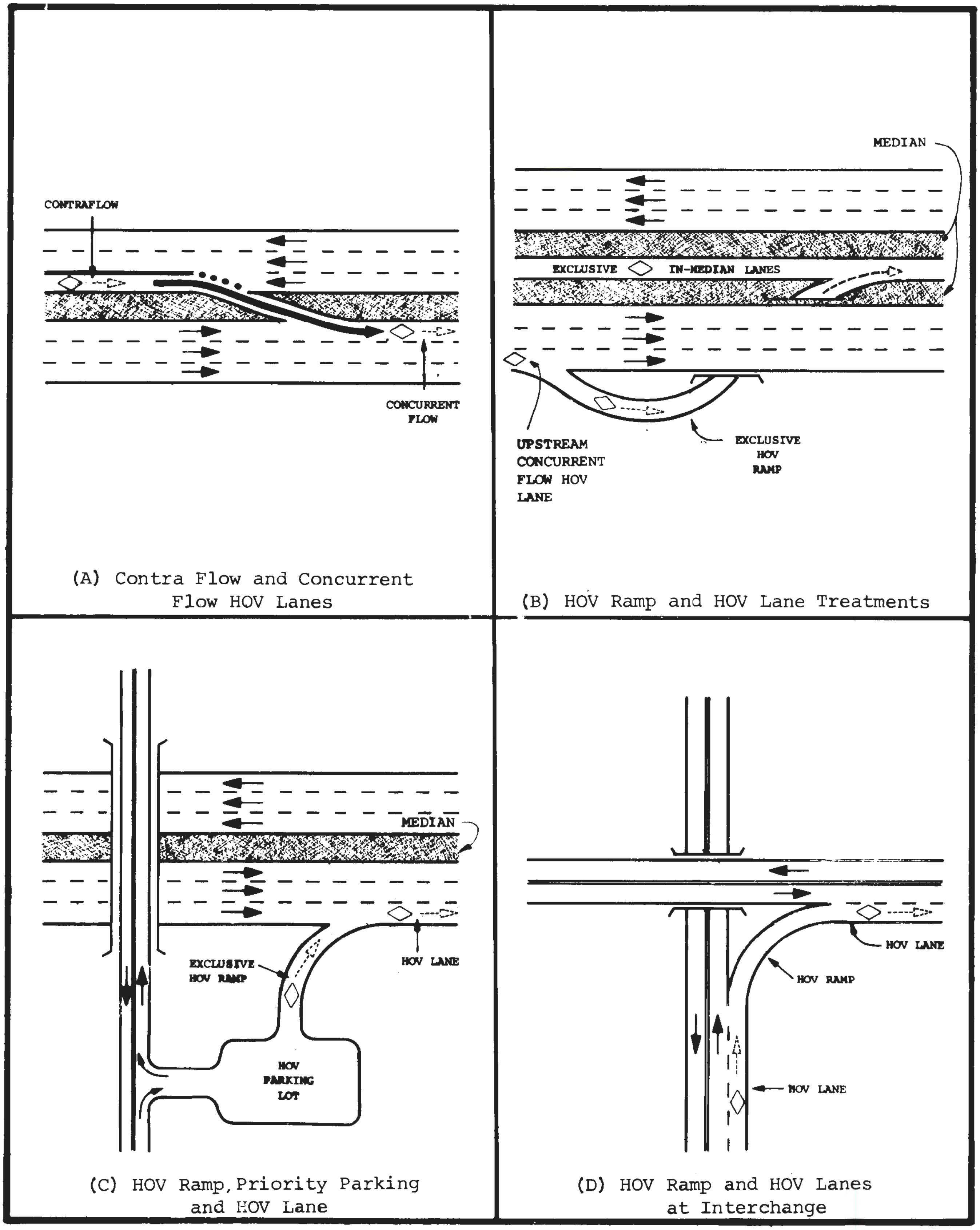
8-4C).

HOV lane treatments can also be linked between adjacent facilities. Activity centers are a common location for networks of concurrent flow lanes, contraflow lanes, and exclusive HOV streets. Intersections usually provide the transition point between these HOV treatments (Figure 8-4D).

Sequential Applications on Grade Separated Facilities (Figure 8-5) - Grade separated facilities offer good potential for sequentially linking HOV treatments. Using HOV ramp treatments and median crossovers, various concurrent flow, contraflow and exclusive lane HOV treatments can be linked along the same facility or between two or more facilities at interchanges. Ramps can also provide priority access to HOV parking lots (e.g., park and ride; activity center HOV lots). Toll pricing strategies often are implemented sequentially with HOV toll plaza lanes and ramp treatments. Figure 8-5 presents some typical sequential combinations of HOV lane, ramp and priority parking treatments on grade separated facilities.

Simultaneous Applications on Surface Streets (Figure 8-6) - Surface streets offer several opportunities for simultaneous HOV treatment applications. Signal priority techniques can be implemented in conjunction with HOV priority lanes (Figure 8-6A). The priority lane allows HOV's to bypass intersection queues while signal priority reduces signal delay. Similarly, HOV priority signal phases help facilitate HOV access to and from priority lanes, park and ride lots, or activity center HOV lots (Figure 8-6 B & C). Reduced HOV parking rates within activity centers have been used in conjunction with HOV priority lanes or designated HOV parking lots (Figure 8-6C). Toll pricing activities can also be occasionally combined with surface street HOV lane treatments.

Simultaneous applications of two or more HOV lanes along the same facility segment are more difficult. Streets with less than three lanes in each direction have limited capacity to offer more than one lane for exclusive HOV use. However, where sufficient capacity exists, or where add-a-lane options are feasible, multiple use of HOV lanes may be desirable. The designation of multiple HOV lanes is likely to become more widespread as single lane HOV treatments become overloaded.



(A) Contra Flow and Concurrent Flow HOV Lanes

(B) HOV Ramp and HOV Lane Treatments

(C) HOV Ramp, Priority Parking and HOV Lane

(D) HOV Ramp and HOV Lanes at Interchange

Figure 8-5. Conceptual Sequential HOV Treatments on Grade Separated Facilities

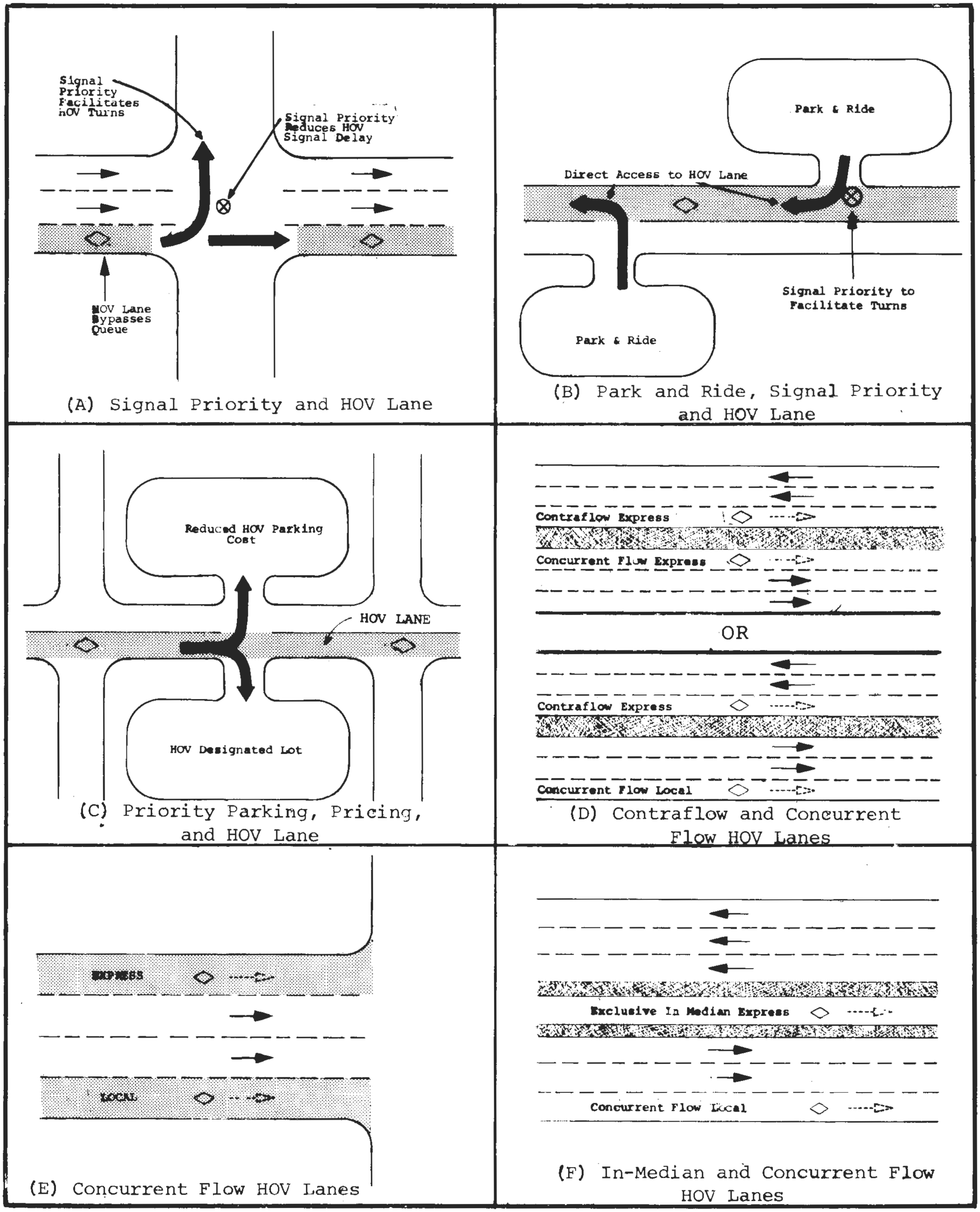


Figure 8-6. Conceptual Simultaneous HOV Treatments on Surface Streets

Contraflow and concurrent flow HOV lanes have been combined along two-way streets. This strategy allows the separation of carpools, express buses and local buses (Figure 8-6D). Simultaneous but separated concurrent flow lanes are also possible on one-way or two-way streets (Figure 8-6E). Both strategies may create turning problems for non HOV traffic. Exclusive in-median express HOV lanes can be considered along with concurrent flow curb lanes for local buses (Figure 8-6F).

Simultaneous Applications on Grade Separated Facilities (Figure 8-7) - Several simultaneous HOV treatments are possible on grade separated facilities. Toll pricing treatments are easily combined with HOV priority lanes through toll plazas (Figure 8-7A). Park and ride or activity center HOV lots may be strategically located adjacent to facilities which have HOV lanes (Figure 8-7B). Similarly, HOV ramp meter bypass lanes or exclusive HOV ramps complement left or right side HOV lane treatments (Figure 8-7C).

Some simultaneous combinations of concurrent flow, contraflow, and in-median HOV lanes may be feasible (Figure 8-7 D & E). In several cases, however, multiple HOV lane treatments on high-speed grade separated facilities can create geometric and safety problems, especially at transition points and in the vicinity of interchanges. One option is to restrict all lanes to HOV's (e.g., I-66 in Northern Virginia), thus eliminating the conflicts between non HOV's and HOV's.

Applications on Surface Street and Grade Separated Facilities - In order for a HOV system to be complete, there must be consideration of how HOV treatments on surface streets and on grade separated facilities can be combined. A typical corridor HOV system might consist of a series of surface street HOV treatments extending from one or more activity centers onto grade separated or exclusive facility HOV treatments. Ramp treatments provide the major link between surface street and grade separated facility HOV treatments. Signal priority treatments can also ease movements from surface street HOV lanes to grade separated HOV lanes.

The transition between these two facility types in the vicinity of activity centers is especially important, since congestion is usually greatest in this location. Ramp treatments should lead directly from grade separated facility treatments into activity center surface street HOV lanes, parking lots, or signal priority systems. Otherwise, HOV's may become backed up on grade separated priority lanes with their time advantage lost to activity center congestion.

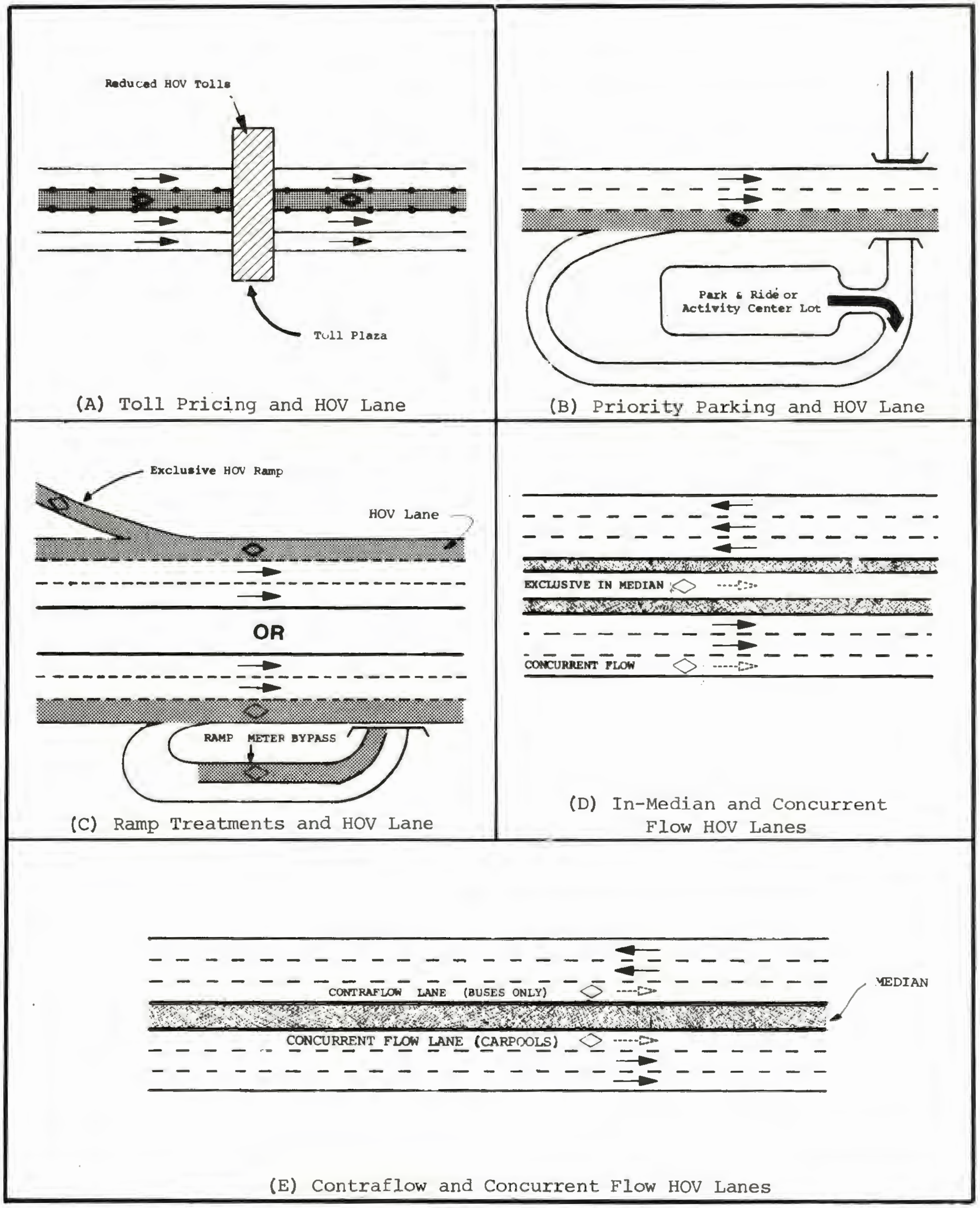


Figure 8-7. Conceptual Simultaneous HOV Treatments on Grade Separated Facilities

Effects on Parallel Facilities

Applying HOV treatments on parallel facilities can produce complementary or conflicting effects. In some cases, closely parallel HOV treatments can cause conflicting incentives and indecision for motorists. As a result, neither HOV treatment may be efficiently utilized. Conversely, some parallel HOV treatments can be efficiently combined. Consider, for example, a corridor situation where a grade separated facility HOV lane project has limited access points. In this case, HOV treatmentts could also be implemented along surface streets (e.g., frontage roads) which run parallel to the grade separated facility. These surface street HOV treatments can help ease feeder HOV movements between interchanges prior to gaining access to the grade separated HOV lanes. A network of parallel HOV treatments within an activity center can also accommodate multiple HOV movements.

Effects on Diversion

In an effort to provide continuous HOV priority along major travel movements, it may be necessary to occasionally divert HOV's from one facility segment to a HOV treatment on an adjacent facility segment. However, HOV's should never be forced to make frequent or large route diversions just for the sake of HOV system continuity. Frequent diversions between widely spaced facilities greatly diminish any travel time savings which may be evident by using the HOV treatments. At the same time, these diversions reduce the visibility of the HOV system.

Route diversions can be especially disruptive to local buses, which may be shifted from existing routes in order to utilize the HOV treatment. Patronage losses due to the change in route coverage might offset any gains produced by using the HOV treatments. In order to minimize the detrimental effects of diversion, every attempt should be made to concentrate HOV priority treatments along a single facility or along a minimum number of closely spaced facilities.

Regional HOV Systems

The primary emphasis on HOV system development is at the corridor level. However, radial corridors generally intersect at a hub as do spokes in a wheel. An activity center is this hub where corridor HOV systems must be coordinated with one another.

In order to effectively penetrate an activity center, corridor HOV systems should often join together on the periphery of the activity center. These concentrated corridor HOV movements can then feed into a system of activity center HOV treatments. By providing focal points and linkages between corridor and activity center HOV systems, the basis for a regional HOV system is laid. The resulting regional HOV system becomes a clearly visible element of the transportation network.

The concept of a HOV system has often been discussed but never formalized. In many localities, the elements of an HOV system are present; however, the commitment to combine these elements into an efficient and effective HOV system has been lacking. A case example of an attempt to create HOV systems within a metropolitan region is provided in Supplement 8A.

SUMMARY

Planning and evaluation activities do not stop once a HOV project is implemented. Continuing evaluation is necessary to: assess the project, "fine-tune" the project and document the project. An ongoing data collection plan should be prepared with a timetable for collection of the data. This information is important for both "before" and "after" data collection.

Public attitudes, both positive and negative, often play an important role in project evaluation. Methods for obtaining public attitudes include various types of surveys, logging pro and con telephone calls or letters and holding public hearings.

As the number of HOV treatments grow within a corridor or region there is a strong need to see how they should relate to one another. A continuous and efficient combination of HOV treatments could possibly be developed with an activity center, corridor or region. This is known as an HOV system. Several combinations of sequential and simultaneous HOV systems may be applicable within a corridor or activity center.

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