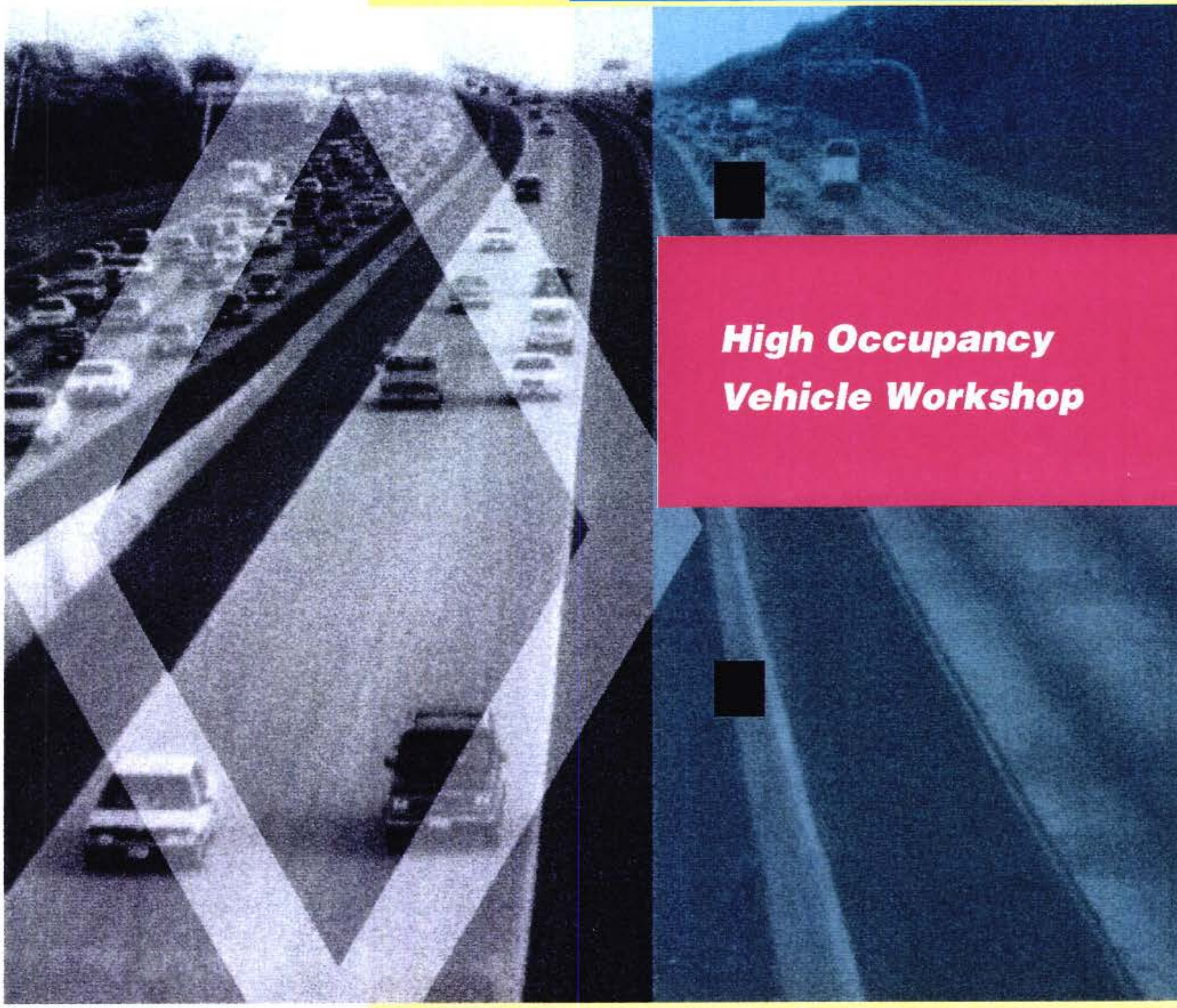
Transportation Research Board



High Occupancy Vehicle Workshop

W O R K S H O P

Los Angeles, California

June 5, 1994

PROGRAM

High-Occupancy Vehicle Seminar

Los Angeles, California

June 5, 1994

Opening Remarks
8:30 - 8:45 a.m.

Session 1: Introduction
8:45 - 9:30 a.m.
Tim Lomax

- Why Consider HOV Lanes?
- Role and Purpose of HOV Concepts
- Typical Markets Served
- Effectiveness of Treatments
- Examples of Successful Applications
- Inventory of Current Projects
- Questions and Discussion

Session 2: Planning - Part 1
9:30 - 10:00 a.m.
Donald Samdahl and Kern Jacobson

- Typical Planning Issues
- Evaluation Criteria Usually Applied to Define Viability
- Identifying Alternative Treatments and Screening Alternatives
- Modeling of Demand and Traffic Impacts
- What Planning Lessons Have We Learned?
- Questions and Discussion

Break
10:00 - 10:15

Session 2: Planning - Part 2
10:15 - 11:00 a.m.

Session 3: Arterial HOV Treatments
11:00 - 11:30 a.m.
Kern Jacobson

- Key Issues for Arterials
- Operational Objectives and Criteria
- Design Treatments
- Signal Priority Treatments
- Vehicle Identification and Control Strategies
- Implementation Issues
- Questions and Discussion

Lunch
11:30 - 12:30 p.m.

Session 4: Operations
12:30 - 1:45 p.m.
Donald Samdahl and Kern Jacobson

- Eligibility and Periods of Operation
- Enforcement
- Incident Management
- Advanced Roadway Technology Applications
- Support Programs

Break
1:45 - 2:00 p.m.

Session 5: Design
2:00 - 3:15 p.m.
Tim Lomax

- Design Guidelines
- Cross Sections
- Access Treatment
- Other Considerations
    - Enforcement
    - Signing and Marking
    - Incident Management

Session 6: Public Involvement and Marketing
3:15 - 4:15 p.m.
Heidi Stamm

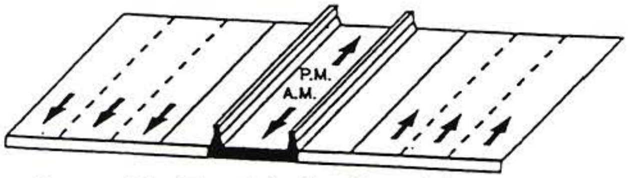
- Role of Public Involvement and Marketing
- Constituency Building
- Issues Influencing Bus/HOV Development Marketing
- Review of Experiences from Various Projects
- Questions and Workshop

Wrap Up
4:15 - 4:30 p.m.

HOV
OVERVIEW

HOV Operation Concepts

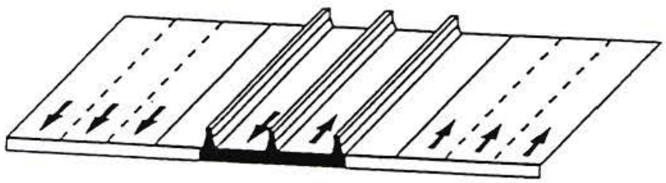
Reversible-Flow



Reversible-Flow Median Lane(s)

Katy Transitway, Houston, Texas

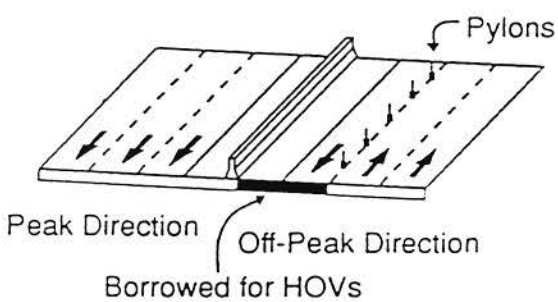
Two-Way (Concurrent Flow)



Two-Way Barrier-Separated Lanes
(Also Buffer-Separated or Nonseparated Lanes)

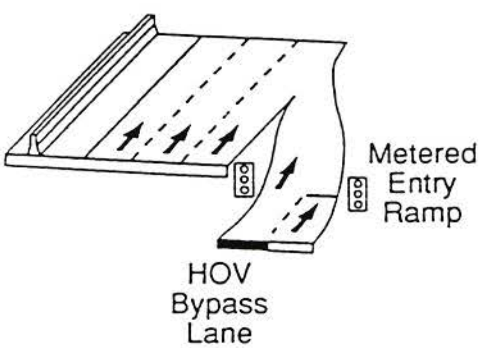
El Monte Busway, Los Angeles, California

Contraflow



Route 495, New Jersey

Queue Bypass



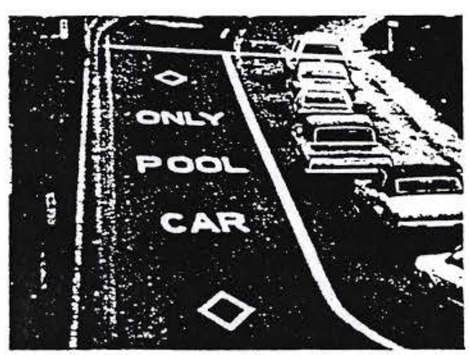
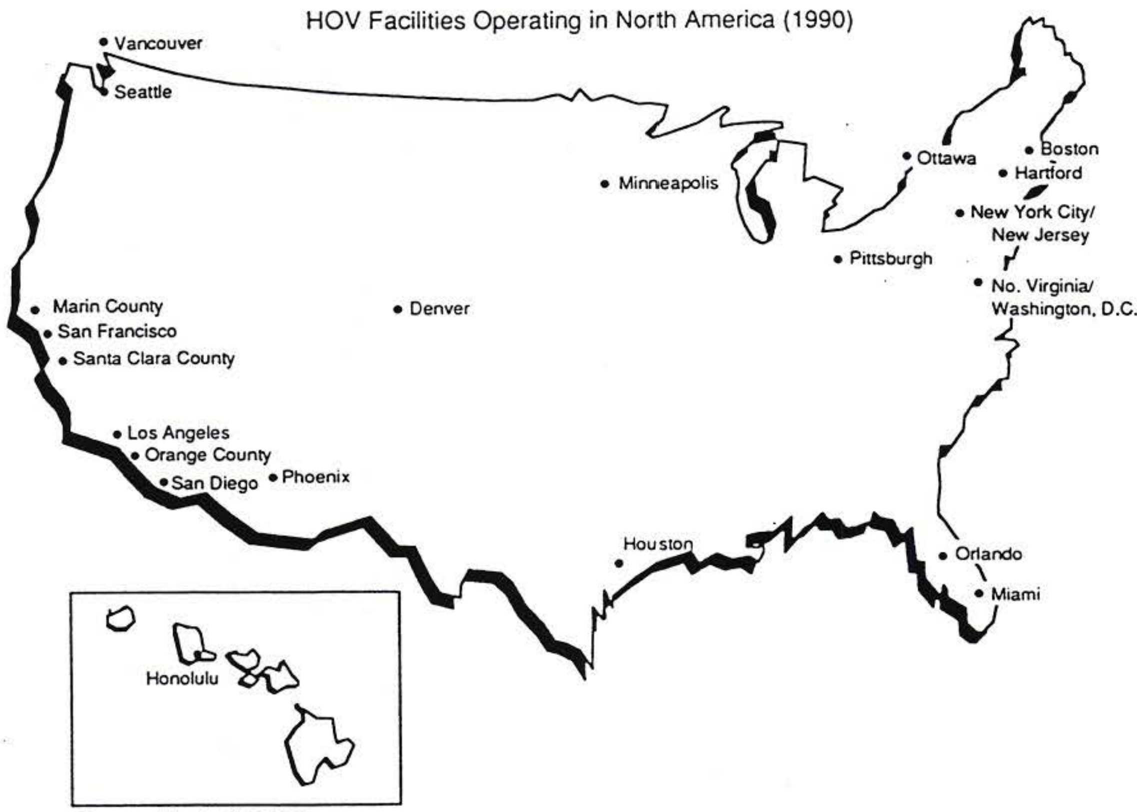


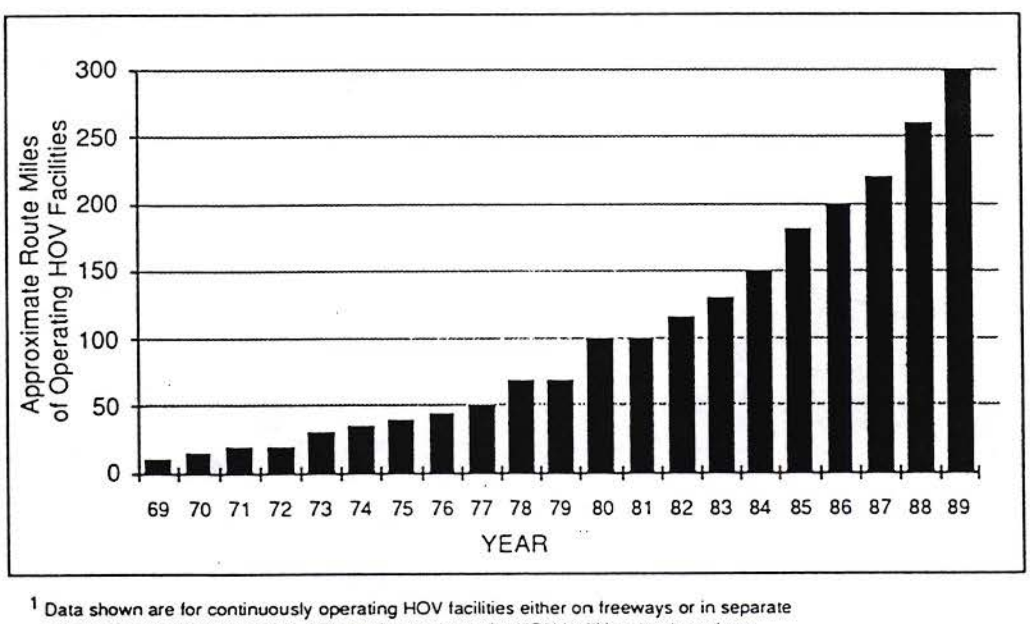
Photo: California DOT

Ramp meter bypass, California



Source: Turnbull 1990,3.

Miles of Operating HOV Facilities [1]



[1] Data shown are for continuously operating HOV facilities either on freeways or in separate rights-of-way in North America. Mileage is not shown for HOV facilities that have been discontinued.

Source: Turnbull 1990, 4.

Figure 7
HOV Facilities Operating in North America (1990)

Operational Characteristics of Various Transit Technologies

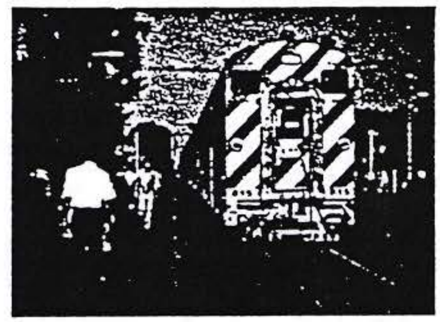
HOV facility in freeway right-of-way

- Limited access (typically no on-line stations)
- Long distance trips
- Satisfies directional or bidirectional demand (depending on type)
- Can serve all forms of HOVs — transit, vanpools, carpools
- Operating speed varies by user (express bus averages 65 to 90 KPH)

HOV facility in freeway right-of-way

Commuter rail

- Limited access (station spacing typically 6.5 or more miles apart)
- Long-distance trips
- Typically satisfies directional demand
- Can substitute for commuter bus and possibly other directional HOV modes, depending on trip destinations
- Operating speed averages 65 to 90 KPH



Commuter rail

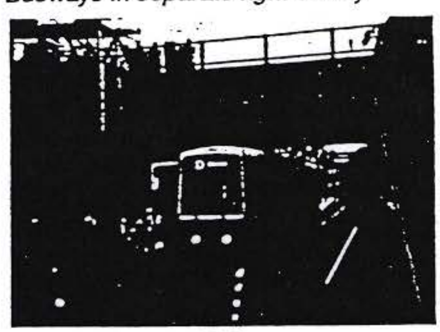
Busway in separate right -of-way

- Requires on-line stations
- Close station spacing (1.5 km or less)
- Intraurban trips (bidirectional demand)
- Replaces conventional bus routes on parallel city streets
- Operating speed averages 40 to 65 KPH

Busways in separate right-of-way

Light rail transit (LRT)

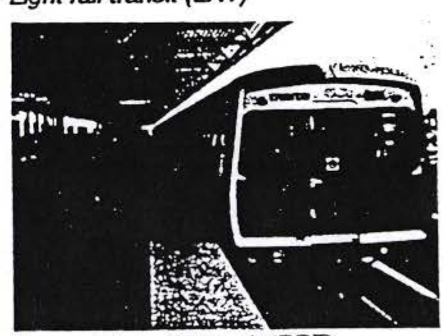
- Does not require separate right-of-way (can share street)
  Close station spacing (1.5 km or less)
- Intraurban trips (bidirectional demand)
- Replaces conventional bus routes on parallel city streets
- Operating speed averages 30 to 65 KPH



Light rail transit (LRT)

Heavy rail rapid transit (RRT)

- Requires separate right-of-way
- Station spacing usually close (1.5 km or less)
- Intraurban trips (bidirectional demand)
- Replaces conventional bus routes on parallel city streets
- Operating speed averages 40 to 65 KPH



Heavy rail rapid transit (RRT)

OPERATIONAL CHARACTERISTICS OF SELECTED FREEWAY/EXPRESSWAY HOV FACILITIES AS OF JUNE 1994

HOV Facility	Number of Lanes	Project Length (mi.)	HOV Operation Period	General Eligibility Requirements	Changes in Rules since Opening
Busway:					
Ottawa, Canada					
Southeast Transitway	1 each direction	3.0	24 hours[1]	Buses only	No
West Transitway	1 each direction	6.5	24 hours[1]	Buses only	No
Southwest Transitway	1 each direction	2.5	24 hours[1]	Buses only	No
Pittsburgh, PA					
East PatWay	1 each direction	6.2	24 hours[1]	Buses only	No
South PatWay	1 each direction	4.1	24 hours[1]	Buses only	No
Minneaplis, MN					
U of M intercampus busway	1 each direction	1.1	24 hours[1]	Buses only	No
Barrier-Separated: Two-Way					
Los Angeles, CA					
1-10 (El Monte)	1 each direction	4 (barriers) 8 (pylons)	24 hours[1]	3+ HOVs	Changed from buses only
I-105/I-110 ramps	Connections to I-105 East and West	1.0	24 hours[1]	2+ HOVs	No
I-10/I-710 ramps	1 each direction	1.5	24 hours[1]	3+ HOVs	Changed from buses only
Northern Virginia I-66	2-3 each direction	9.6	6:30-9am EB 4:00-6:30pm WB mixed-flow other times	3+ HOVs	Changed operation period
Seattle, WA I-90	1 each direction	1.5	24 hours	2+ HOVs	No
Barrier-Separated: Reversible-Flow					
Northern Virginia					
I-395 (Shirley)	2 (reversible)	11	6-9am NB, 3:30-6pm SB, mixed-flow other times	3+ HOVs	Changed from 4+
Houston, TX					
I-10 (Katy)	1 (reversible)	13.0	5am-12noon, 2-9pm 5am-9pm WB Sat. 5am-9pm EB Sun.	3+ peak hours, 2+ other times	Opened for authorized buses and vanpools, lowered and raised since
I-45 (Gulf)[3]	1 (reversible)	12.1[3]	5am-12noon, 2-9pm	2+ HOVs	No
US 290 (Northwest)	1 (reversible)	13.5	5am-12noon, 2-9pm	2+ HOVs	No
I-45 (North)	1 (reversible)	13.5	5am-12noon, 2-9pm	2+ HOVs	Changed operation periods, started with authorized buses and vanpools only
US 59 (Southwest)	1 (reversible)	11.5	5am-12noon, 2-9pm	2+ HOVs	No
San Diego, CA	2 (reversible)	8	6-9am, 3-6:30pm	2+ HOVs	No
Minneapolis, MN I-394	2 (reversible)	5	6-10am, 2-7pm	2+ HOVs	No
Pittsburgh, PA I-279/579	1 (reversible)	4.1	5am-noon, 2-8pm	2+ HOVs	Changed from 3+
Norfolk, VA I-64	2 (reversible)	8	5-8:30am WB 3-6pm EB mixed-flow other times	2+ HOVs	No
Seattle, WA					
I-5 North Express Lanes	2-3 (reversible) w/mixed-flow	2.6 SB 1.6 NB	5:00am-11:00am SB 12:00pm-4:00am NB	2+ HOVs	Changed from 3+ NB
I-90	2 (reversible)	6.2	24 hours	2+ HOVs	No
Concurrent-Flow: Buffer-Separated/Non-Separated					
Vancouver, BC, Canada					
H-99	1 each direction	4 SB 1 NB	24 hours	Buses only	No
Hartford, CT					
I-84	1 each direction	10	24 hours[1]	2+ HOVs	Changed from 3+
I-91	1 each direction	9	24 hours[1]	2+ HOVs	No

(Continued)

OPERATIONAL CHARACTERISTICS OF SELECTED FREEWAY/EXPRESSWAY HOV FACILITIES AS OF JUNE 1994

HOV Facility	Number of Lanes	Project Length (mi.)	HOV Operation Period	General Eligibility Requirements	Changes in Rules since Opening
Honolulu, HI					
Moanaloa Fwy.	1 each direction	2.4	6-8am, 3:30-6pm	2+ HOVs	No
Kalanianaole Hwy.	1 (WB only)	2.0	5-8:30am	2+ HOVs	No
H-1	1 each direction	8	6-8am, 3:30-6pm	2+ HOVs	No
Los Angeles, CA					
SR 91	1 each direction	8	24 hours[1]	2+ HOVs	No
I-405	1 each direction	9.4	24 hours[1]	2+ HOVs	No
I-105	1 each direction	16.0	24 hours[1]	2+ Hovs	No
I-210	1 each direction	18.5	24 hours[1]	2+ HOVs	No
Orange County, CA					
I-5	1 each direction	10	24 hours[1]	2+ HOVs	No
SR-55	1 each direction	11	24 hours[1]	2+ HOVs	No
I-405	1 each direction	24	24 hours[1]	2+ HOVs	No
SR-57	1 each direction	10	24 hours[1]	2+ HOVs	No
Riverside County, CA, Rte. 91	1 each direction	8	24 hours[1]	2+ HOVs	No
Santa Clara/San Mateo Counties, CA					
US 101	1 each direction	21	5-9am, 3-7pm	2+ HOVs	No
SR 237	1 each direction	6	5-9am, 3-7pm	2+ HOVs	No
SR 85	1 each direction	4	5-9am, 3-7pm	2+ HOVs	No
I-280	1 each direction	11	5-9am, 3-7pm	2+ HOVs	No
San Tomas Expy.	1 each direction	8	6-9am, 3-7pm	2+ HOVs	No
Montague Expy.	1 each direction	6	5-9am, 3-7pm	2+ HOVs	No
Alameda County, CA					
I-880	1 each direction	5	5-9am, 3-7pm	2+ HOVs	No
I-80	1 each direction	12	5-10am, 3-6pm	2+ HOVs	No
Contra Costa County, CA I-580	1 each direction	6.1	7-8am, 5-6pm	2+ HOVs	No
Marin County, CA					
US 101	1 each direction	13	6:30-8:30am 4:30-7:00pm	2+ HOVs	Changed from 3+
Phoenix, AZ					
I-10	1 each direction	19	24 hours[1]	2+ HOVs	Changed from 3+
SR-202	1 each direction	4	24 hours[1]	2+ HOVs	No
Miami, FL I-95	1 each direction	12	7-9am SB, 4-6pm NB	2+ HOVs	No
Ft. Lauderdale, FL I-95	1 each direction	27	7-9am, 4-6 pm	2+ HOVs	No
Orlando, FL I-4	1 each direction	30	7-9am SB, 4-6pm NB	2+ HOVs	No
Ottawa, Ontario, Canada					
Hwy 17	1 (WB shoulder only)	3	7-9am	Buses only	No
Rockville, MD					
I-270 (eastern connection)	1 each direction	2.5	Peak periods only	2+ HOVs	No
Boston, MA, I-93 North	1 (SB only)	1.07	6:30-9:30am	2+ HOVs	Changed from 3+
Minneapolis, MN, I-394	1 each direction	7	6-9am EB, 4-7pm WB	2+ HOVs	No
Morris County, NJ, I-80	1 each direction	11	Peak periods only	2+ HOVs	No
Nassau/Suffolk Counties, NY, I-495	1 each direction	10	Peak periods only	2+ HOVs	No
Nashville, TN, I-65	1 each direction	5.1	7-9am NB, 4-6pm SB	2+ HOVs	No
Northern Virginia					
I-95 (interim)[2]	1 each direction[2]	5[2]	6-9am, 3:30-6pm[2]	3+ HOVs	No
I-66	1 each direction	7	NA	2+ HOVs	No
Norfolk/Virginia Beach, VA					
I-564	1 (EB only)	2	3-6pm EB	2+ HOVs	No
SR 44 (right shoulder)	1 each direction	4	5-8:30am WB 3-6pm EB	2+ HOVs	No
I-64	1 each direction	5	Peak periods only	2+ HOVs	No
Seattle, WA					
I-5 North of CBD	1 each direction	7.4 SB, 4.3 NB	24 hours[1]	2+ HOVs	Changed from 3+ NB&SB
I-90	1 (WB only)	7.3	24 hours[1]	2+ HOVs	G.P. lane conversion

(Continued)

OPERATIONAL CHARACTERISTICS OF SELECTED FREEWAY/EXPRESSWAY HOV FACILITIES AS OF JUNE 1994

HOV Facility	Number of Lanes	Project Length (mi.)	HOV Operation Period	General Eligibility Requirements	Changes in Rules since Opening
I-5 South of CBD	1 each direction	10.0 SB 10.6 NB	24 hours[1]	2+ HOVs	Changed from 3+ NB&SB
I-405	1 each direction	8.1 SB 8.6 NB	24 hours[1]	2+ HOVs	No
SR 167	1 (NB only)	1.1	24 hours[1]	2+ HOVs	No
SR 520	1 (WB shoulder only)	2.3	24 hours[1]	3+ HOVs	Changed from bus-only in AM peak period
Contraflow					
Honolulu, HI,					
Kalanianaole Hwy.	1 1	4.4 WB 1.0 EB	5-8:30am 4-6:30pm	2+ HOVs	Changed from 3+
Kahekili Hwy.	1 each direction	1.1	5:30-8:30am 3:30-7pm	2+ HOVs	No
Northern New Jersey					
Rte. 495 (Lincoln Tunnel)	1	2.5	6-10am EB	Buses only	No
New York					
Long Island Expy.	1	4	7-10am WB	Buses, vanpools, taxis	No
Dallas, TX	1 each direction	5.2WB, 3.3EB	6-9am, 4-7pm	2+ HOVs	Changed from 3+, extended AM period
Montreal, Quebec, Canada					
Champlain Bridge Rt. 10, 15, 20	1	4.3	6:30-9:30am NB 3:30-7pm SB	Buses only	Speed limit reduced
Queue Bypasses					
Bay Area, CA					
Bay Bridge Toll Plaza, I-80	3 (WB only)	0.9	6-9am, 3-6pm	3+ HOVs	No
Dumbarton Bridge Toll Plaza, Rte. 84	1 (WB only)	2	Peak periods	2+ HOVs	Changed from 3+
San Mateo Bridge, SR-92	1 each approach	1	Peak periods	3+ HOVs	No
Various entry ramps	1	0.1	When demand warrants	2+ HOVs	No
Los Angeles and Orange Counties, CA					
Over 250 entry ramps	1	0.1	When demand warrants	2+ HOVs	No
SR-14 Emergency bypass	1 (SB only)	5	24 hours	2+ HOVs	No
San Diego, CA					
Various entry ramps	1	0.1	When demand warrants	2+ HOVs	No
Denver, CO					
U.S. 36, Boulder Turnpike	1 (EB only)	4.1	6-9am	Buses only	No
Honolulu, HI, H-2	1 (SB only)	0.8	6-8am, 3:30-6pm	2+ HOVs	No
Minneapolis, MN					
Various entry ramps	1	0.2	Peak periods	2+ HOVs	No
Ft. Lee, NJ (New York City), I-95	1 (EB only)	1	7-9am	3+ HOVs	No
Northern New Jersey					
Rte. 495 (Lincoln Tunnel)	1	0.3	6-10am	Buses only	No
Seattle, WA					
SR 509	1 (NB shoulder only)	0.8	24 hours[1]	2+ HOVs	Changed from 3+
SR 526	1	0.5	Buses only	24 hours	No
Various entry ramps[4]	1	0.1	24 hours	2+ HOVs	No
Ferry terminal docks	1	0.1	24 hours	Registered carpools only	No

[1] 7-day week; all others are 5-day week
[2] Interim operation
[3] Includes 5-mile extension opened on March 14, 1994
[4] Included are 23 metered ramps and 20 non-metered ramps

LISTING OF PROPOSED MAJOR FREEWAY/EXPRESSWAY HOV FACILITIES AS OF JUNE 1994 (Listed by State/Province)

	Project Length (mi.)	Lane-miles	Anticipated Opening
Arizona, Phoenix			
Route Loop 202 (East Papago Freeway)	9	18	1992
I-10, extensions to concurrent-flow,buffer-separated lanes	8	16	1992-95
British Columbia, Vancouver, CANADA			
H-7 (Barnet Highway), concurrent-flow lanes	6	NA	1993
Trans Canada Highway, concurrent-flow lanes	12	NA	Late 1990s
California, Bay Area			
US 101 (San Jose), extension to concurrent-flow lanes	7	14	1993
I-80/580, concurrent-flow lanes	NA	NA	Late 1990s
I-80 (Contra Costa), concurrent-flow lanes	35.2	70	Staged thru 1998
US 101 (Marin), extension to concurrent-flow lanes	3	6	Late 1990s
I-880 (Alameda) concurrent-flow lanes	NA	NA	Late 1990s
SR-4 (Contra Costa), queue bypass	0.5	0.5	1993
I-880 (Santa Clara), concurrent flow-lanes	10	20	Late 1990s
SR-237 (Santa Clara), concurrent-flow lanes	15	30	Mid-1990s
SR-85 (Santa Clara), concurrent-flow lanes	16	32	1994
SR-101 (Santa Rosa), concurrent-flow lanes	3	6	Late 1990s
California, Los Angeles			
I-10 (San Bernardino), extension to concurrent-flow lanes	20.2	41	1999-2022
I-10 (Santa Monica), concurrent-flow lanes	9.3	18.6	2020
I-110 (Harbor), transitway and ramps	14	41	1995-2011
I-710 (Long Beach), concurrent-flow lanes	23	46	2006-2024
I-405, concurrent-flow lanes	49	98	1993-2002
I-605, concurrent flow lanes	20	40	1996-1997
I-5, concurrent-flow lanes	45.6	91.2	Staged 1999-2018
SR-2, concurrent-flow lanes	4.6	9.2	2004
SR-14, concurrent-flow lanes	36	72	1997-2002
SR-30, concurrent-flow lanes	8.3	16.6	1997-1999
SR-60, concurrent-flow lanes	30	60	Staged 1996-2006
SR-91, westbound concurrent-flow lane	14	18	1994
US 101, concurrent-flow lanes	37	74	2009-2024
SR-118, concurrent-flow lanes	11.4	22.8	1996
SR-134, concurrent-flow lanes	13	26	1995
SR-170, concurrent-flow lanes	6.1	12.2	1995
California, Orange County			
I-5, concurrent-flow lanes	36	72	1995-99
I-5, barrier-separated lanes	3.3	12	1996
Routes 55/405, 57/91 and 55/91, HOV interchanges	6	13	Mid/Late 1990s
SR-91, concurrent-flow lanes	19	38	1994
California, San Bernardino County			
I-10, concurrent-flow lanes	10	20	1999
SR-60, concurrent-flow lanes	10	20	1996
SR-71, concurrent-flow lanes	8	17	Mid/Late 1990s
SR-30, concurrent-flow lanes	22	44	Late 1990s
I-215, concurrent-flow lanes	4	8	
California, Riverside County			
SR-60, concurrent-flow lanes	20	39	Planning studies
SR-91, concurrent-flow lanes	11	21	Planning studies
I-215, concurrent-flow lanes	7	15	Planning studies
California, Sacramento			
Route 99, concurrent-flow lanes	11	22	1993
California, San Diego			
I-5, concurrent-flow lanes	21	42	Late 1990s
I-15, concurrent-flow lanes	12	24	Late 1990s

LISTING OF PROPOSED MAJOR FREEWAY/EXPRESSWAY HOV FACILITIES AS OF JUNE 1994 (Listed by State/Province)

	Project Length (mi.)	Lane-miles	Anticipated Opening
Colorado, Denver			
I-25, reversible-flow lanes and ramps	12	18	1995
Connecticut, Hartford			
I-84, WB concurrent-flow lane	1.5	1.5	1996-98
Florida, Ft. Lauderdale			
I-95, concurrent-flow lanes	29	58	Beyond 2000
Georgia, Atlanta			
HOV lane conversions on I-85, I-75	58	116	1995-1996
Illinois, Chicago			
I-55 (Stevenson Expy.) concurrent-flow lanes and ramps	13	26	1998-1999
Maryland			
I-270, concurrent-flow lanes	12+	24+	Mid/Late 1990s
SR-141, concurrent-flow lanes	NA	NA	Late 1990s
Massachusetts, Boston			
I-93 south, contraflow lane	6	12	1995
I-93 north, concurrent-flow lanes (extension)	1	1	1994
SR 3 south, concurrent-flow lanes	3	3	Late 1990s
I-93, reversible flow lane	8	8	2004
I-93 (Central Artery) concurrent-flow lanes	4-5	4.5	2004
Minnesota, Minneapolis			
I-35W, concurrent-flow lanes	17	35	1994-1996
I-94, concurrent-flow lanes	35	70	Late 1990s
New York			
I-495 (Long Island Expressway) concurrent-flow lanes	13	26	1995-99
I-287 (Cross Westchester Expressway) reversible-flow lane	5	10	Mid-1990s
Gowanus Expressway, concurrent-flow lanes	5	10	Mid-1990s
New Jersey, Morris County			
I-287, queue bypasses, concurrent-flow lanes	21	42	staged 1996-1998
North Carolina, Charlotte			
US 74, reversible-flow lane	3.3	3.3	1998
Ontario, Toronto area, CANADA			
H-403 concurrent-flow lanes (outside)	1	2	Mid-1990s
H-403 concurrent-flow lanes (median)	5	10	Late 1990s
H-401, H-404, H-427 concurrent-flow lanes	Varies	Varies	Late 1990s
Ontario, Ottawa, CANADA			
Extensions to busway system	5+	10+	Staged thru 2000
Concurrent-flow freeway bus lanes	NA	NA	Mid-1990s
Pennsylvania, Pittsburgh			
Airport Busway	8	16	Mid-1990s
Pennsylvania, Philadelphia			
I-95, reversible-flow lanes	13	26	Beyond 2000
Texas, Dallas			
I-635, concurrent-flow lanes	7	13	1995
I-35E, concurrent-flow lanes	8	15	Late 1990s
I-35E, US 67, contraflow lane, reversible ramps	8	12	Mid-1990s
I-30, contraflow lanes	3	6	Late 1990s
Texas, Houston			

(Continued)

LISTING OF PROPOSED MAJOR FREEWAY/EXPRESSWAY HOV FACILITIES AS OF JUNE 1994 (Listed by State/Province)

	Project Length (mi.)	Lane-miles	Anticipated Opening
US 59 (Southwest), reversible-flow lane	2	2	1996
US 59 (Eastex), reversible-flow lane and ramps	20	20	Staged 1995-2000
I-45 (North), extension to reversible-flow lane	6.2	6.2	Late 1990s
I-45 (Gulf), extension to reversible-flow lane	4	4	Mid-1990s
<u>Virginia, Norfolk/Virginia Beach</u>			
I-64, reversible-flow lanes	10	20	Mid-1990s
I-264, concurrent-flow lanes	4	8	1996
Route 44, concurrent-flow lanes	10	20	Mid-1990s
<u>Virginia, Washington D.C. Area</u>			
I-95, extension to reversible-flow lanes	19	38	Mid-1990s
I-66, concurrent-flow lanes	7.5	15	Mid-1990s
I-95/495 Capitol Beltway	20	40	1998 thru 2010
<u>Washington, Seattle/Tacoma/Everett</u>			
I-405, extensions to concurrent-flow lanes	22	44	Staged thru 2000
I-5 south, extensions to concurrent-flow lanes	22	40	Staged thru 2000
I-5 north, extensions to concurrent-flow lanes	13	22	Staged thru 2000
I-90, concurrent-flow lanes[1]	7	7	1994
SR-520, concurrent-flow lanes	6	12	Staged thru 2000
SR-525, concurrent-flow lanes	3	6	Staged thru 2000
SR-167, extensions to concurrent-flow lanes	13	26	1996
SR-16, concurrent-flow lanes	15	30	Staged thru 2000
SR-526	1	1	2000

1 Four and a half miles of lane conversion opened WB. Remainder of project may also be converted lanes for the EB direction.

SESSION 2: PLANNING CONSIDERATIONS

TYPICAL PLANNING STEPS

STEP 1

- Does HOV make sense ?
- Are there other TDM/TSM measures that also make sense ?

↓ YES

STEP 2

- What HOV operation alternatives could address the problem(s) ?
  - Two-Way (Concurrent flow)
  - Reversible flow
  - Contraflow
  - Queue bypasses
- What design alternatives ?
  - Barriers
  - Buffer-separations
  - No physical separations

↓ BEST COMBINATIONS

STEP 3

TYPICAL PLANNING STEPS

STEP 3

- What is the feasibility of identified alternatives ?
  - Public/agency support
  - Physical impacts
  - Enforceability
  - Incident management/safety
  - Environment
  - Market/technology compatibility
  - Cost effectiveness/funding practicality

- Access alternatives ?
  - At-grade with adjacent lanes
  - Grade-separated ramps

- What supporting needs for incident management, enforcement and collection/distribution ?
  - Shoulders
  - Dedicated enforcement areas
  - Park & ride lots, etc.

SHORTLIST TO RECOMMENDED ALTERNATIVES

↓

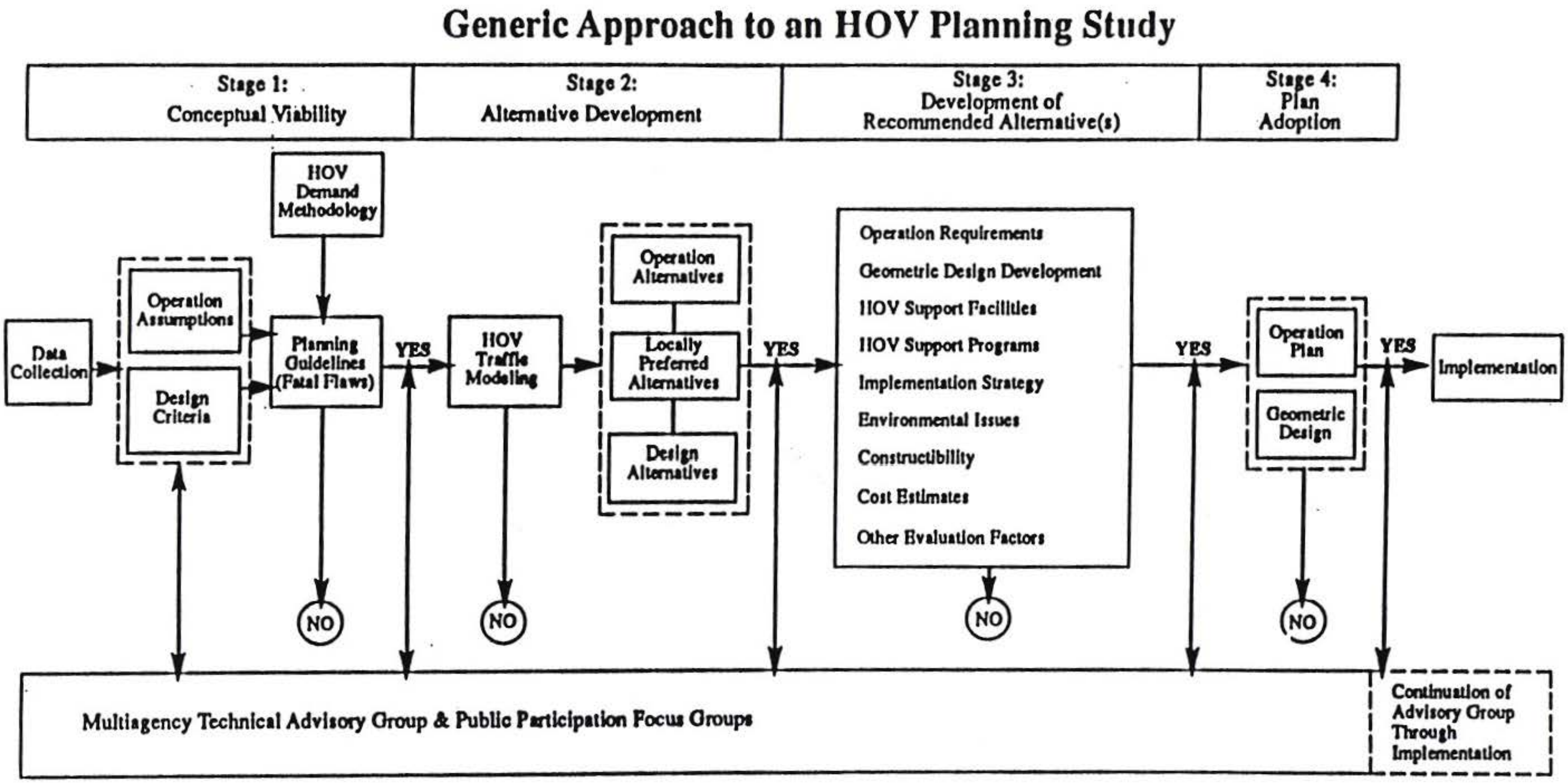
STEP 4

- Build consensus

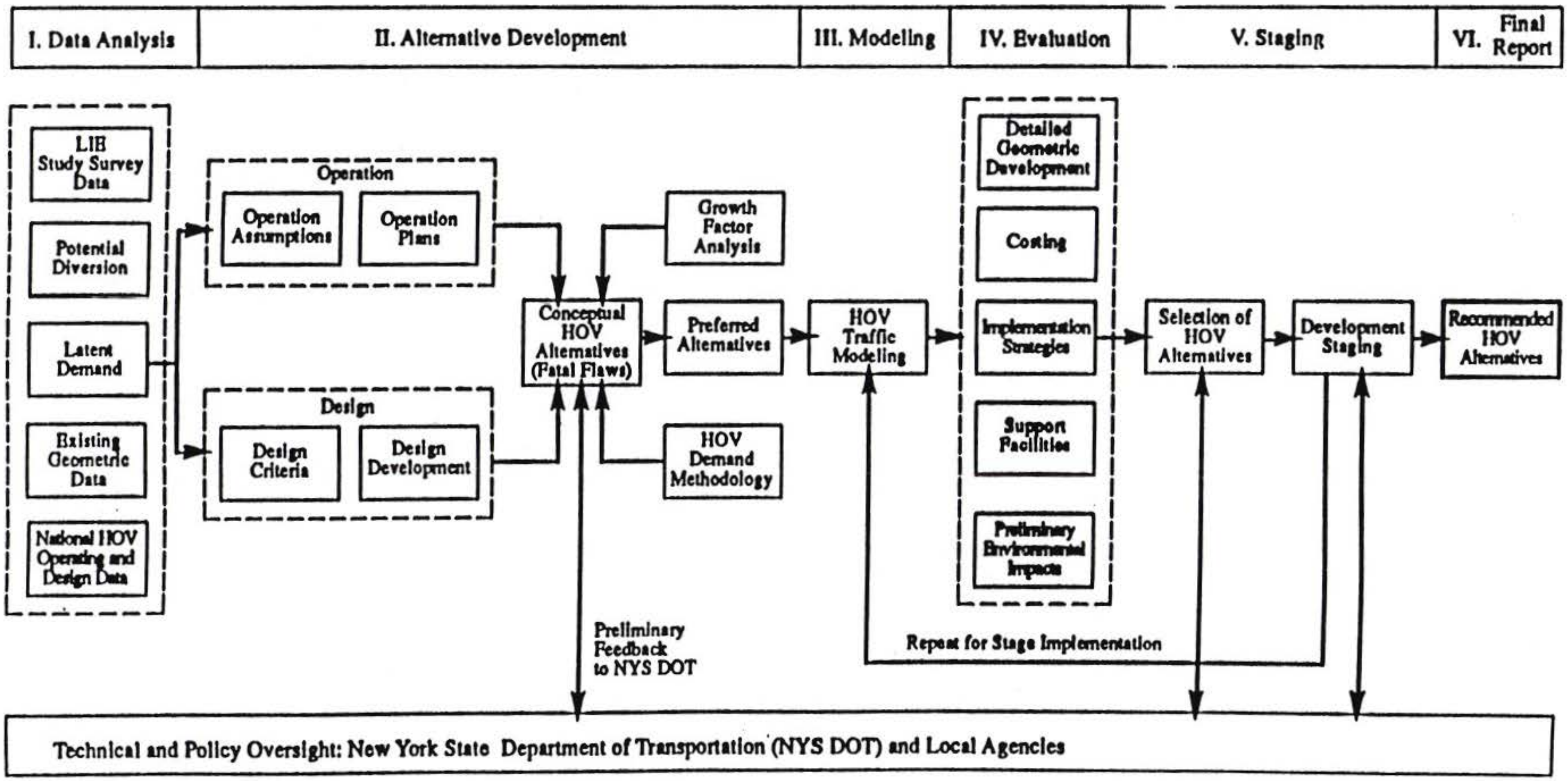
- Adopt an HOV plan

- Identify a process for reassessing plan

Generic Approach to an HOV Planning Study



Sample Planning Process for Long Island Expressway HOV Evaluation



Determining Conceptual Viability

The purpose of conceptual viability is to determine, at the earliest appropriate opportunity in a study process, if any HOV concepts make sense now or in the future.

Determination may be made by:

- Cursory investigation of existing and forecast traffic conditions
- Public attitudes/agency attitudes
- Affinities for transit and ridesharing
- Testing selected criteria with "rules of thumb," based on experiences elsewhere

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.

ELEMENTS OF AN HOV POLICY

(Not Corridor or Project Specific)

PURPOSE AND ROLE OF HOV TREATMENT
- (i.e. markets served, criteria for consideration, relation to other TSM/TDM measures)

ROLES OF VARIOUS AGENCIES

FUNDING AND IMPLEMENTATION RESPONSIBILITIES

REGIONAL PLAN
- criteria for funding and implementing plan
- setting priorities

OPERATION
- criteria for elegility
- criteria for operation periods
- enforcement
- incident management
- maintenance

DESIGN
- standards
- interim design policies
- staging

METHODS FOR UPDATING THE HOV POLICY

WSDOT Committee Structure and Responsibility

HCT/HOV Policy Board

- Identify major HCT/HOV issues and assign to Policy Task Force *(or Issues Team)* for development of recommended resolution.
- Decree final decisions as they relate to policy and aspects of the state-owned portion of the HOV and future HCT systems, and initiate program implementation or change.
- Resolve funding and use of resource differences regarding WSDOT HOV and HCT programs.
- Create ad hoc Issue Teams and assign tasks for study (if needed).

Policy Board Members:
Ed Ferguson, chair
Stan Moon
Jim Toohey
Ron Anderson
Gary Demich
Randall Hain
Barry Morehead, FHWA

HOV/HCT Policy Task Force

At the pleasure of the Policy Board:

- Work HOV/HCT issues as assigned by Policy Board.
- Develop "white papers," recommending WSDOT actions and positions on these HOV and HCT issues.
- Serve as an advisory board; functioning between Policy Board, Issue Teams and others studying the issues.

Policy Task Force Members:
Jim Slakey, chair
Kieth Ahola
Bob Aye
Skip Burch
Chuck Chappell, FHWA
King Cushman, PSRC
Miguel Gavino
Paula Hammond
Bob Huss, WSP
Jim Jacobson, Metro
Jerry Lenzi
Bill Mac Cully, CT
Don Nelson
Tim Payne, PT
Dave Peach
Toby Rickman
Leslie Salisbury
Ed Switaj, SED
Helga Morgenstern

Policy Task Force Support Staff:
Jerry Ayres, principal
Lois Anderson
Rob Fellows
Kim Henry
Les Jacobson
Ron Kuchenreuther, Metro
Greg Lippincott
John McLaughlin

ad hoc HCT/HOV Issue Teams

- Teams assigned to address specific tasks.
- Examples include:
  - HOV Issues Group (Core Lane Acceleration Committee)
  - I-5 North HOV 2+ Demonstration Steering Committee
  - Design Manual Revision Task Force
  - WSDOT Technical Review Team for HCT Planning
  - HOV Core Lane 2000 Financing Committee

updated 9/30/92

Support

- Local Agencies
- Users and Non-Users
- General Public
- Media
- Politicians

HOV Conceptual Viability Worksheet

Guidelines			
Number	Criteria	Met	Not Met
Primary Guidelines			
1	Congestion	☐	☐
2	Travel Time Savings	☐	☐
3	Person Throughput	☐	☐
4	Vehicle Throughput (minimum)	☐	☐
5	Capacity Improvement	☐	☐
6	Local Agency/ Public Support	☐	☐
7	Enforceability	☐	☐
8	Cost Effectiveness	☐	☐
9	Physical Roadway Characteristics	☐	☐
Secondary Guidelines			
10	Support Facilities	☐	☐
11	Bottleneck Bypass *	☐	☐
12	Safety	☐	☐
13	System Development *	☐	☐
14	Staging Improvements	☐	☐
15	Environmental Enhancement	☐	☐
16	Technology Compatibility *	☐	☐

DATA COLLECTION

Freeway Applications

Mainline Pk Hour Volumes
Average Vehicle Occupancy
Average Travel Time
Existing Geometrics
Bus Usage
Average Section Speeds

Arterial Applications

Pk Hour Intersection Counts
Average Vehicle Occupancy
Average Intersection Delay
Existing Geometrics
Bus Usage
Signal Timing

Analysis Tools

- DEMAND ESTIMATION
  - Standard Modelling Packages (e.g. EMME/2)
    Apply mode split model to trip table and assign to network
    Poor estimation of mode shift
  - CRA Model
    Workbook Procedures
    Spreadsheet formulation
    Good estimation of mode shift within 1 year of opening
- COST EFFECTIVENESS
  - Cy Ulberg Model
    Fortran, See TRR 1181.

2.1 TITLE: Predicting HOV Facility Demand

2.2 PROBLEM: It is widely accepted that HOV ridership is a function of travel time savings over travel on congested roadways. However, predicting the ridership on HOV facilities, especially on a 20 year horizon, is less widely understood. For instance, clean air laws have prompted legislation that requires employers to promote transportation demand management programs. The likely spread of these programs and their effects is just beginning to be understood. In addition, marketing studies could improve our knowledge of mode choice decisions made in the presence of HOV lanes. For instance, previous research has shown that people make transportation decisions based on their perceived travel times. The differences between perceived and actual travel times can mean that models wrongly predict mode shift and HOV lane usage. In addition, knowledge about the differences would be useful in marketing HOV lanes. More information is needed on the correlation between ridership demand and travel time savings (real and perceived) as well as other contributing factors. Impacts of different occupancy requirements on HOV ridership are also required.

2.3 OBJECTIVE: Develop and evaluate methods to predict carpool and bus ridership on HOV facilities with sensitivity to general-purpose lane capacity, HOV occupancy requirements, peak period freeway congestion, transportation demand management programs, and better understanding of mode choice through market research.

2.4 KEY WORDS: HOV demand, HOV facility planning, transit ridership, mode choice modeling, transportation demand management, market research

2.5 RELATED WORK: Many planning models include some mode choice routine for predicting carpool and transit ridership. A few deal specifically with the impact of HOV lanes. The 1982 model developed by Charles Rivers Associates is in common use. There have been several studies of transportation demand management programs and their impact on mode choice, but little direct connection to HOV facilities.

2.6 URGENCY/PRIORITY: High. With the heightened emphasis on HOV lanes in the ISTEA legislation and Clean Air Act Amendments, inclusion of HOV lanes in regional transportation plans will only increase. More reliable methods of predicting HOV ridership must be developed to aid in successful projects being selected for future construction.

2.7 COSTS: $250,000

2.8 USER COMMUNITY: FHWA, FTA, state and local transportation departments, consultants, transportation researchers

2.9 IMPLEMENTATION: Results of the research would be widely disseminated for integration into research and planning efforts.

2.10 EFFECTIVENESS: Improved HOV ridership predictions would aid in the determination of successful projects which in turn would result in more projects beings implemented with greater utilization and impact on urban mobility.

Workšheet for "Predicting Travel Volumes for HOV Priority Treatments"

Based on Charles River Associates, April, 1982 Report

SAMPLE WORKSHEET

Worksheet #1
Initial/Before Data

V-o-npa	7275
V-o-pa	175
V-o-hov	0
B-o-peb	16
B-o-hov	0
V-o-b	1500
L-o-b	50
V-o-T	0
T-o-npa	28.5
T-o-pa	28.5
T-o-hov	
T-o-b	28.5
S-o-gp	8
S-o-c	
S-o-b	
L-o-gp	3
L-o-hov	0
C-o-gp	6000
C-o-hov	0

Worksheet #2
HOV Policy

Defn	3
HOV Lgth	1.8
L-1-gp	3
L-1-hov	1
C-1-gp	6000
C-1-hov	1500
B-1-hov	16
t-0-npa	13.5
t-0-pa	13.5
t-o-b	13.5
t-off-npa	15.0
t-off-pa	15.0
t-off-b	15.0

Worksheet #3
Travel Times

	T-1-b	
	Est Spd	50
	T-1-b	17.2
	T-1-pa	
	Est Spd	50
	T-1-pa	17.2
ForcdFlo	T-1-npa	28.5
FreeFlo	S-1-gp	2.2
	adjstd	12.0
	T-1-npa	24.0

ChooseForcdFlo(G31)orFreeFlo(G34)

T-1-npa	28.5
S-1-gp	8
EFCTR	1.03

Worksheet #4
NPA Volume

DLTA-npa	-0.099
V-1-npa	6554

If ForcdFlo Goto Wksht 5

Check v/c 1.092
If >1,Redo from F36
w. ForcdFlo

Chk S1gp 12.6

If about 12
Goto 5, If not redo
from G33 or G36

Worksheet #5
Priority Auto Volume

DLTA-pa	0.951
V-1-pa	341

Check v/c 0.238
If >.8 reduce speed to
60 and repeat

Worksheet #6: Bus Volume

DLTA-b	0.054
V-1-b	1581
B-1-hov	32

Worksheet #7
Summary Results

1. Volumes (Peak Hour)

Carpools on HOV Lane	341
Buses on HOV Lane	32

2. Total Travel Time on Highway (min)

Autos, Nonpriority	13.5
HOV Lane	2.2

3. Speeds (mph)

Genl Purpose Lanes	8.0
HOV Lane	50

Variable Definitions

---------------------- * = Calculated by spreadsheet

1. Baseline (Initial/Before) Data

Peak Hour Volumes:

V-o-npa	Autos, nonpriority, vph
V-o-pa	Autos, priority eligible, vph
V-o-hov	Carpools on existing HOV Lane, vph
B-o-peb	Buses, priority eligible, bph
B-o-hov	Buses on existing HOV Lane, bph
V-o-b	Bus Passengers per hour, pph
L-o-b	Bus Load Factor, ppb
V-o-T	Trucks, vph

Total Ave Travel Time, door to door, peak hour:

T-o-npa	Autos, nonpriority, min.
T-o-pa	Autos, priority eligible, min.
T-o-hov	Carpools on existing HOV lane, min.
T-o-b	Buses, min.

Speeds, average peak hour:

S-o-gp	Gen'l purpose lanes, mph
S-o-c	Existing HOV lane, carpools, mph
S-o-b	Existing HOV lanes, buses, mph

Existing supply/capacity:

L-o-gp	Number of gen'l purpose lanes
L-o-hov	Number of HOV lanes
C-o-gp	Capacity, gen'l purpose lanes, vph
C-o-hov	Capacity, HOV lanes, vph

2. HOV Policy and Initial Calculations

Defn	Proposed carpool definition (people/veh)
HOV Lgth	Length of proposed HOV lane

Proposed supply/capacity:

L-1-gp	Number of gen'l purpose lanes
L-1-hov	Number of HOV lanes
C-1-gp	Capacity of gen'l purpose lanes,vph
C-1-hov	Capacity of HOV lanes, vph
B-1-hov	Buses/hr if exogenously determined

Existing Travel Times over hwy bounded by HOV lanes:

t-o-npa	* Autos, nonpriority, min.
t-o-pa	* Autos, priority eligible, min.
t-o-b	* Buses, min.

Existing Travel Times off hwy bounded by HOV lanes:

t-off-npa	* Autos, nonpriority, min.
t-off-pa	* Autos, priority eligible, min.
t-off-b	* Buses, min.

3. Travel Time Estimates for forecast period

Buses and autos on or eligible to use HOV lanes:

T-1-b	* Buses, min.
T-1-pa	* Autos (carpools), min.
Est Spd	Suggests 50 mph in absense of better data

Autos on general purpose lanes:

T-1-npa	* Autos, nonpriority, min.
S-1-gp	* Speed in gen'l purpose lanes
EFCTR	* "Eligibility Factor"

4. Forecast of Nonpriority auto volume

DLTA-npa	* Parameter calculated by spreadsheet
V-1-npa	* Nonpriority auto forecast, vph

5. Forecast of Priority Auto volume

DLTA-pa	* Parameter calculated by spreadsheet
V-1-pa	* Priority auto volume in HOV lane (= carpools in HOV lane when L-o-hov=0)

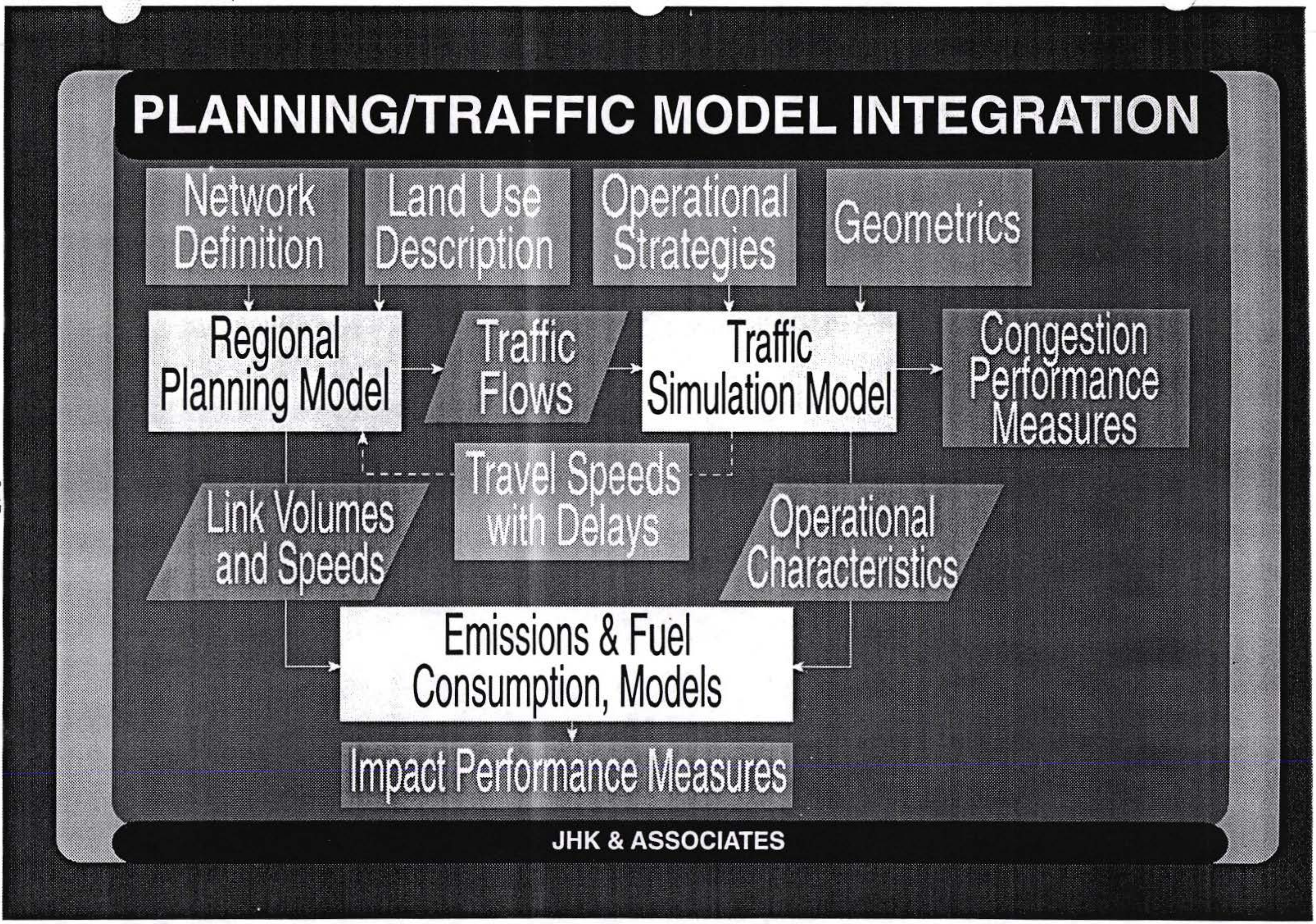
6. Forecast of Bus Volume

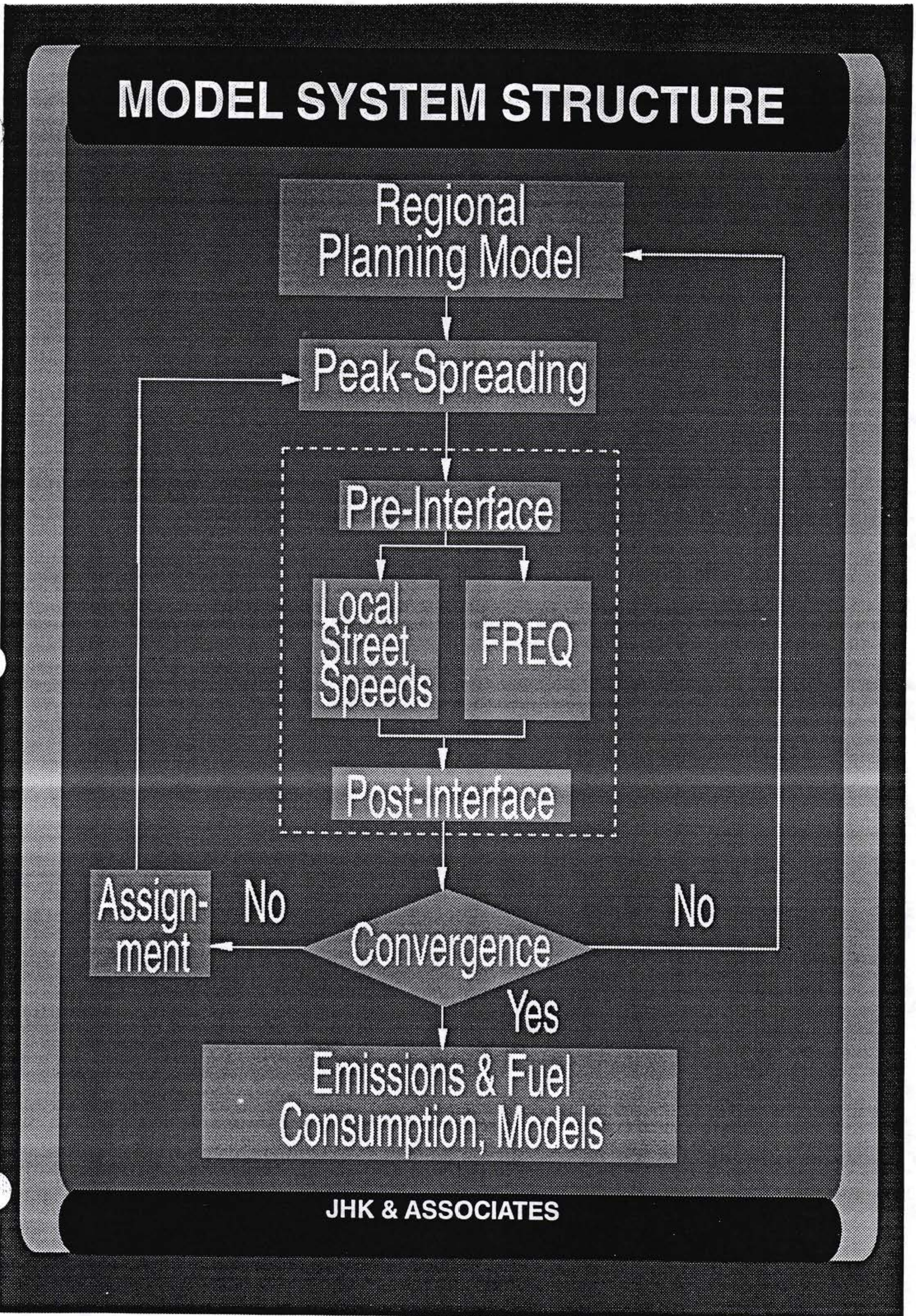
DLTA-b	* Parameter calculated by worksheet
V-1-b	* Number of bus riders
B-1-hov	* Number of buses in HOV lane

I-880 DEMONSTRATION CORRIDOR
HOV % Comparison
AM Peak Hour

Location	Dir	Field Study Source	Field Study Date	Field Study % HOV	Planning Model % HOV	Difference
I-880 @ Farnsworth	NB	jhk/880	1992	14.0	11.6	-2.4
SR 238 (E of I-880)	WB	jhk/880	1992	10.3	12.6	2.3
SR 238 (E of I-880)	EB	jhk/880	1992	7.3	11.6	4.3
I-880 (from SR 92 to SR 238)	NB	Caltrans	1992	12.0	11.8	-0.2
		Caltrans	1992	12.1		
		jhk/880	1992	14.7		
I-880 (from SR 238 to SR 92)	SB	jhk/880	1992	12.1	12.7	0.6
		Caltrans	1992	9.9		
SR 92 (W of I-880)	WB	jhk/880	1992	11.3	12.6	1.3
		Caltrans	1992	18.2		
SR 92 (W of I-880)	EB	jhk/880	1992	12.0	10.3	-1.7
SR 84 (W of I-880)	WB	Caltrans	1992	16.2	22.8	6.6
		jhk/880	1992	14.6		
SR 84 (W of I-880)	EB	jhk/880	1992	15.0	13.2	-1.8
I-880 @ Paseo Padre Pkwy	NB	jhk/880	1992	13.2	12.2	-1.0
I-880 @ Paseo Padre Pkwy	SB	jhk/880	1992	13.7	13.3	-0.4

(#20026/Table122.wk3)


PLANNING/TRAFFIC MODEL INTEGRATION
Network Definition
Land Use Description
Operational Strategies
Geometrics
Regional Planning Model
Traffic Flows
Traffic Simulation Model
Congestion Performance Measures
Travel Speeds with Delays
Link Volumes and Speeds
Operational Characteristics
Emissions & Fuel Consumption, Models
Impact Performance Measures
JHK & ASSOCIATES


MODEL SYSTEM STRUCTURE
Regional Planning Model
Peak-Spreading
Pre-Interface
Local Street Speeds
FREQ
Post-Interface
Assign-ment
No
Convergence
No
Yes
Emissions & Fuel Consumption, Models
JHK & ASSOCIATES

EXPERIMENTAL DESIGN

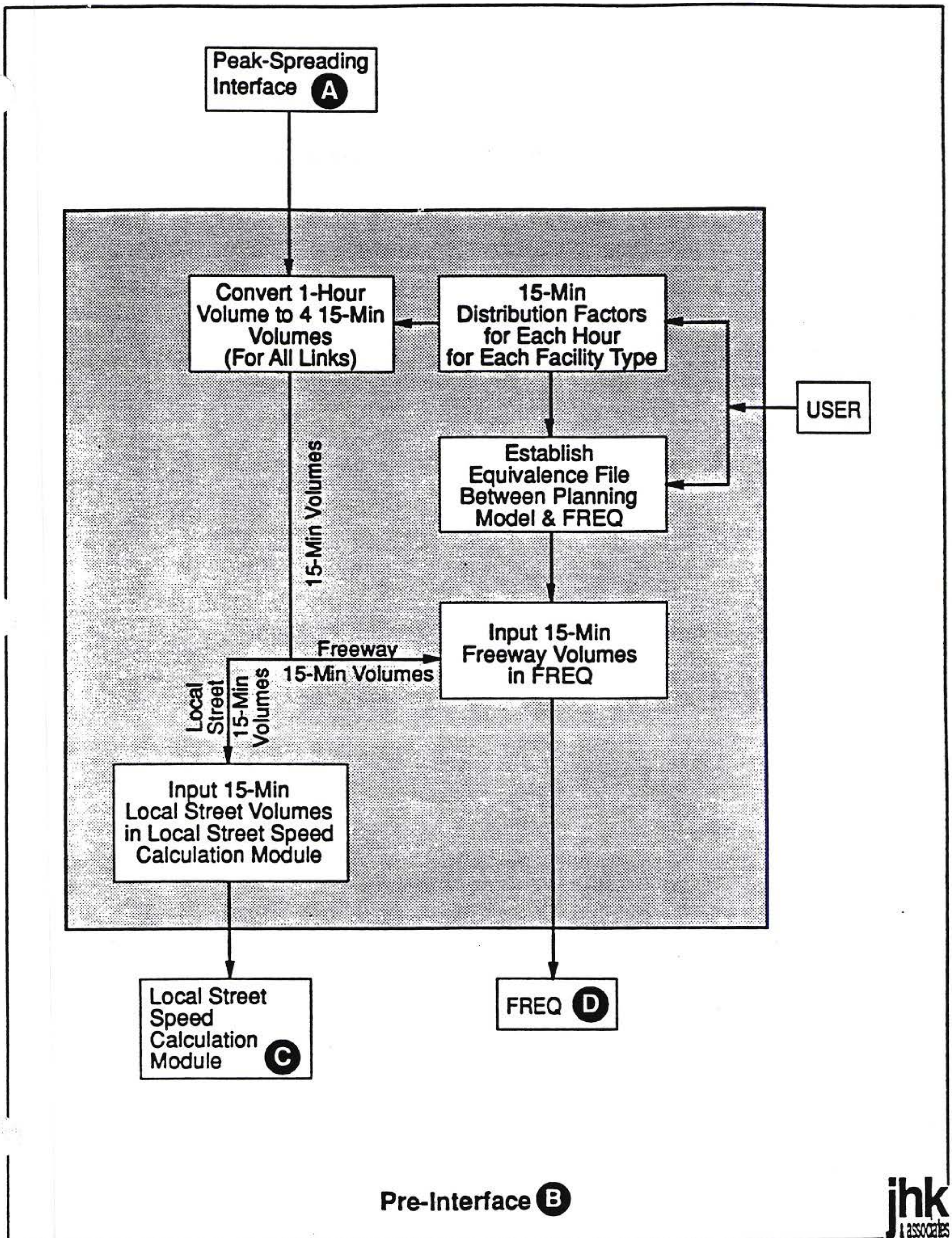
MOE	FACILITY TYPE	BASELINE	BASELINE W/ HOV LANE	BASELINE W/ HOV LANE & RAMP METERING
VMT	Freeway	0%	6%	12%
	Parallel Arterial	0%	-7%	-12%
	Area Total	0%	-5%	-4%
SPEED	Freeway	0%	0%	17%
	Parallel Arterial	0%	9%	16%
	Area Total	0%	25%	52%

JHK & ASSOCIATES

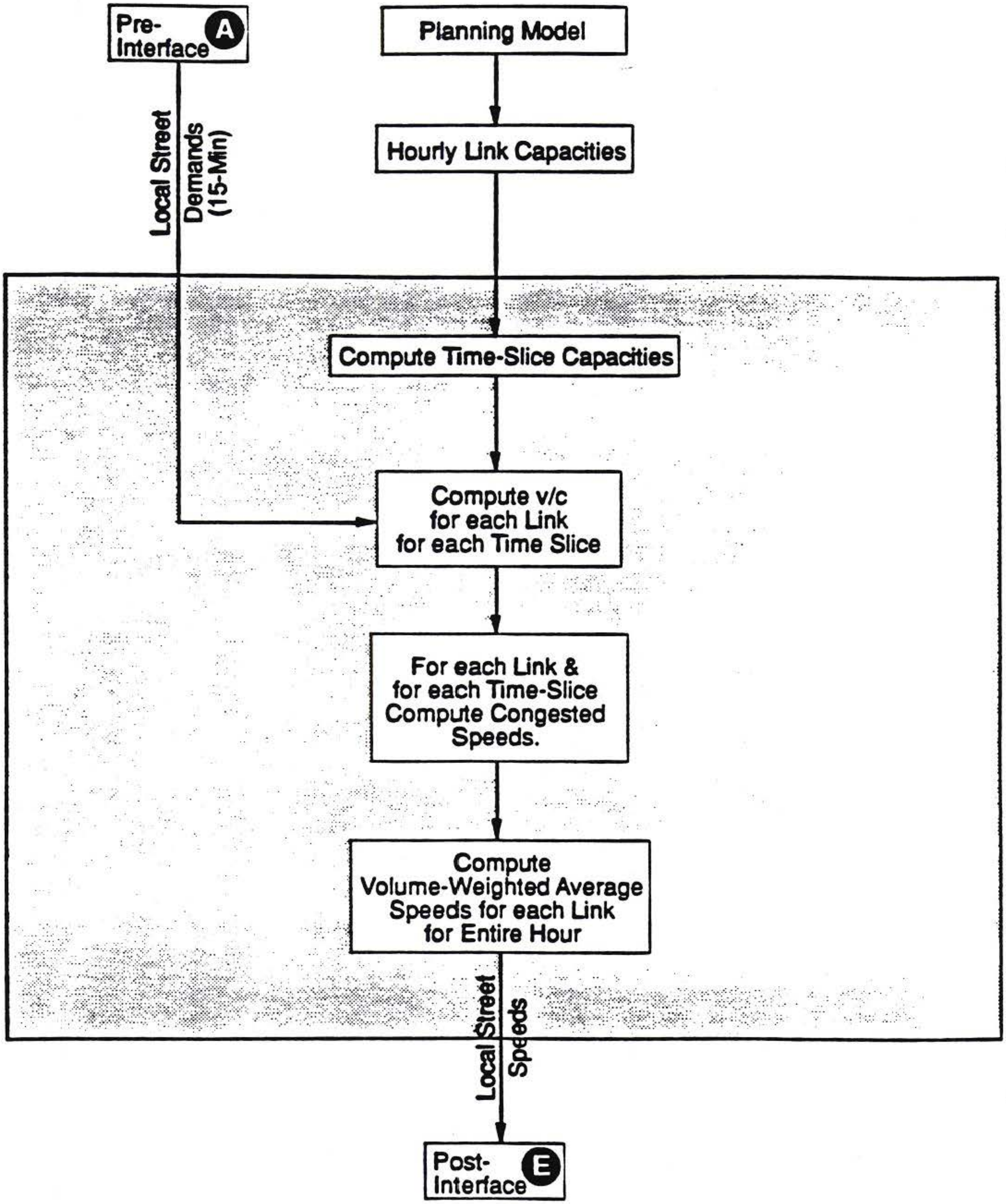
CALINK TESTS

- Performance of Convergence
- Model Framework Validation
- Improved Accuracy in Speed Estimation
- Reasonableness of Results

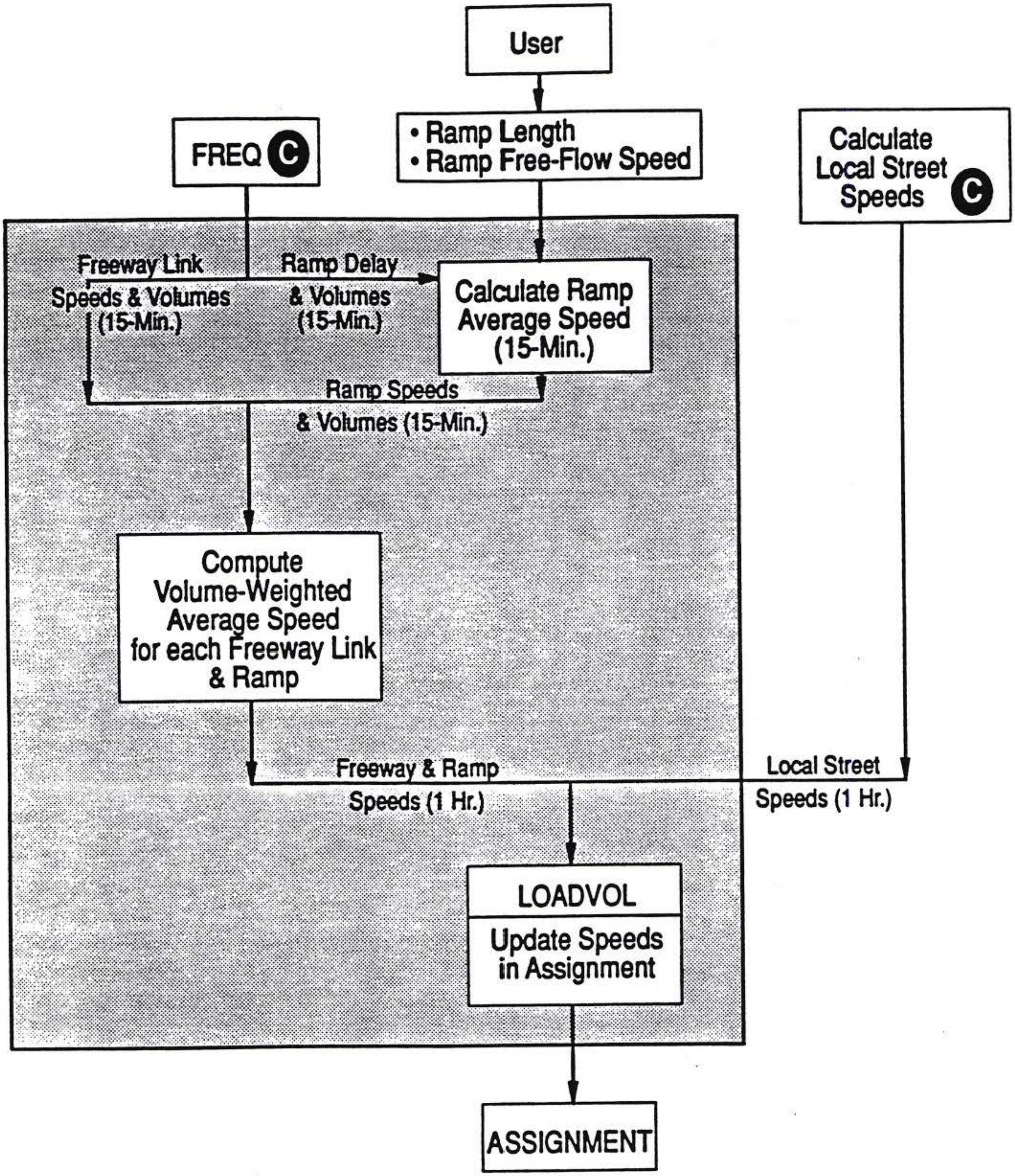
JHK & ASSOCIATES



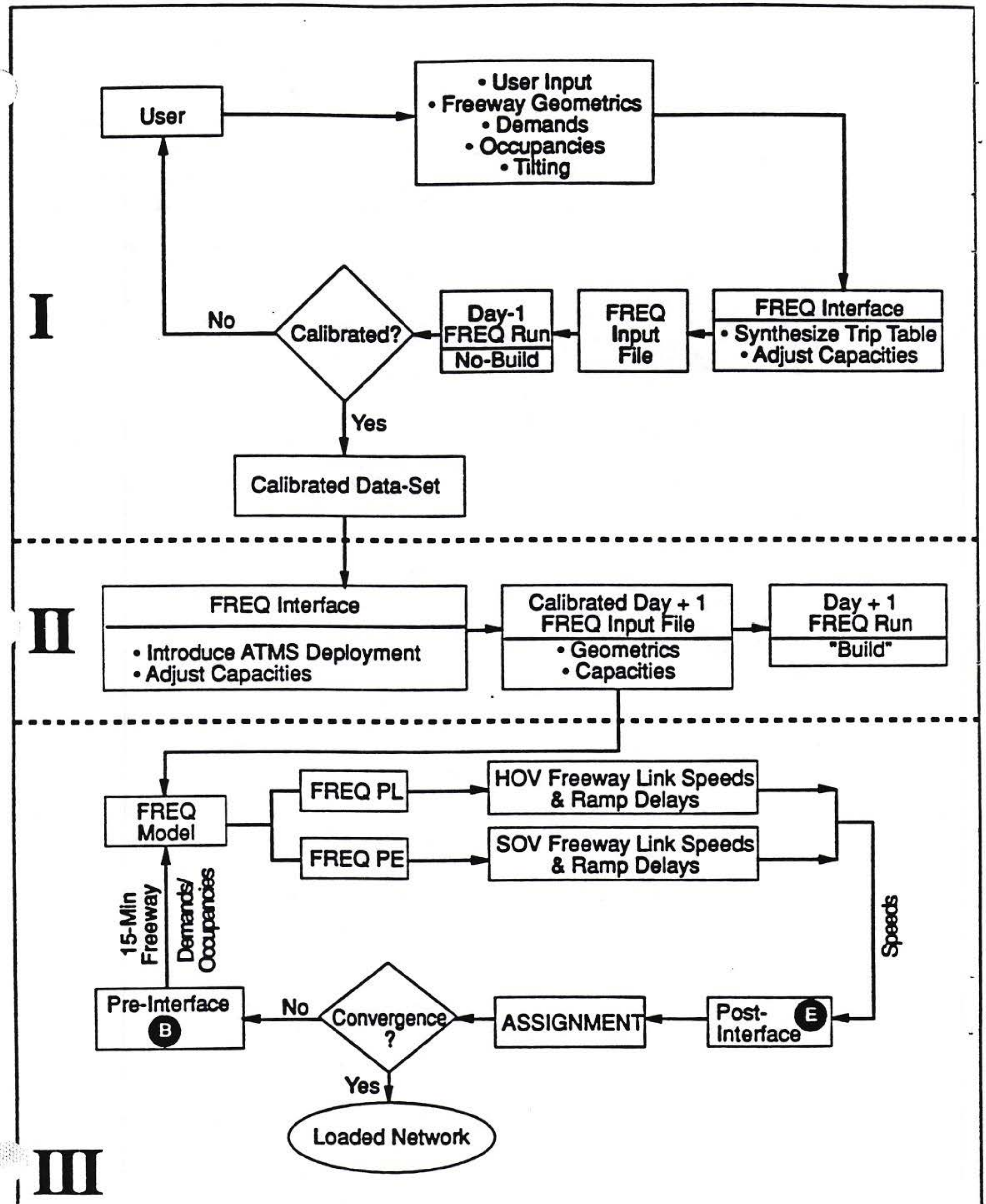
Peak-Spreading Interface A
Convert 1-Hour Volume to 4 15-Min Volumes (For All Links)
15-Min Distribution Factors for Each Hour for Each Facility Type
USER
Establish Equivalence File Between Planning Model & FREQ
15-Min Volumes
Freeway 15-Min Volumes
Input 15-Min Freeway Volumes in FREQ
Local Street 15-Min Volumes
Input 15-Min Local Street Volumes in Local Street Speed Calculation Module
Local Street Speed Calculation Module C
FREQ D
Pre-Interface B
jhk & associates



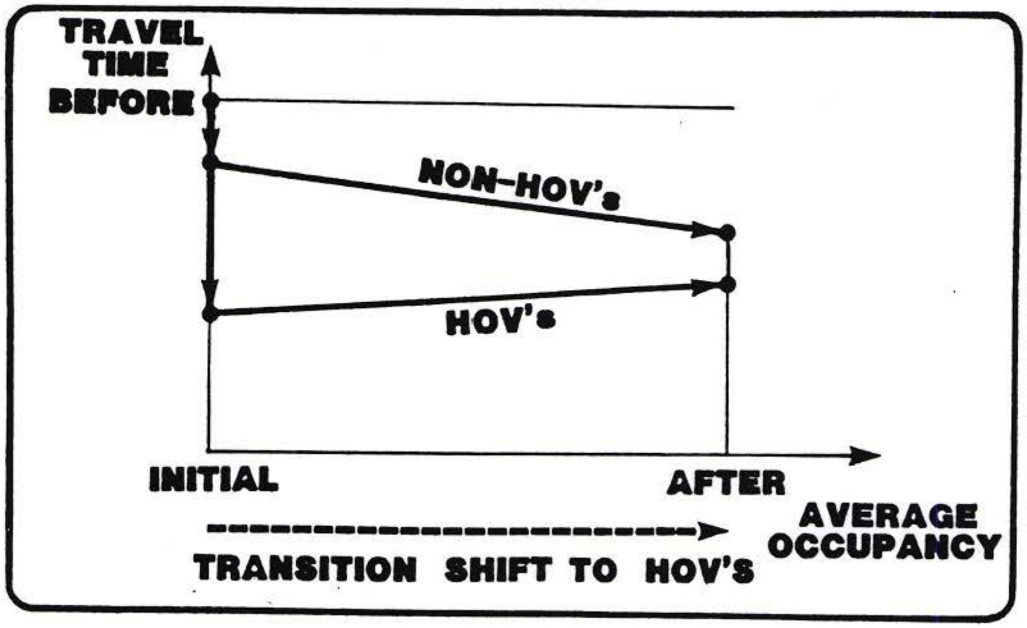
Calculation of Local Street Speeds C



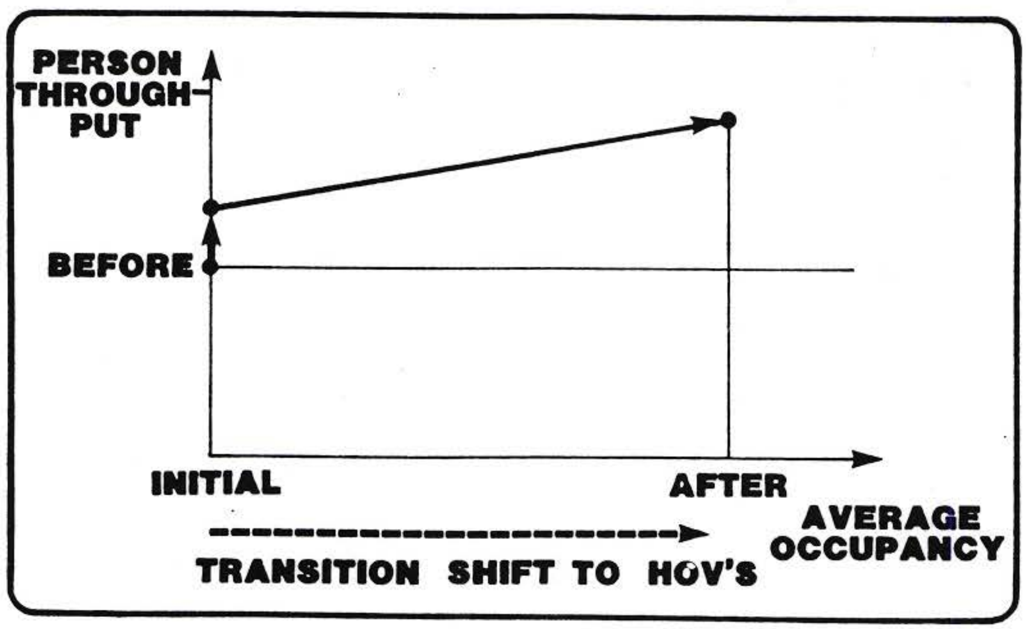
Post-Interface E



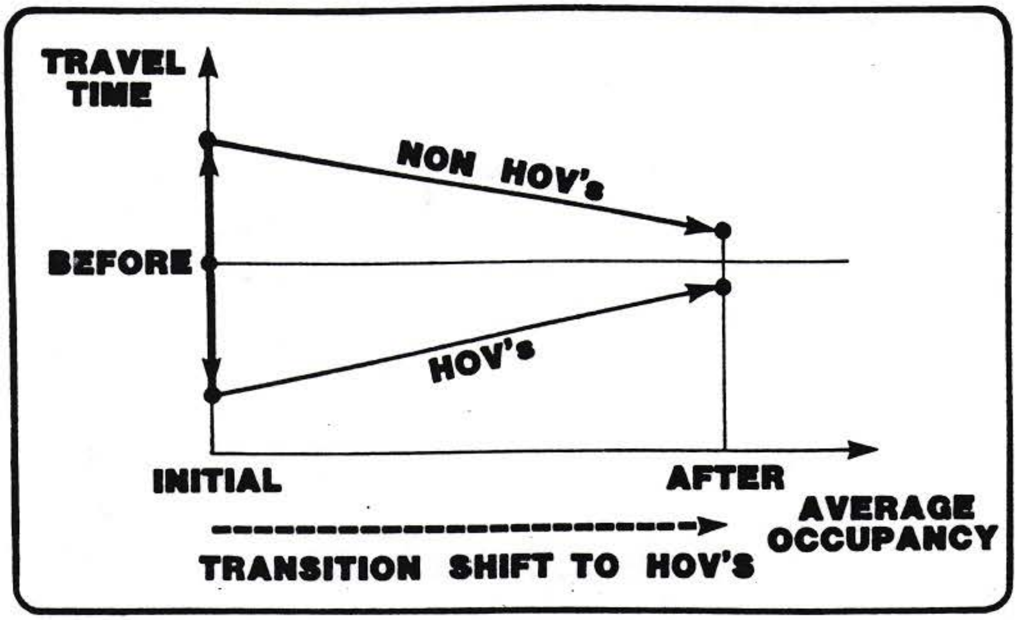
FREQ Interface D



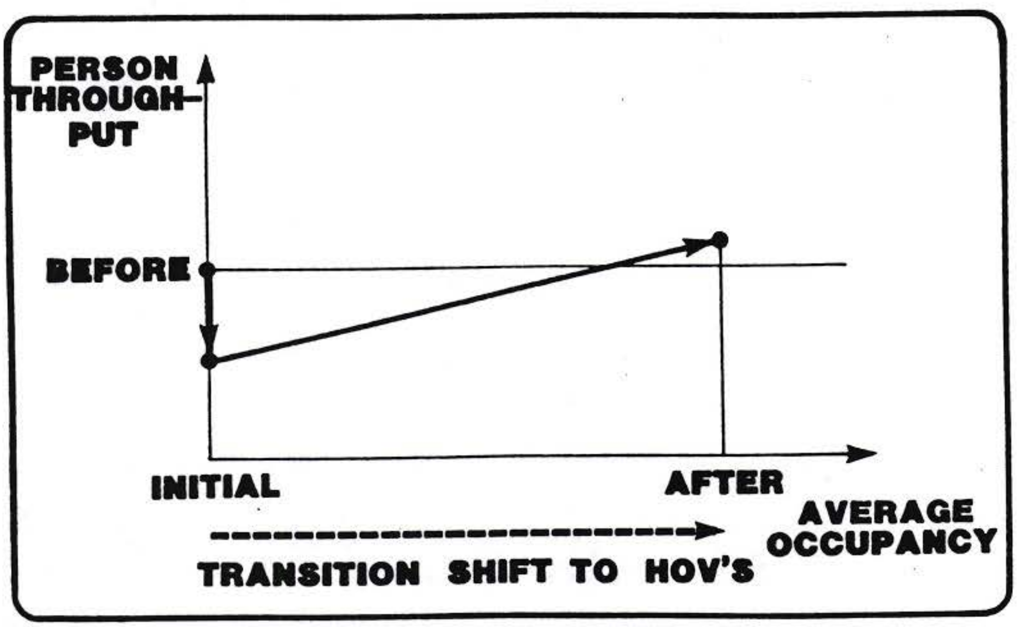
Travel Time Impacts of "Add-a-Lane" HOV Treatments



Person Throughout Impacts of "Add-a-Lane" HOV Treatments



Travel Time Impacts of "Take-a-Lane" HOV Treatments



Person Throughput Impacts of "Take-a-Lane" HOV Treatments

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LANE CONVERSION ISSUES

- HOV BENEFITS
- IMPACTS ON OTHER TRAVELERS
- TRADEOFFS
- SHORT AND LONG TERM IMPACTS
- PUBLIC PERCEPTIONS
- ROLE IN PUGET SOUND HOV SYSTEM

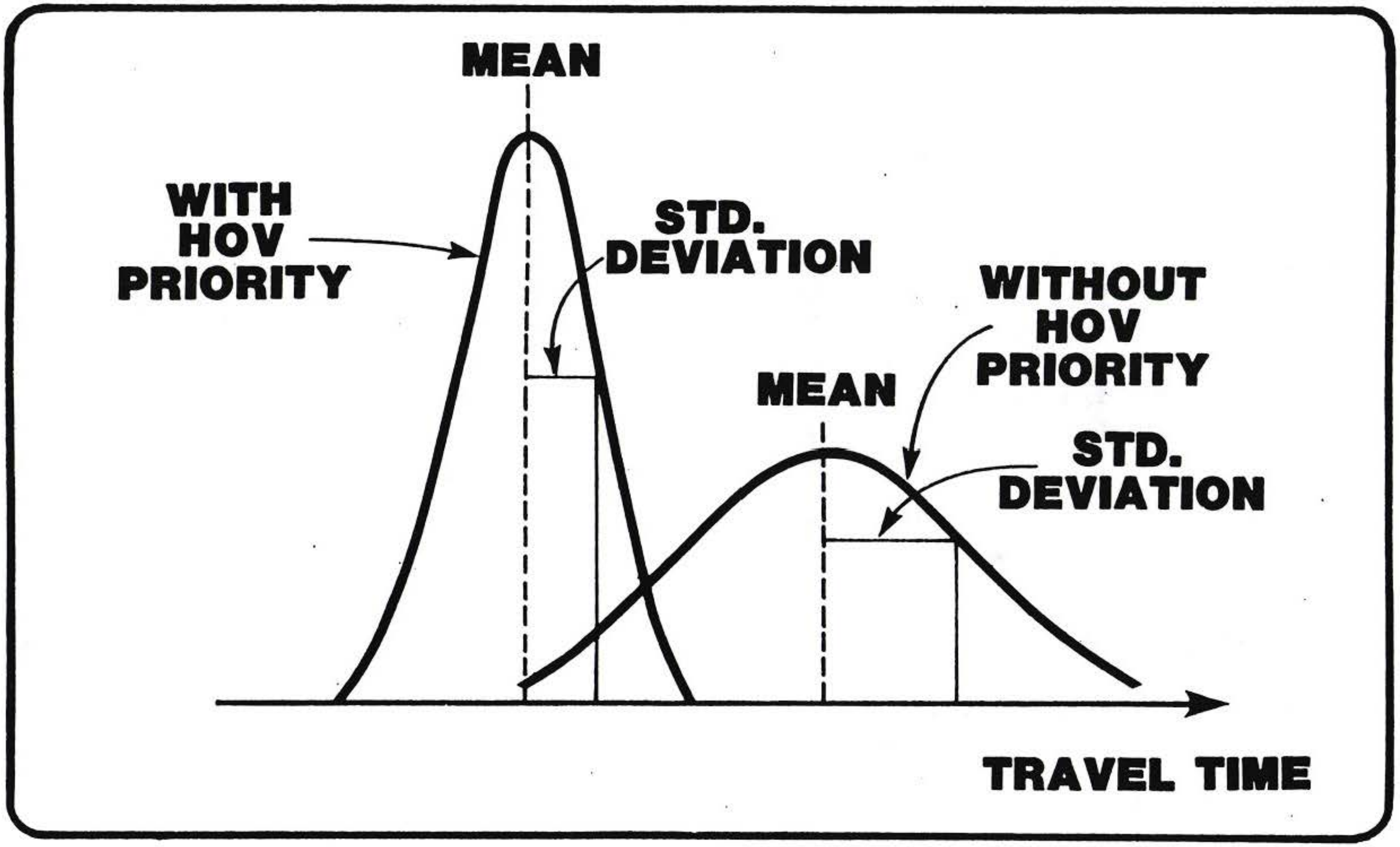
Marabase.cdr 05-02-94

OUTCOME

- PUBLIC ATTITUDES
- ADVANTAGES AND DISADVANTAGES
- POLICY GUIDELINES
- POSSIBLE APPLICATIONS OF HOV LANE CONVERSION

Take-A-Lane Alternative

- SANTA MONICA EXPERIENCE
  - Converted 12.5 miles of left lane to 3+
  - 21 weeks in 1976
  - Very adverse media and commuter reaction
  - Set back HOV lanes in California 10 years
  - Studies showed increased person throughput & energy savings
- SEATTLE AREA STUDY
  - Computer simulations combined with capacity analysis
  - Relatively few opportunities exist without severe GP impact
  - Public opposition
  - Usually MOE's much better for add-a-lane alternative



Travel Time Reliability

Comparison of HOV and Adjacent Mixed-Flow Facility Accident Rates

	Number of Accidents Per Million Vehicle Miles	
	HOV Lane(s)	Adjacent Mixed-Flow Lanes
Barrier-Separated Facilities		
Houston, TX, I-10 (Katy)	1.0	2.4
Houston, TX, I-45 (North)	2.0	2.4
Los Angeles, CA, I-10 (El Monte)*	0.4	1.1
Virginia, I-395 (Shirley Highway, Washington, DC)	2.3	--
Buffer-Separated and Nonseparated Facilities		
Seattle, WA, I-5 (median lanes)	3.2	2.1
I-405 (outside lanes)	3.6	1.3
Los Angeles, CA, I-10 (Santa Monica Freeway)	3.6	1.4
Marin County, CA, US 101	2.4	2.0
Miami, FL, I-95	1.9	3.6

-- Information not available.
*Barrier-separated portion (downtown to I-710) only

Source: ITE, *Effectiveness Report*, 1986.

Possible Benefit Components for a Benefit/Cost Analysis

Component	Value	Comments
Delay	$/hour	Any reduction in total freeway delay (travel time) can be converted to a benefit by applying a dollar value to a person's time.
Fuel Consumption	gals/hour	Gasoline saved because of decreased congestion is a benefit to motorists. A byproduct of reduced fuel consumption is the reduction of pollutants emitted into the atmosphere.
Bus Operating Cost Savings	$/hour	Higher speeds on the HOV facility will mean that fewer bus hours are needed to provide the required service.

Source: AASHTO, HOV Guidelines,1991; and Turnbull and Henk, 1990.

Possible Cost Components for a Benefit/Cost Analysis

Component	Value	Comments
Initial Capital	$/year	This should include the costs for planning, designing and constructing the HOV facility. The costs should be annualized as a function of the projected lifetime of the facility.
Day-to-Day Operation	$/year	Depending on the type of HOV facility, this should include costs for reversing one-way operation, setup and removal of pylons and/or barriers, incident response, manning of a central control center, enforcement, etc.
Bus Operation	$/year	Implementation of an HOV facility will generally increase the number of buses needed on a day-to-day basis. This additional cost should be considered.
Maintenance	$/year	Any additional maintenance cost for an HOV facility, especially a separated roadway, should be included in the analysis.

Source: AASHTO, HOV Guidelines, 1991; and Turnbull and Henk, 1990.

Elements of an HOV Plan

Sample Outline for an HOV Study Plan

Introduction

Background and Description of the Problem
Purpose of Study
Explanation of the HOV Concept and Its Study Potential

Planning Elements

Assumptions and Background Data
Travel and Demand Characteristics
Identification of Major Activity Centers
Identification of HOV Criteria
Assessment of General HOV Concept Viability

Operational Considerations

Operation Criteria
Hours of Operation
Directionality
Limits of Treatment
User Eligibility
Enforcement Requirements
Safety
Incident Management
Administration
Future Capacity/Operation Issues
Summary of the Selected Operation Concept(s)

Description of the Preferred Alternative(s)

Description of the System or Corridor
Typical Design
Ingress/Egress
Support Facility Requirements
Support Program Requirements
Systemwide Features (where applicable)
Conversion to Rail (where applicable)

Implementation

Phasing
Scheduling
Capital and Operating Costs and Funding

Checklist to Success

Characteristics for Successful HOV Facility Implementation

- ☞ Clear set of objectives and measures of success
- ☞ Develop the HOV lane as an additional lane
- ☞ Existing congestion in corridor (able to save 1/minute/mile & 5 to 8 minutes total)
- ☞ Projections for continued increase in demand
- ☞ Enforcement commitment/collaborative working relationships with enforcement agencies/ courts along the corridor
- ☞ Reason to believe you can get support from both agencies and public
- ☞ Reason to believe you can provide a lane that can be safely operated and enforced
- ♥ Policies and programs supporting transit use
- ♥ Rideshare program in corridor
- ♥ Successful HOV facilities already in operation in same corridor or adjacent corridors
- ♥ High existing volume of 2+ HOV's (700 or more vehicles per hour)
- ♥ Traffic system management system program already in place along the corridor
- ♥ High level of convenient transit service along the corridor (local/express/Park & Ride routes)
- ♥ Commute trip reduction legislation
- ♥ Existing communication network with employers along the corridor
- ♥ Collaborative working relationships with environmental agencies/groups along the corridor
- ♥ Collaborative working relationships with neighborhood/community groups along the corridor
- ♥ Collaborative working relationships with local jurisdictions/transit agencies/DOT's along the corridor
- ♥ Commitment to evaluation to accurately show benefits/disbenefits
- ♥ Origin-destination pattern that can benefit from the HOV lane

Legend

☞ = Essential Characteristic ♥= Desirable Characteristic

- OVER -

Potential Pitfalls to Successful HOV Facility Implementation

- ✱ Converting existing general purpose lane to HOV lane which results in negative impacts (increased accidents, increased travel time, etc.) in general purpose lanes or protest by the public
- ✱ High accident rate along the corridor that will not be improved by HOV lane
- ✱ Little support from enforcement authorities (State Police/Patrol, municipal judges/magistrates)
- ✱ Low existing volume of HOV's
- ✱ Poor working relationships with local media
- ✱ Poor working relationships with neighborhood/community groups along the corridor
- ✱ Poor working relationships with elected officials (especially critical during election years)
- ◘ Changing lane designation from general purpose to HOV during lane construction (example: begin construction as general purpose, change designation during construction phase to HOV)
- ◘ Low level of transit service
- ◘ Lack of transit funding
- ◘ No/low level of support facilities
- ◘ No incident management program in place
- ◘ No/inadequate ridematching services
- ◘ Poor pavement maintenance of existing facility that would not be helped by HOV lane construction

Legend

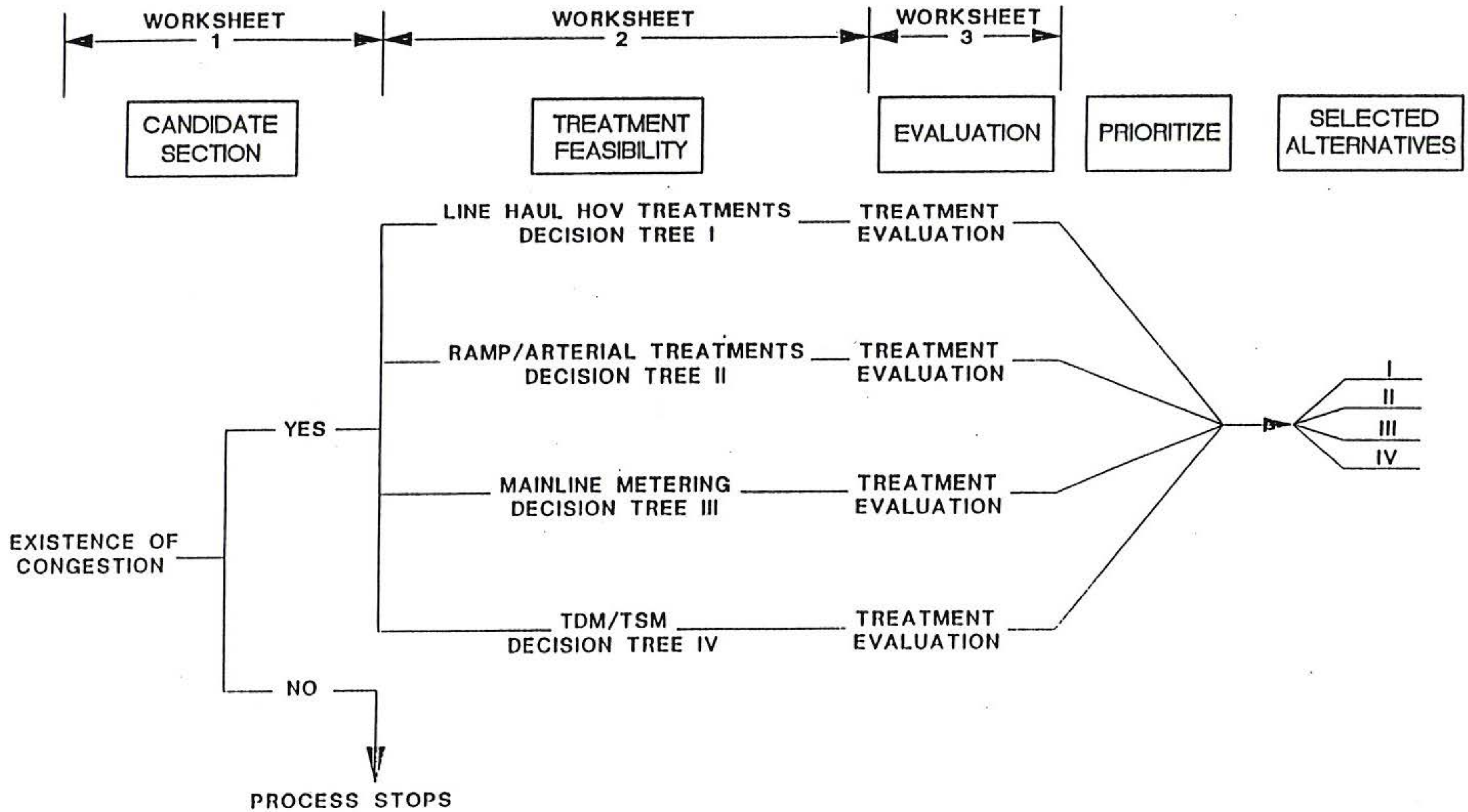
✱ = Potential Fatal Flaw ◘ = Possible Problem

What Have We Learned

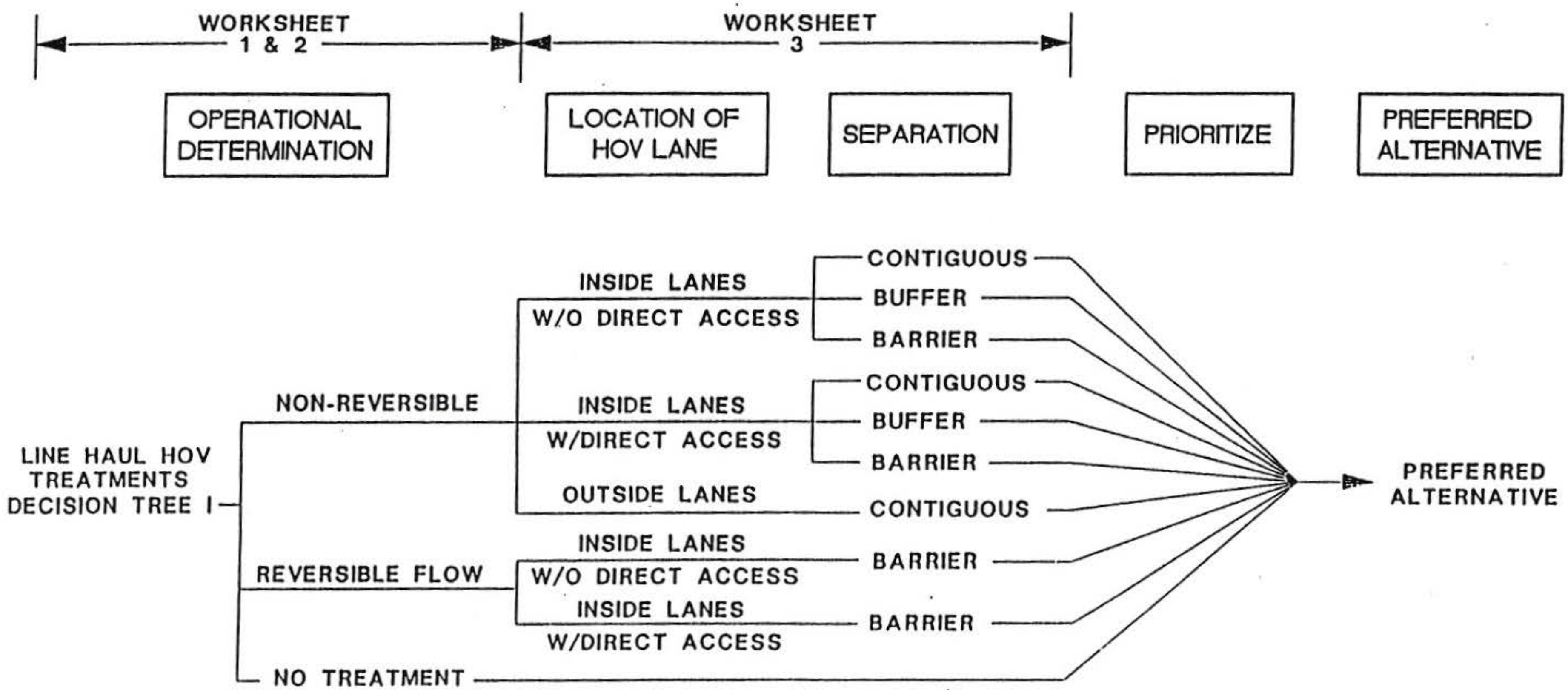
- Planning for "success" can vary from one locale to another.
- No single right answer
- HOV planning means more than just studying feasibility of lanes.
- Public and local agency involvement can be critical.
- Most effective treatments meet unique operational shortcomings.
- HOV should be part of a broader strategy to manage congestion.

Sample Project Process #1

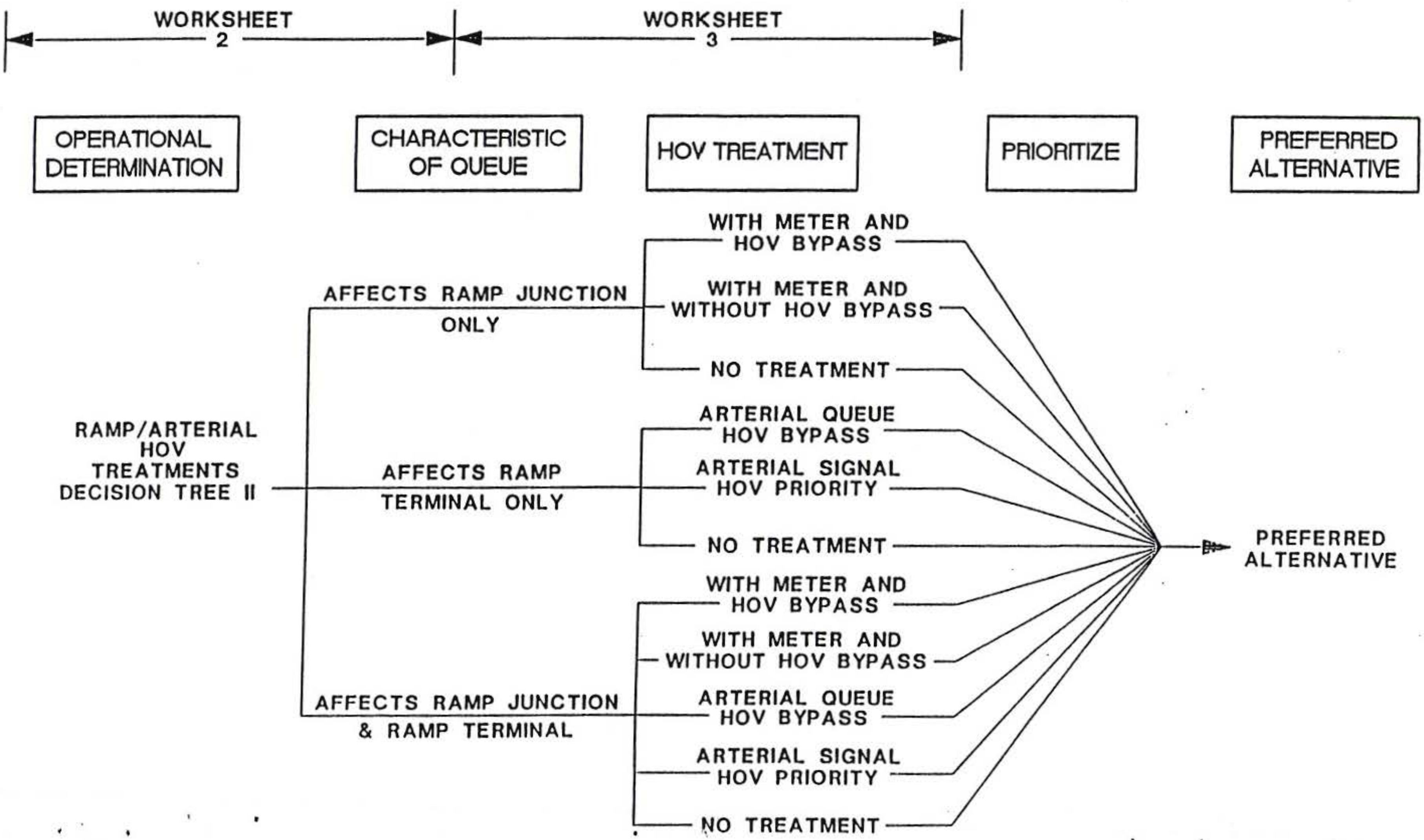
ALTERNATIVE SELECTION PROCESS - DECISION TREE I-IV



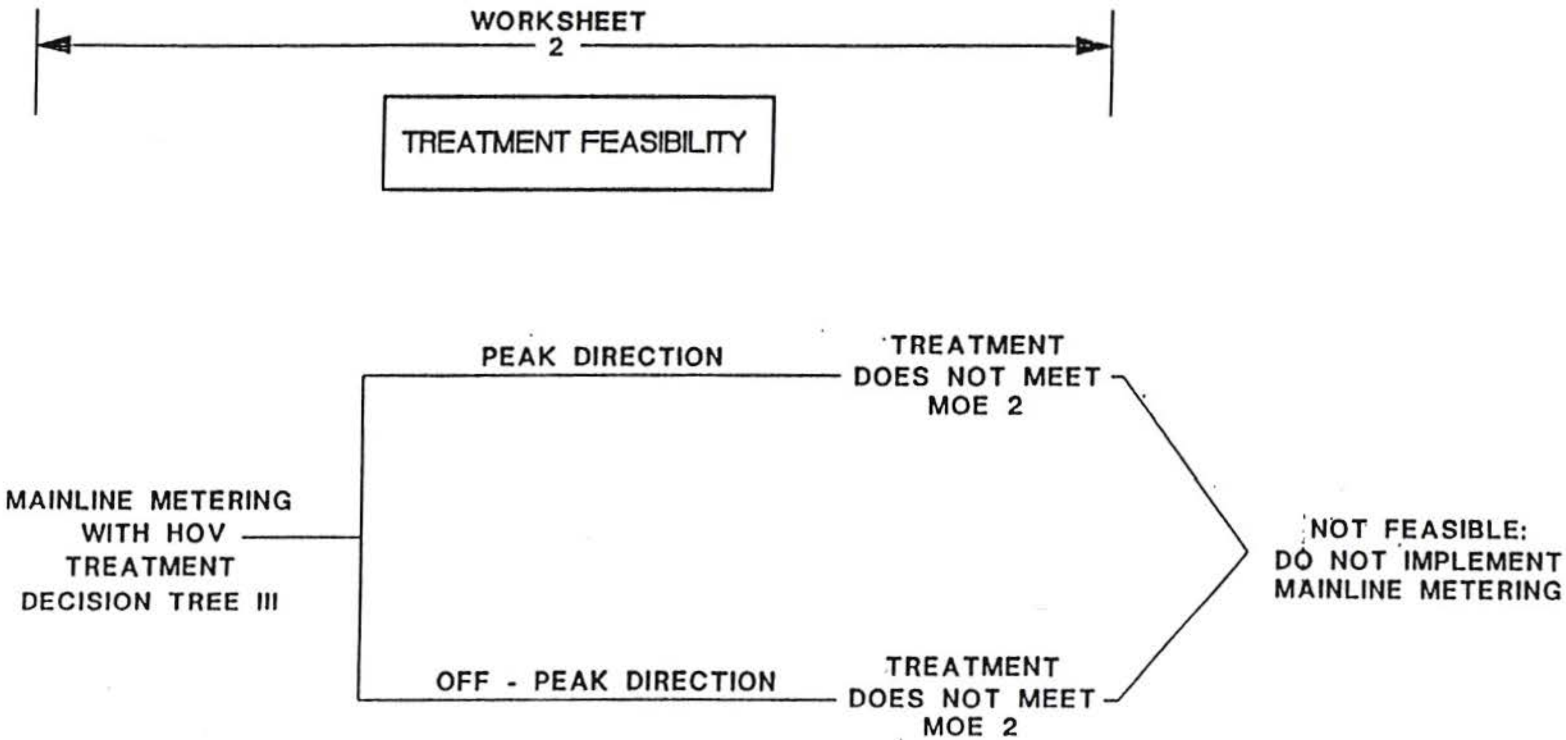
LINE HAUL HOV TREATMENTS - DECISION TREE I



RAMP/ARTERIAL HOV TREATMENTS - DECISION TREE II

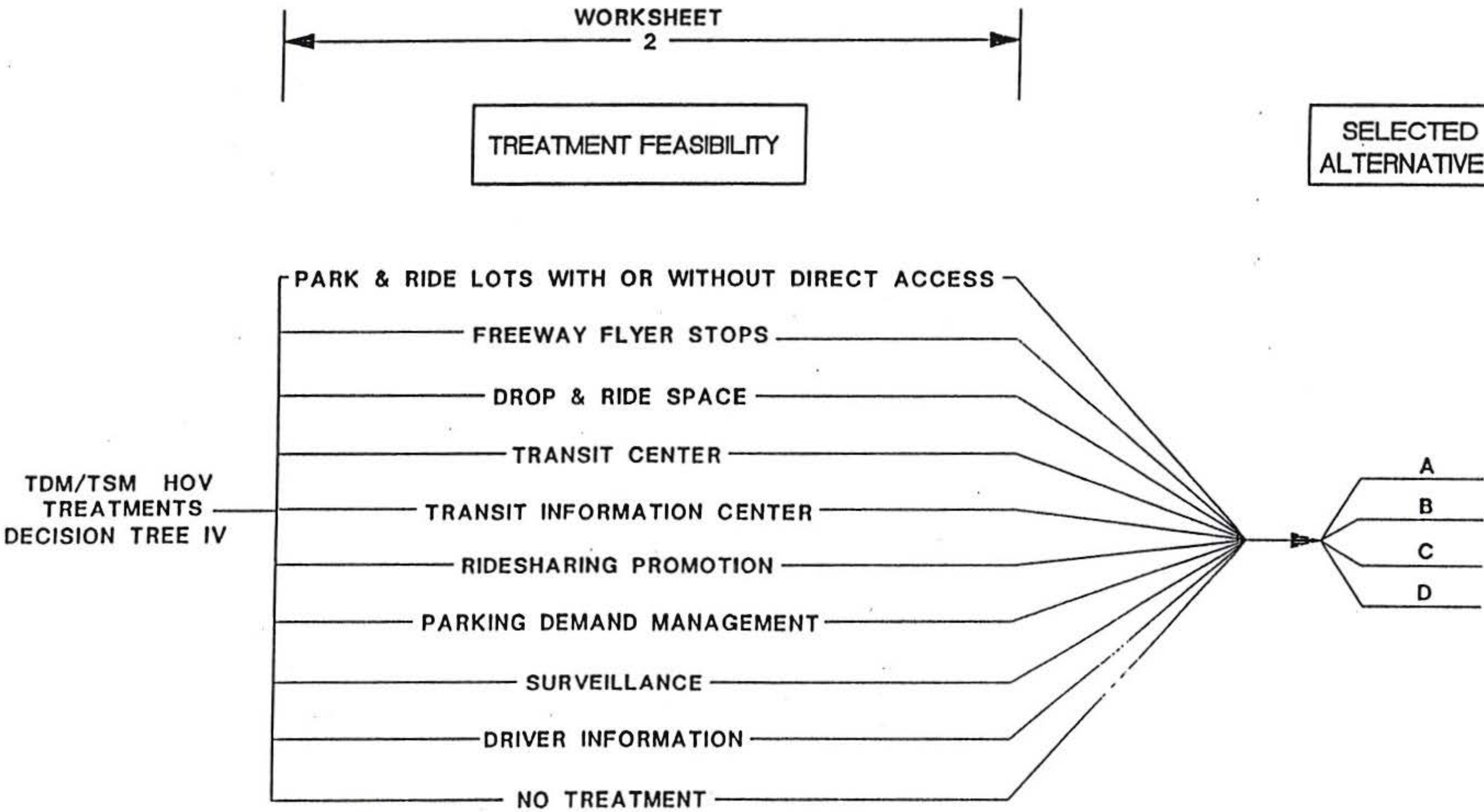


MAINLINE METERING HOV TREATMENT - DECISION TREE III



MOE 2: MEASURE OF EFFECTIVENESS 2,
IMPACT ON GENERAL PURPOSE
LANES

TDM/TSM HOV TREATMENTS - DECISION TREE IV



PRIMARY ELIGIBILITY CRITERIA SCREENING
EXISTENCE OF CONGESTION

		1991				*2000*				*2010*				*YEAR CRITERIA MET*			
		Eastbound/ Northbound		*Southbound/ Westbound*		*Eastbound/ Northbound*		*Southbound/ Westbound*		*Eastbound/ Northbound*		*Southbound/ Westbound*		*Eastbound/ Northbound*		*Southbound/ Westbound*	
	Segment	*AM*	*PM*	*AM*	*PM*	*AM*	*PM*	*AM*	*PM*	*AM*	*PM*	*AM*	*PM*	*AM*	*PM*	*AM*	*PM*
1	SR 512, I-5 to Pacific Ave. (2.2 miles)						R(1)	R(1)	R(1)		R(1)	R(1)			2000R	2000R	2000R
2	SR 512, Pacific Ave. to South Hill I/C (6.5 miles)							R(1)			R(2)	X 3.6 R(5)	R(2)		2010R	2010X 2000R	2010R
3	SR 512, South Hill I/C to SR 167 (3.3 miles)	R(1)			R(1)	R(2)	R(1)		R(2)	X 3.3 R(4)	X 0.9 R(3)	R(2)	X 1.9 R(6)	2010X 1991R	2010X 2000R	2010R	2010X 1991R
4	SR 167, SR 512 to SR 410 (1.1 miles)					R(1)	R(1)		X 1.1 R(2)	R(1)	X 1.1 R(1)	X 1.1 R(2)	X 1.1 R(2)	2000R	2010X 2000R	2010X 2010R	2000X 2000R
5	SR 167, SR 410 to Ellingson Rd. (5.2 miles)	R(1)				X 3.1 R(5)			X 5.2 R(5)	X 1.6 R(3)			X 5.2 R(5)	2000X 1991R			2000X 2000R
6	SR 167, Ellingson Rd. to SR 18 (1.9 miles)				R(1)	X 1.6 R(2)			X 1.6 R(2)	X 1.6 R(2)			X 1.9 R(3)	2000X 2000R			2000X 1991R
	Total Segments	2	0	0	2	4	3	2	5	4	4	4	5	N/A	N/A	N/A	N/A
	Total Length (20.2 miles)	0	0	0	0	4.7	0	0	7.9	6.5	2.0	4.7	10.1	N/A	N/A	N/A	N/A

X - Meets Threshold
R(x) - No. of Ramp Junctions Meeting Threshold
L - Estimated Length of Congestion in Miles
? - Not Sure
Shaded Area - Threshold Not Met
N/A - Not Applicable

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WORKSHEET 2 - SECONDARY ELIGIBILITY CRITERIA SCREENING

Route SR 16
Year 1991 & FUTURE

Segment I-5 to TNB
Direction EB & WB

Time Period AM & PM
Level of Congestion E/F

TREATMENT		MEASURE OF EFFECTIVENESS				
		MOE 2 IMPACT ON GENERAL PURPOSE LANES	*MOE 3 MIN. HOV LANE HOURLY VOLUME WITH 2+ HOV DEFINITION*	*MOE 4 GEOMETRIC FEASIBILITY*	*MEETS ELIGIBILITY CRITERIA*	*COMMENTS*
LINE HAUL						
1	Inside HOV Lane With Direct Access Ramp	X	1991 AM X PM X 2000 AM X PM X 2010 AM X PM X	X	X	
2	Inside HOV Lane Without Direct Access Ramp	X	X	X	X	
3	Outside HOV Lane	X	X	X	X	
4	Buffer Separated HOV Lane	X	X	X	X	
5	Barrier Separated HOV Lane(s)	X	X	X	X	
6	Reversible HOV Lane	X	X	X	X	
7	Mainline Queue HOV Bypass Lane	X	X	X	X	
8	Convert General Purpose Lane to HOV Lane (Take A Lane)		X	X		
RAMP/ARTERIAL						
9	Ramp Queue HOV Bypass Lane	X	N/A	X	X	

Route SR 16
Year 1991 & FUTURE

Segment I-5 to TNB
Direction EB & WB

Time Period AM & PM
Level of Congestion E/F

WORKSHEET 2 - SECONDARY ELIGIBILITY CRITERIA SCREENING

MEASURE OF EFFECTIVENESS

	TREATMENT	*MOE 2 IMPACT ON GENERAL PURPOSE LANES*	*MOE 3 MIN. HOV LANE HOURLY VOLUME WITH 2+ HOV DEFINITION*	*MOE 4 GEOMETRIC FEASIBILITY*	*MEETS ELIGIBILITY CRITERIA*	*COMMENTS*
10	Ramp Metering With HOV Bypass Lane	X	N/A	X	X	
11	Arterial Queue HOV Bypass Lane	X	N/A	X	X	
12	Arterial Signal HOV Priority Treatment	X	N/A	X	X	
MAINLINE METERING						
13	Mainline Metering With HOV Bypass Lane		X	X		
TDM/TSM						
14	Transportation Demand Management (TDM)	X	N/A	X	X	
15	Transportation System Management (TSM)	X	N/A	X	X	
16	Public Transfer Facilities	X	N/A	X	X	

X = Meets Threshold
N/A = Not Applicable
? = Not Sure
Shaded Area = Threshold Not Met
MOE 2 = Measure of Effectiveness 2, Impact on General Purpose Lanes
MOE 3 = Measure of Effectiveness 3, Minimum HOV Lane Hourly Volume with 2+ HOV Definition
MOE 4 = Measure of Effectiveness 4, Geometric Feasibility

HOV TREATMENT EVALUATION

Route SR 16
Segment I-5 to TNB
Treatment NON REVERSIBLE
Direction EB

Yr. 2000
Time: AM/PM

	MEASURE OF EFFECTIVENESS	Inside Lane w/o Direct Access	Inside Lane w/ Direct Access	Outside Lane
1	Existence of Congestion	√	√	√
2	Impact on General Purpose Lanes	√	+	√
3	HOV Lane Hourly Volume with 2+ HOV Definition			
4	Geometric Feasibility	√	-	√
5	Travel Time Savings			
6	Person Thruput in HOV Lane			
7	Environmental Compatibility of Construction	√	-	√
8	Safety Benefits	√	+	-
9	Public Support	√	+	√
10	Local Agency Support	√	√	√
11	System Continuity Importance	+	+	√
12	Enforceability	√	√	-
13	Traffic Operations Benefits	√	+	-
14	Impact on Mode Shift	√	√	√
15	Compatibility with Land Use and Transportation Policies	√	-	√
16	Cost			

MEASURES OF EFFECTIVENESS

	MEASURE OF EFFECTIVENESS		MEASURE
1	Existence of Congestion	-	LOS E w/maximum of one segment on either side at LOS E or F
		√	LOS F w/maximum of one segment on either side at LOS E or F
		+	LOS F segments on both sides at LOS E or F
2	Impact on General Purpose Lanes	-	Less than two lanes per direction or severe impact (severe reduction in speeds, clearly unsafe operation) except at TNB
		√	Two lanes per direction and low impact (noticeable reduction in speeds
		+	Two lanes per direction and no impact (general purpose lanes would operate as if the HOV treatment didn't exist.)
3	Minimum HOV Lane Hourly Volume with 2+ HOV Definition	-	Less than 180 vph
		√	180-300 vph
		+	300+ vph
4	Geometric Feasibility	-	Low feasibility
		√	Somewhat feasible
		+	Highly feasible (simple design, adequate right-of-way, little difficulty retrofitting, no serious geometric constraints).
5	Travel Time Savings (on mainline)	-	Less than 1.0 min/mile
		√	1.0 - 1.5 min/mile
		+	1.5+ min/mile
6	Person Thruput in HOV Lane	-	Less than 1800 pplph
		√	Between 1800 to 2200 pplph
		+	2200+ pplph
7	Environmental Compatibility of Construction	-	Not compatible
		√	Compatible
		+	Highly compatible

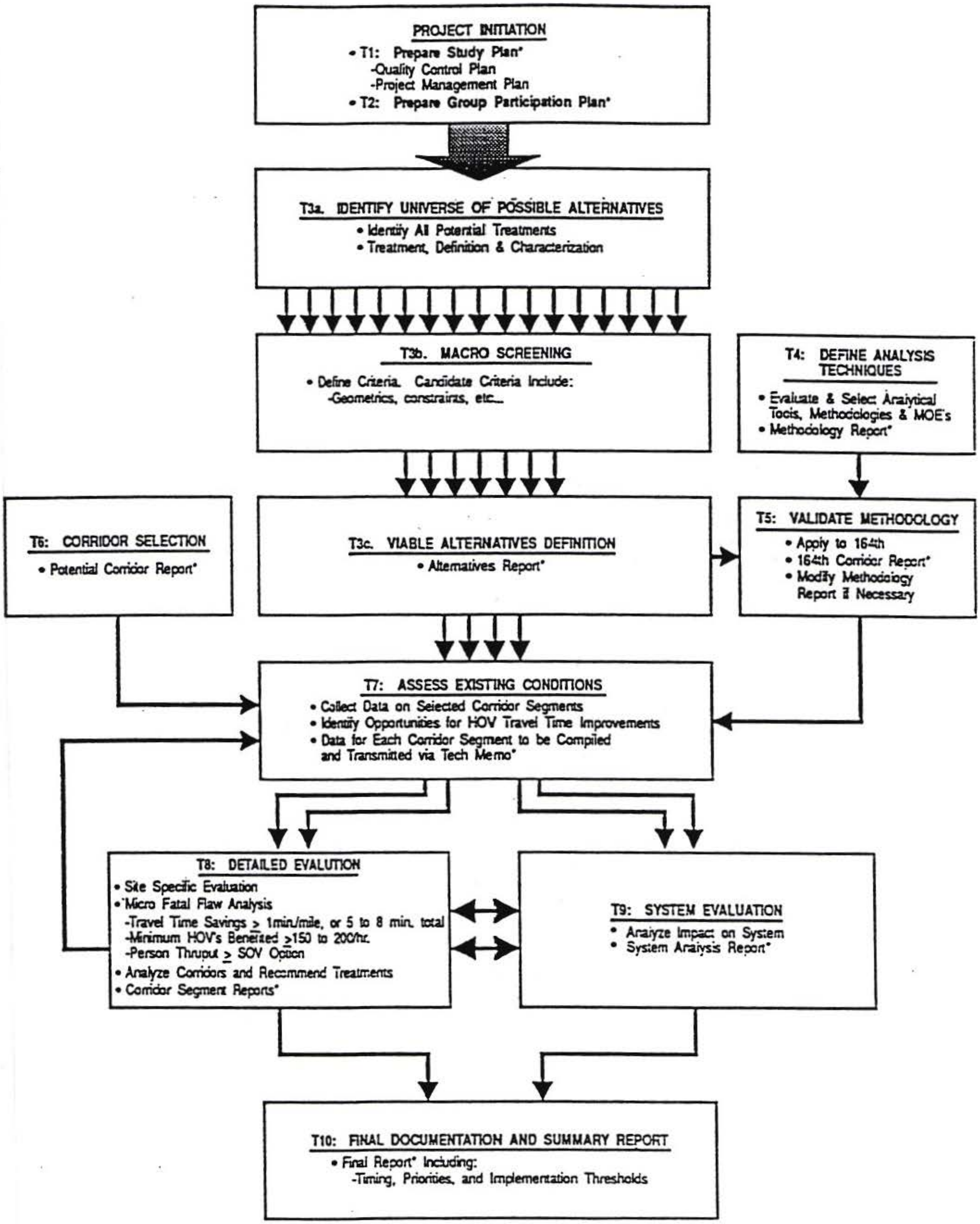
MEASURES OF EFFECTIVENESS

	MEASURE OF EFFECTIVENESS		MEASURE
8	Safety Benefits	-	Extremely unsafe (little or no clearances/shoulders provided, extremely high potential for increase in accidents, incidents severely affect traffic flow).
		√	Somewhat safe
		+	Extremely safe (adequate clearances/shoulders provided, very low potential for increase in accidents, incidents have little to no effect on traffic flow).
9	Public Support	-	Low support
		√	Moderate support
		+	High Support
10	Local Agency Support	-	Low support
		√	Moderate support
		+	High support
11	System Continuity Importance	-	Treatment needed only on segment being studied
		√	Treatment needed on either side one segment away
		+	Treatment needed on either side of study segment
12	Enforceability	-	Low enforceability
		√	Moderately enforceable
		+	Highly enforceable (plenty of room for monitoring, apprehending violators or clearing incidents, clear delineation of HOV lane)
13	Traffic Operations Benefits	-	Low operations benefits
		√	Some operations benefits
		+	Numerous operations benefits
14	Impact on Mode Shift	-	Low operations benefits
		√	Some operations benefits
		+	Numerous operations benefits

MEASURES OF EFFECTIVENESS

	MEASURE OF EFFECTIVENESS		MEASURE
15	Compatibility w/Landuse and Transportation Policies	-	Low compatibility
		√	Moderate compatibility
		+	High compatibility
16	Cost	-	Low cost
		√	Moderate cost
		+	High cost

Sample Project Process #2



* = Deliverable

Macro-Level Fatal Flaw Analysis

X = Treatment Has Potential to Meet the Criteria
0 = Treatment Has No Potential to Meet the Criteria

	TREATMENT	FINANCIAL VIABILITY	GEOMETRIC FEASIBILITY	FUNCTIONAL ADEQUACY	PUBLIC ACCEPTANCE
PASSING TREATMENTS	Signal Priority Treatments	X	X	X	X
	Continuous Right-Side HOV Lanes	X	X	X	X
	Continuous Left-Side HOV Lanes	X	X	X	X
	Reversible HOV Lanes w/ Signal Cntrl.	X	X	X	X
	Signal Queue Jump	X	X	X	X
	Double Left-Turn Lanes/One HOV Lane	X	X	X	X
	SOV Turn Restrictions	X	X	X	X
	Off-Route Alternatives	X	X	X	X
	Mid-Block "Gating" Signal	X	X	X	X
	New Corridor with HOV Emphasis	X	X	X	X
	HOV Support Measures & Facilities	X	X	X	X
	Convert Gen. Purp. Lanes to HOV Lanes	X	X	X	X
FAILING TREATMENTS	Buffer-Separated HOV Lanes	0	X	X	X
	Barrier-Separated HOV Lane	0	X	X	X
	Reversible HOV Lane w/ Moveable Barr.	0	0	X	X
	Barrier-Separated Reversible HOV Lanes	X	0	X	X
	Contra-Flow HOV Lanes	0	X	X	X
	Bus Streets	0	0	X	0

Community Transit Arterial System HOV Study
Validation of Analysis Methodolgy

MICRO-LEVEL FATAL FLAW SCREENING ANALYSIS

X = Treatment Has Potential to Meet the Criteria
O = Treatment Has No Potential to Meet the Criteria

Treatment	Financial Viability	Geometric Feasibility	Functional Adequacy			Safety	Public Acceptability
			eneral Adequac	Avg Person Delay	Persons/Hr		
No Action Alternative	X	X	X	X	X	X	X
Tadltional Priority	X	X	X	X	X	X	X
Specialized Phasing	X	X	X	X	X	X	X
HOV-Weighted OPAC-RT	X	X	X	X	X	X	X
Continuous Right Side HOV Lanes	X	X	X	X	X	X	X
Continuous Left Side HOV Lanes	X	X	X	X	X	X	X
Lane Control for Reversible HOV Lanes	X	X	X	X	X	X	X
New Corridor with HOV Emphasis	X	X	X	X	X	X	X
Signal Queue Jump	X	X	X	X	X	X	X
DoubleTurn Lanes/One HOV Lane	X	X	X	X	X	X	X
Special Access Provisions for HOVs	X	X	X	X	X	X	X
SOV Turn Restrictions	X	X	O	O	O	X	O
Off-Route Alternatives	O	O	O	O	O	X	X
Preferential Gating	X	X	X	O	O	X	X
Convert General Purpose Lanes	X	X	X	O	O	X	O

MOE = measure of effectiveness

Alternatives Surviving Macro-Level Screening	Corridor-Specific Fatal Flaw Screening Process (Pass or Fail)	MOE 1 HOV Travel Time Savings	MOE 2 Capacity in Person/Hour	MOE 3 Throughput in Person/Hour	MOE 4 Cost-Effectiveness	MOE 5 Traffic Operations	MOE 6 Safety	MOE 7 Supports Regional HOV Continuity	MOE 8 Enforceability	MOE 9 Local Agency Support	MOE 10 HOV Travel Time-Reliability	Recommended ?
No Action	Pass	○	○	○	N/A	◕	◑	○	N/A	◑	○	
Traditional Priority	Pass	◕	◑	○	●	◔	◑	◑	◔	◑	◕	
HOV-weighted OPAC-RT	Pass	◕	◑	○	●	◕	◑	◑	◔	●	◕	✔
Continuous Right-Side HOV Lanes	Pass	◑	●	○	○	◔	◔	●	◕	◑	●	
Right-Turn Only Except HOV	Pass	◑	●	○	○	◔	◔	●	◕	◑	●	
Continous Left-Side HOV Lanes	Pass	◑	●	○	○	◔	◔	●	◑	◑	●	
Lane Control for Reversible HOV Lanes	Pass	◔	●	○	○	◔	◔	●	◑	◑	●	
New Corridor with HOV Emphasis	Pass	N/A	●	○	N/A	◕	◑	●	●	◑	●	✔
Signal Queue Jump/Specialized Phasing	Pass	○	◑	○	◕	◔	◑	○	◔	◑	◕	
Double Turn Lanes/One HOV Only	Pass	○	◑	○	●	◕	◑	○	◑	●	◑	✔
Special Access Provisions	Pass	◕	◑	○	◕	◕	◑	●	●	●	●	✔
Preferential Mod-Block "Gating"	Fail											
SOV Turn Restrictions	Fail											
Convert General Purpose Lane	Fail											
Off-Route HOV Alternative	Fail											

LEGEND

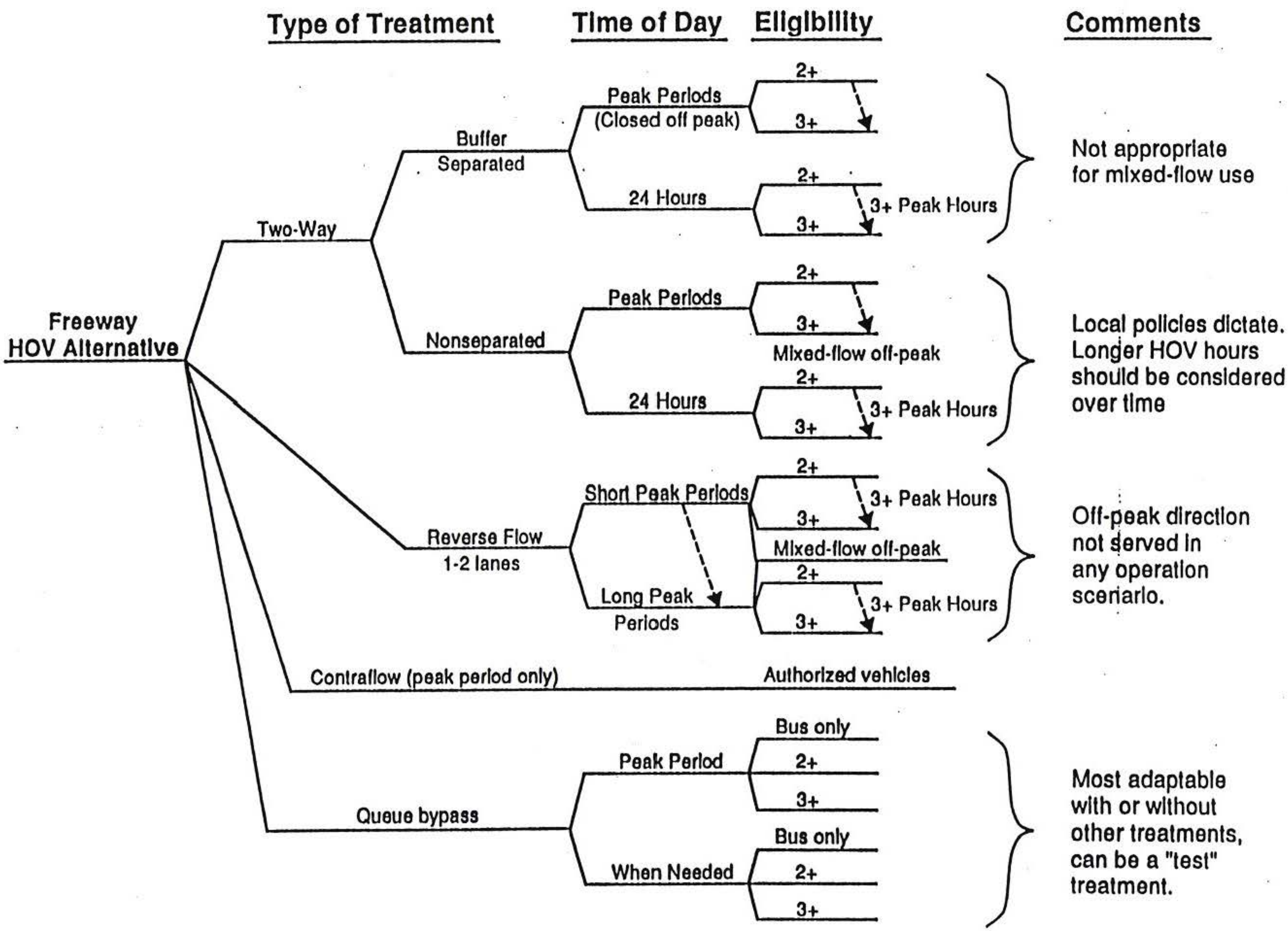
Least Effective ←→ Most Effective

○ ◔ ◑ ◕ ●

N/A = Not Applicable

Note: Recommendations are preliminary, pending results of simulation analysis.

HOV Operational Decisions



SECOND STAGE PROBLEM STATEMENT

I. PROBLEM NUMBER: 95-B-8

II. TITLE: ***The Impacts of HOV Improvements on Air Quality***

III. RESEARCH PROBLEM STATEMENT:

The impacts of HOV requirements on air quality are more complex and less well understood than other HOV impacts. The requirements of ISTEA and the Clean Air Act Amendments have created a critical research need to determine whether HOV facilities have a significant impact on reducing vehicle emissions, thereby influencing major investment decisions regarding HOV. Research is needed to quantify the vehicle occupancy/congestion tradeoffs involved in HOV lane implementation, and model the impacts of HOV lanes on air quality.

IV. RESEARCH PROPOSED

The objective of this research would be to develop standard methodologies for evaluating the emissions impacts of HOV lanes and networks; and to address other key issues. Issues to be resolved include:

- How to model HOV networks to estimate air quality
- Impacts of HOV facilities on traffic operations and air quality (e.g., ramp metering bypass, toil bypass, HOV lane merge/diverge and weave impacts on mixed flow traffic)
- Effects of supporting HOV services on air quality (e.g., ride matching services, park and ride lots, toll bypasses, ramp metering with HOV bypass, parking pricing)
- Impact of HOV facilities on air quality changes caused by land use patterns (e.g., trip length, density, sprawl)
- Effects of lane conversion compared to added HOV lane
- Effects of HOV lanes compared to fixed rail transit systems
- Effects of HOV lanes on transit (e.g., "casual" carpooling, diversion from transit to HOV)
- Effects of vehicle size and weight (e.g., vanpools, carpools) on air quality on mainlines, ramps, and arterials
- Effects of elevated versus at-grade HOV lanes
- Effects of "induced" trips on air quality

The research will also validate the methods' accuracy through case study corridor measurements. The following tasks will be performed:

1. **Literature Search** - A literature search will be performed to assemble all relevant information on transportation/air quality relationships and impacts of HOV facilities.

2. **Develop Emissions Impacts Methodology** - A methodology will be developed to estimate impacts of HOV treatments on air quality emissions. The method should be sensitive to the issues identified above.

3. **Test Sensitivity of Methodology** - Tests will be performed to determine the sensitivity of the methodology to various HOV characteristics. The statistical variation in the estimates will be identified.

4. **Conduct Case Study Measurements** - The method's accuracy will be tested against actual before/after HOV case study measurements, where data are available.

5. **Report** - A report will be prepared documenting the study process, methodologies developed, and results of the method validation.

Related work to the proposed research includes the following:

- JHK & Associates, "Predicting the Impact of Transportation Control Measures on Travel Behavior and Pollutant Emissions";
- TTI, "Evaluation of the Houston High-Occupancy Vehicle Lane System";
- SYSTAN's "Evaluation of the Santa Monica Freeway Diamond Lanes';
- California Air Resources Board, "High Occupancy Vehicle System Plans as Air Pollution Control Measures";
- MTC, "Air Quality Impacts of a Regional HOV System";
- JHK & Associates, "Travel Demand and Simulation Modeling for Caltrans";
- Cambridge Systematics, "Transportation Control Measures Information Documents"; and
- Oak Ridge National Laboratory, "Network Performance Evaluation Model for Assessing the Impacts of High-Occupancy Vehicle Facilities".

V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Recommended Funding: Estimated funding for this project is $350,000 for the tasks noted.

Research Period: The research should require approximately 18 months to complete

VI. URGENCY AND PAYOFF POTENTIAL

The need for this research is very high. The Clean Air Act has established deadlines that make this research critical. By law, air quality is a key element in future transportation decision-making, and accurate models are essential for projecting the impacts of transportation demand management decisions on air quality. Accurate models of the impact of HOV lanes on air quality will raise the quality of decisions-making at state and local levels and improve the accuracy of air quality modeling, which is becoming increasingly important in transportation planning. This will influence major investment decisions with federal funds, according to ISTEA and CAA requirements.

VII. PERSON(S) DEVELOPING THE PROBLEM

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SELECTING HOV ANALYTICAL TOOLS

PROJECT TASKS	SPREAD SHEET	HCM	FRESYS	FREQ	FRESIM	TRANSYT
System-Wide Analysis		X	X			
HOV Lane Conversions	X	X	X	X		
Freeway to Freeway Interchanges				X	X	
HOV Lane Access Analysis		X	X	X		
Arterial Corridors		X				X
Air Quality & Energy				X		X

CONSIDERATIONS FOR ARTERIALS

KEY ISSUES

- Treatments Applicable to the Arterial Environment
  - Influence of Signalized Intersections
  - Multiplicity of Driveways/Side Friction
  - Re-entry from Bus Stops
  - Proximity of Adjacent Development

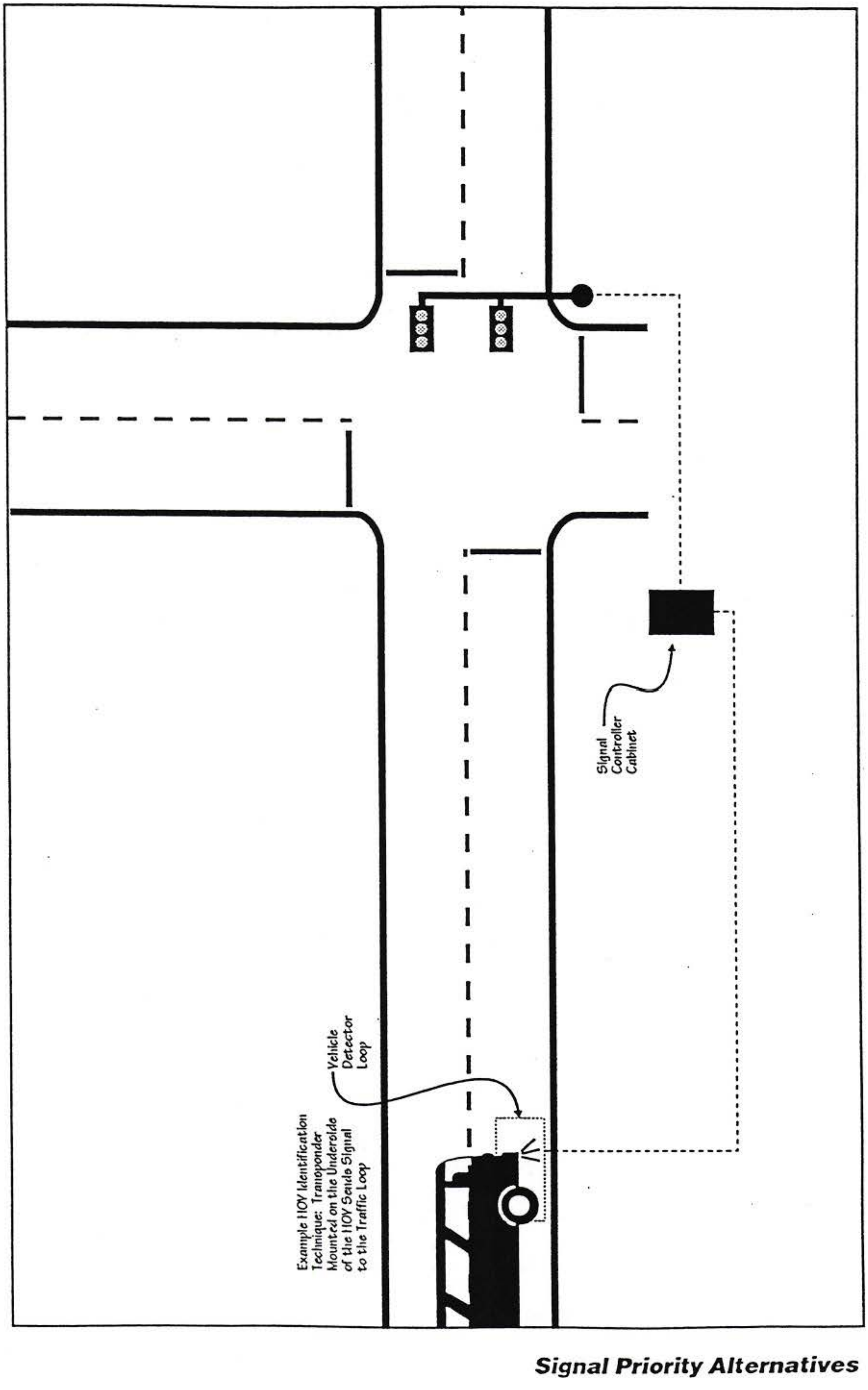
- Operational Objectives and Criteria Applicable to the Arterial Environment

- Integration of HOV Philosophies with State-of-the-Art Signal Control Strategies

- Consensus Building Among Various Constituencies

- Deterministic vs. Stochastic Analytical Tools

- Funding Viability



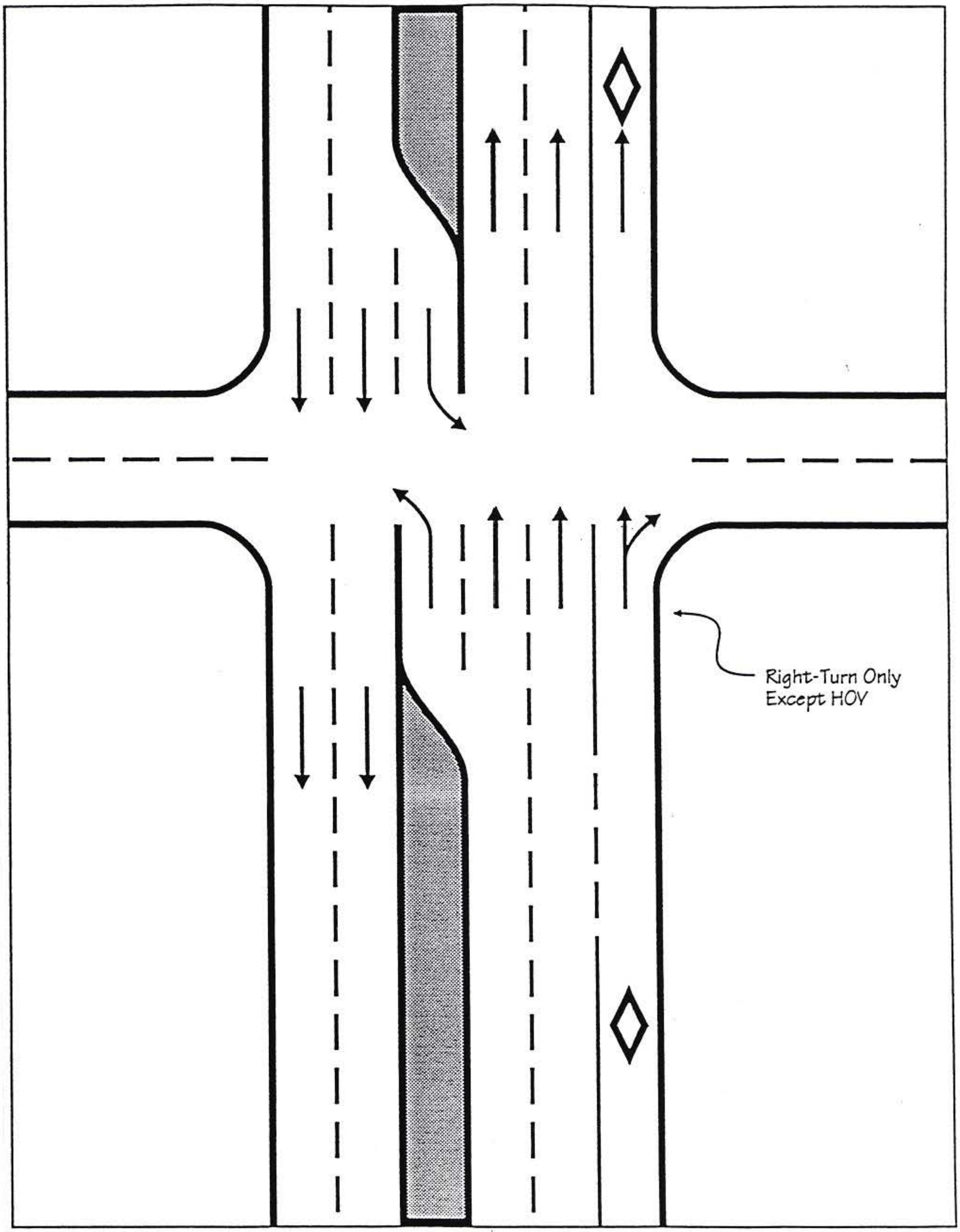
Signal Priority Alternatives

Automatic Vehicle Identification Systems

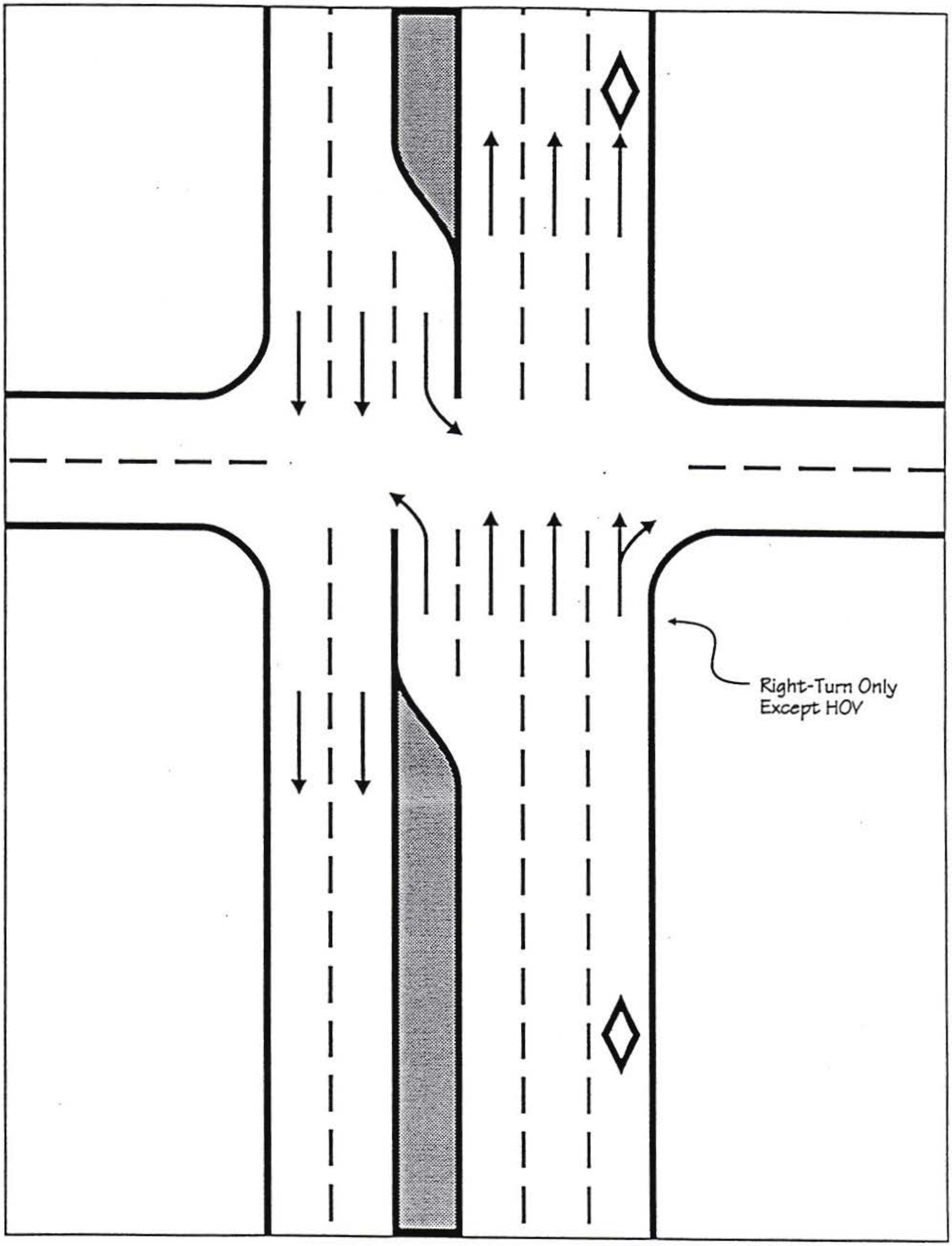
Technology	Configuration	Functions Available	Compatibility with Carpools	Advantages	Disadvantages
Radio Frequency Transmission (RF)	Tags and readers or other roadside or in-pavement antenna; compatible with loop detectors.	ID only; two way communication; voice; transmission of information	Compatible with the use of tags	The most applicable equipment available; compatible with simple tags and more sophisticated systems; used for two-way communication; compatible with roadside or in-pavement antenna.	The amount of data which can be transmitted with a loop configuration is limited.
Microwave	Tags and roadside readers; requires line-of-sight	Same as Radio Frequency Transmission	Compatible with the use of tags	Compatible with tags and two-way communication; transmission is at higher rates than RF.	Line-of-sight transmission, therefore signal can be screened by intervening vehicle; required power levels are high.
Optical/Infrared	Tags or bar-code tags; roadside readers; requires line-of-sight and good visibility.	ID only.	Compatible with the use of tags and bar codes	Compatible with tags/strict mounting requirements for tags and reader; can use bar codes.	Same as for microwave; requires good visibility; susceptible to dirt.
Surface Acoustical Waves (SAW)	Tags and roadside readers.	ID only.	Compatible with the use of tags	Same as for Optical except for use of bar codes.	Insufficient accuracy.

Alternative Signal Control Strategies

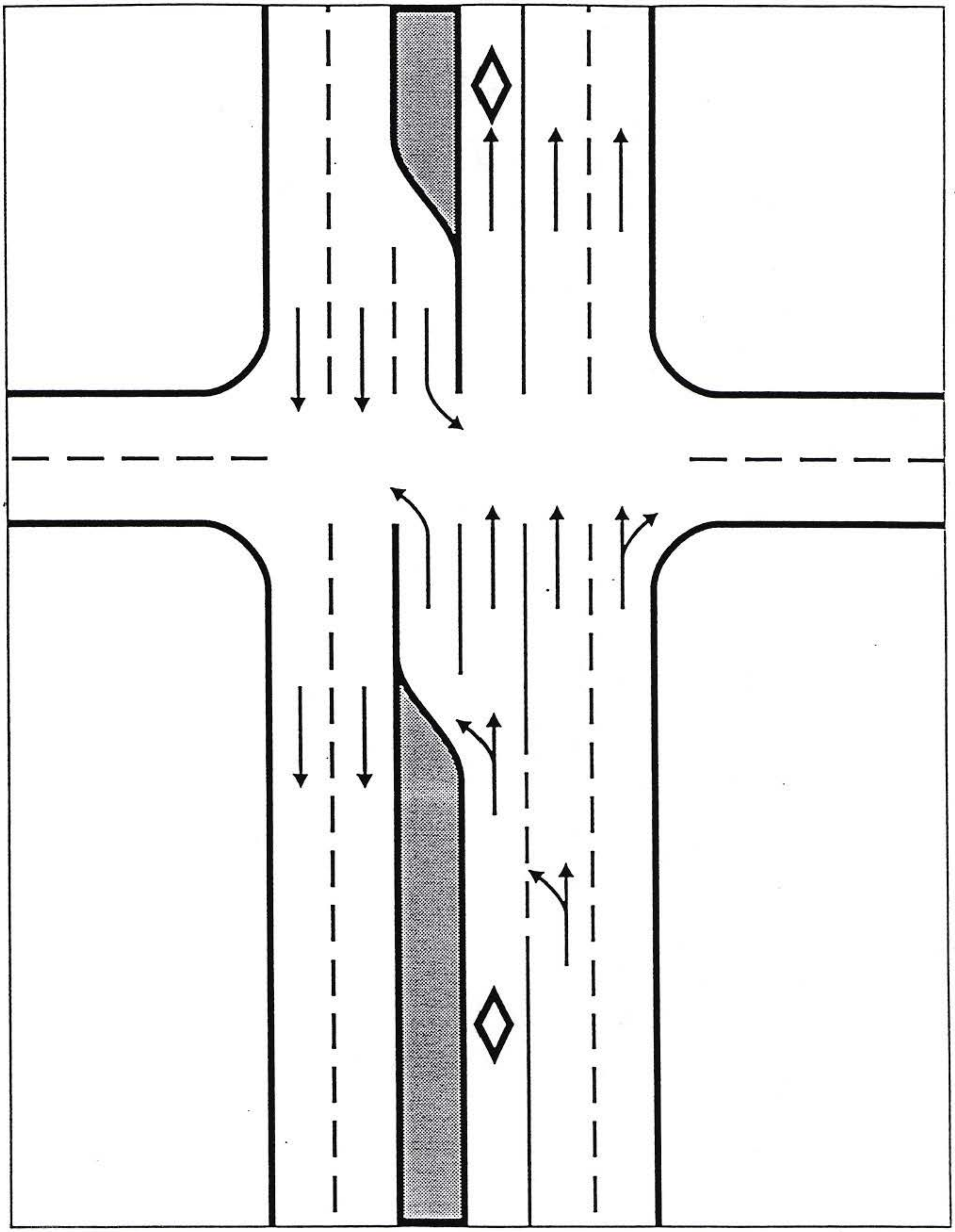
Strategy	Configuration	Function	AVI Technology	Advantages	Disadvantages
Traditional Premption	Local preemptor connected to controller; may be under system control.	Strict preemption.	Opticom; tag with roadside reader; loop detector with transponder on underside of vehicle.	Simple configuration; inexpensive.	No flexibility of control; possible safety problems with shor t intervals; disruption of general purpose traffic can be severe; legislative prohibition.
Traditional Priority	Requires traffic control system modification.	Flexible priority treatment.	All of the above.	Very flexible control options; simple concept.	Requires customized equipment.
Specialized Phasing	HOV lane at signal.	Provides priority to HOV lane.	Standard loop detection.	High service level to HOVs.	Directly impacts general traffic movements; requires HOV lane.
OPAC-RT with HOV Preemption	OPAC coordinator unit on standard controller with advanced detection (25 seconds) implements OPAC.	Strict preemption with facilitated recovery.	Same as traditional preemption.	OPAC provides control efficiency to minimize negative preemption impacts.	New technology; disadvantages of preemption.
HOV-Weighted OPAC-RT	Same as above.	Minimizes person delay and stops/maximizes throughput.	Same as traditional preemption.	Maximizes people movement efficiency.	New technology; disadvantages of preemption.



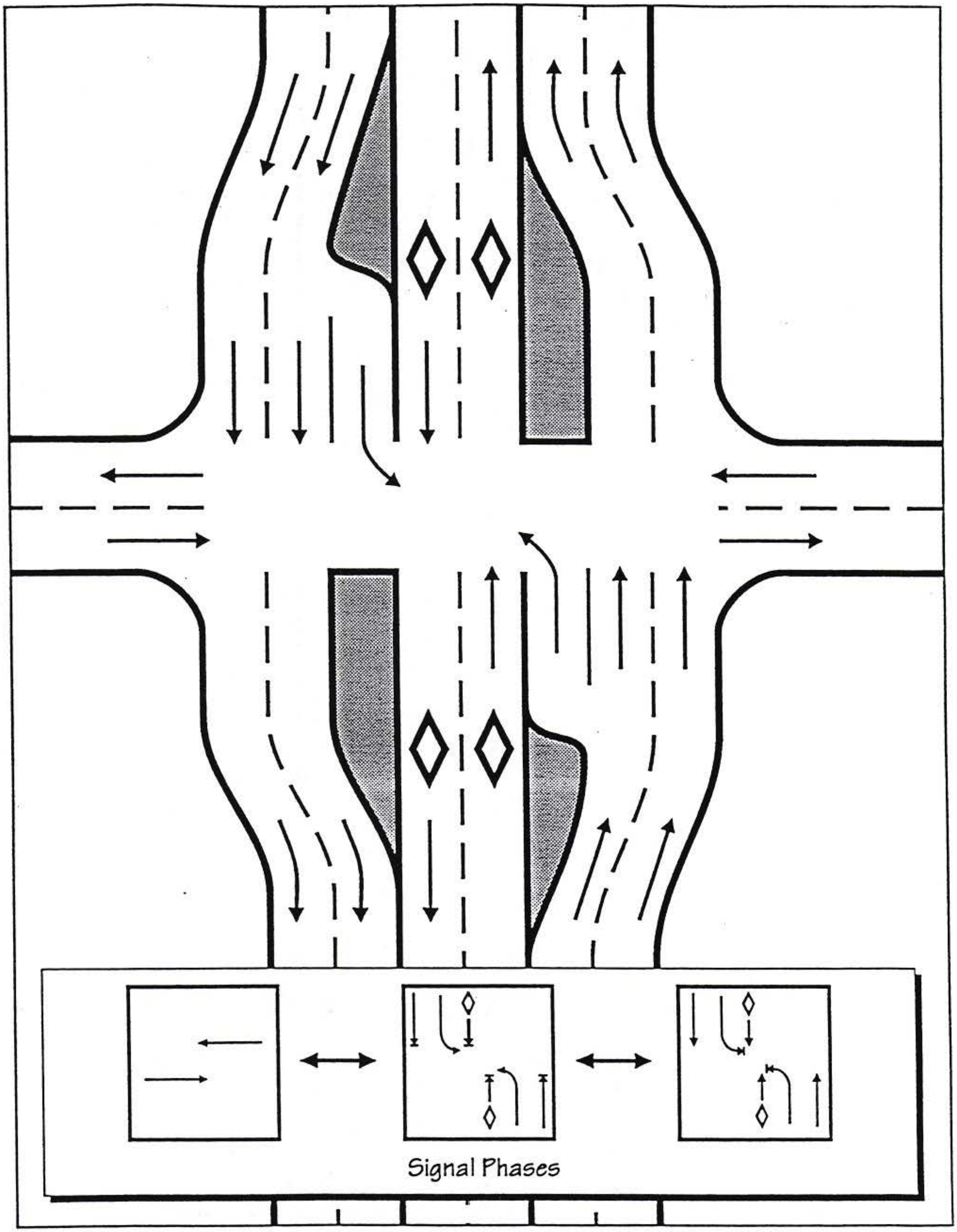
Continuous Right-Side HOV Lanes



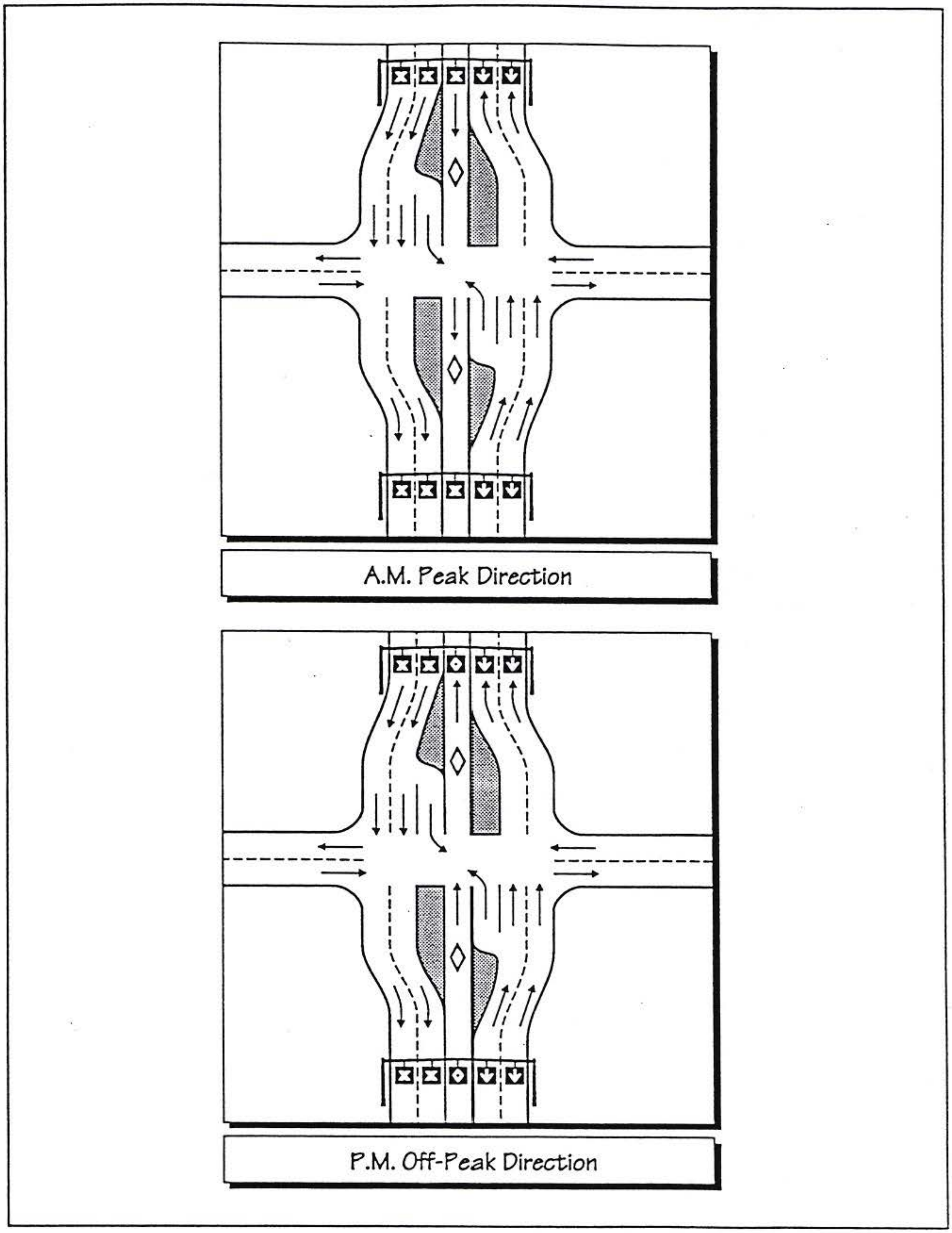
Right-Turn Only Except HOV



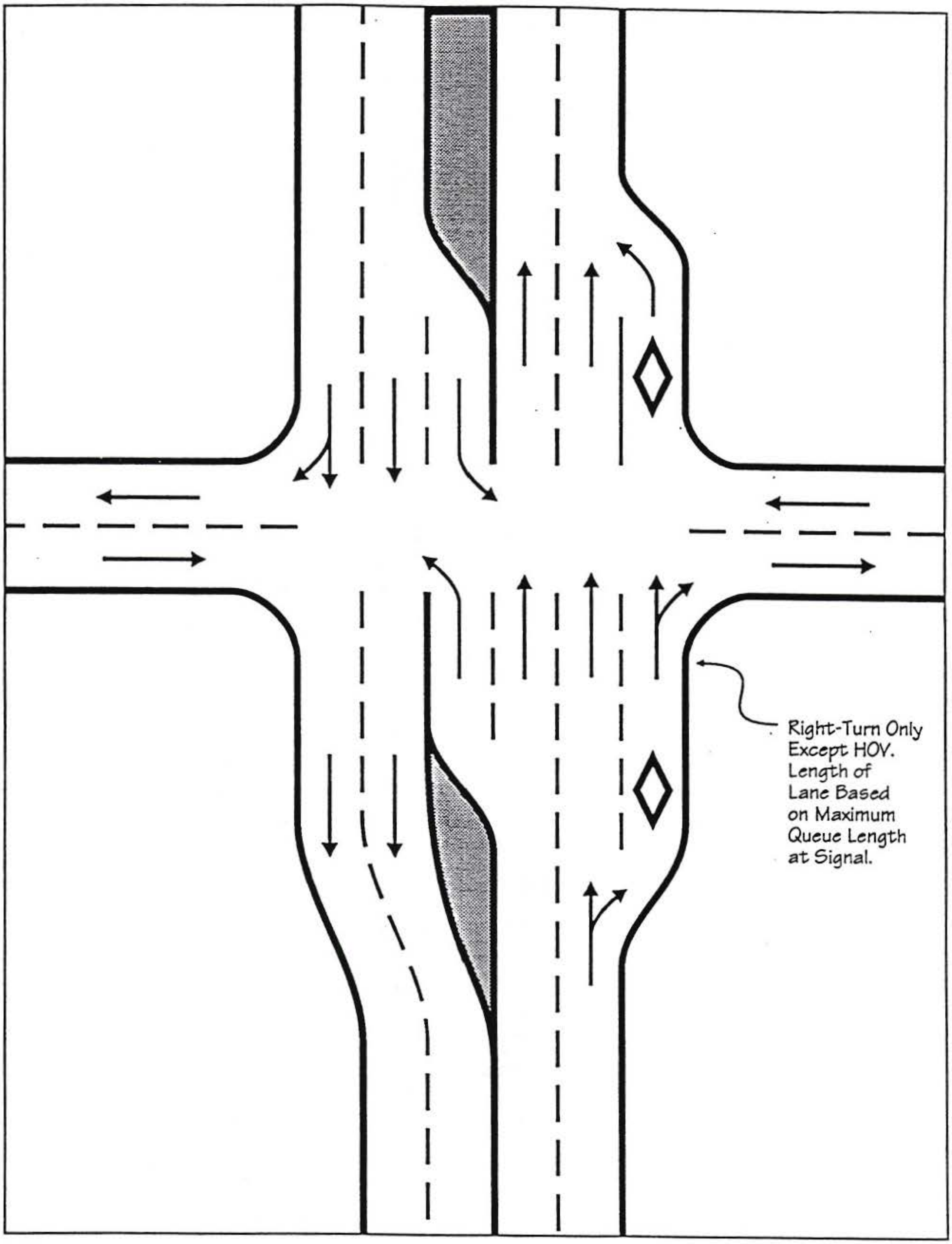
Continuous Left-Side HOV Lanes - Type A



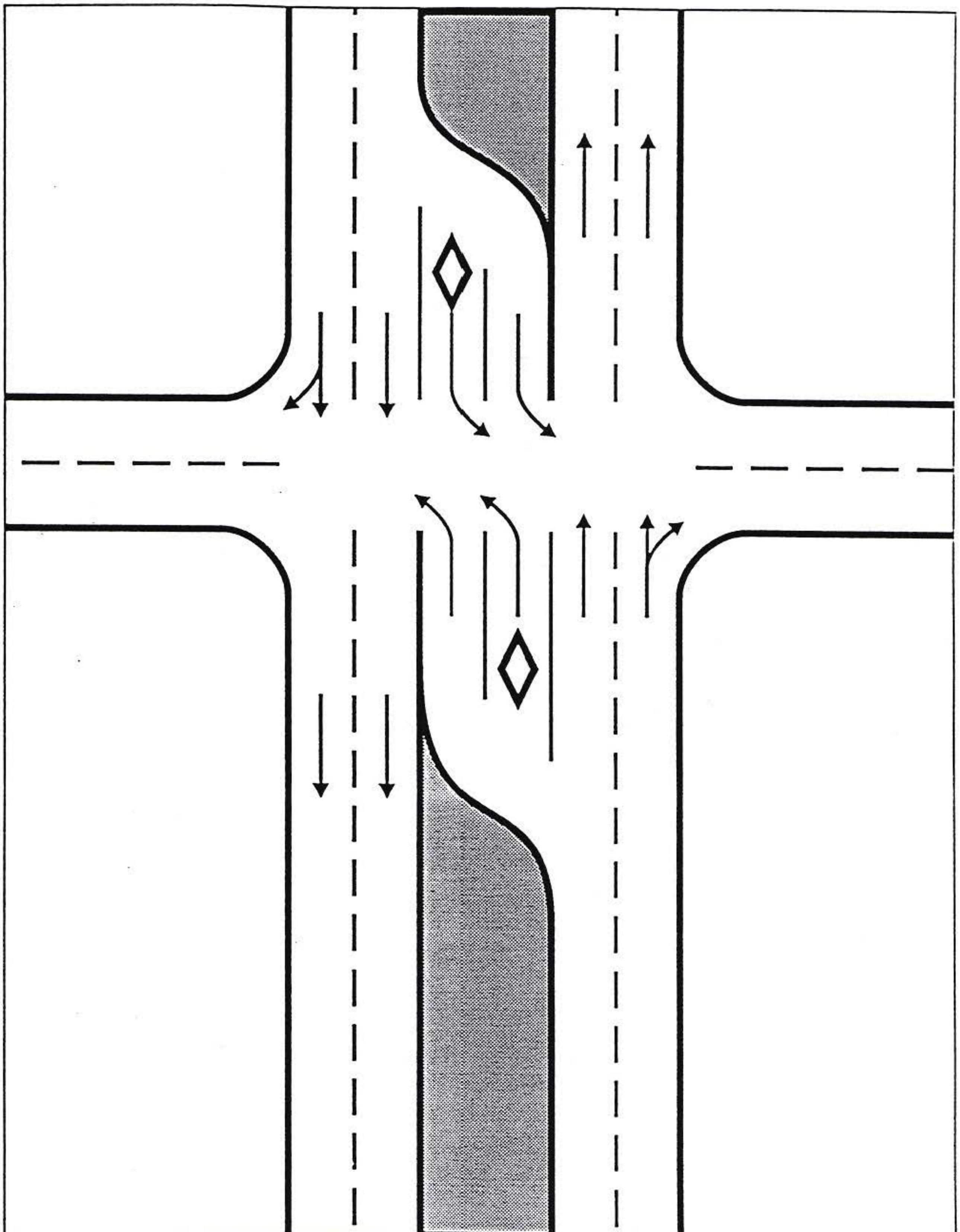
Continuous Left-Side HOV Lanes - Type B



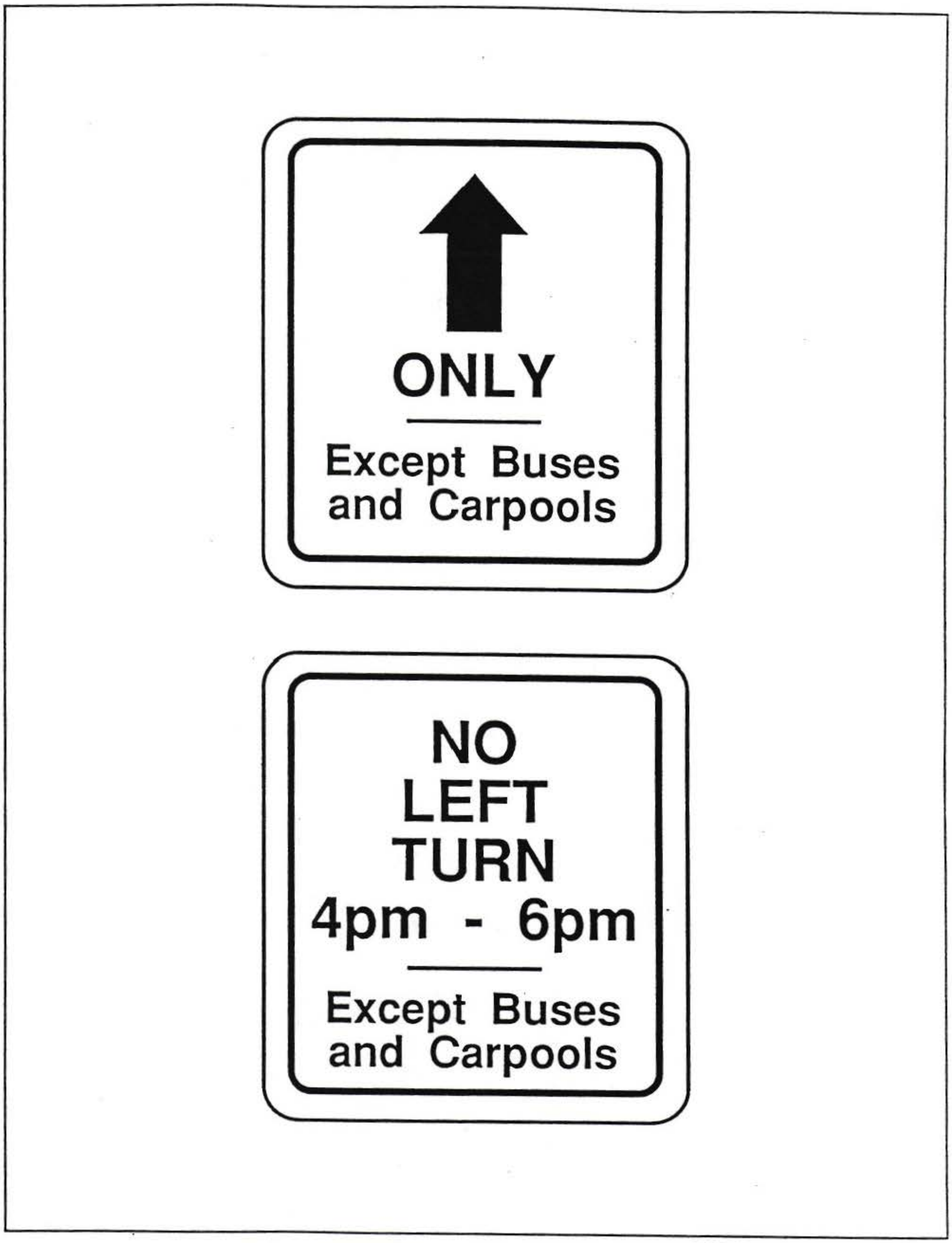
Reversible HOV Lanes with Signal Control



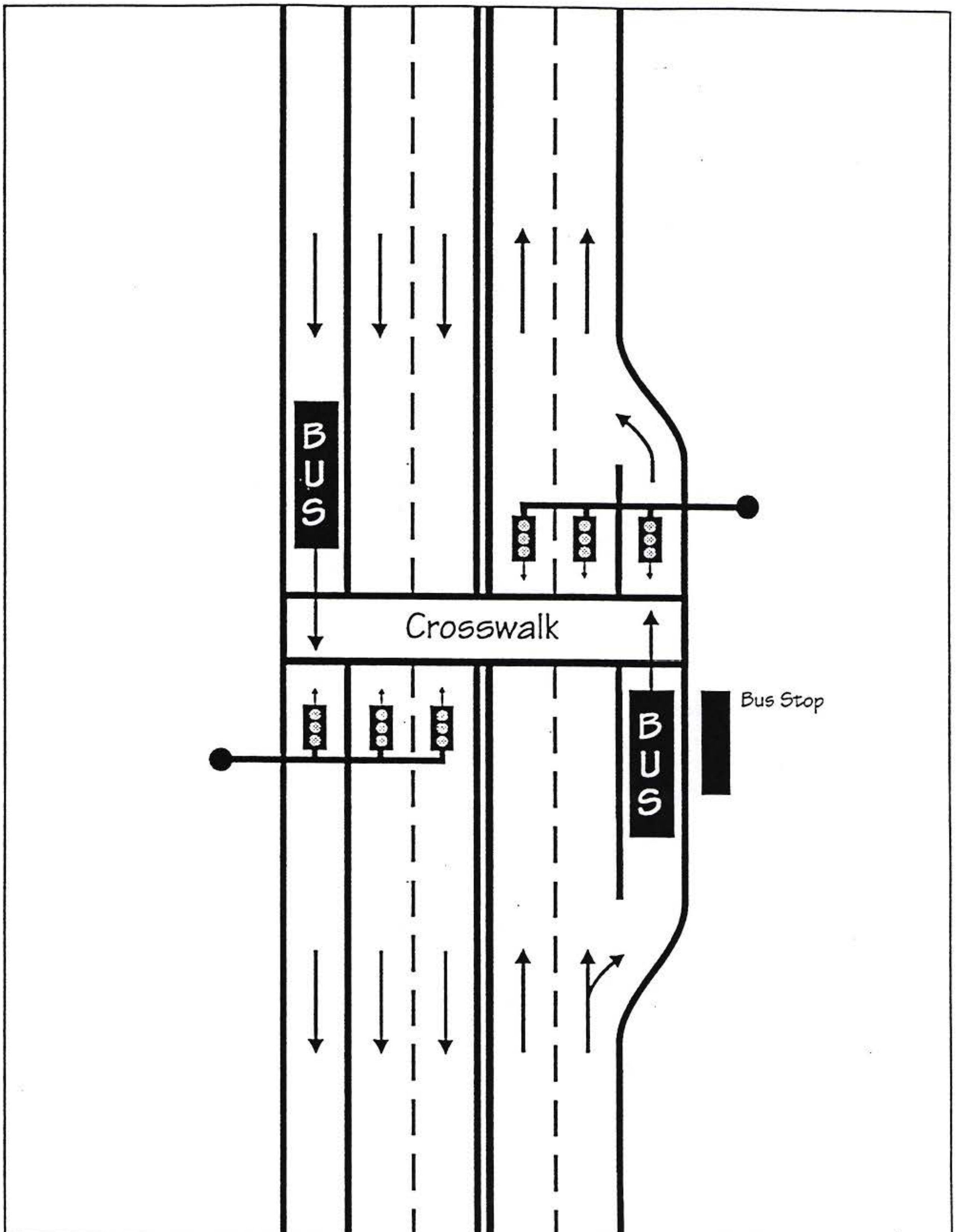
Signal Queue Jump



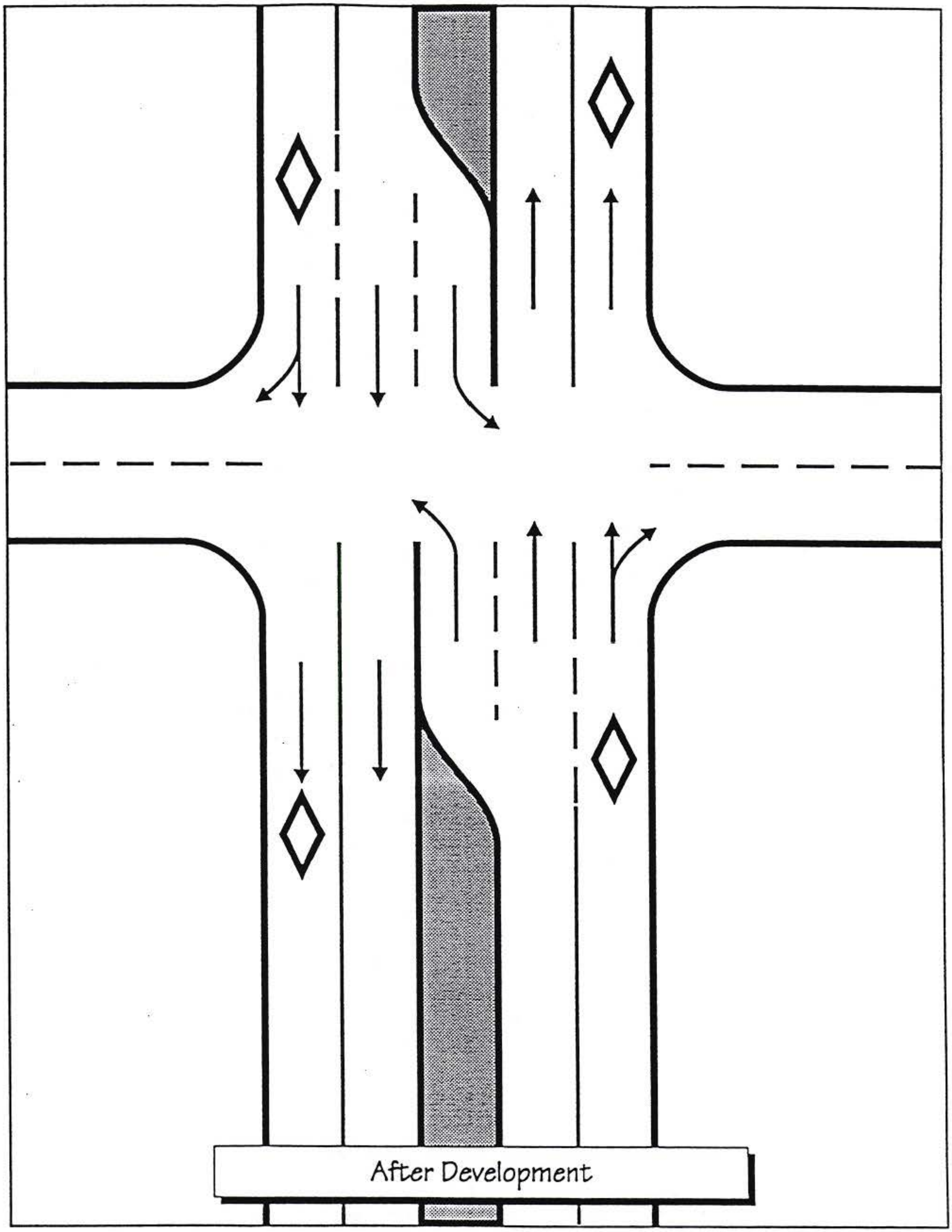
Dual Left-Turn Lanes with One Lane Reserved for HOV



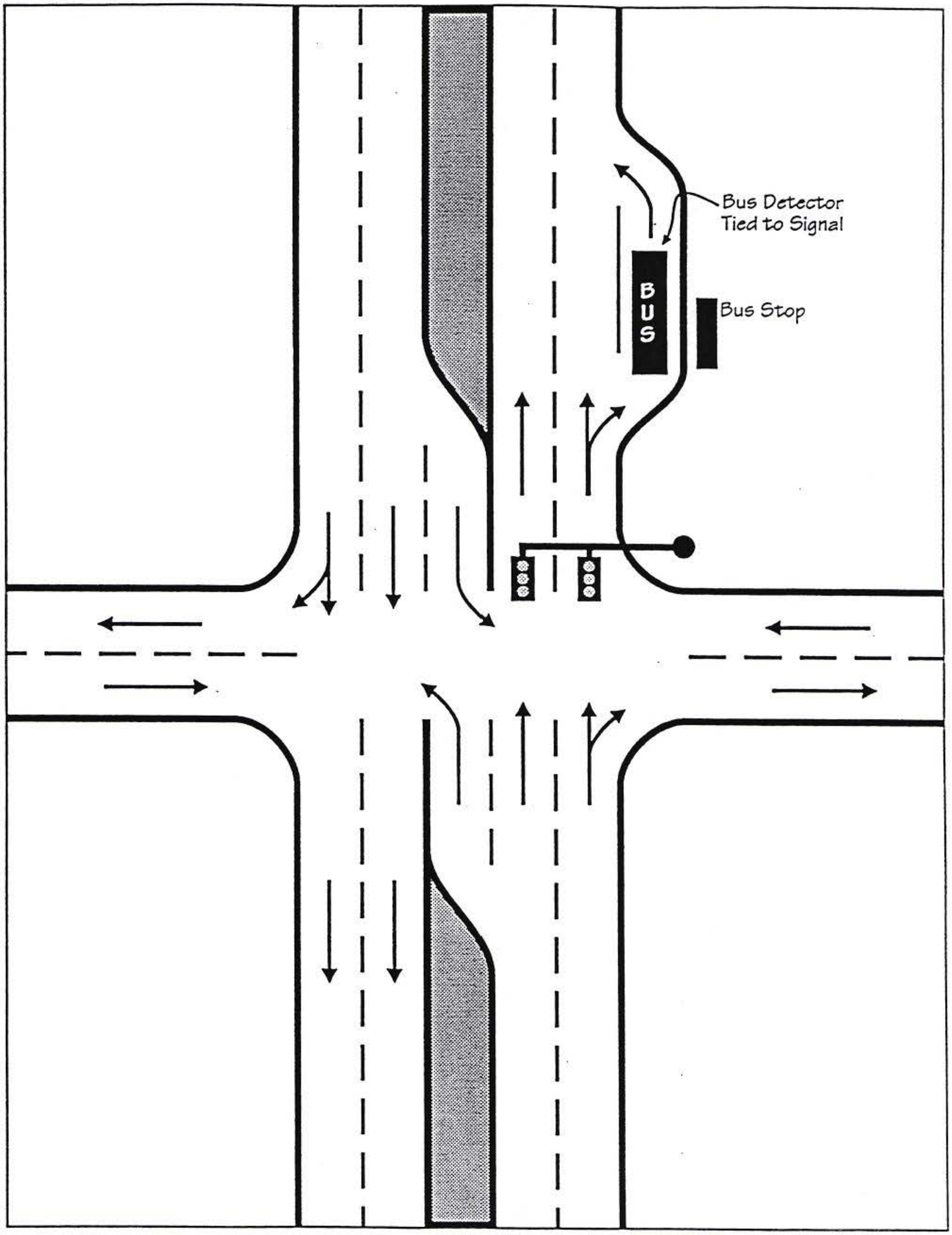
SOV Turn Restrictions



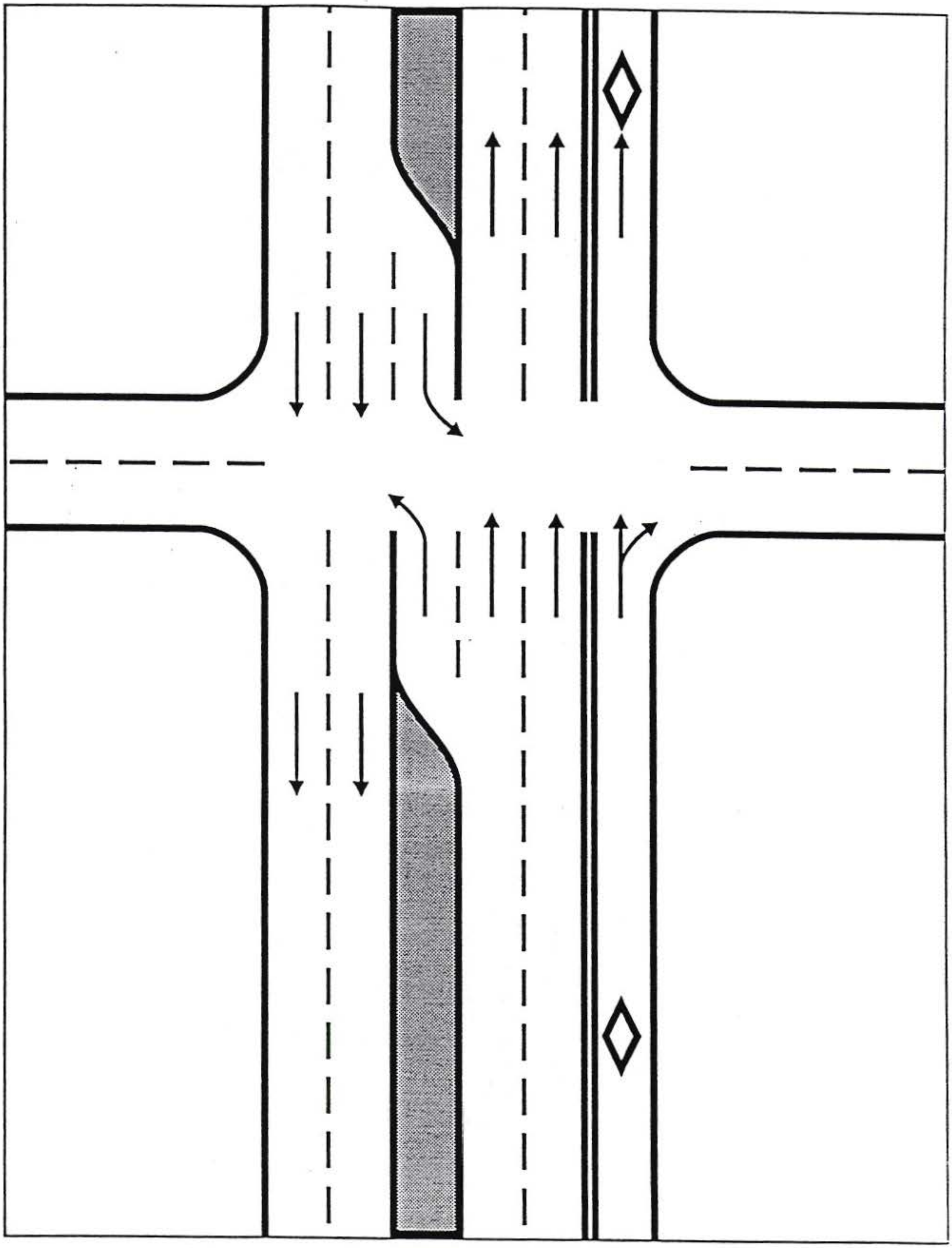
Mid-Block Preferential "Gating"



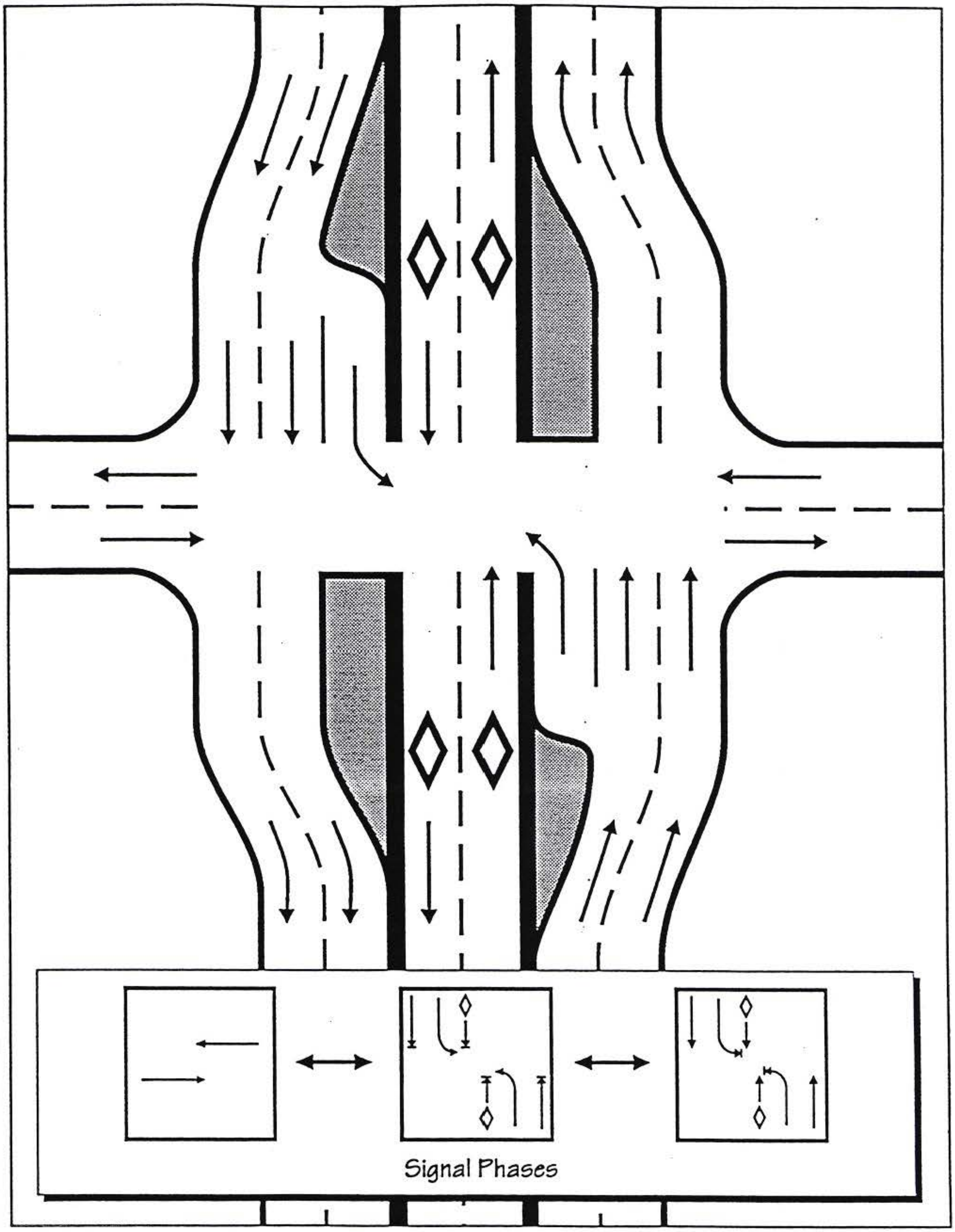
New Corridor with HOV Emphasis



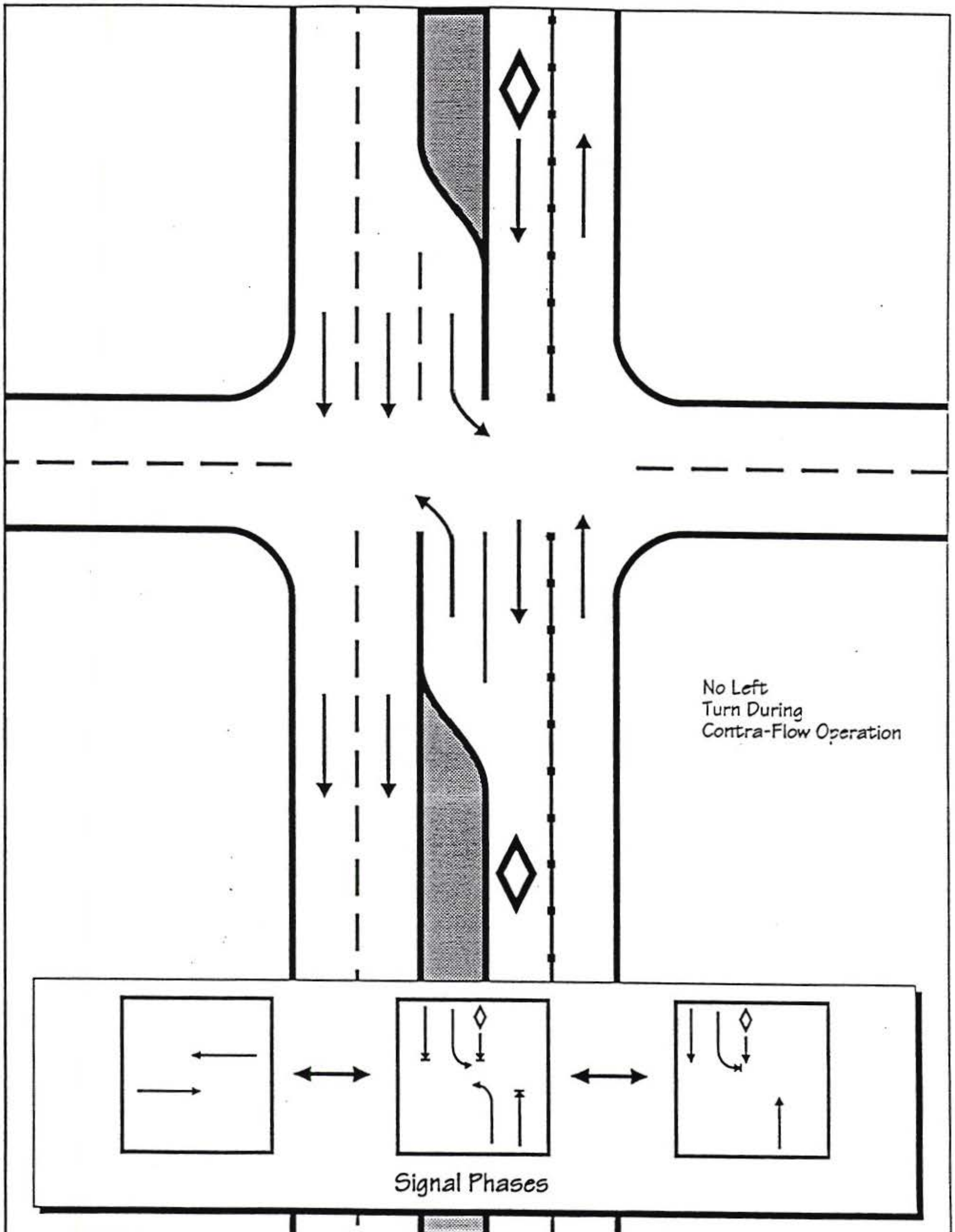
Bus Turnouts and Re-Entry of Traffic Flow



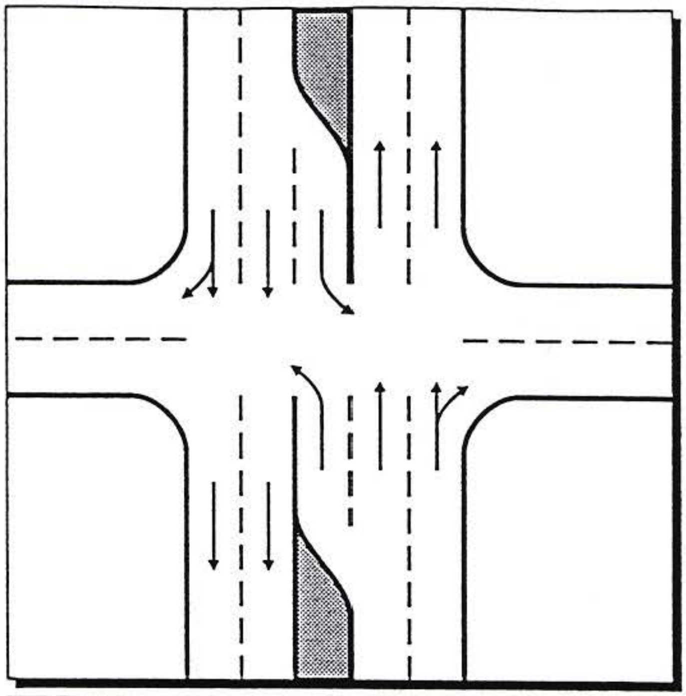
Buffer-Separated HOV Lanes



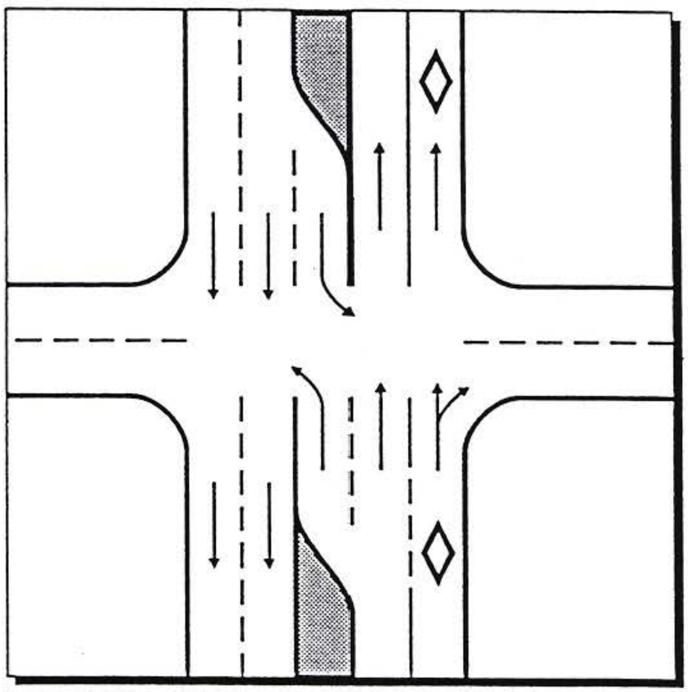
Barrier-Separated HOV Lanes



Contra-Flow HOV Lanes

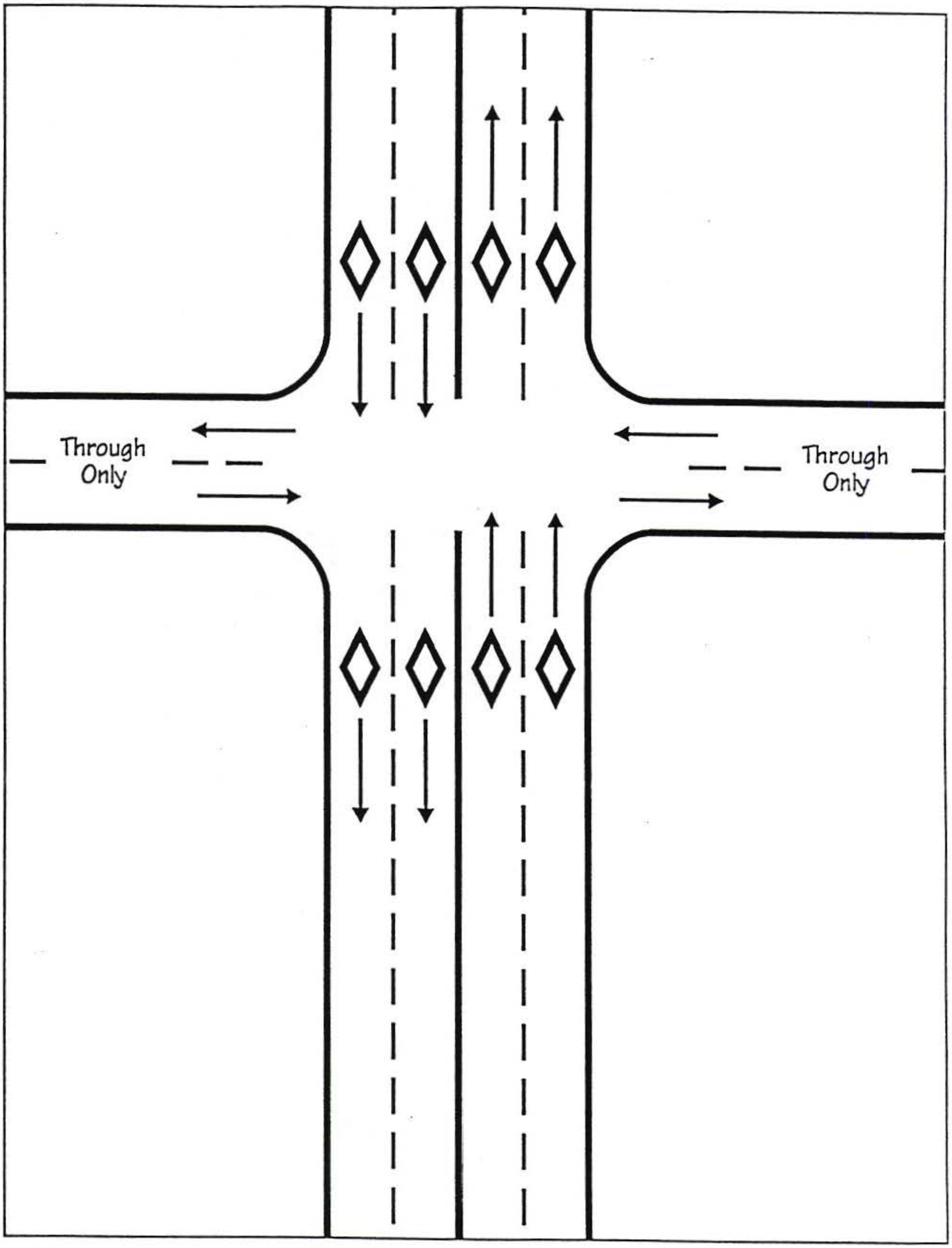


Before Conversion



After Conversion

Convert General Purpose Lanes to HOV Lanes



Bus Streets

ARTERIAL HOV TREATMENTS

ANNOTATED BIBLIOGRAPHY

ARTERIAL HOV TREATMENTS ANNOTATED BIBLIOGRAPHY

Batz, Thomas M., High Occupancy Vehicle Treatments, Impacts, and Parameters (A Synthesis); Volume I - Procedures and Conclusions, Final Report, FHWA/NJ-86-017-7767-1, New Jersey Department of Transportation, Division of Research and Demonstration, Trenton NJ, August 1986.

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Benevelli, David A., Radwan, A. Essam, and Hurley, Jamie W., "Evaluation of a Bus Preemption Strategy by Use of Computer Simulation," Transportation Research Record, No. 906, 1983, pgs. 60 - 67.

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Communications, and HOV Facility Operations, and appendices on AVL systems nationwide and internationally.

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Curtis, Owen, "The Hartford Study," 6th National Conference on High-Occupancy Vehicle Systems, 1992 Conference Proceedings, Arterial Street HOV Applications, Ottawa, Ontario, Canada, October 25 - 28, Transportation Research Circular No. 409, June 1993, pg. 41.

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Identifies and summarizes characteristics of 17 freeway and 37 city arterial priority techniques. Also covers planning, implementation guidelines, information sources, legal, financial and institutional considerations, and includes a transit authority, operating agency, and governmental unit directory.

Transpo Group, Inc., Highway 99 High Occupancy Vehicle Study, Technical Report 1, Summary of the Literature Review and Existing Data Collection Efforts, METRO, Seattle WA, January 11, 1991.

First of a series of four technical reports of the Highway 99 HOV Study. Summarizes results of a national and local literature review regarding HOV applications on arterials. It focuses on the definition and types of arterial HOV applications, warrants and guidelines used to determine whether an arterial HOV improvement should be implemented, performance measures used to evaluate the success of an application, and potential difficulties with implementation, design, and enforcement. Also includes information on planned improvements, traffic volumes, and level of service for the year 2000 for this corridor.

Transpo Group, Inc., Draft Highway 99 High Occupancy Vehicle Study, Technical Report 2, Alternatives Evaluation and Preferred Alternative Recommendation, METRO and Community Transit, Seattle WA, May 20, 1991.

Second of the above-mentioned series. Summarizes the results of the alternatives analysis using year 2000 operating conditions for the SR 99/Evergreen Way study corridor, between 145th and Casino Road in Everett.

Turnbull, Katherine F., International HOV Facilities, paper presented at the 71st Annual Meeting of the Transportation Research Board, Washington, DC, January 1992, Paper No. 920628, Texas Transportation Institute, College Station TX.

Provides an overview and description of HOV lanes in operation in non-North American countries. Compares similarities and differences between HOV projects in North America and other parts of the world. Makes suggestions for improving the exchange of information on international HOV projects.

Turner, Shawn M., "High-Occupancy Vehicle Treatments on Arterial Streets," ITE Journal, November 1993, pgs. 22 - 29.

This article attempts to fill in the lack of guidelines for HOV faciliites on arterial streets. It contains a discussion of the major issues associated with arterial street HOV facilites for CBD's, freeway-to-arterial connections, and line-haul arterial streets.

Turnquist, Mark A., "Strategies for Improving Reliability of Bus Transit Service," Transportation Research Record, No. 818, 1981, pgs. 7 - 13.

Analyses and reports principal findings regarding four transit reliability improvement strategies: vehicle-holding, stops reduction, signal preemption, and exclusive right-of way.

Wattleworth, J. A., et al., Evaluation of the NW 7th Avenue Express Bus and Priority System, Reports I-1 through I-9, UMTA-FL-06-006, Urban Mass Transportation Administration, Washington DC, 1977.

Wheeler, Linda M., "Operation Green Light: A Comprehensive Plan to Combat Congestion in Northeastern Illinois, Compendium of Technical Papers. Institute of Transportation Engineers, 60th Annual Meeting, Orlando FL, August 5 - 8, 1990, ITE Pub. No. PP-020, Washington DC, pgs. 8 - 11.

Discussion of the Operation Green Light initiative underway in Illinois, an effort to involve all transit, highway and transportation planning agencies in resolving urban congestion. Specifically discussed are transit signal preemption and HOV treatments being recommended for demonstration projects.

Williams, Thomas, Haselkorn, Mark, and Alalusi, Kathy, Impact of Second Priority Signal Preemption on Kitsap Transit and Bremerton Travelers, Draft, Transportation Northwest, University of Washington, Seattle WA.

This nine-month study focused on four bus routes and eight intersections in Bremerton, Washington, attempting to assess the impact of a second priority signal preemption system on bus travel time and delay to automobiles at cross streets.

Willis, Cecil O., "High-Occupancy Vehicle Considerations on an Arterial Corridor in Pensacola, Florida," Transportation Research Record, No. 722, 1979, pgs. 97 - 105.

An arterial corridor study to determine the feasibility of implementing HOV priority techniques. Discusses the decisions made as to data collection, data analyses, alternatives selection, and the elimination of parts of the corridor from further consideration.

Yagar, Sam, "Efficient Transit Priority at Intersections," Transportation Research Record, No. 1390, July 1993, pgs. 10 - 15.

Discusses adverse affects of not including transit operations when modeling traffic flow and designing signal timing, and outlines fixed- and real-time methods for providing appropriate transit priority to reduce travel times for transit passengers SOV's alike.

Yedlin, M., et al., Bus Signal Priority Strategies Review and State of the Art Assessment, unpublished report, DOT-FH-11-9609, U.S. Department of Transportation, Washington DC, 1979.

Yedlin, M., and Lieberman, E. B., "Analytic and Simulation Studies of Factors that Influence Bus-Signal-Priority Strategies," Transportation Research Record, No. 798, 1981, pgs. 26 - 29.

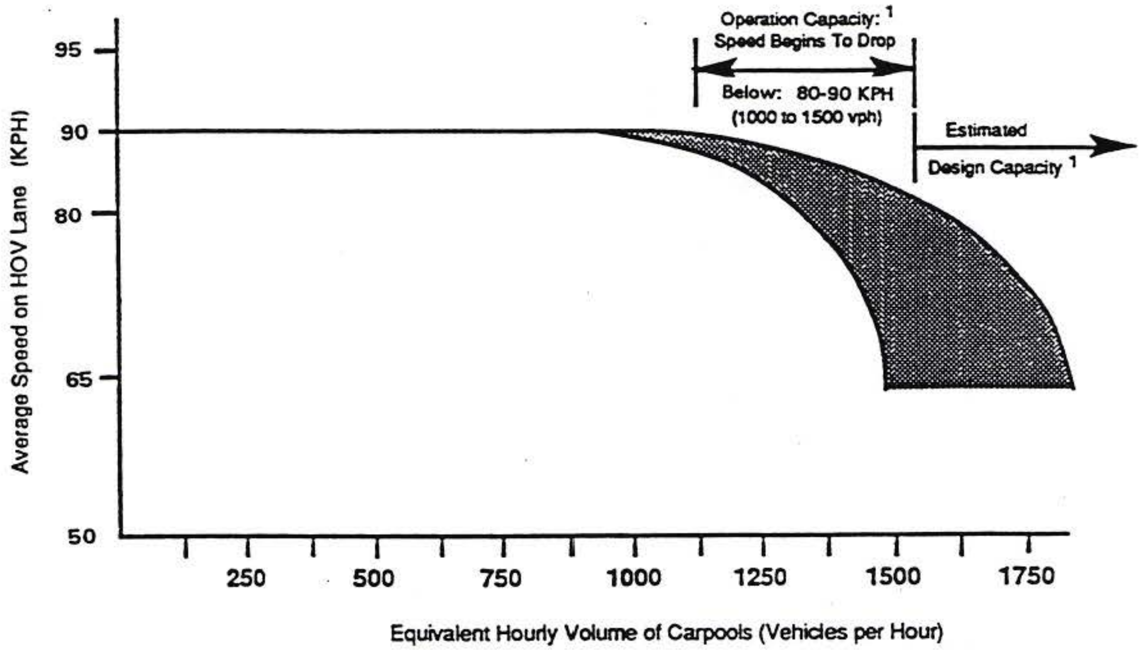
Presents two techniques to identify optimum conditions for implementation of bus-signal-priority strategies: an analytic model to compare the performance of bus systems operating with and without bus signal preemption, and the NETSIM model which has been modified to incorporate a bus-signal preemption strategy.

Zahavi, Yacov, and Roth, Gabriel, "Measuring the Effectiveness of Priority Schemes for High-Occupancy Vehicles," Transportation Research Record, No. 770, 1980, pgs. 13 - 21.

Discusses using the total distance traveled on a system per day by all travelers as a useful measurement of system output, and using the product of daily distance traveled and speed per household and per traveler as a useful measurement of mobility. Applies these measurements to the Singapore Area Licensing Scheme in June 1975.

HOV OPERATION

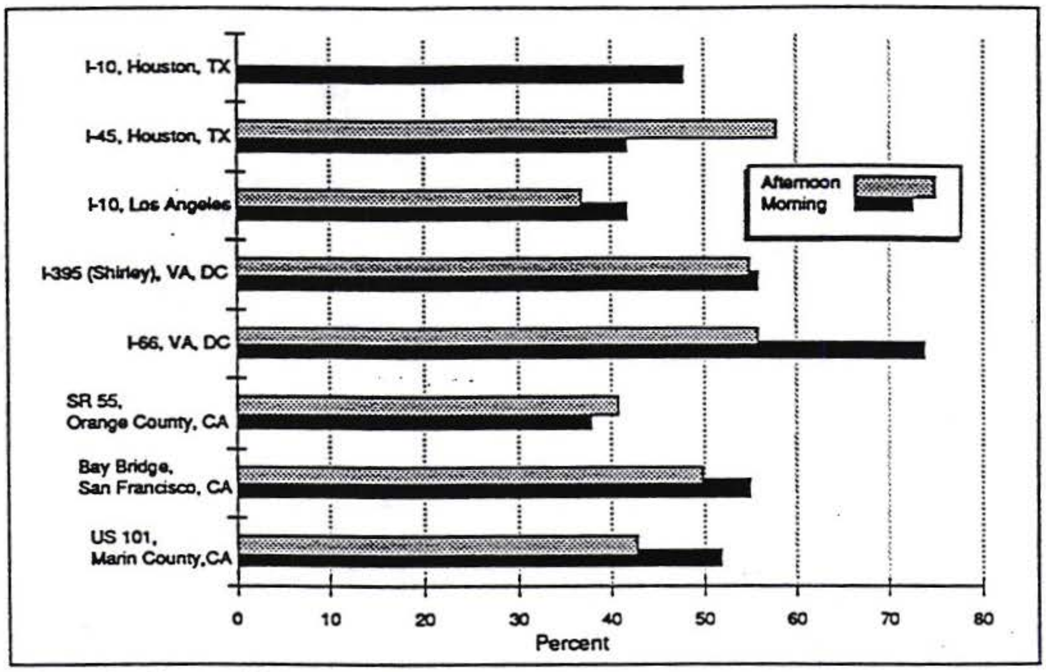
HOV Lane Speed/Volume Relationship



[1] Specific values depend on vehicle mix, type of facility and project geometrics. For definitions of terms, see Appendix A.

Source: Adapted from Mounce & Stokes 1985.

HOV Lane Volume Ratio of Peak Hour to Peak Period on Various Projects



Source: Cechini 1989 and Christiansen 1988.

Vehicles Allowed to Use High-Occupancy Vehicle Facilities

HOV Facility	Public/ Private Transit Buses	School Buses	Vanpools	Carpools	Taxi	Police	Emergency	Motor-cycles	Other Vehicles	Carpool Occupancy Requirements
BUSWAY FACILITIES IN SEPARATE R.O.W.										
• Ottawa, Canada										
Southeast Transitway	X					X	X		Intercity Bus	NA
Other Transitways	X					X	X			
• Pittsburgh, PA										
East PatWay	X					X	X			NA
South PatWay	X					X	X		LRT	NA
FACILITIES IN FREEWAY R.O.W.										
Reversible-Flow Facilities										
• Houston, TX										
I-45 (Gulf & North), US 290	X	X	X	X	X	X	X		Airport Bus	2+
I-10 (Katy)	X	X	X	X	X	X	X		Airport Bus	3+ AM peak, 2+ other times
• Minneapolis, MN, I-394	X	X	X	X	X	X	X	X		2+
• San Diego, CA, I-15	X	X	X	X	X	X	X	X		2+
• Northern Virginia (Washington, DC)										
I-395 (Shirley)	X	X	X	X		X	X			3+
• Pittsburgh, PA, I-279	X	X	X	X	X	X				3+
Two-Way Facilities										
• Los Angeles, CA, I-10	X	X	X	X		X	X	X		3+
• Northern Virginia, I-66	X	X	X	X		X	X			
• Honolulu, HI, Moanalua Fwy.	X	X	X	X	X	X	X			2+
• Los Angeles, CA, Rte. 91	X		X	X	X	X	X	X		2+
• Miami, FL, I-95	X	X	X	X	X	X	X			2+
• Orange County, CA, Rte. 55 & I-405	X		X	X	X	X	X	X		2+

Vehicles Allowed to Use High-Occupancy Vehicle Facilities

HOV Facility	Public/ Private Transit Buses	School Buses	Vanpools	Carpools	Taxi	Police	Emergency	Motor-cycles	Other Vehicles	Carpool Occupancy Requirements
Two-Way Facilities (continued)										
• Santa Clara County, CA, US 101, San Tomas, others	X	X	X	X	X	X	X	X		2+
• Orlando, FL, I-4	X	X	X	X	X	X	X	X		2+
• Marin County, CA, US 101	X	X	X	X	X	X	X	X		2+
• Seattle, WA										
I-5	X	X	X	X	X	X	X	X		3+/2+
SR 520	X	X	X	X	X	X	X	X		2+
I-405, I-90	X	X	X	X	X	X	X	X		2+
• Hartford, CT										
I-84	X	X	X	X	X			X		3+
• Phoenix, AZ, I-10	X	X	X	X				X		2+
Contraflow Facilities										
• New Jersey, Rte. 495 (Lincoln Tunnel)	X									Not applicable
• New York City, NY										
Long Island Expressway	X	X	X		X	X	X			Not applicable
Gowanus Expressway	X	X	X		X	X	X			Not applicable

Eligibility Issues

- Maximize People Moving Capacity
- Facilitate Car Pool Formation
- Level of Service in HOV lane
  (At least two levels higher than GP lanes)
- Empty Lane Syndrome
  (Minimum use 180 to 400 vph)
- Lane Capacity
  (500 to 1100 for right lane, 1500 to 1900 for left lane)
- Number of buses per hour
- Quality of Geometrics
- Radial vs. suburban facility
- Variation by time of day
- Other users
  (motorcycles, taxis, empty buses, emergency vehicles, trucks)

Comparison of User/Eligibility Trade-Offs

Primary User Definition*	Advantages	Disadvantages
Three or more (3+) during peak periods, two or more (2+) during off-peak periods	• Allows for separate control of peak/off-peak period volumes once peak period exceeds design capacity • More flexible than strict 2+ or 3+ definitions • Easier to modify • Promotes a broader distribution of peak period demand over a longer period • Can be an intermediate step in gradually increasing overall occupancy requirements from 2+ to 3+	• Harder to understand • Harder to enforce, promotes violations in transition periods • May not be applicable from a corridor or regional perspective (justification for consideration may be a point-specific bottleneck) • Limited experience (Virginia I-66 and Houston I-10)
Two or more person (2+) vehicles	• Most frequently applied definition for opening new projects • Easily understood • Initial use generally meets minimum requirements • Most flexible definition to encourage ridesharing • Most appropriate for corridors with low bus transit affinities • Suitable for 24-hour operation	• Can quickly overwhelm the facility's design capacity • Difficult to alter once established (easier to lower than raise requirements) • Limits the improvement in person-carrying capacities on most projects to no more than two equivalent mixed-flow lanes
Three or more (3+) vehicles (or 4+)	• Adequately preserves future person-moving capacity for most projects • Easily understood • A more suitable long-term definition after an HOV market has been created with lower occupancy rules • More suitable to peak periods only	• Will not sustain an adequate initial perception of use on all projects • Makes rideshare formation harder to achieve and sustain

Comparison of User/Eligibility Trade-Offs

Primary User Definition*	Advantages	Disadvantages
Bus only	• Controlled user group that is easily managed • Maximizes person-moving capacity • Minimizes enforcement needs • Works well in slower-speed busway environments on separate R.O.W. where public cannot perceive the facility as underutilized	• Speeds hard to sustain when volumes are high (greater than 200 vehicles per hour) • Offers no benefits to other HOVs; ignores a potentially large market of users • Not practical for most corridors
Authorized vehicles only (usually buses, taxis, and possibly vanpools)	• Potential to control use of HOV facilities that are not safe if opened to unfamiliar users (e.g., contraflow) • More effective regulation of users, allowing for more precise design capacity management • Minimizes enforcement needs • Easier to modify definition without changing signs and rules	• Increases administrative costs for authorization procedures and training • More difficult to communicate definition to the public • Not consistent with general terminology used throughout the US • Limited experience

24 Hour vs Peak Period Only

- Off Peak Benefit to GP = ?
  (Contribute to Speeding?)
- Safety issues if geometric compromises
- Enforcement issues
- Signing complexities
- Incentive to HOV off peak
- Basic Philisophy
  (Does lane "belong" to HOV's?)

Selected HOV Operations Shared with Mixed-Flow Traffic

HOV Facility	No. of Lanes	Length (mi.)	Facility Shared	Hours of Operation	Status
• Miami, FL, I-95	1 each direction	7.5	Mixed-flow	7-9 am SB	Operational, not enforced
• Orlando, FL, I-4	1 each direction	6.2 NB 14.5 SB	Mixed-flow Mixed-flow	4-6 pm NB 7-9 am, 4-6pm	In operation
• Marin County, CA, US 101	1 direction	3.7	Mixed-flow	6-9 am SB 4-7 pm NB	In operation
• Santa Clara County, CA					
I-280	1 each direction	10	Mixed-flow	5-9 am, 3-7 pm	In operation
Rte. 237	1 each direction	4.5	Mixed-flow	5-9 am, 3-7 pm	In operation
US 101	1 each direction	12 SB 11 NB	Mixed-flow	5-9 am, 3-7 pm	In operation
San Tomas Expy.	1 each direction	8	Mixed-flow	6-9 am, 3-7 pm	In operation
Montague Expy.	1 each direction	6	Mixed-flow	5-9 am, 3-7 pm	In operation
• San Francisco, CA Rte. 280	1 (SB only)	4	Mixed-flow	3-7 pm	In operation (temp.suspended, 1990)
• Fort Lee, NJ, I-95 (New York City)	1 (EB only)	1	Mixed-flow & right shoulder	7-9 am	In operation
• Honolulu, HI Moanalua Fwy.	1 each direction	2.3	Mixed-flow	6-8 am, 3:30-5 pm	In operation
• Northern Virginia I-95	1 each direction		Mixed-flow	6-9 am, 3:30-6 pm	In operation

Source: Turnbull and Hanks 1990.

HOV Operations Using Available Shoulders -- Past and Present

	HOV Facility	No. of Lanes	Length (mi.)	Shoulder Location	Hours of Operation	Status
1.	Miami, I-95[1]	1 each direction	7.5	Median (inside)	7-9 am SB 4-6 pm NB	Shoulder converted to mixed-flow lane during off-peak[1]
2.	Los Angeles, Rte. 91	1 (EB only)	8	Median (inside)	3-7 pm	Converted operation to 24 hours
3.	Seattle[2]					
	SR 520	1 (WB only)	3	Outside (right)	24 hours	Both projects in operation as interim facilities
	I-405	1 each direction	6	Outside (right)	24 hours	

[1] Construction is now underway to add buffers and inside shoulders.
[2] Another interim right shoulder conversion is being implemented on I-5 south.

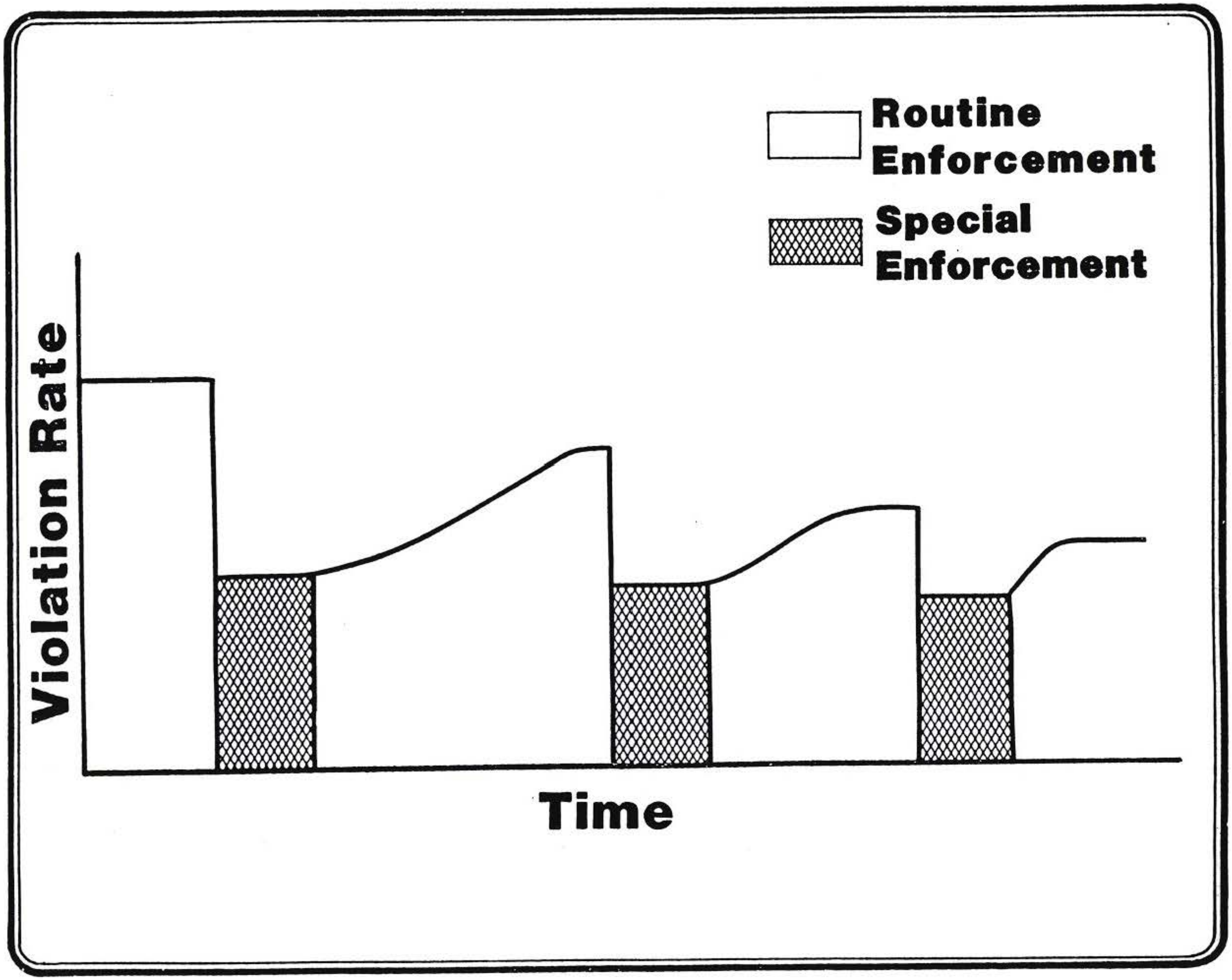
HOV ENFORCEMENT FACTORS

- ENFORCEMENT AREAS
  - Placement
  - Safety
- HOV SIGNING
- ENFORCEMENT POLICIES
- ENFORCEMENT AND SAFETY

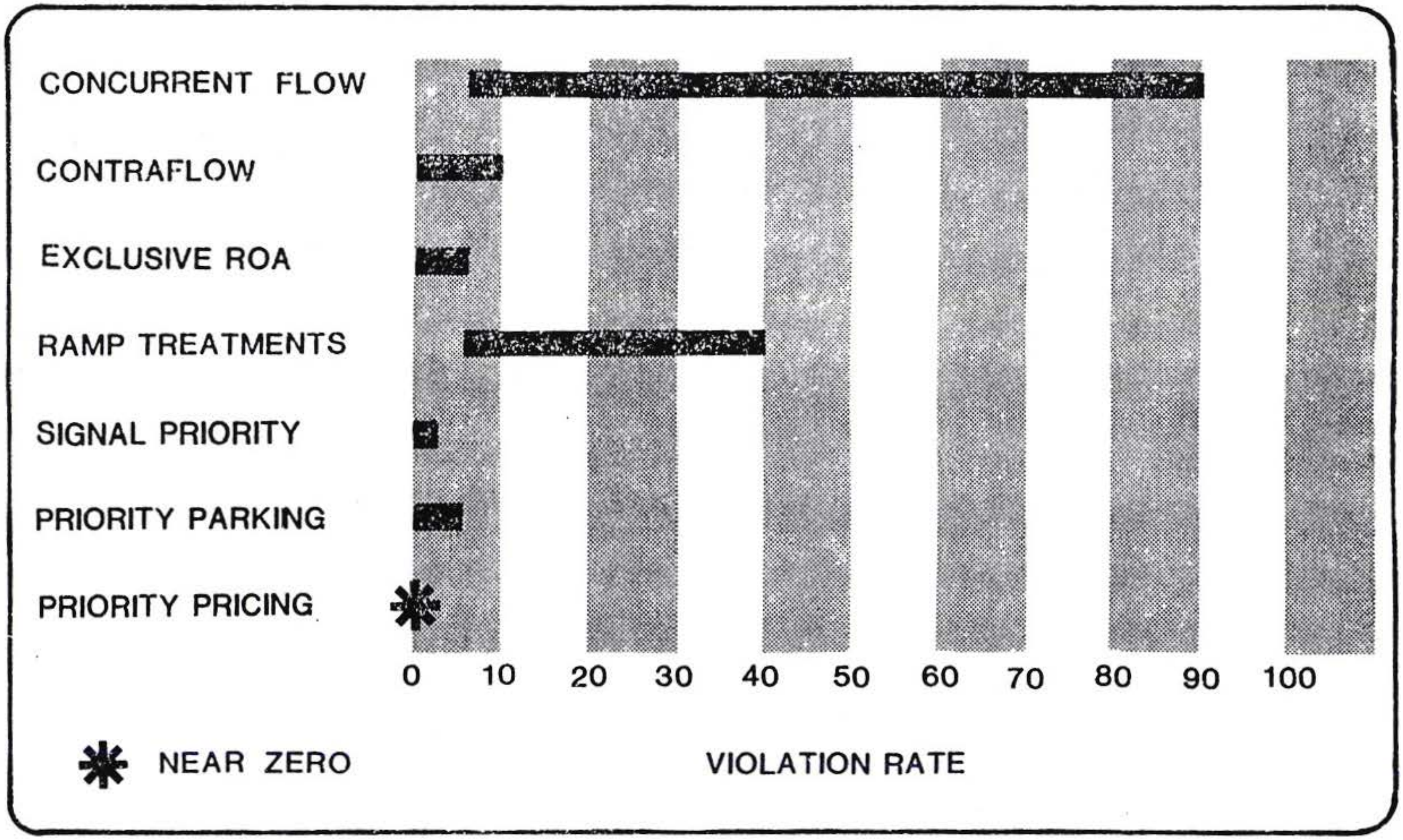
KEYS TO EFFECTIVE HOV ENFORCEMENT

- LEVEL OF ENFORCEMENT IS DEPENDENT UPON FACILITY TYPE
- OFFICERS MUST HAVE SAFE AND CONVENIENT PLACES TO ENFORCE
- A HIGHLY VISIBLE ENFORCEMENT PRESENCE SHOULD BE MAINTAINED
- TRY TO DIVERT POTENTIAL VIOLATORS BEFORE THEY CAN TRAVERSE SOME PART OF AN HOV LANE
- INVOLVE ENFORCEMENT PERSONNEL DURING HOV PLANNING AND DESIGN

Source: Texas Transportation Institute (1988)
WSDOT Design Manual (June 1989)



Effects of Selective Enforcement Strategies on Violation Rates



Range of Violation Rates

Enforcement Provisions Employed by Various HOV Projects

	Full Shoulder(s) or Wide Buffer	Designated Enforcement Areas: At Entrance or Termination	Designated Enforcement Areas: Along Guideway	Designated Enforcement Areas: Designated Pad(s)	Self Enforcement	Citation by Mail	No Provisions
REVERSIBLE							
Houston, TX							
I-45 (North)		X		X			
I-45 (Gulf)		X		X			
US-290 (NW)		X					
I-10 (Katy)		X					
Virginia (Washington, D.C.)							
I-395 (Shirley)	X				X	X	
I-66	X				X	X	
San Diego, CA, I-15	X						
Pittsburgh, PA, I-279	X						
Minneapolis, MN, I-394			X				
TWO-WAY							
Barrier-Separated							
Los Angeles, CA, I-10 (El Monte)	X						
Orange County, CA, I-5 (Proposed)	X		X				
Hartford, CN, I-91	X						X
Buffer-separated and Nonseparated							
L.A./Orange County							
I-405	X[1]		X				
SR 91			X				
Santa Clara County, CA, US 101	X						X
Marin County, CA, US 101							X
Seattle, WA							
I-405					X		X
SR 520					X		X
I-5					X		X
N. Virginia, I-95					X	X	X
Miami, FL, I-95							X
Phoenix, AZ, I-10	X						X
CONTRAFLOW							
New Jersey, Route 495		X		X			
New York City, NY, Route 495 (LIE)		X					
New York City, NY, Gowanus		X					

[1]A short portion of this project has a wide buffer separation, but this area is not used for enforcement. Continuous shoulders are not available in all sections.

Source: Adapted from *ITE Effectiveness of HOV Facilities 1986.*

Enforcement Procedures For Selected HOV Projects

		Detection					Apprehension/Citation				
HOV Facility	HOV Code*	Foot Patrol	Line Patrol	Mobile Patrol	Stationary Patrol	Hidden Enforcement	Standard Procedure	Stationary Apprehension	Wave-off Violator	Mail-out Warnings	Team Approach
Washington, DC, I-395 (Shirley)	1A		X		X		X				
Houston, TX, I-10, I-45 (Katy and Gulf)	1A				X			X	X		
Los Angeles, CA, I-10 (El Monte)	1B		X				X				
Miami, FL, I-95	2		X				X				
Los Angeles, CA, Route 91	2		X			X	X	X			
Marin County, CA, US 101	2		X		X		X				
Minneapolis, MN, I-394	1, 2		X		X		X				
New Jersey, Route 495 (Lincoln Tunnel)	3				X			X	X		
Minneapolis, MN, I-35W	4		X		X	X	X	X		X	X
Los Angeles, CA, I-10 (Santa Monica)	4		X		X		X	X			X
Seattle, WA, I-5	5		X	X	X	X	X			X	
San Francisco-Oakland Bay Bridge, CA	6	X	X		X		X	X		X	X

* HOV Code
1A Barrier-Separated Facility (Reversible-Flow)
1B Barrier-Separated Facility (Two-Way)
2 Buffer-Separated or Nonseparated Facility (Two-Way)
3 Contraflow Facility
4 Entry Ramp with HOV Bypass
5 Direct Connection Access Ramp
6 Toll Plaza Queue Bypass Lane(s)

Sources: Miller et al., *Enforcement*, 1978; Turnbull and Hanks 1990; and project data.

Self-Enforcement Program Begun in the Seattle Area

Sign Of The Times

Times are changing. Sharing the ride is no longer just a vision of the future. It's the present. That's why the Washington State Department of Transportation developed new Transportation System Management (TSM) programs that support the Diamond Lanes. (These are also called "HOV lanes," for use by high-occupancy vehicles).

One element of the TSM program is **Thanks for Being a HERO**. The Department of Transportation, Metro, and the Washington State Patrol work together and with the public to discourage improper use of the special Diamond Lanes reserved for carpools, vanpools, buses, and motorcycles only!

The **HERO** program is an example of the ongoing commitment to the best management of our transportation system. The following pages of this brochure tell more about how to use these special lanes, and tell the story of other TSM techniques that make the best use of our existing transportation system.

Comments or questions are welcome.
Please contact the:
Washington State Department of Transportation
15325 S.E. 30th Place
Bellevue, Washington 98007-6538
206 562-4000

Thanks For Being A HERO

Here's one we can all get involved in! By encouraging motorists to phone **764-HERO** when they see a vehicle (motorcycles are okay) with one occupant (or only two people in a car where three or more are required) in a Diamond Lane, we can all be winners! So exercise that memory . . . we need to know the license number of the vehicle, plus a date, time, the location, number of people (children count!), and some description of the vehicle. Vehicle owners are informed by mail about the proper use of the lanes in order to deter repeat violations. The Washington State Patrol is kept informed about repeating violators. Whenever possible,the State Patrol contacts them, or they are issued a moving violation on the road. Violation reports also help the Washington State Patrol determine where to focus officer enforcement.

Looking at 1987 records:

Less than five percent of those reported were reported a second time.

Fewer than one percent were reported three or more times!

Source: Reprinted from Seattle HOV Task Force Brochure, 1989

Enforcement Issues

- What is an acceptable violation rate?
  Example rates:
  - SR520: 24% of 300 vph (3+)
  - I405 SB @ Kennydale: 8% of 600 (2+)
  - I405 NB @ Kennydale: 18% of 600 (2+)
  - I5 @ NE175th (SB & NB): 15% of 450 (3+)
- Violation Rate vs. Compliance Rate
- HERO Program
  - 1500 calls per week
  - Violation rates before HERO = 17.3%
  - Violation rates 6 months after HERO= 8.5%
  - Violation rates 6 years after HERO= 15%
- Emphasis Enforcement

Summary of Enforcement-Related Information for Selected HOV Projects

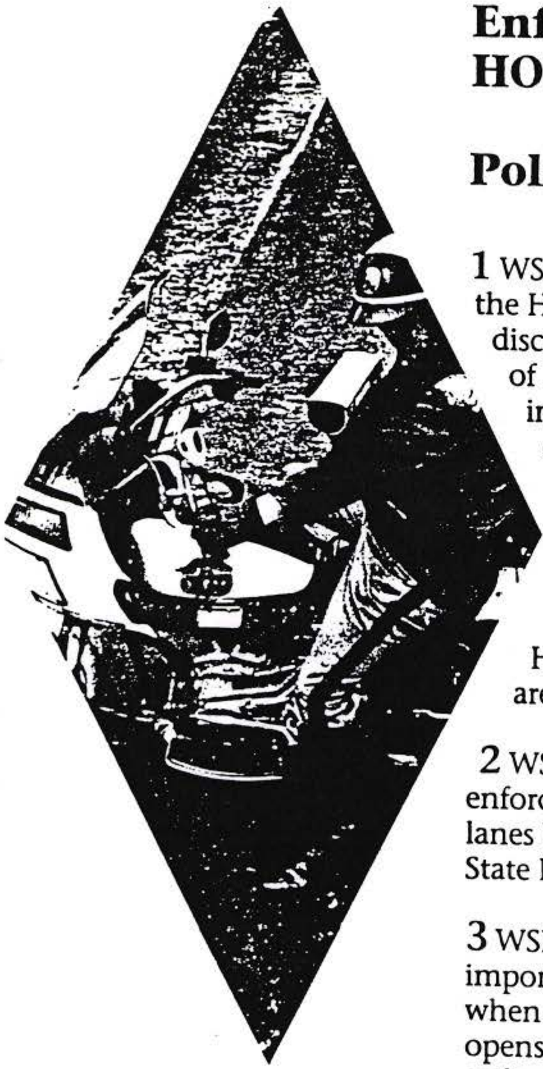
HOV Facility	Method of Enforcement	Yearly Cost	Violation Rate[1] (%) Peak Hour	Violation Rate[1] (%) Peak Period	Fine Amount	Enforcement Features	Assigned to Enforcement: Number of Persons	Assigned to Enforcement: Adequate?	Enforcement Responsibility (agency)
FACILITY IN SEPARATE R.O.W.									
• Ottawa, Canada	Charged w/trespassing	$200,000	1	1	$53.75	Use shoulder	3	Yes	Transit
• Pittsburgh, PA	Citation	$100,000	1	1	$300 + court	None	4	Yes	Transit
FACILITY IN FREEWAY R.O.W.									
Reversible-Flow									
• Houston, TX I-45, I-10, US 290	Special citation areas, vehicles diverted	$60,000	1	14am, 1pm	$75	Enforcement areas, widened or separate ramps to exit violators	2	Yes	Transit
• Virginia (Washington, DC) I-395 (Shirley)	Vehicles identified[2]	$35,000 each officer	5	15	$50	Shoulder, HERO program	2-5	No	State
• Pittsburgh, PA, I-279	Vehicles stopped	---	---	---	$82.50	Continuous shoulder	---	Yes	State
• San Diego, CA, I-15	Vehicles stopped	---	3	5	$246 + court	Shoulder	2	Yes	State
Two-Way Barrier-Separated									
• Los Angeles, CA, I-10	Citation on HOV Shoulder	$20,000	11	11	$246 up + court	Wide shoulder on HOV lane	2	Yes	State
Two-Way Buffer-Separated									
• Hartford, CT, I-84	Citation on HOV buffer	---	---	---	$40	None	---	---	State
• Orange County, CA, Route 55 & I-405	Special citation areas	$30,000	6	7	$246 + court	Protected median areas	6[3]	Yes	State
• Los Angeles, CA, Route 91	Special citation area	$30,000	7	7	$246 up + court	Protected median areas	6[3]	Yes	State
• Miami, FL, I-95	Vehicles diverted, not enforced	---	40	---	$43.50	None	10-12[3]	Yes	State
• Ft. Lee, NJ, I-95	Vehicles stopped	---	30	30	$50	None	1	Yes	State, Regional Auth.
• Honolulu, Moanalua Fwy.	Vehicles diverted	$35,000	20	20	$40	None	3	No	State
• Orlando, I-4	Not enforced	0	75	75	$43.50	None	0	No	State
• San Francisco, CA area (Santa Clara, Marin, San Francisco Counties) US 101, Rte. 237	Vehicles diverted	$215,000	5	10	$50-500	None	1-7	Yes	State
• Seattle, WA I-5[4] and I-405	License plates identified, routine, special, & HERO program	---	11	11	$47	None	---	Yes	State
SR 520		---	8	8	$47	None	---	Yes	State

Summary of Enforcement-Related Information for Selected HOV Projects

HOV Facility	Method of Enforcement	Yearly Cost	Violation Rate[1] (%) Peak Hour	Violation Rate[1] (%) Peak Period	Fine Amount	Enforcement Features	Assigned to Enforcement Number of Persons	Assigned to Enforcement Adequate?	Enforcement Responsibility (agency)
Contraflow									
• Honolulu, Kalanianaole Hwy.	Vehicles diverted	$25,000	5-10	---	$35	User permit	1	No	State
• New Jersey, I-495 (Lincoln Tunnel)	Vehicles diverted	$35,000	---	---	---	Vehicle check point and diversion lanes	3	Yes	State,Regional, Auth.
• New York City, NY Gowanus and L.I.E.	Stopped at termination	---	---	---	$65	None	1 each	No	City
Queue Bypasses									
• San Francisco-Oakland Bay Bridge, CA	Vehicles diverted	$200,000	2	2	$50-500	Wide shoulder	4	Yes	State
• Los Angeles - ramp bypasses	Vehicles diverted	---	5	10	$160	Wide shoulder	Varies	Yes	State
• Minneapolis - ramp bypasses	Vehicles diverted	---	---	---	---	Wide shoulder	Varies	Yes	State

---Data not available or not provided.
[1]As a percentage of legal HOV traffic.
[2]Citations issued by mail.
[3]For entire freeway, not specifically HOV.
[4]Violation rates vary widely by location and time of day.

Source: Adapted from ITE, *Guidelines for HOV*, 1986, and Turnbull and Hanks 1990.



Enforcement Issues and HOV Lane Violations

Policy

1 WSDOT fully supports the HERO program to discourage improper use of HOV lanes by providing a telephone hotline citizens can use to report HOV lane violators. WSDOT will continue to promote the program in regions where HOV systems exist or are planned.

2 WSDOT encourages enforcement of the HOV lanes by the Washington State Patrol.

3 WSDOT recognizes the importance of enforcement when a HOV facility first opens and shall fund enforcement for the first six months of HOV lane operation.

4 WSDOT is committed to designing and constructing HOV facilities that incorporate safe enforcement features and solicit the Washington State Patrol's involvement in design and review of HOV lane development.

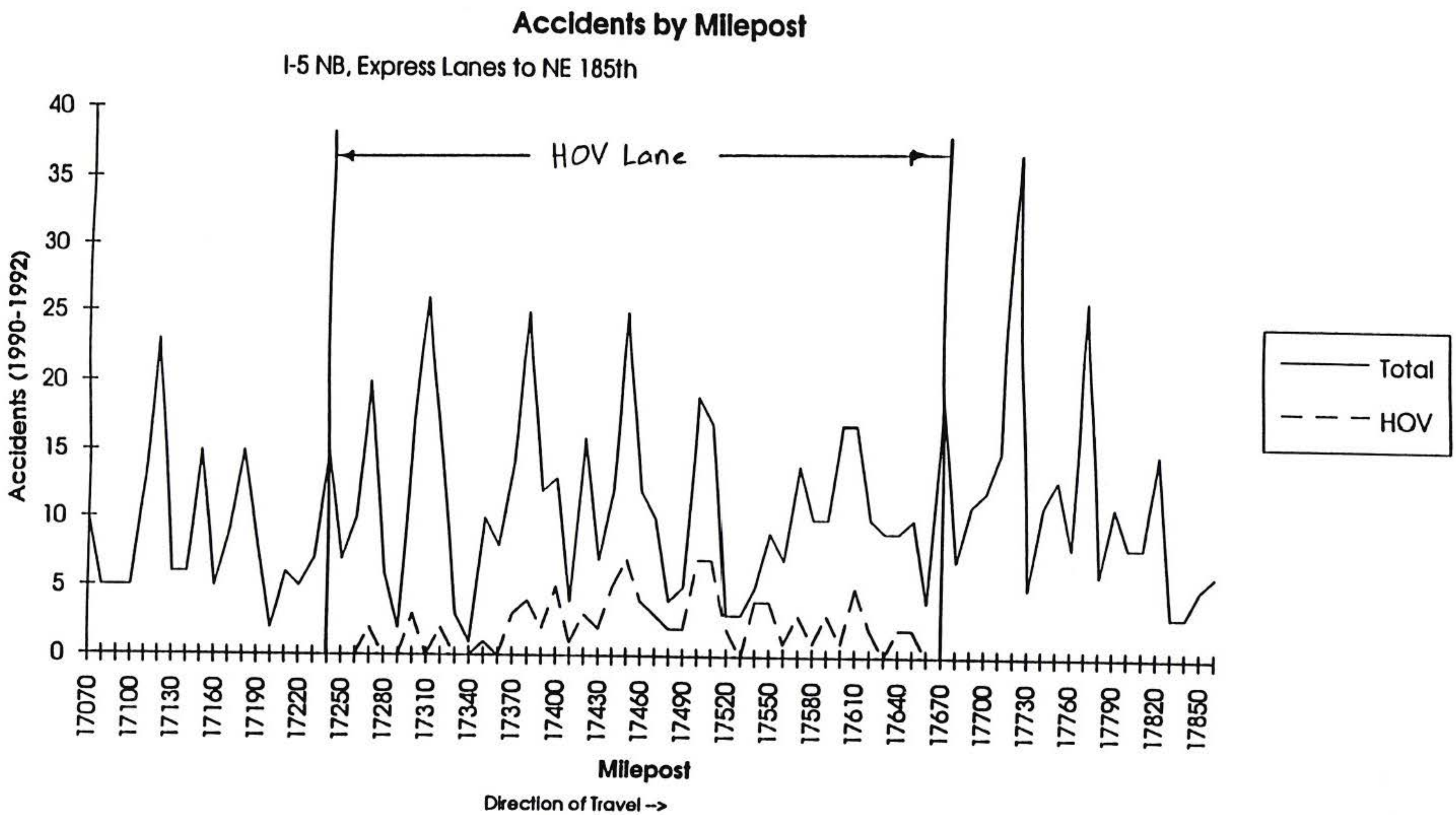
5 WSDOT shall keep regulations and signing clear and consistent to avoid driver confusion.

6 To deter violations, WSDOT shall assign a team to work with the Washington State Patrol to develop and propose legislation creating a separate citation category for HOV violations and which carries an increased, graduated penalty.

Source: "Washington State Freeway HOV System Policy", Executive Summary, WSDOT, November 1990

HOV SAFETY FACTORS

- HOV LANE DESIGN
- OPERATING CONDITIONS
- CONGESTION LEVELS
- HOV VOLUMES


Accidents by Milepost
I-5 NB, Express Lanes to NE 185th
HOV Lane
Accidents (1990-1992)
40
35
30
25
20
15
10
5
0
17070
17100
17130
17160
17190
17220
17250
17280
17310
17340
17370
17400
17430
17460
17490
17520
17550
17580
17610
17640
17670
17700
17730
17760
17790
17820
17850
Milepost
Direction of Travel -->
Total
HOV

Safety and Incident Response Characteristics of Selected HOV Facilities

HOV Facility	Use of Special Vehicles (For Emergency Response)	Emergency Detection & Accident Reporting Methods	Agency Responding to Emergencies
TWO-WAY BUSWAY IN SEPARATE R.O.W.			
• Ottawa, Canada	No	Bus radios & transit personnel in marked vehicles	Local Police Transit supervisory & security personnel
• Pittsburgh, PA			
East Busway	Dedicated agency tow trucks	Bus radios	Transit Police
South Busway	Dedicated agency tow trucks (not adequate to remove LRT blocking South Busway)	Bus radios	Transit Police
FACILITIES IN FREEWAY R.O.W.			
Reversible-Flow Facilities			
• Houston, TX			
I-10 (Katy)	Short-wheelbase tow truck able to turn around	Bus radios & transit induction loops buried in pavement	Transit Police
I-45 (North)	Short-wheelbase tow truck able to turn around	Bus radios	Transit Police
• Virginia (Washington, DC)			
I-395 (Shirley)	No	CCTV (closed-circuit TV) & use of variable message signs	State DOT & State Police
Two-Way Barrier-Separated Facility			
• Los Angeles, CA, I-10 (El Monte)	No	Bus radios, freeway surveillance system	State Highway Patrol, Transit Police and State DOT incident response team
Two-Way Buffer-Separated Facilities			
• Honolulu, HI, Moanalua Fwy.	No	–	City Police
• Los Angeles, CA, Rte. 91	No	–	State Highway Patrol & State DOT incident response team
• Miami, FL, I-95	No	Bus radios, CB & mobile phones	State Highway Patrol
• Orange County, CA, Rte. 55	No	Same as general traffic	State Highway Patrol & State DOT incident response team
• Orlando, FL, I-4	–	Same as general traffic	State Highway Patrol
• San Francisco - Oakland Bay Bridge, CA	Tow Truck	Periodic phones Camera to be installed & linked to variable message signs	–
• Marin County, CA, US 101	Transit tow trucks	Bus radios & flashing lights at HOV lane entrance	State Highway Patrol & Golden Gate Bridge, Highway & Transportation District
• Seattle, WA			
I-5	No	Bus radios, air traffic reporters, CCTV, electric surveillance	State Highway Patrol and incident mgt. teams
I-405	No	Bus radios, air traffic reporters, CCTV, HAR	State Highway Patrol and incident mgt. teams
Contraflow			
• Honolulu, HI, Kalanianaole Hwy.	No	Same as general traffic	City Police
• New Jersey, Rt. 495 (Lincoln Tunnel)	Port Authority recovery vehicles	CCTV. Bus radios on some coaches	Port Authority
• San Francisco, CA, US 101 (project terminated)	Transit tow trucks	Bus radios & flashing lights at HOV lane entrance	State Highway Patrol & Golden Gate Bridge, Highway & Transportation District

– Data not available or not provided.

Source: Adapted from ITE, *Effectiveness Report*, 1986; Miller et al., *Safety*, 1979.

HOV FACILITY DESIGN

HOV FACILITY DESIGN

Line - haul

Collection and Distribution

Support facilities

DESIGN GUIDELINES

AASHTO

ITE

State DOTs

Local Agencies

Project Standards

Fuhs' Manual

DESIGN VEHICLE ENVELOPE

Characteristic	Desirable	Ultimate
Length	12 to 18 m	18.0 m
Width	2.6 m	2.6 m
Height	3.4 m	4.4 m
Turn Radius		
Outside	15.6 m	16.5 m
Inside	9.9 m	9.9 m
Eye Height	1.1 m	1.1 m

DESIGN TREATMENTS

Desirable

New Construction
Reconstruction
Initial Design Consideration

Reduced

Temporary Projects
Interim Projects
Limited Right-of-way

HOV CROSS SECTIONS

CROSS SECTION DESIGN CONSIDERATIONS

Type of Project

Pavement Width

Isolated Constraints

HOV CROSS SECTION TRADEOFFS

Line-haul or Isolated Locations

State or Federal Guidelines

Temporary/Interim or New Construction

TYPICAL CROSS SECTION GUIDELINES

Lane Width

Desirable:	**3.6 m**
Reduced:	**3.3 m**

Lateral Clearances

Desirable:	**0.6 to 1.2 m or 3+ m**
Reduced:	**0.6 m**

Shoulders

Desirable:	**3.0 to 3.6 m**
Reduced:	**2.4 to 3.0 m**

REVERSIBLE FLOW HOV FACILITIES

Significant Reconstruction

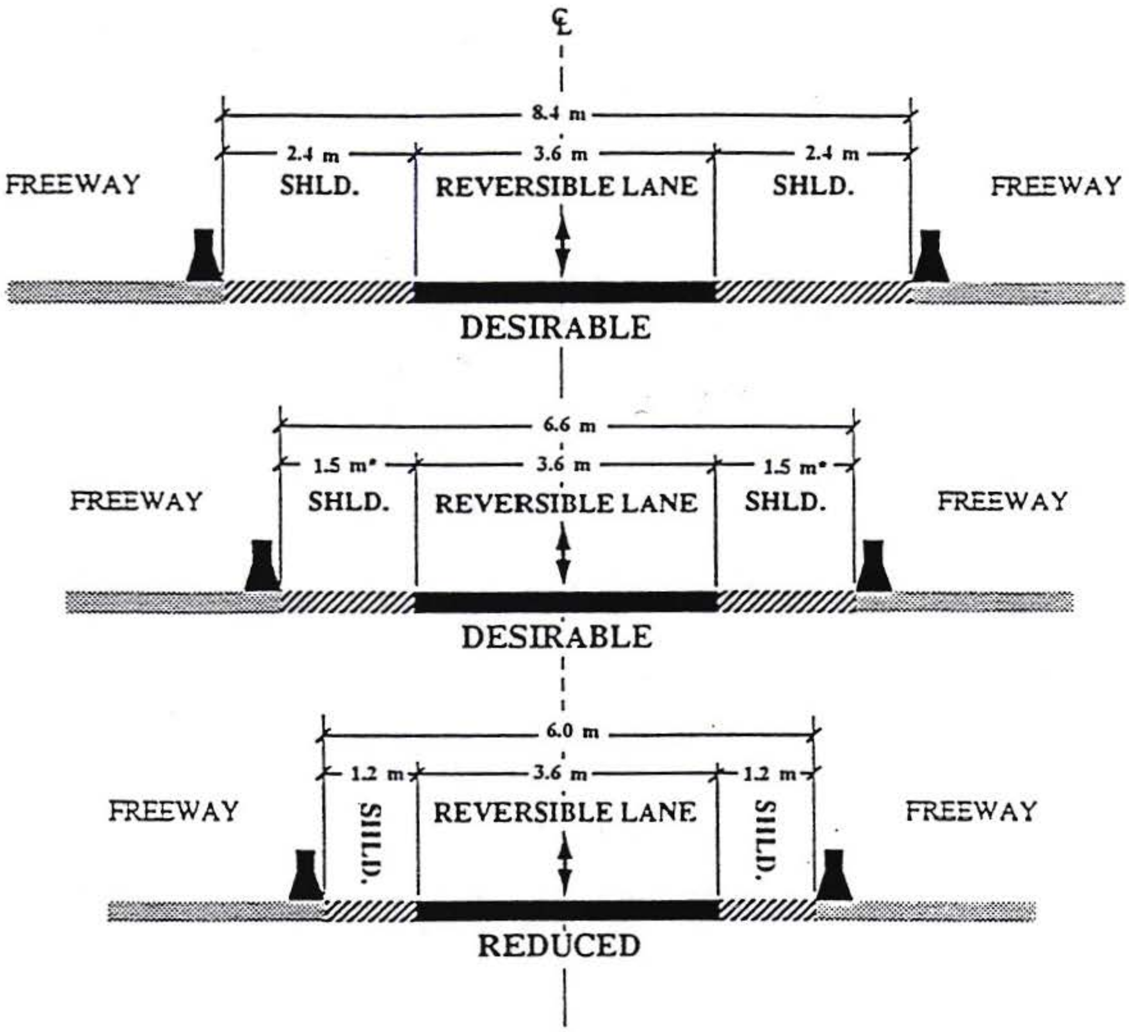
Barrier Separation

Bridge Columns

Peak Direction Service

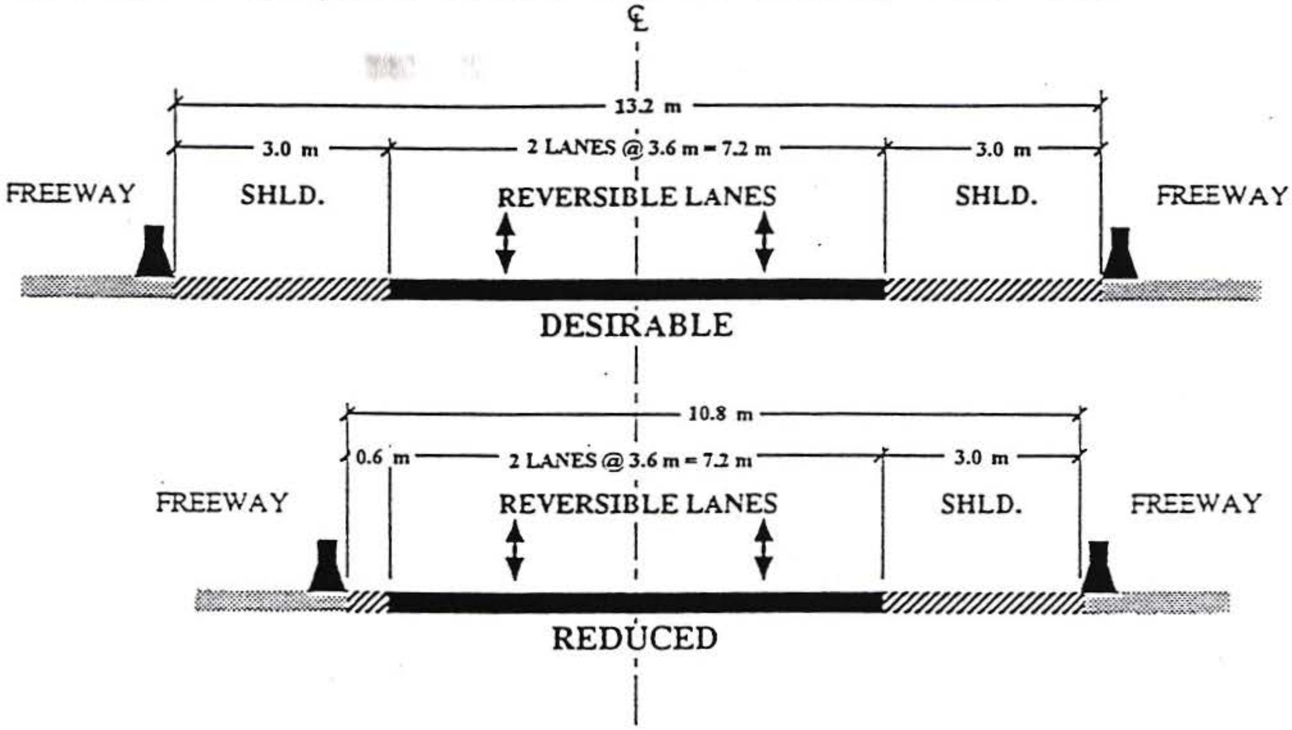
B

Recommended Single-Lane Reversible-Flow HOV Facility Cross Sections



* Lateral clearances may be combined to provide a dedicated 2.4 m shoulder on one side or the other.

Recommended Multiple-Lane Reversible-Flow HOV Facility Cross Sections



TWO-WAY BARRIER-SEPARATED HOV FACILITIES

Significant Reconstruction

Compatibility with Existing Cross Section

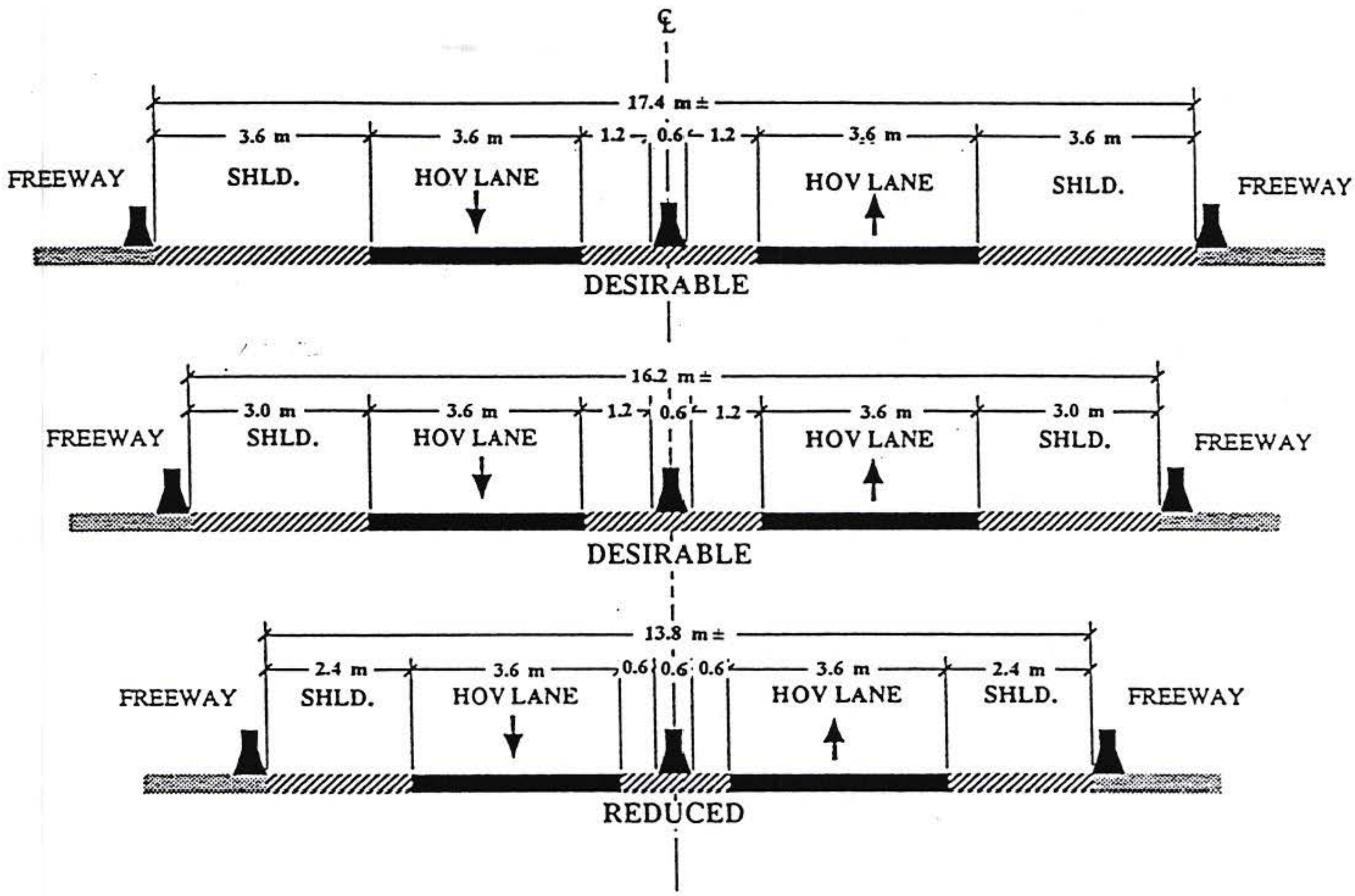
Operational Simplicity

Serves Suburban Development Pattern

Deadheading Bus Service

E

Recommended Two-Way Barrier-Separated HOV Facility Cross Sections



CONCURRENT FLOW HOV FACILITIES

Most Typical Application

Compatible with Bridge Columns

Peak / Off-peak Direction Service

Varying Width Lateral Clearances

CONCURRENT FLOW
RIGHT SIDE vs. LEFT SIDE

Capacity Difference

Right: 500 to 1100 vph

Left: 1500 to 1900 vph

Accessibility to Buses

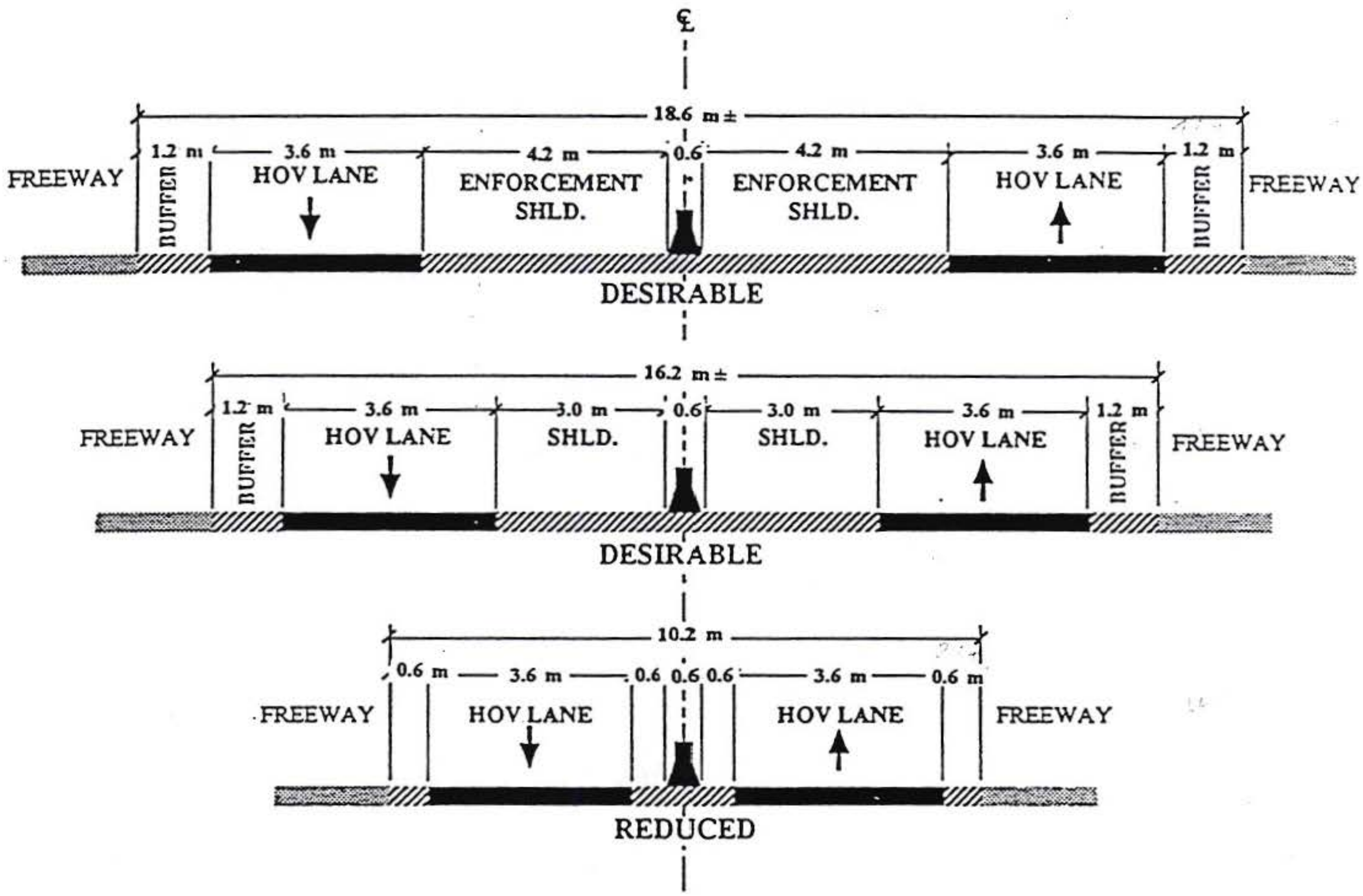
Left side may require special access

Conflict with On/Off ramps

Average HOV Trip Length

H

Recommended Two-Way Buffer-Separated Concurrent HOV Facility Cross Sections



CONTRAFLOW HOV FACILITY

Directional Imbalance in Traffic Volume

Temporary Lane -
Operating Costs may be a Concern

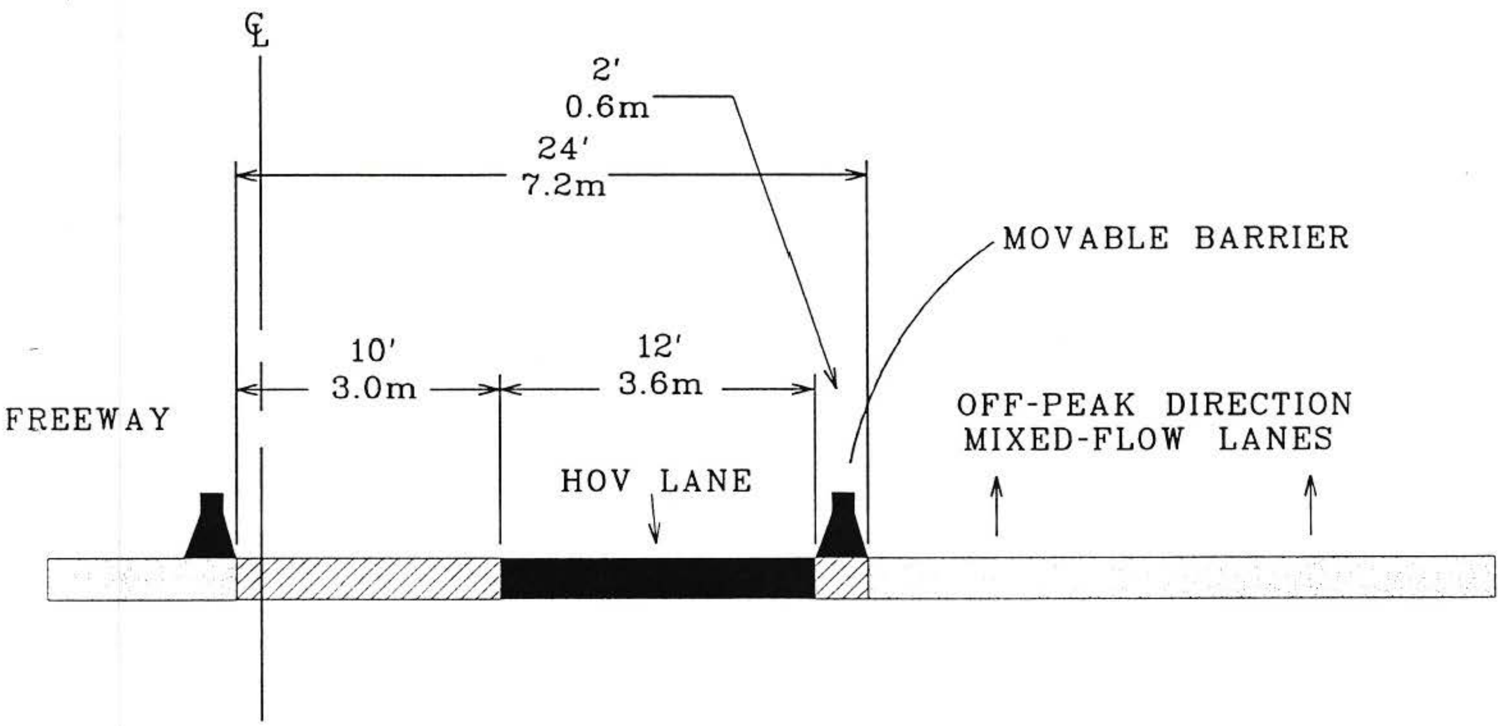
Coordination Between Agencies
- **Planning**
- **Design**
- **Operation**
- **Enforcement**
- **Incidents**

SEPARATION OF CONTRAFLOW HOV FACILITY

Pylons
- **Proven Technology**
- **Bus Oriented**
- **Requires Trained Drivers**
- **Visible Vehicles**

Movable barrier
- **Operated in Dallas, Texas for 2 Years**
- **Bus and Carpools**
- **Maximize Eligible Vehicles**
- **Positive Separation of Traffic**

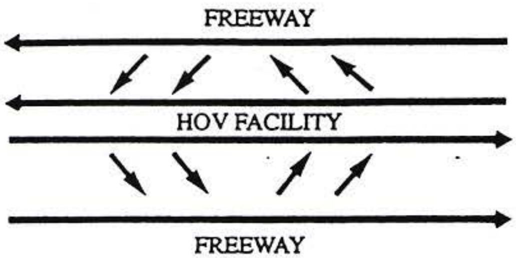
Recommended Contraflow HOV Facility Cross Section

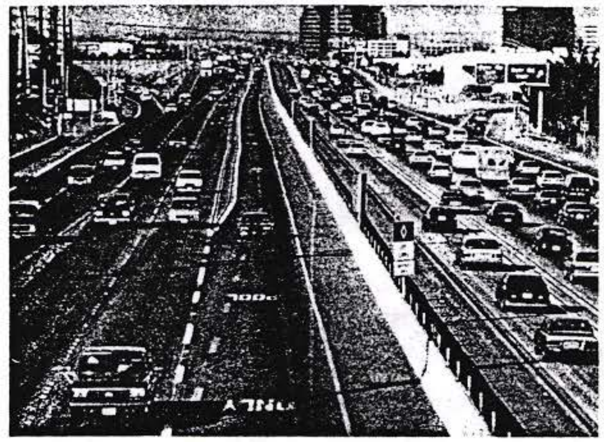


HOV ACCESS

Types of Ingress/Egress

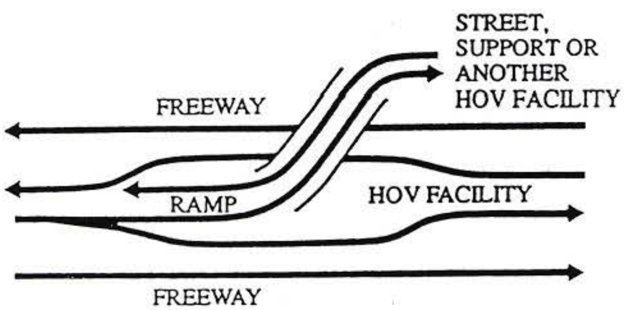
At-Grade with Adjacent Mixed-Flow Lanes





Route 55 at-grade access, Orange County, California

Direct Connections



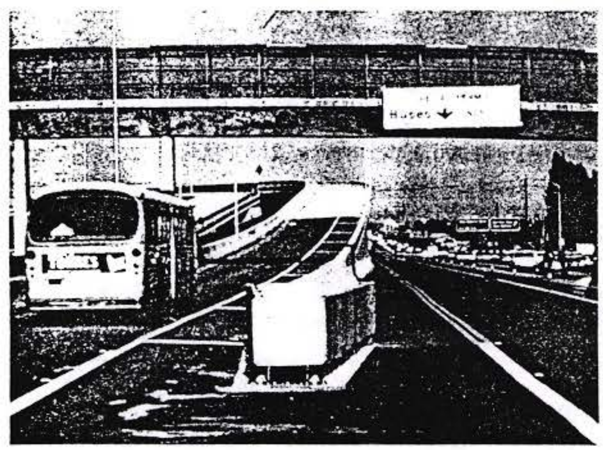
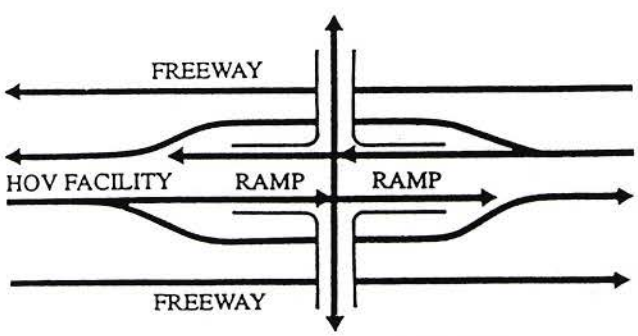
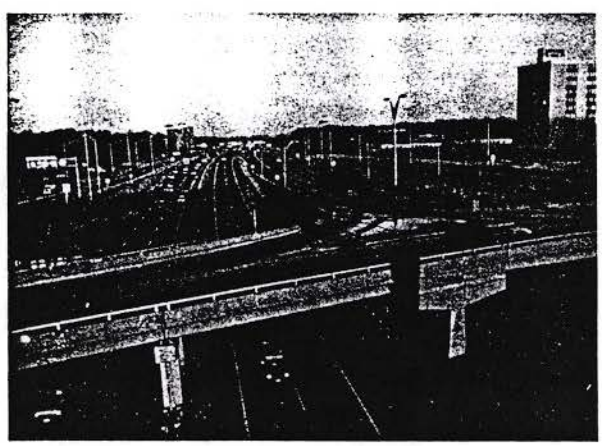


Photo: California DOT

I-10 Del Mar ramps, Los Angeles, California





I-395, Shirley Highway Ramp, Northern Virginia

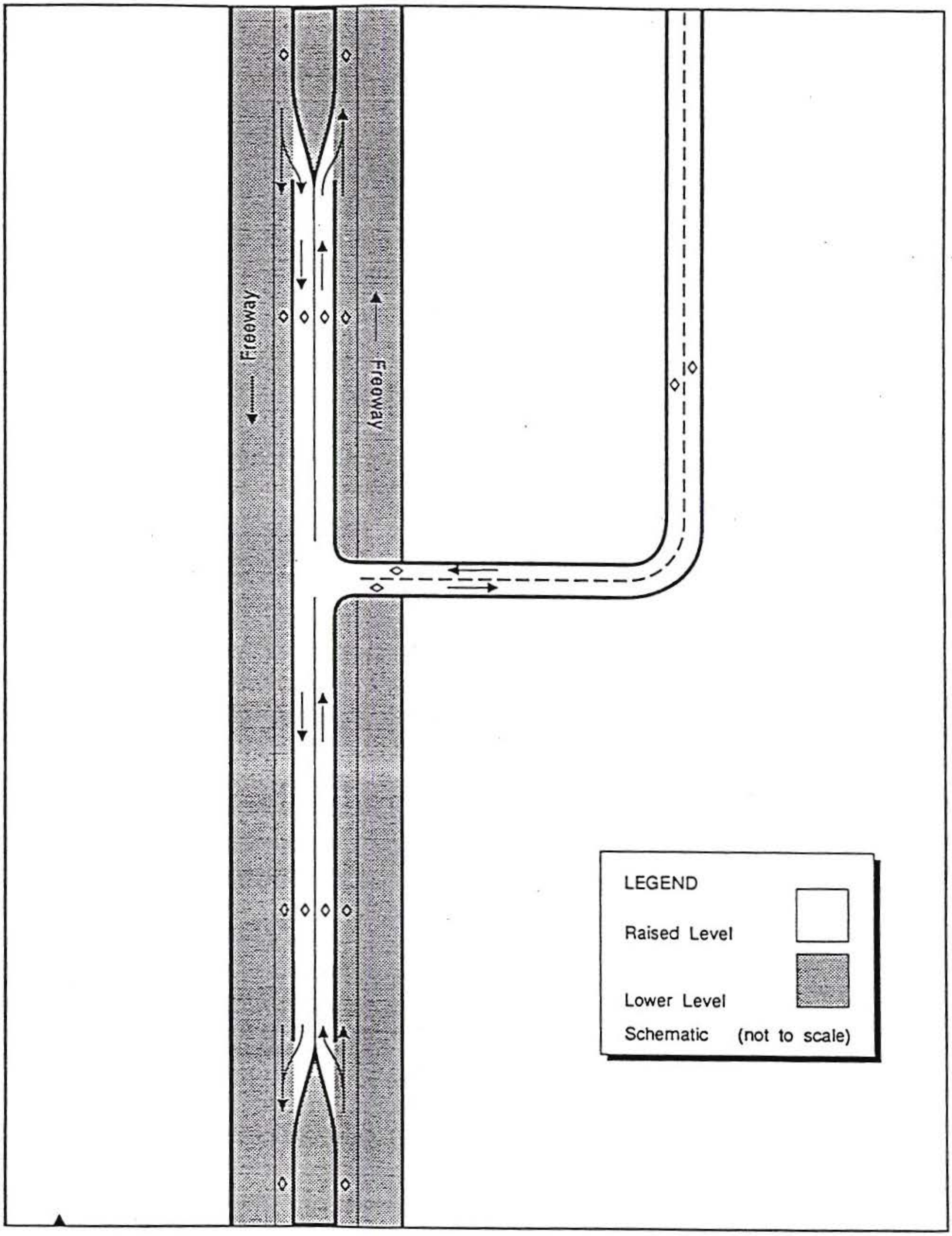
GUIDELINES FOR APPLYING INGRESS/EGRESS TREATMENTS

Objective	Type of Treatment[1]			
	At-grade slip ramp with freeway	Drop ramp or "T" ramp with street	Drop ramp or "T" ramp with P&R lot or transit station	Flyover ramp
Frequent spacing (<3 miles)	+	+	+	-
Maximize bus travel time savings	O	O	+	O
User mix requirements:	-	+	+	-
Buses only	+	+	-	+
Buses and other HOVs	+	+	-	+
Primarily carpools and vanpools	+	+	-	+
Safety	O	+	O	+
Enforceability	-	+	+	O
Traffic regulation capability[2]	-	+	+	+
Capital Cost	+	O	O	-
High vehicle volumes	Terminations + Intermediate sites -	+	-	+
Low vehicle volumes	+	+	+	-
High design speed	+	-	-	+
Low design speed	-	+	+	NA
Retrofit compatibility with existing freeway	+	+	O	O
Flexibility to modify later	+	-	-	-

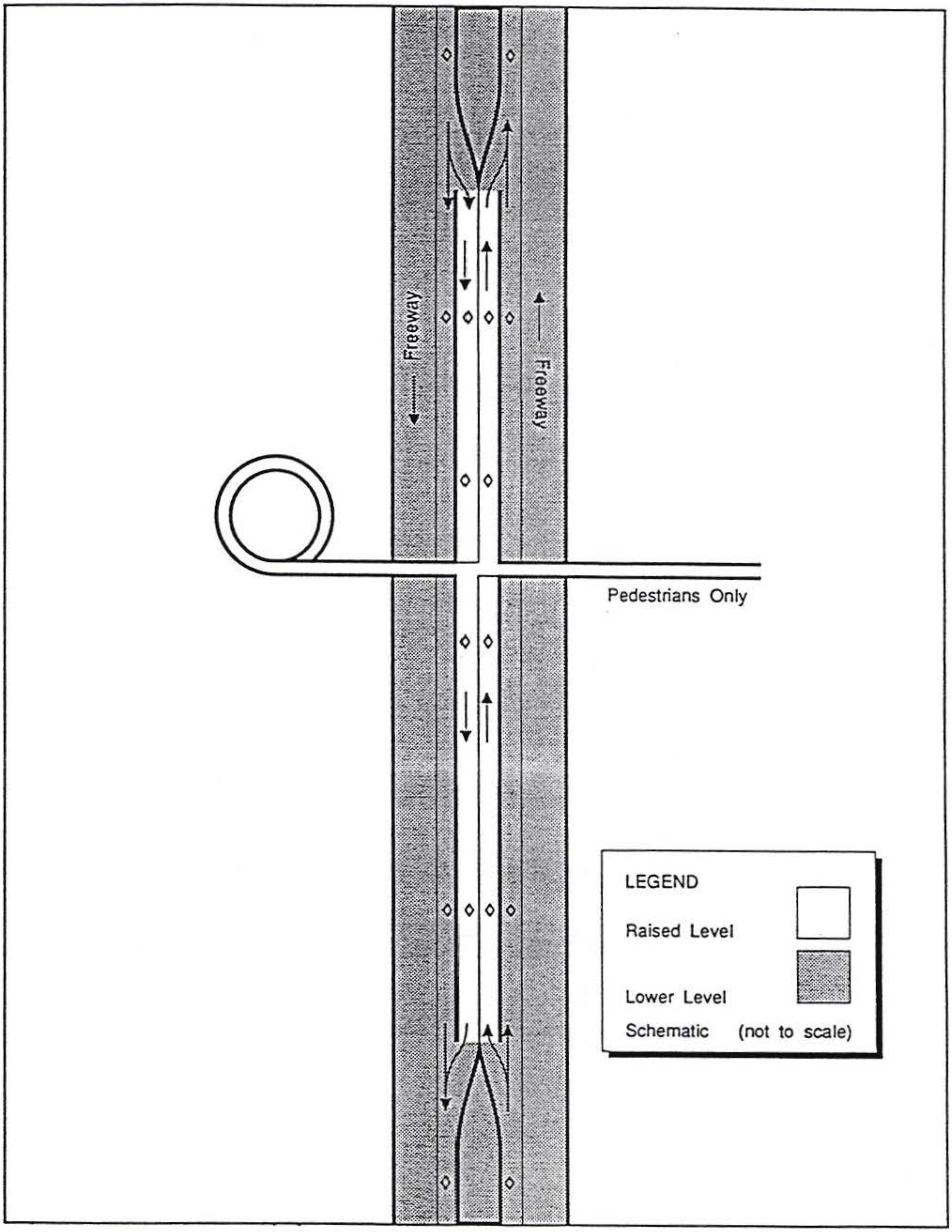
\+ Favorable
o Neutral, often depends on the design or site specifics
\- Not favorable
NA Not applicable

1 Not included are busway street intersections used for low-volume, bus-only operation in separate right-of-way.
2 Assumes use of meters to regulate entering flow of vehicles.

DIRECT ACCESS CONCEPTS


Freeway
Freeway
LEGEND
Raised Level
Lower Level
Schematic (not to scale)

Texas T



Pedestrian Access

OTHER CONSIDERATIONS

ENFORCEMENT
SIGNING AND MARKING
INCIDENT MANAGEMENT

HOV FACILITY ENFORCEMENT

Type of HOV facility

Enforcement Agency Policy

Right-of-way and Budget Available

High-tech Enforcement Strategies

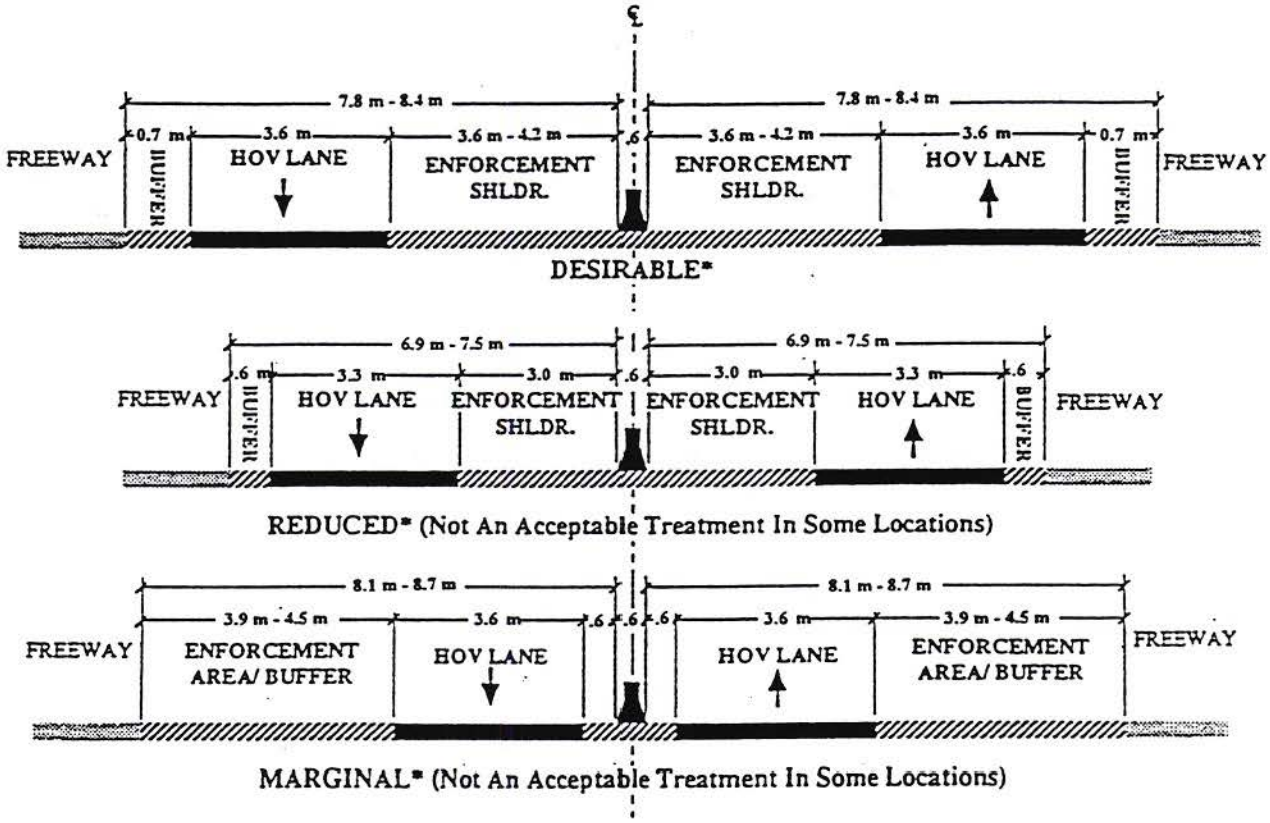
Dedicated Area vs. "Remainder" Locations

Diversion Route at Access Points

Low Speed Areas

AA

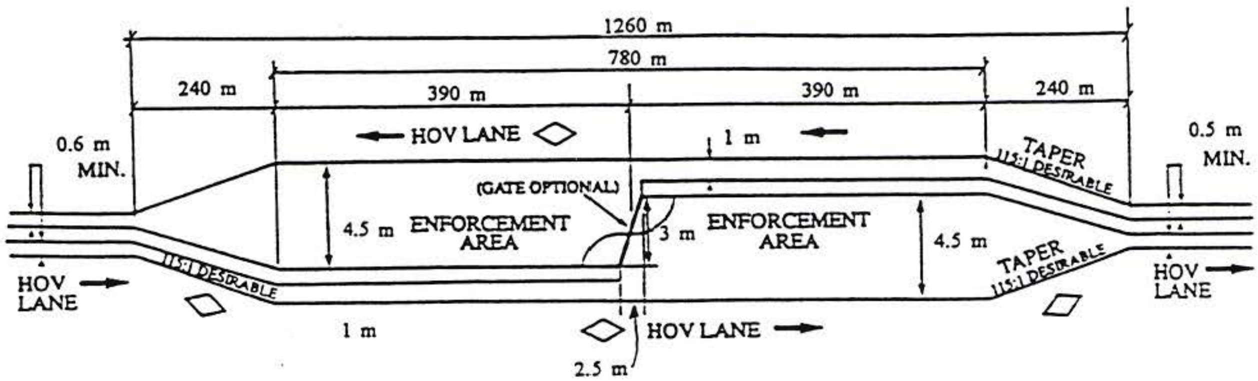
High-Speed Enforcement Areas along Two-Way Buffer-Separated HOV Facilities



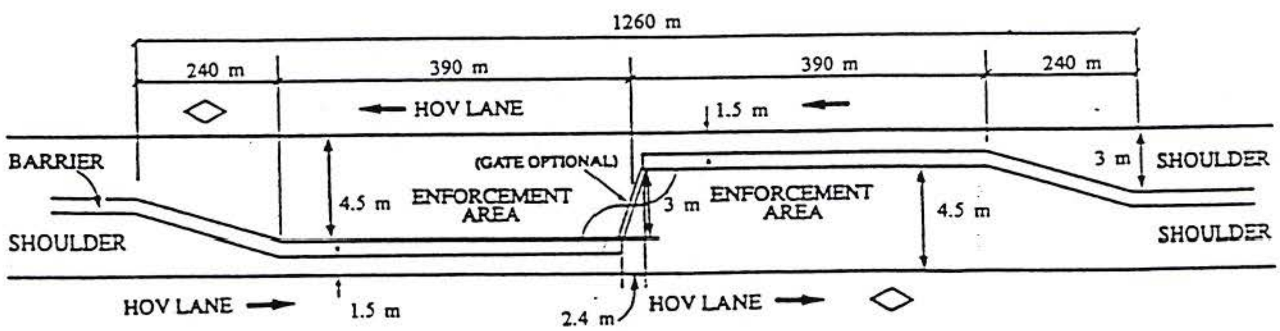
AB

Recommended Layout for Designated High-Speed Enforcement Areas

Typical Layout With Inside Shoulders

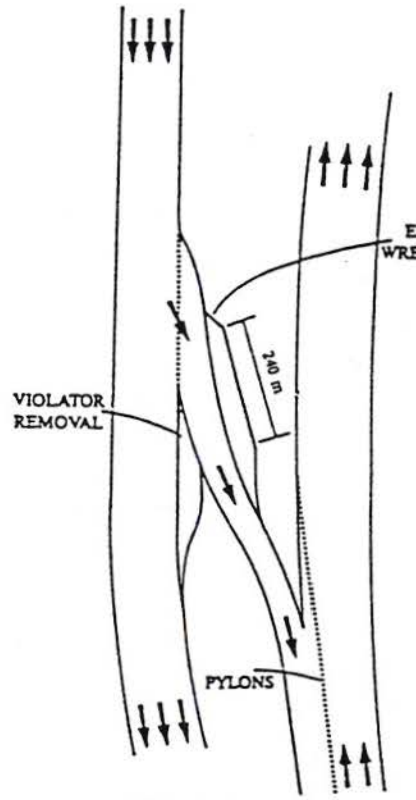


Typical Layout Wtihout Inside Shoulders



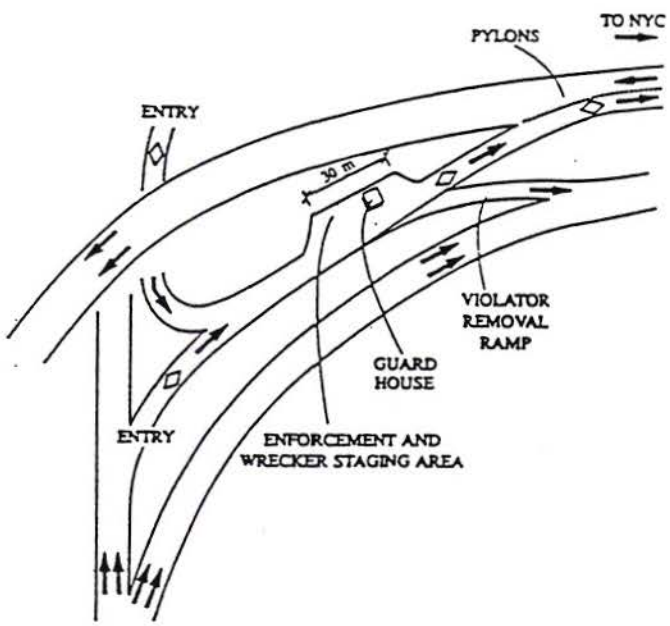
AC

Enforcement and Violator Removal Facilities on Selected Contraflow Facilities



I-45(NORTH) HOUSTON, TEXAS
A.M. CONTROL FLOW ENTRANCE
AT NORTH SHEPHERD
1979-1984

NOT TO SCALE



ROUTE 495/NEW JERSEY TURNPIKE, N. NEW JERSEY
A.M. CONTRAFLOW ENTRANCE

NOT TO SCALE

SIGNING AND MARKING

Diamond Symbol on HOV Signs

Overhead Mounting

Regulatory Information

Guide Sign Confusion

INCIDENT HANDLING PROVISIONS

Breakdown Shoulders

Surveillance and Communication

Intermediate Openings in Barrier

Special Vehicles

SESSION SUMMARY

Existing Design Guidelines

Design Applications

Relationship to Planning

Operational Effects of Design

PUGET SOUND REGION AVI SELECTION PROJECT

Minimum Data Packet Requirements:

Static Data | Dynamic Data

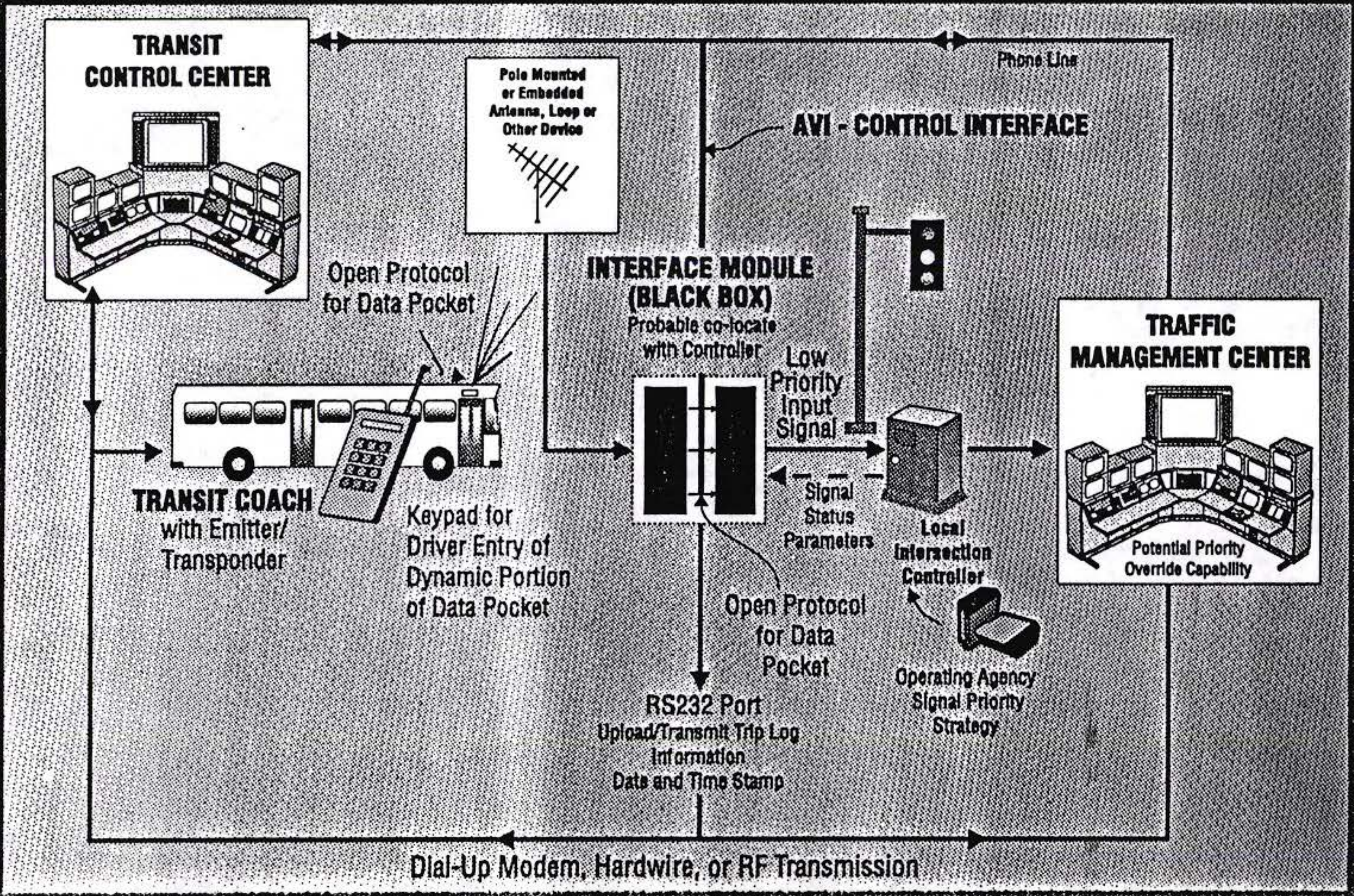
System ID	Agency ID	Vehicle ID	Driver ID	Route #	Run #	Trip #	APC Data	Spare	Spare
(0-31)	(0-7)	(0-9999)	(0-999)	(0-999)	(0-999)	(0-999)	(0-255)	(0-255)	(0-255)

Keypad Log-in Data (Driver ID through Trip #) — Future (APC Data through Spare)

METRO

PB 100

TRANSIT PRIORITY SIGNAL SYSTEM CONFIGURATION: PUGET SOUND REGION



METRO

PB

COST EFFECTIVENESS

Intersection LOS: B

Passengers	BUSES PER HOUR				
	2	4	6	8	10
20	0.1	0.3	0.4	0.5	0.7
30	0.2	0.4	0.6	0.7	1.0
40	0.3	0.5	0.8	1.0	1.3

Intersection LOS: C

Passengers	BUSES PER HOUR				
	2	4	6	8	10
20	0.3	0.6	0.9	1.1	1.5
30	0.5	0.9	1.4	1.7	2.3
40	0.6	1.2	1.8	2.3	3.0

Intersection LOS: D

Passengers	BUSES PER HOUR				
	2	4	6	8	10
20	0.4	0.8	1.3	1.6	2.1
30	0.6	1.3	1.9	2.4	3.2
40	0.8	1.7	2.5	3.2	4.2

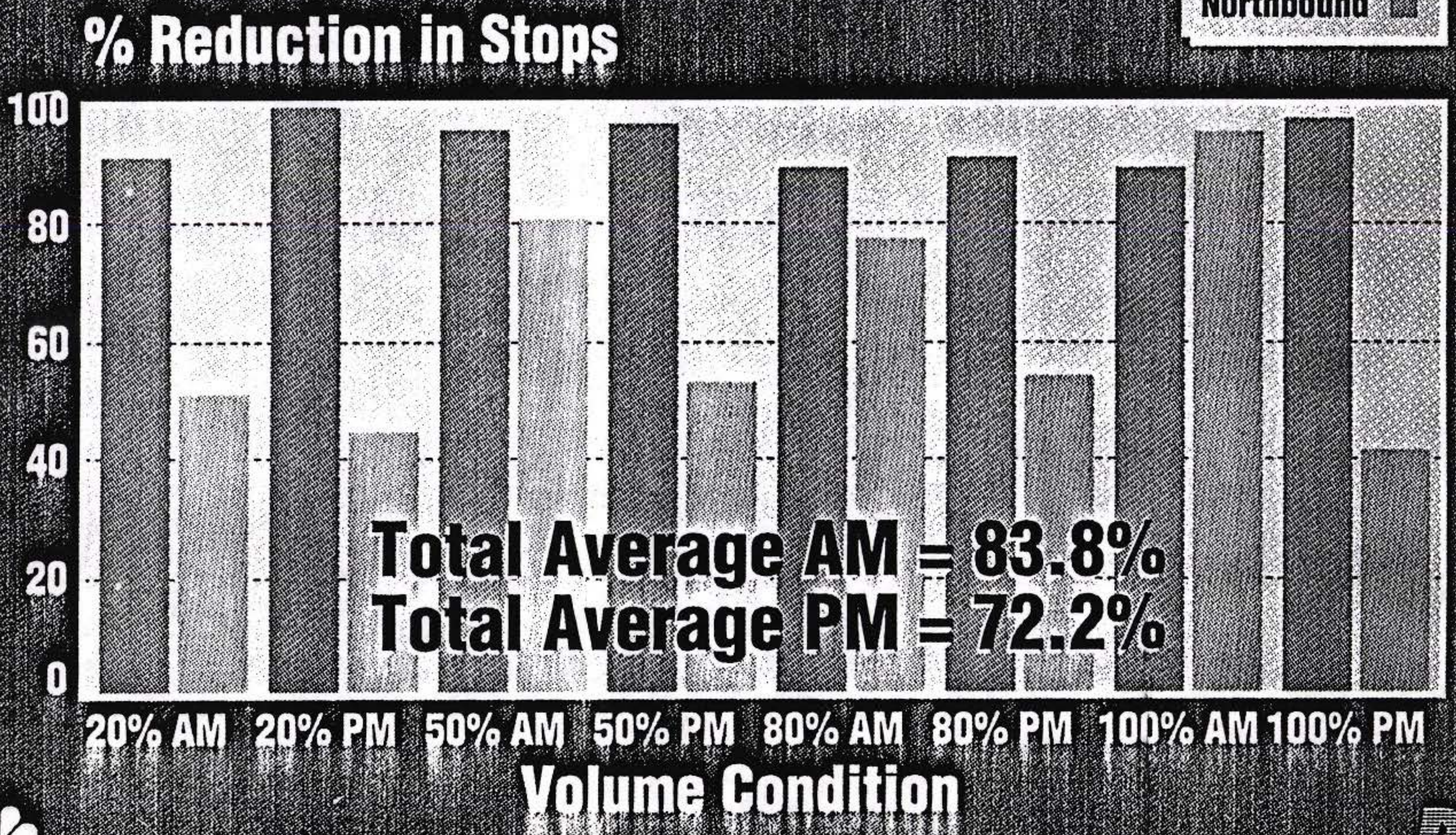
Intersection LOS: E

Passengers	BUSES PER HOUR				
	2	4	6	8	10
20	1.0	2.0	3.0	3.7	5.0
30	1.5	3.0	4.5	5.6	7.5
40	2.0	4.0	6.0	7.5	10.0

METRO

STOPS REDUCTION

NETSIM Results: Bus Priority vs. Base Case



Six replications, 120 minutes each

SAMPLE CONTROL STRATEGIES

- Conditional Preemption
- Green Extension/Truncation
- HOV-Weighted OPAC
- LIFT

METRO

SAMPLE AVI TECHNOLOGIES

LOOPCOMM
- Inductive Radio
- Transmitters on Bottom of Vehicle
- Standard Loop Detectors as Antenna

OPTICOM
- Optically Based
- Used Extensively for Emergency Vehicles
- Strobe on Vehicle, Receiver at Intersection

AMTECH
- RF Tags
- Transmitter Tags on Vehicle
- Roadside or Overhead Mounted Antennas

METRO