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Study of Current and Planned High Occupancy Vehicle Lane Use: Performance and Prospects

Frank Southworth
Fred Westbrook

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Energy Division

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We would also like to thank Patrick Sutton and Lew Pratsch of the U.S. Department of Energy in Washington, D.C. for their support and suggestions during the course of this work.

ABSTRACT

This report details the results of a nationwide study of HOV lanes: their characteristics and performance as traffic congestion mitigating and rideshare enhancing facilities. The study took the form of telephone interviews with a variety of planning agencies in each of the 48 contiguous states and Hawaii over the period April through June 1985, with subsequent receipt of the most current documentation on regional HOV lane operations.

Since the last comprehensive survey of HOV lane activity, in 1980, many changes have taken place: 6 HOV lane projects have been implemented and 3 abandoned since early 1982, while 2 other projects were recently suspended to allow highway reconstruction. At the time of writing there were 13 freeway plus 4 arterial HOV lanes in operation around the country that allow access to carpools and/or vanpools as well as to express buses.

Chapter 1 describes the survey and its objectives. Chapter 2 details the major physical and operational characteristics of each current or recently operational HOV lane project; including project inception date, lane number and length, HOV modes allowed and hours of daily access. In Chapter 3, the most up-to-date evidence on each lane's performance is presented: its hourly and peak period person throughput vis-a-vis the highway's adjacent, conventional mixed traffic lane(s), its vehicle throughput and occupancy, travel speed and travel time savings for HOVs, lane rule violation rates, lane construction and maintenance costs and accident data. Estimates are provided of the growth in ridesharing over the life of the HOV-only lanes, of the number of vehicles removed from the highway through ridesharing, and of the subsequent fuel savings attributable to HOV lane projects. The relationship between bus patronage and carpool/vanpool mode adoption is looked at, and it is concluded that both forms of HOV can do well on properly planned lanes. Annual fuel savings from ridesharing alone (bus use excluded) are estimated to be in the range 40,000 to 340,000 gallons of gasoline per lane mile. Lanes on the Shirley Highway in northern Virginia, with a rideshare growth of 1,300% over the past decade, and on the San Bernardino Freeway in Los Angeles carry 2.5 to 3 times more commuters to work during the peak traffic hour than an adjacent conventional lane. The vanpool and bus only lane on Houston's I45N has an average vehicle occupancy of over 15 persons per vehicle, and again moves far more people, and much more quickly, than a regular freeway lane.

In Chapter 3 the authors also point out the very partial nature of the existing evidence upon which to base HOV lane project evaluation, and the subsequent difficulty associated with "selling" the HOV lane concept to many planners and members of the public. In Chapter 4 they identify those characteristics associated with clearly successful HOV lane projects. Finally, Chapter 5 describes the current state of planning for new HOV lanes, in cities around the nation, and discusses the major reasons given for rejection or abandonment of HOV lane projects. It is concluded

that while a case might be made for more HOV lanes in our larger cities by year 2000, the lack of a widespread belief in the HOV lane concept among both planners and public is likely to significantly limit the number of new lanes introduced over the next 15 years. This may prove to be a mistake, as the growth in traffic on existing HOV lane corridors during the eighties suggests that some of these lanes are becoming increasing necessary and viable planning options.

An executive summary provides an eight page precis of the report's major findings. An appendix lists the results of a state by state survey of planned HOV lane operations.

EXECUTIVE SUMMARY

This report details the results of a nationwide survey of HOV lane and related rideshare enhancing capital facility operations. The purpose behind the survey was to find out (a) the current status of HOV lane operations, and specifically how effective such lanes are in terms of their use of roadway capacity and in the promotion of ridesharing modes (i.e. carpooling and vanpooling), and (b) what current plans exist for further HOV lane projects in the various states of the U.S. Emphasis was placed upon recording reported measures of HOV lane costs and benefits, and upon assessing the current attitudes towards, and potential for, further implementation of such high occupancy vehicle corridor projects.

The survey took the form of telephone interviews with a variety of planning agencies in each of the 48 contiguous states and Hawaii over the period April through June 1985, with in most cases subsequent receipt of the most current documentation on regional HOV lane operations. In brief here, the major findings of this survey are as follows:

A. Existing and Planned HOV Lane Projects: A Dynamic Situation

(1) Currently there are 17 "mainline" HOV lanes projects in operation around the country that allow carpools and/or vanpools as well as buses exclusive access. Thirteen of these projects are on freeways, on the facilities listed below:

- Route 101 in Marin County, CA.
- Interstate 280 (I-280) San Francisco, CA.
- Route 237 Santa Clara County, CA.
- I-10 (San Bernardino Freeway) Los Angeles, CA.
- I-95, Miami, FL.
- I-45N, Houston, TX.
- I-10 (Katy Transitway), Houston, TX.
- I-5 Seattle, WA.
- Route 520, Seattle, WA.
- I-395 (Shirley Highway), northern Virginia.
- I-66, northern Virginia.
- I-93, Boston, MASS.
- Moanalua Freeway, Honolulu, HI.

Four HOV lanes currently operate on limited access major arterials. These are:

- San Tomas Expressway, San Jose, CA.
- Montague Expressway, San Jose, CA.
- Kalanianaole Highway, Honolulu, HI.
- N. Washington St., Alexandria, VA.

(2) Four mixed rideshare/bus HOV lane projects offer toll booth bypass and toll exemption. These facilities are located on/at:

- New Jersey's/New York's Holland Tunnel.
- New Jersey's/New York's Lincoln Tunnel.
- New York's Gowanus Expressway.
- San Francisco-Oakland Bay Bridge Plaza.

(3) The 1980s have seen a good deal of HOV lane activity: 6 HOV lane projects have been implemented since November of 1982, and since 1982 3 HOV lane projects have been abandoned, while 2 others have recently been suspended to allow highway reconstruction. At the time of writing there were approximately 118 miles of HOV lane in operation around the country, and approximately another 135 miles awaiting highway construction/reconstruction and currently scheduled to become operational by 1989.

(4) Besides these mainline HOV lane operations, there are numerous HOV freeway bypass lanes associated with freeway ramp metering schemes. The majority of these HOV bypasses (224) are to be found on the southern California freeways.

B. HOV Lane Characteristics

(5) Sixteen of the 21 currently operational mainline or toll booth related HOV lane projects employ an HOV rule of 3 or more persons per vehicle for legitimate access to the HOV lane; 5 projects require only 2 persons per vehicle. Two projects require 4 or more persons, and 3 projects allow only vanpools access. Eighteen of the 21 projects allow carpools and/or vanpools in the same lane with buses. Only 7 of the 21 projects operate HOV restrictions on a continuous or essentially full day basis. The rest provide HOV priority treatment only during the a.m. and usually p.m. peak commuter traffic periods: typically 2 to 3 hours at either end of the working day.

(6) In terms of lane design, where physically separated lanes are not feasible, concurrent median HOV lanes are preferred to the potentially less safe contraflow lane approach. Once Houston's I-45N physically separated transitway HOV lane becomes operational in 1985, only two, very short contraflow HOV lanes will remain operational. The physically separated HOV lanes [the Shirley Highway (I-395), Houston's Katy Transitway, Boston's I-93 and Los Angeles' San Bernardino (I-10) freeways] are the most successful HOV facility projects in the nation. The I-66 HOV lane in Virginia is an experiment in dedicating a complete (2 lane) highway to HOVs only during peak commuter hours. It is too early to tell if this approach will also prove as successful. Three projects use a right-hand "shoulder" lane, dedicated to HOV only use during peak traffic hours.

C. Assessment of HOV Lane Performance

(7) For the 10 HOV freeway and 2 arterial lane projects from which sufficiently comprehensive data could be obtained, it is concluded that 11 have become effective as movers of peak hour commuters (vis-a-vis use of the same lanes for mixed or non-HOV traffic), 9 projects currently have visibly high levels of usage, 6 of 7 for which data is available are associated with significant increases in the use of carpooling and vanpooling modes, and 4 out of 5 are found to provide significant energy savings and emissions reduction associated with reduced vehicle miles of commuter travel.

(8) A number of the HOV lanes currently operating carry many more commuters than would be possible on a normal, non-prioritized mixed traffic lane. These lanes carry between 1.0 to 3.5 times as many riders as their adjacent, conventional traffic lanes, at travel speeds over 48 mph versus 18 to 30 mph for non-HOVs: and with still considerable (typically over 70%) lane capacity available on most of these HOV lanes, even at 48+ mph operation. (See Figure E.1).

(9) A number of lanes have been very successful in generating large numbers of bus <u>and</u> carpool/vanpool users who would otherwise have been drive-alone or lower occupancy HOV users. Increases in ridership on these HOV lanes are in the range 100% to 300%, with much higher increases in bus ridership on the San Bernardino and I-45N Houston lanes. Vehicle occupancy has increased as much as 10% to 20% on 5 of the more successful projects. The HOV lane in such cases acts as a focus for, and major incentive to, existing rideshare promotions in the corridor. (See Figure E.1).

(10) Very little effort has gone into determining the energy savings potential of different HOV lane projects. However, the major savings will come from removal of vehicles from the peak commute hours, through the formation of carpools and vanpools. It is estimated that ridesharing on currently operational lanes is saving between 40 and 340 thousand gallons of gasoline per constructed HOV lane mile, on an annual basis: and this does not take into account the considerable savings due to bus ridership increases due to such lanes.

(11) The annual growth in vehicle miles of travel (VMT) in our largest urban areas has contributed to the effectiveness of these HOV lanes, and the expected continued growth in VMT to Year 2000 is likely to enhance further the effectiveness of the more recently implemented projects.

D. Project Features Required for Success

(12) The most successful HOV lane projects benefit greatly from either (a) being physically separated from the adjacent, general traffic lanes, or (b) from effective HOV bypasses at metered freeway entry ramps.

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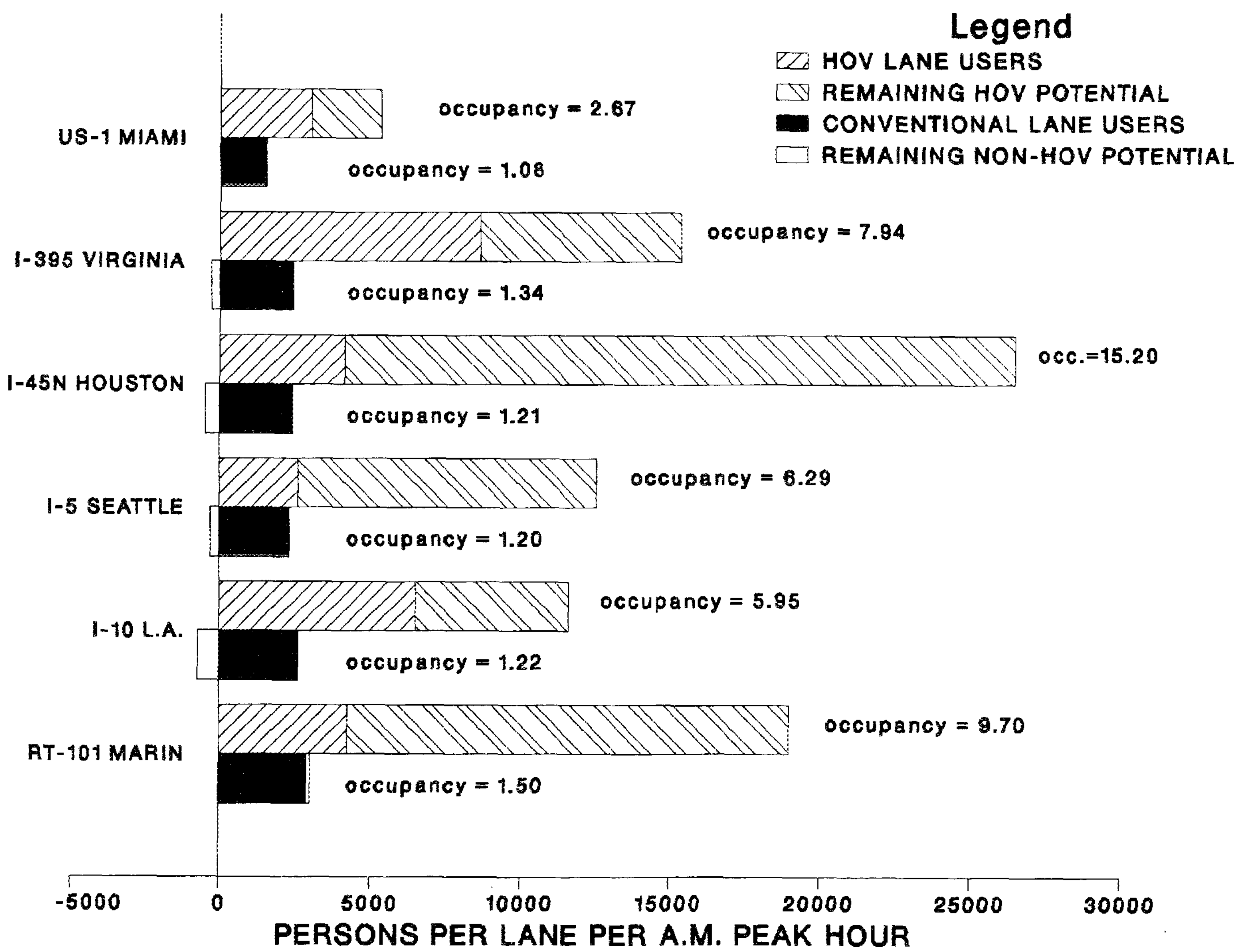

Figure E.1. HOV Versus Conventional Lane Throughputs and Potentials.

(13) A major contribution to project success is a high level of bus patronage, encouraged by appropriately sited park and ride lots and express service. While competition does exist between traditional transit and ridesharing modes, effective joint marketing of commuter transportation alternatives has proved effective in diverting ride-alone auto users to higher occupancy modes, given a receptive commuting environment.

(14) Major ingredients for an environment conducive to HOV adoption include long commutes and hence a long HOV mainline lane, residential and employment growth in the corridor (especially of interurban migrants) and a strong transit/rideshare marketing campaign (especially one oriented towards the corridor's major employers).

(15) In terms of public acceptance of new HOV lanes, it is important to avoid reducing the level of service provided to non-HOV users of the same facility/corridor. For this reason adding new capacity to a highway in the form of a HOV lane requires a demonstrated demand for HOV benefits: thereby avoiding a public reaction against seemingly "underutilized" roadspace (for which all commuters must pay).

(16) There is evidence to suggest that a potentially effective HOV lane project can be abandoned because of its seeming lack of use during its early days (New Jersey's Garden State Parkway HOV lane was dropped for this reason). Public education with respect to lane benefits needs to be emphasized if such a situation is thought to be likely (since removing a general traffic lane for subsequent HOV only use when traffic eventually becomes too congested seems, on past experience, doomed to generate strong adverse public reaction).

(17) Some planning agencies clearly have more sympathy for the HOV lane concept than others, or are perhaps better informed. Despite some concern, no evidence exists for higher accident rates being due to HOV lane versus conventional lane use over any reasonably long operational period, and properly patrolled and signed HOV lanes do operate with relatively low violation rates in a number of cities (down to less than 1% of all highway users, or less than 3% of all HOV lane users with enforcement and lane separation).

E. Potential for Future HOV Lanes

(18) The major motivation behind HOV lane implementation is the desire to ensure continued ease of access to the major employment center by a region's workforce; and to do so at the least public expense. HOV lanes can in many instances represent a viable travel option that will prove far less expensive than the other traditionally touted alternatives to capacity expansion involving more conventional lanes or new rail transit lines. If population, and hence the number of commuters on our major highways, continues its projected growth, the HOV lane alternative is likely to appear more attractive to a number of our larger cities should current fiscal problems continue to

plague public spending in the highway sector. The only alternatives for some conurbations come Year 2000 may prove to be significant journey to work mode and/or destination shifts, or real changes in our present approach to daily travel.

(19) Of particular concern is the growth in the length of the a.m. and p.m. commuting hours on some of our major freeways. This spreading of the daily "rush hours" has not led, however, to any significant reductions in peak hour congestion. As a result, the viability of some HOV lanes has been enhanced: since the argument that such lanes cause unnecessary congestion on the adjacent non-HOV lanes during the "shoulders" of the peak period has become less tenable.

(20) The potential for more HOV lane projects to be implemented in the future is, however, likely to be limited considerably by a number of factors. Such projects will be effective only on freeways and expressways linking suburban residents to the major employment centers in our largest cities. It is only here that the pressure on existing highway facilities will become sufficiently strong as to warrant actions aimed at controlling the expenditures needed to provide large freeway capacity increases.

(21) The most successful HOV mainline lane projects to date have either a relatively long HOV lane (10 miles may be a reasonable minimum length to plan for: i.e. San Bernardino, Houston's I-45N and Virginia's Shirley and I-66 Highways) or act as traffic congestion mitigating facilities located at major downtown freeway or expressway traffic bottlenecks (as in the case of Boston's I-93 and Honolulu's Muanalua Freeway). Available land upon which to build lengthy lanes is very limited in the majority of our older, eastern cities.

(22) Because of their continued rapid population growth and greater ease of land acquisition, it is in the "sun-belt" cities of the south and west (California, Texas, Florida), in Washington State and the Washington, D.C. region, that the major, and possibly only, opportunities for regionwide or connurbationwide HOV lane systems exist. A number of other cities, including Hartford, Newark, Pittsburgh and Minneapolis-St. Paul, may also warrant a HOV lane in the near future, but with planning on a more limited, corridor by corridor basis.

F. <u>Quality of Current Planning Data on HOV Lane Projects</u>.

(23) Considerable difficulties exist with obtaining all of the relevant planning information upon which to make a judgement of HOV project effectiveness, and upon which to base project comparisons. Monitoring of lane use and speeds is not a frequent activity on many of the lanes discussed in this report. Of more concern is the lack of data on the off-highway effects of HOV lane operation: on route switching, departure time changes, commuter door-to-door trip lengths and central area congestion.

(24) Little work has gone into discovering which aspects of a HOV lane project generate the major benefits: is it the lane itself, express bus service improvements, park and ride spaces, effective rideshare promotions, or (where appropriate) ramp metering and HOV lane bypass. More (rider survey) data is needed to make clear the synergistic relationships involved in project success.

(25) The additional cost of adding a HOV lane versus a conventional lane is relatively small unless a physically separated lane is required. Annual maintenance costs exceed conventional lane costs largely as a result of police surveillance requirements, as a means of minimizing lane violations. Where a physical barrier is required a cost-benefit analysis is required to determine the viability of HOV lane implementation. Such an analysis should take into account the relative highway life and fuel use under HOV versus non-HOV lane use. There would seem to be no single, widely used, method of carrying out this analysis in practice.

(26) As the concept of integrated Transportation System Management (TSM) practice becomes more accepted by the appropriate State, Regional and Local Planning Agencies more comprehensive data will likely become available to all types of HOV facility based planning. The major data problem facing definitive HOV lane project evaluation is the need to adopt a truly corridor (and not just freeway or expressway facility specific) approach to project evaluation. Where a number of HOV lane projects are planned along a number of different commuter corridors leading into and urban area (as in the case of Houston, Washington D.C. and Seattle) this corridor focus should be expanded to consider such impacts as central city congestion and inter-suburban impacts on residential values, on employment and on equity in both public transit service and dedication of highway taxes to new capacity.

STUDY OF CURRENT AND PLANNED HIGH OCCUPANCY VEHICLE LANE USE: PERFORMANCE AND PROSPECTS

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1. PURPOSE OF THE STUDY

1.1 BACKGROUND TO THE STUDY

The work reported below was carried out in partial fulfillment of a study of current HOV facility operations and use required by the DOE National Rideshare Program Plan [42]. The removal of any immediate energy shortage and the fall in the price of at the pump motor fuel prices during the early 1980's has caused some concern for the future of ridesharing as a means of cost and energy efficient commuting within the nation's urban conurbations. One approach to the encouragement of carpooling and vanpooling to work during the oil embargo crises of the 1970s was the implementation of high occupancy vehicle (HOV) lanes dedicated for use only by vehicles with a specified minimum number of passengers (i.e. at least 2, 3, 4 or more riders per vehicle required for lane access). The incentive to use such lanes instead of the adjacent general traffic lanes is a congestion free and time saving trip.

While receiving a lot of publicity, both pro and con, during the seventies, as well as a good deal of project- specific study and comparison towards the end of that decade, it was felt that some of the benefits of HOV lane projects may have been underestimated because insufficient time had passed between lane implementation and the growth in traffic for which such lanes are meant to offer a no-construction alternative. This present study therefore was commissioned by the Office of Transportation Systems within the U.S. Department of Energy as part of a study to assess the performance of current HOV lane projects as both rideshare promoting and energy saving facilities, and to determine whether their implementation should be promoted, and under what circumstances.*

The concern here is with not only the daily savings in energy that may result from reduced vehicle miles of travel (VMT) by commuters riding in HOVs, but also with the need to deal most efficiently with the demand

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*In conjunction with this present study, a companion study was also commissioned with the goal of using the most advanced simulation modeling techniques to estimate the energy savings potential in a range of HOV lane project situations (i.e. for different lane lengths, vehicle occupancies, number of lanes, number of access ramps, and different traffic volumes, etc.).

for additional roadspace created by a projected annual growth in VMT of 2.0% to 2.8% per annum to year 2000 [39]. Such growth is expected to take place largely in urban areas, where the U.S. Department of Transportation currently estimates that 44% of the highway mileage in use has a road surface condition defined as "noticeably inferior to a new pavement and may be barely tolerable for high speed traffic": and that 42% of this urban traffic is currently operating in highly congested conditions [39]. As one alternative to extensive new road building HOV lanes therefore continue to remain a topic of interest.

With approximately 1 in 5 commuters in the U.S. ridesharing to work (excluding the 6.5% who take public transit), as estimated by the 1980 U.S. Census [9], any facility investments, whether mainline HOV lanes, HOV bypass lanes on freeway entry ramps, or park and ride lots at the start of busy urban corridors need to be treated as potentially essential components of our future urban land use mix and accordingly given planning consideration in the development and evaluation of alternative transportation improvement plans. Each of these three rideshare-enhancing HOV facilities is discussed in this report but with interest centered upon those urban corridors containing a HOV "mainline" traffic lane, associated with which are usually one or more park and ride lots and, where geometrics allow, HOV bypass ramps at freeway entry points. In this sense then this report deals with "HOV Lane Projects" that rely on such capital facility created synergisms, and where express bus service will also typically make use of this same set of facilities.

1.2 OBJECTIVES AND NATURE OF THE STUDY

The objectives of the HOV lane current and planned activity survey were to ascertain (a) what is the current status of HOV lane operations across the U.S., with emphasis on (i) the effectiveness of such lanes as people movers vis-a-vis a general, nonprioritized traffic lane, and (ii) the ability of such high occupancy vehicle lanes to generate shifts to carpooling and vanpooling, and thereby encourage the use by commuters of fuel efficient modes of travel to work; and (b) what is the current status of planning for future HOV lane operations in our major cities, and what sort of an attitude exists in the various regions of the country within the planning profession, and within the public at large, to the introduction of such lanes.

The survey took the form of one or more telephone interviews with various individuals and planning agencies in each of the 48 contiguous states and Hawaii, with emphasis placed upon contacting a number of different agencies in those states where considerable HOV lane activity was known to exist prior to the start of the survey. Selection of agencies/individuals to contact was based initially upon the following address lists:

(1) Listing of all Metropolitan Planning Organizations in the U.S. (October 1983 Listing).

(2) The Directory of Ridesharing Agencies and State Contacts, June 1984, published by the National Ridesharing Information Center of the Federal Highway Administration (FHWA) in Washington D.C.

(3) DOE's State and Local Assistance Program (SLAP) contacts in the State Energy Conservation Program (SECP), by selected states - typically in State Energy Offices.

(4) Other contacts made by the principal investigators as a result of their recent work in the ridesharing area.

In addition, FHWA also provided the study with a 1980 listing of current and planned HOV lane projects; as the latest available listings to date. Since 1980 it was found that a good deal had changed in terms of both new HOV lane and bypass ramp projects beginning, some projects going out of service, an a number of planned projects being either introduced or abandoned.

Every attempt has been made to cover existing and planned HOV lane projects, as reported by the various planning agencies contacted, although a number of potential HOV lane projects in the very earliest planning stages have been omitted, since it is not unusual to report consideration of such projects as one of a number of alternatives for urban traffic corridor management as part of a requirement to consider all possible solutions to a traffic congestion problem.

Data provided in the many tables contained in this report is the most up-to-date available at the time of writing. This meant using data for a handful of projects that was collected in the late seventies. This information is included for completeness along with the much more current (1982-85) information we obtained for the majority of the projects we have reported on.

A listing and brief description of HOV lane projects reported to us as seriously proposed, in the planning or design phase, or currently under construction are given, by state, in the Appendix. Currently operational mainline HOV lane projects are listed and discussed in Chapter 2 of this report. Chapter 3 is devoted to a description of the types and ranges of operation practiced by these projects. An effort has been made to make the results as consistent across cases as possible, and to use only the information reported to derive appropriate travel speed and time, cost and mode selection, volume, fuel saving and emissions savings statistics.

In Chapter 4 a more in-depth look is taken at a few of the most successful projects to date, with an emphasis placed upon trying to identify those characteristics of a busy urban corridor that best suit HOV promotions. That is, we are looking here for "lessons to be learned" that may help us to select, or to predict the future success of HOV facility projects. Of particular concern is the need to relate future population and employment growth, and the physical access characteristics of a corridor to the location and length of an HOV lane. The second part of Chapter 4 is then devoted to a look at the evidence for synergisms between HOV lane implementation on freeways, and the simultaneous use of (a) HOV bypasses on metered access ramps, (b) park and ride lots serving express bus riders and (c) toll exemptions and bypasses. The most successful, HOV lane projects will likely need to benefit from such synergisms.

Finally, in Chapter 5 we assess the potential for further HOV lane projects and examine the reasons for past project rejection or abandonment: including inappropriate highway design, insufficent patronage, adverse public reactions, and preference among local or state planners for either less costly HOV bypass ramps or for the alternative of rapid transit service.

2. STATUS OF CURRENT HOV LANE ACTIVITY

2.1 STATED OBJECTIVES BEHIND HOV LANE IMPLEMENTATIONS

The following list summarizes the stated objectives behind the introduction of prioritized flow experiments, as culled from the many planning reports reviewed as part of the HOV lane and related facilities survey:

(1) To improve traffic flow by encouraging the use of shared ride vehicles (i.e. HOVs), and thereby creating more space on the highways during the peak commuting hours.

(2) To reduce energy consumption through reduced vehicle miles of daily commuter travel.

(3) To reduce air pollution (hydrocarbons, carbon monoxide, nitrogen oxides, sulphur and particulates) through reduced vehicle miles of daily commuter travel.

(4) To reduce the cost of transportation to the commuter through the encouragement of shared ride and hence shared cost, modes of travel.

(5) To remove or reduce the need for new highway construction or highway repair by reducing the volume of traffic that is responsible for road surface damage.

Taken down to the level of individual projects more detailed objectives were of course stated: from the need to plan for a current or expected significant growth in a corridor's population or employment base, to the need to eliminate unacceptably long waiting lines at the entry to a major commuter freeway.

2.2 LISTING OF RECENT AND CURRENTLY OPERATIONAL HOV LANE PROJECTS

Tables 2.1 and 2.2 list those "mainline" high occupancy vehicle (HOV) lane projects either currently in operation or in operation until sometime during 1984, and on freeways and non-freeways (arterials) respectively. In addition, as discussed in Section 4.3 of this report, well over 250 HOV bypass lanes also operate in various cities around the nation, associated with metered access to freeway ramps, where the freeway may or may not carry a HOV mainline lane. Of the 21 projects listed in Tables 2.1 and 2.2, 17 were in operation as of June 1985. Currently operational projects range in physical length from the two 12 mile long physically separated HOV lanes on the Shirley Highway (I-395) in northern Virginia to the 1.4 mile essentially congestion bottleneck bypass lane on Boston's I-93.

Table 2.1. Rideshare Supporting Freeway HOV Lane Projects

Project	HOV modes	Route length (direction)	Priority hours	No. of lanes		HOV lane type	Opening date
				General	HOV		
California							
Rt.101, Marin Co.	Bus, +3CP	3.7	6-9 a.m., 4-7 p.m.	3	1	Median	6/76
I-280, San Francisco	Bus, +3CP	1.6(s)	Continuous	3	1	Median	10/75
Route 237, Santa Clara Co.	Bus, CP	4.6(e) 4.4(w)	5-9 a.m., 3-7 p.m.	2	1	Right lane (shoulder)	10/84
I-10, Los Angeles (San Bernardino)	Bus, +3CP	11.0	Continuous	4-5	1	Median (separated)	6/77
Florida							
I-95, Miami	Bus, CP	7.5	7-9 a.m.,4-6 p.m.	4	1	Median	3/76
I-4, Orlando[a]	Bus, CP	31.0	7-9 a.m., 4-6 p.m.	2	1	Median	11/79
Texas							
I-45N, Houston	Bus, VP	12.9	6-8:30 a.m., 3:45-6:30 p.m.	3-4	1	Median 9.6=CF 3.3=CCF	8/79CF 3/81CCF
I-10, Houston (Katy)	Bus, +4CP	6.5	5:45-9:15 a.m. 3:30-7 p.m.	3-4	1	Median (separated)	11/84
Washington							
I-5, Seattle	Bus, CP, +3CP, MC	6.9(s) 5.0(n)	Continuous	3-4	1	Medians (1 each way)	8/83
Rt. 520, Seattle	Bus, +3CP	2.0(w)	6 a.m.-6 p.m.	2	1	Right lane (shoulder)	8/77
Virginia/D.C.							
I-395, N. Virginia (Shirley Hwy.)	Bus, +4CP	12.0	6-9 a.m., 4-7 p.m.	4	2	Median (separated)	12/73
I-66, N. Virginia	Bus, +3CP	10.0	7-9 a.m., 4-6 p.m.	0	2	Dedicated	12/82
Dulles[b] Access Extension to I-66	Bus, CP	13.5	7-9 a.m.	0	2	Dedicated	12/83
Massachusetts							
I-93, Boston	Bus, +3CP	1.4	6:30-9:30 a.m.	2	1	Median (separated)	2/74
Oregon							
Banfield[a] Fwy. Portland	Bus, +3CP	1.7(w) 3.3(e)	6:30-9:30 a.m., 3:30-6:30 p.m.	2	1	Median	12/75
Hawaii							
Moanalua Fwy., Honolulu	Bus, +3CP	2.7(e) 1.3(w)	Continuous	2	1	Medians (1 each way)	12/74

[a]Those HOV lanes not currently enforced, due to highway construction.

[b]HOV lane closed December 1984.

Note: See bottom of Table 2.2 for definition of abbreviations used.

Table 2.2. Rideshare Supporting Non-Freeway HOV Lane Projects

Project	HOV modes	Route length	Priority hours	No. of lanes General	No. of lanes HOV	HOV lane type	Opening date
California							
San Tomas Expressway, San Jose	Bus, CP	8.0	6-9 a.m., 3:30-7 p.m.	2-3	1	Right hand (shoulder)	11/82
Montague Expressway, San Jose	Bus, CP	7.0	6-9 a.m., 3:30-7 p.m.	2-3	1	Right hand	2/85
Florida							
US-1[a] Miami (South Dixie Hwy.)	Bus, CP	5.5	7-9 a.m., 4-6.p.m.	2	1	Median (+adjacent bus lane)	6/76
Hawaii							
Kalanianaole Hwy., Honolulu	Bus, +3CP	2.5	6-8 a.m.	2-3	1	Median 1.9CF 0.6CCF	9/75
Virginia							
N. Washington St., Alexandria, VA	Bus, +3CP	3.0	7-9 a.m., 4-6 p.m.	2	1	Right hand	8/84

[a]US-1's HOV lane was closed Spring 1984.

Note: CP means that all forms of carpool and vanpool are allowed HOV lane access.
+3CP means HOV's must carry at least 3 people to use priority lane(s).
VP means that only vanpools (as well as buses) allowed on HOV lane.
MC means motorcycles allowed HOV lane access (on Seattle's I-5).
Buses are always given access to the HOV lane projects listed above.
CF = contraflow HOV lane; CCF ≠ concurrent HOV lane.

These HOV projects can be usefully cross-classified according to four criteria:

- freeway versus arterial.
- physical configuration.
- type of HOVs given priority.
- hours of priority operation.

Freeway based HOV lanes account for 13 of the 17 currently operational projects, and these will be the main subject of this report. Also recorded in Tables 2.1 and 2.2 are 4 recently closed HOV lanes: on the I-4 Orlando, Dulles Airport Access to I-66 and Banfield, Portland freeways, as well as on the US-1/South Dixie Highway arterial in Miami.

The most common way to classify HOV lanes is by their physical configuration [43]. The most significant distinction is between those HOV lanes that are (1) physically separated from other, adjacent traffic lanes (2) those which run unseparated alongside the other "General Traffic Lanes", and (3) dedicated HOV highways on which only HOVs are allowed at certain times of day. The projects listed in Tables 2.1 and 2.2 break down as follows:

(1) Physically Separated Lanes. Separation is by a concrete barrier (Shirley Highway in Virginia, Katy Transitway in Houston, San Bernardino Freeway in Los Angeles), or bituminous berm (I-93 in Boston) and with buffer lanes at access/egress sections. On the Shirley Highway (I-395) HOV lanes feeding District of Columbia bound commuters two adjacent HOV lanes are operated along the same length of highway, in the same direction (with flow reversed on both lanes during the p.m. peak rush hour).

(2) Dedicated HOV Lanes. In the case of northern Virginia's I-66, HOVs are the only vehicles allowed between 7-9 a.m. and 4-6 p.m. on what is essentially a 10 mile, 2 lane stretch of freeway.

(3) Physically Non-Separated Lanes. These lanes may be divided by their operational characteristics as follows:

(a) Concurrent Flow (also termed With-Flow) Lanes. These lanes are abbreviated CCF in the two tables. Traffic in these lanes moves in the same (peak) direction as that in the adjacent general traffic lanes. The HOV lane in this instance may be either a median CCF lane, occupying the left-most lane on a freeway or major arterial (Route 101 in Marin County, California, I-280 in downtown San Francisco, I-95 in Miami, I-4 in Orlando, I-5 in Seattle, the Moanalua Freeway in Honolulu, a section of I-45N in Houston, and until recently the Banfield Freeway in Portland): or the lane may be an outside, right-hand lane, added by taking and converting an existing shoulder lane to HOV use during peak hours (Route 237 in Santa Clara County, California, Route 520 Seattle), or by adding a right hand lane to a restricted access arterial, as in the case of the San Tomas and Montague Expressway lanes in San Jose and N. Washington St., Alexandria.

(b) <u>Contraflow (also termed Reverse-Flow) Lanes</u>. These are abbreviated by CF in the tables. These lanes are made HOV by taking a lane away from the off-peak traffic direction. That is, one lane less is given to reverse-peak direction traffic, and as a result the HOVs using the CF lane are moving in the opposite direction to traffic in the adjacent general use lane. Both I-45N in Houston, and the Kanianaole Highway in Honolulu have a CF HOV lane, and in both cases this lane has been linked with a concurrent flow lane, extending the existing prioritized lane beyond the point where CF operation was considered infeasible/unsafe.

A third means of differentiating among projects is by the type of HOVs that are allowed on the prioritized lanes. Of the 21 projects listed in Tables 2.1 and 2.2 only the I-45N Houston contraflow-cum-concurrent flow lane bans carpools in favor of the higher occupancy (typically 15 seater) vanpools. The reason given was to better ensure safety, on a lane that also carries a significant number of express buses.

Among the other 16 currently operational projects, Houston's Katy Freeway and Virginia's I-395 (Shirley Highway) both currently restrict HOV lane use to vehicles carrying at least 4 occupants (+4CP), while 9 projects restrict lane use to vehicles with at least 3 occupants (+3CP), and 4 projects (Route 237 in Santa Clara County, Miami's I-95 and the two San Jose arterial HOV lanes) accept any vehicle with more than one person in it (abbreviated as CP). On I-5 in Seattle the general rule is +3CP but selected segments do allow two person CP's also, as an experiment in the more efficient use of road space (versus the fragmentation of 3 or greater person carpools into 2 person 'pools). In all currently operational projects these carpools and/or vanpools are allowed to operate on the same lane with buses, where the latter are usually of the express service type. Historically, many of these HOV lanes began as bus only lanes and were later opened up to other forms of ride sharing.

According to our fourth criterion, hours of lane dedication to HOVs, 4 currently operational projects employ continuous HOV only rules (I-280 in downtown San Francisco, the San Bernardino freeway in L.A, Seattle's I-5 and Honolulu's Moanalua Freeway). Seattle's Route 520 has recently expanded its hours from a.m. only enforcement to a 6 a.m. to 6 p.m. HOV day, while Houston's I-45N and Katy HOV lanes recently reduced their HOV hours from most of the day, to those hours shown. All of the other projects enforce HOV-only rules 2 to 3 hours during the a.m. and usually the p.m. peak commuter periods on the ends of each working day. When all 21 schemes are seen in overview, no obvious correlation exists between lane type, traffic volume and hours of operation.

Not listed or investigated further in this report are previously operated but now long abandoned HOV lane projects such as the Santa Monica Freeway in Los Angeles that operated for only 21 weeks during March of 1976 [49], or the Southeast Boston Expressway that operated for 26 weeks in May of 1977 [24]. It is worth pointing out however that as a result of such experiments with the removal of existing highway capacity for use by HOVs only, the current wisdom recognizes the need to add highway capacity whenever HOV lanes are being considered.

3. REPORTED COSTS AND BENEFITS OF RECENT HOV LANE OPERATIONS

3.1 PERSON THROUGHPUT AND VEHICLE OCCUPANCIES

Table 3.1 shows the person throughput, measured in terms of number of travelers passing along all or part (usually all) of each HOV lane supporting highway project, either for the duration of the a.m. peak hour, a.m. peak period or both. Person throughput rather than vehicle throughput is the appropriate measure here since in the final analysis it is the number of travelers (of which typically 98% or more are commuters) that are served that we are concerned with. Shown in Table 3.1 are the average weekday peak volumes of persons per lane, for both the HOV lane (or in the cases of Shirley Highway and I-66 in Virginia, averaged across the two HOV lanes), compared with the per lane person volume in a general, mixed traffic lane. Also shown alongside these figures are the average vehicle occupancies on the various lanes, as well as that averaged over all traffic on the highway (i.e. including both HOV and non-HOV lanes).

It is important to note, in looking at this table, that those per lane person volumes associated with peak period flows (i.e. the "a." rows of figures) refer to a period that varies from 2 to 3 hours, and even 4 hours on the San Bernardino freeway in Los Angeles. Hence the much higher values reported than for the ("b." row) peak hour volumes.

For the purpose of assessing the ridesharing (RS) contributions to these person volumes Table 3.1 also carries the number of peak bus users separated out in the first column of the table. To compliment this information the table also contains two separate HOV lane vehicle occupancy values: one for all HOV lane users, and one for rideshare mode users only. (In this and subsequent tables RS is taken to mean carpool and vanpool users only).

Scrutiny of Table 3.1 will on occasion indicate that summing the number of bus and RS HOV lane users gives a total that is lower that the column labelled "All" travelers using the lane. In such cases the discrepancy is accounted for by the number of violators using the lane: which in the case of a 2 person plus rule implies drive alone violators, but may in the case of a +3CP rule include 2 occupant vehicles, and so on. Table 3.2 contains the available evidence on such violations, given in terms of two rates:

(1) the percent of vehicles in the HOV lane that are in violation of the priority use rule.

(2) the percent of HOV lane violations taking all vehicles on the highway (HOV plus all general lanes) as the base.

While this information is far from complete it would seem that there is a strong positive correlation between police enforcement and reduction in the number of violations; while differences across projects are also

Table 3.1. Person Throughput and Vehicle Occupancies by Lane Type

Project		Average person volumes/lanes				Average vehicle occupancies			
		HOV lane(s)			General lane(s)	HOV lane(s)		General lane(s)	All lanes (inc. bus)
		Bus	RS	All[a]		RS	All		
Rt-101, Marin Co. (April 1984)[b]	a.	4,915	2,140	7,080	5,253	3.90	9.80	1.44	2.00
	b.	2,910	1,315	4,235	2,865	3.70	9.70	1.50	2.10
I-280, San Francisco (May 1984) (a = p.m.)	a.	400	545	970	5,502	3.11	4.41	1.50	1.56
Rt-237, Santa Clara Co. (Nov. 1984)	a.	380	4,000	4,540	4,190	2.14	2.22	1.00	1.24
	b.	160	1,705	1,950	1,513	2.15	2.20	1.00	1.30
I-10, San Bernardino, L.A. (1984)	a.	8,470	6,865	15,800	9,400	3.17	6.01	1.22	1.59
	b.	3,450	2,855	6,490	2,588	3.15	5.95	1.22	1.76
I-95, Miami (1984)	b.	700	3,005	3,705	2,162	1.51	1.85	1.20	1.34
I-45N, Fwy., Houston (contraflow) (May 1982)	a.	3,274	4,526	7,800	4,700	12.3	16.56	1.21	1.81
	b.	1,300	2,830	4,130	2,400	12.3	15.20	1.21	1.82
Katy Transitway, Houston (Dec. 1984)	a.	2,030	886	2,916	4,703	10.9	22.8	1.18	1.49
	b.	1,020	745	1,765	1,918	10.9	19.4	1.16	1.38
I-5, Seattle (Sept. 1983)	b.	1,476	758	2,580	2,300	3.62	6.29	1.20	1.42
Shirley Hwy., VA (March 1985)	a.	7,512	9,228	16,740	6,725	4.96	8.05	1.25	2.35
	b.	3,672	4,942	8,614	2,400	5.06	7.94	1.34	2.88
I-66, VA, (Spring 1984)	a.	701	4,652	5,353	-	1.99	2.23	-	2.23
	b.	374	2,577	2,951	-	2.17	2.46	-	2.46
I-93, Boston (1980)	a.	2,170	3,220	5,390	3,256	2.61	3.40	1.22	1.72
Banfield Fwy., Portland (1977)	a.	633	864	1,497	4,046	2.72	6.07	1.18	1.58
	b.	570	505	1,075	2,272	2.81	4.87	1.18	1.38
US-1/S, Dixie, Miami (1984)	b.	600	2,416	3,016	1,470	2.17	2.67	1.08	1.55
San Tomas Expressway, San Jose (Spring 1985)	a.	195	2,477	2,612	2,443	2.07	2.16	1.00	1.16

[a]Bus + RS + Violaters = All where (1) + (2) = (3) (see Table 3.2).

[b]Dates refer to time of latest reported survey.

Note: a. = per peak period, b. = per peak hour.

Table 3.2. HOV Lane Violation Rates and Enforcement Levels

Project	Violation rates		Enforcement level and other factors
	% HOV	% All vehicles	
Rt. 101, Marin Co.	2.1% 1.2%	0.1% 0.1%	a.m. 2 hr. peak period a.m. peak hour
I-280, San Francisco	11.4%	0.2%	p.m. 2 hr. peak period
Rt.237, Santa Clara Co.	7.8% 9.6%	1.5% 2.2%	a.m. 3 hr. peak period a.m. peak hour HOVs on outside shoulder
San Bernardino, L.A.	10.5% 10.1%	0.8% 1.1%	a.m. 4 hr. peak period a.m. peak hour Physically separated lane
I-95, Miami	50%	11%	+2CP rule, a.m. peak hour values, nowhere for police to pull over violators.
US-1/S, Dixie,	5%-10%	1.5%-3%	High level of Miami enforcement.
I-45N, Houston	Very low	(14/month)	Contraflow VP lane.
I45N, Houston CCF lane		<1% <2%	With police enforcement Without police enforcement Bus and VP only lane
I-5, Seattle	18%-20% rates halved during a week with regular enforcement.	4% to 5%	CCF flow median lane. Values for a.m. and p.m. peak hour average. High violation rates of 30-44% near end of lanes.
Shirley Hwy.	<3%		Physically separated HOV lanes with limited access.
I-66	10%		Physically separated lanes with 50 citations per day given out in early 1983. Major problems are on ends of peak period.
I-93, Boston	Very low		Buffer lane between HOVs and general traffic. Continuous police surveillance.
Banfield Fwy., Portland	12%	<1%	CF Flow median lane. Police enforcement hampered by absence of pull over spaces.
Moanalua Fwy., Honolulu	15%		

due in part to the different physical configuration of the prioritized lanes. Other things being equal we would expect that physically separated HOV lanes with limited access and egress would be easier to enforce. The major problems seem to occur, as reported for I-5 in north Seattle, where the HOV lane ends.

A second important requirement of effective enforcement, that at the same time avoids disruption to legitimate HOV lane users, is the presence of pull-over bays alongside the HOV lane, at reasonably frequent intervals. This allows police to access and leave the lane at will, to better spot violators, and to show a presence along its length.

No documented systematic assessment of the optimal level of enforcement necessary could be uncovered by our survey. The best trade-off between compliance levels (and their resulting positive effects on encouraging greater public acceptance of the HOV lane concept) versus the costs of enforcement remains unknown at this time. Florida Department of Transportation did however indicate that they were about to have a consultant look into this issue. Past literature in this area, as summarized in [40], indicates that higher violation rates are likely where one or more of the following conditions exist:

(1) Low utilization of the HOV lane with congestion in the adjacent general traffic lanes.

(2) Absence of an effective HOV lane marketing effort geared at informing the public in a positive way.

(3) Public opposition to the lane, especially opposition that gains media exposure.

As an example of the combined effects of (1) and (3) the 10 mile long HOV lane opened on New Jersey's Garden State Parkway in 1980 was closed in 1982 after public complaints. These complaints were given added impetus when a local television station positioned a camera on a bridge overlooking the lane and recorded and reported a 1.5 minute period without a single vehicle passing by. This adverse publicity was apparently a major reason for closure of the lane, despite an attempt to generate greater usage by reducing the HOV ridership requirement from +4CP to +2CP.

Using the information on person throughput presented in Table 3.1 the following measure of HOV lane effectiveness (the MCU), termed the Measure of Highway Capacity Usage, was derived and is reported in Table 3.3:

$$MCU = \frac{\text{\% of persons per peak period (or hour) on the HOV lane}}{\text{\% of road capacity devoted to HOV traffic}} .$$

Table 3.3. Highway Capacity Usage Associated With HOV Lane Operations

$$\text{Measure of Capacity Usage (MCU)} = \frac{\text{\% of persons per peak hour (period) on HOV lane}}{\text{\% road capacity given to HOV traffic}}$$

Measure of Extra Capacity (MEC) = 100 - % of HOV lane capacity in use

Mix = Number of buses/all vehicles in HOV lane (and % buses)

Project		MCU	MEC[1]	MIX[2]
Rt-101, Marin Co.	a.	(31.0/25) = 1.24	78%	125/720 (17%)
	b.	(33.0/25) = 1.32	73%	75/435 (17%)
I-280, San Francisco	a.	(5.5/25) = 0.22	94%	20/220 (9%)
Rt-237, Santa Clara Co.	a.	(35.1/33) = 1.06	62%	20/2045 (1%)
	b.	(39.2/33) = 1.19	50%	10/888 (1%)
I-10, San Bernardino	a.	(29.6/20) = 1.48	62%	190/2630 (7%)
	b.	(38.5/20) = 1.93	37%	75/1090 (7%)
I-95, Miami	b.	(30.0/20) = 1.50	0%	15/2005 (<1%)
I-45N, Houston	a.	(29.3/25) = 1.17	85%	103/471 (22%)
	b.	(36.0/25) = 1.44	84%	55/250 (22%)
I-10, Katy, Houston	a.	(13.4/25) = 0.54	96%	47/128 (37%)
	b.	(18.7/25) = 0.75	94%	39/91 (30%)
I-5, Seattle	a.	(10.5/20) = 0.52	80%	60/680 (9%)
	b.	(21.9/20) = 1.10	76%	37/410 (9%)
Shirley Hwy., Virginia	a.	(55.4/33) = 1.66	65%	435/4158 (10.5%)
	b.	(64.2/33) = 1.93	36%	216/2169 (10%)
I-93 Boston	a.	(45.3/33) = 1.37	83%	50/650 (8%)
Banfield Fwy., Portland	a.	(15.6/33) = 0.47	90%	28/346 (8%)
	b.	(19.1/33) = 0.58	88%	20/200 (10%)
US-1, Miami	b.	(50.6/33) = 1.53	24%	18/1130 (<2%)
San Tomas, San Jose	a.	(26.2/25) = 1.05	64%	11/1208 (1%)

[1] Assuming 1800 autos per lane per hour as an acceptable design capacity for a freeway HOV lane (1500 per lane on arterials) i.e. allows average speed of approximately 50 mph), and assuming that 1 bus = 1.6 autos.

[2] Includes reported violaters in HOV lane(s).

Note: a. = a.m. = peak period, b. = a.m. peak hour.

For example, Rt-101 in Marin County has 3 general traffic lanes alongside a CCF HOV lane. Hence we have from the data in Table 3.1, and for the a.m. peak period:

$$MCU = \frac{7080/[(5253 \times 3) + 7080]}{1/4} = 0.31/0.25 = 1.24 .$$

What the MCU shows us is how effective the HOV lane is at moving people compared to the average of the adjacent general traffic lanes' use of the same road capacity. What we can infer from this is that replacement of the HOV with another general traffic lane would reduce or increase total highway person throughput by the difference in these two values, <u>assuming that</u> the redistribution of traffic in such a case would be roughly even across all lanes. Such an assumption is likely to be a reasonable one in most cases. An effective HOV lane in terms of throughput then is one where the MCU is equal to or greater than 1.0.

According to this criteria seven of the existing freeway HOV lanes (Marin County, Santa Clara County, San Bernardino Freeway, I-95 Miami, I-45N Houston, I-93 Boston, and the Shirley Highway in Virginia), as well as the San Tomas arterial HOV lane in San Jose, are all very effective people movers, even when we consider the full peak a.m. period. I-5 in Seattle may also be considered to be moving towards acceptability during its peak a.m. hour, given the projected growth in traffic in that corridor and the relative newness of the mainline HOV lane operations there. Also effective, with an MCU of 1.53 in the a.m. peak hour, was the recently closed US-1/South Dixie Highway in Miami. It also seems likely that the Katy Freeway in Houston will attain a MCU of at or near 1.0 given its very recent (1985) inception and its corridor's potential for traffic growth. Only the recently discontinued Banfield HOV lane in Portland and I-280 in San Francisco of the projects listed in Table 3.3 show MCU's much less than 1.0, and the peak hour data for I-280, which might reflect a more effective lane, was not available to the study at the time of survey. Such evidence suggests an improvement in the effectiveness of some of these lanes over their respective 2 to 3.5 hour a.m. peak periods when seen in the light of the previous most recent evidence reported in the literature [43]. That is, growth of traffic in these corridors in recent years may have served to make these HOV lanes more viable in the "shoulders" around the peak traffic hour. Should this trend continue a more positive case for HOV mainline lanes may be justified in a number of additional urban corridors.

It has been assumed for Table 3.3 that all HOV lanes are concurrent flow lanes, and that it is the with peak direction volumes that we are concerned. The same use of the MCU statistic can be applied to a contraflow as well as the more popular concurrent flow HOV lanes, except that here we would always expect the lane to have a value much higher than 1.0, since the peak flow HOVs are replacing an off-peak flow that is usually of much reduced volume. This however may not always be the case.

For example, there has been a significant growth in "off-peak direction" traffic along the I-45N corridor in Houston [1] that may have led to future delays to this "reverse commuting" traffic were this contraflow-cum-concurrent flow HOV lane not due for replacement by a barrier separated transitway later in 1985 (see Appendix).

Table 3.3 also contains a Measure of Extra HOV Lane Capacity (the MEC) given as,

$$MEC = 100 - \% \text{ of HOV Lane Design Volume in Use}$$

where Design Volume refers here to the lane's capacity to move traffic under acceptably safe driving conditions (based on between vehicle driving distances). To ensure an average speed of 50 mph, and thereby maintain a clearly noncongested trip advantage for the HOVs, a base of 1800 vph is used in Table 3.3. While higher volumes are in practice possible, as reported in Table 3.1, under such traffic concentrations (i.e. number of vehicles contained in a given roadspace at a given point in time) the flow characteristics of the highway become increasingly unstable.

To obtain passenger car equivalent vehicles (p.c.e's) for the purpose of assessing the level of HOV lane congestion, a flat terrain equivalence of 1.6 autos = 1 bus is used to derive the MECs in Table 3.3. This value assumes a lane with relatively free-flowing traffic, as would be required to encourage commuters to take advantage of the time savings offered by the prioritized lane. Thus for example, if we look at the third column of figures in Table 3.3, giving the "Mix" of buses to all HOV lane vehicles, we get 125 buses out of 720 HOV's on Rt-101 in Marin County during the a.m. peak period (from an April 1984 traffic count), between the hours 6.30 to 8.30 a.m. [10]. Therefore we have:

$$(720 - 125) + (125 \times 1.6) = 795 \text{ p.c.e}$$

giving

$$MEC = 100 [1 - (795/3600)] = 78\% .$$

Note that (i) all peak period values are necessarily reduced to a measure based on hourly traffic volumes, and it is perhaps most appropriate to use the peak hour figures (i.e. the "b." rows in Table 3.3) to assess remaining HOV lane capacity; and (ii) that whereas a 6 to 9 a.m. peak period is shown for Marin County in Table 3.1 only data for the two hour period 6.30 to 8.30 was available in this case [10]: hence it is not always possible to derive the results in Table 3.3 directly from those in Table 3.1.

In assessing the respective project MECs reported in Table 3.3 some caution has to be exercised. Figures for Houston's Katy Transitway were taken after only 3 months of operation; and therefore do not reflect the likely use of this separated lane. Looking only at the peak hour capacity usage (the "b." rows) the MECs range in value from 0% on Miami's I-95 (where violation rates were as high as 50%) to 88% on the Banfield Freeway in Portland. Virginia's Shirley Highway has clearly the heaviest peak period, and especially peak hour, use: approaching effective HOV lane capacity. Even the Santa Clara and San Bernardino projects, both of which allow ridesharing from 2 person carpools up, have relatively high percentages of unused capacity (50%, 37% respectively); whereas those projects barring 2 person CPs (with the exception of the Shirley) have MECs in the range 76% to 88%.

Taken in isolation the MEC statistic is arguably of little use; but when viewed in conjunction with (i) the MCU, (ii) the modal share given to buses in the HOV lane, as well as (iii) the violation rates reported in Table 3.2 and (iv) the types of HOV allowed (Table 2.1), a largely complete picture of HOV lane use emerges. For example, the Banfield Freeway had a high level of unused roadspace given that it allowed +3CP, had a 12% HOV lane violation rate, and only a 10% bus share. It's MCU is therefore only 0.58 for the a.m. peak hour. In contrast, Rt-101 in Marin County, a lane of similar length, has 1/10 this violation rate, a 17% bus split and 73% extra road capacity still available: with a MCU of 1.32 for the a.m. peak hour. The latter would therefore seem to be a much more effective HOV lane.

Even with the above statistics, care must be taken in making comparisons across projects. What may be a success in one area of the country, or on one corridor within a city may seem less so in a different urban context. In all cases the bottom line should be whether or not the HOV lane is more efficient and economical than its reversion to an additional general traffic lane. The MCU it is argued comes close to indicating this condition using a single statistic. The MEC then indicates how much room is left in a given situation for absorbing extra traffic at no further expansion in highway capacity (i.e. no further construction). Seen in this light the overall conclusion from Table 3.3 is one of a number of effective people mover lanes with still more capacity available for HOV traffic growth: capacity not available to a general traffic lane.

Shown in Figure 3.1 are plots of HOV lane length versus person throughput per lane per hour, for the a.m. peak hour and a.m. peak period. Not shown are the Katy Transitway and I-66 projects, which are in an early stage of development and for which appropriately representative data was not currently available to the survey. While there does appear to be a strong positive relationship between lane length and lane use as measured by throughput for the peak hour, the peak period values are grouped in two clusters, with the much longer Shirley and San Bernardino lanes having by far the greatest per lane throughput. Caution must be exercised when looking at the peak period plot, however, since the duration of the peak periods varies by over 1 hour for the projects

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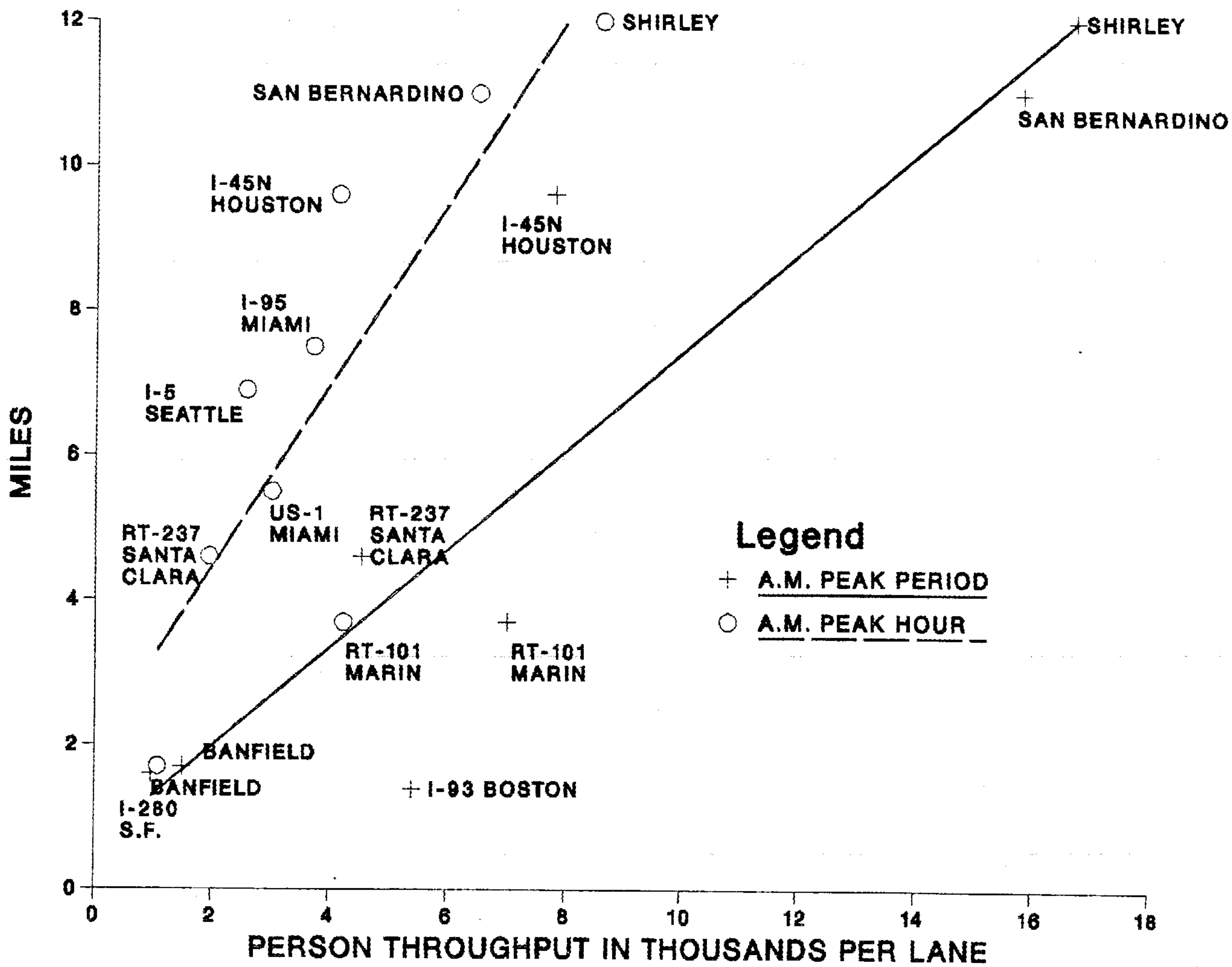

Figure 3.1. HOV Lane Length Versus Person Throughput.

shown. These different peak period durations, among other things, cause the greater variablility shown: although it is clear that Boston's I-93 gets a relatively good throughput per lane mile constructed vis-a-vis many of the other lanes. It should also be noted that while Houston's I-45N appears to be on of the less effective lanes per lane mile, the fact the this project allows only vanpools as well as buses is testimony to its ability to "compete" as a people mover with lanes allowing much lower HOV occupancies. In general, however, it seems appropriate to conclude from the evidence that in the peak hour the longest lanes are getting the most use. This of course is not a causal relationship. It reflects simply the nature of the corridors involved. What we can conclude however is that the longer lanes do compete effectively in terms of use per extra lane mile.

3.2 IMPACTS ON TRAFFIC SPEEDS

It has been usual to introduce HOV lanes to highways suffering from average space mean speeds (defined as the distance travelled along a road section divided by the time taken to travel it) in the range 15 to 30 mph. This contrasts with the approximately 55 mph speed possible under the best possible level of service, or freeflow conditions: such as the conditions it is usual to foster in HOV lanes.

Table 3.4 shows the reported HOV lane and adjacent general traffic lanes' speeds for many of the projects discussed above, where data was available. Of more importance from the policy setting perspective is the resulting travel time savings these average speed differences afford HOV users. Table 3.5 contains two such travel time savings statistics, both given in terms of a one-way commute, usually for the more destination time constrained a.m. peak hour trip. The first statistic is the minutes saved by highway users when comparing their before priority scheme implementation times and their subsequent HOV lane times. Where available both HOV lane and general lane user times are shown.

While peak direction travelers on the Muanalua Freeway in Honolulu and on Boston's I-93, as well as reverse peak direction travelers on Houston's I-45N (where a contraflow HOV lane was created by reversing flow on a previously off-peak direction lane) lost time as a result of priority lane treatment for HOVs, users of the general traffic lanes on Miami's I-95, Houston's I-45N, Seattle's I-5 and Virginia's Shirley Highway actually saved time after HOV lane introduction, typically during both the a.m. and p.m. peak hours of travel.

Difficulties again exist, however, in making such before and after comparisons. Growth in total traffic volumes during the interim must be fully understood if the full benefits or costs of an HOV lane are to be determined. Clearly, if a new lane is added to the highway, whether HOV or not, average traffic speeds will increase immediately. What the figures in Table 3.4 and the first column of Table 3.5 do not show us is how much the average traveler delay has increased or decreased as a result of HOV lane introduction, given the current volume of traffic in

Table 3.4. Reported Impacts on HOV Lanes on Vehicular Traffic Speeds

Project	Before priority: Average all lanes (mph)	With priority: HOV lane (mph)	Average general lanes (mph)
I-95, Miami	31.5	52.9	38.1
I-45N, Houston			
(a) CF a.m. peak hour peak direction	22 to 26	55.0	29.0
off-peak direction	52 to 54	-	50.0
(b) CF p.m. peak hour peak direction	16 to 17	55.0	21.0
off-peak direction	48.0	-	27.0
(c) CCF a.m. peak hour peak direction	26.0	48.0	26.0
Katy Transitway, Houston	22.0	55.0	22.0
I-5, Seattle	30.0	55.0	47.6
Shirley Hwy., VA			
(a) a.m. peak	NA	55.0	19-33
(b) p.m. peak	NA	55.0	27-49
I-66, VA	-	45.0	-
I-93, Boston	29.4	42.2	17.0
Banfield Fwy., Portland	38.0	51.5	37.5

NA - Not applicable.

Note: All speeds are a.m. peak hour average speeds unless indicated.

Table 3.5. Travel Time Savings Associated With HOV Lane Use

Project	Average one-way trip travel time savings: Before vs. after priority (Minutes saved)	Average one-way trip travel time savings: Difference in HOV lane and average general lane, given priority (Minutes saved)
Rt. 101, Marin Co. a.m. peak period		2.0
San Bernardino, L.A. peak period		18.0 a.m. 8.0 p.m.
I-95, Miami a.m. peak hour	3.5 (HOVL)	2.0
I-45N, Houston		
(a) CF a.m. peak hour peak direction	13.5 (HOVL) 4.1 (Gen.L)	9.3
off-peak direction	0.0	
(b) CF p.m. peak hour peak direction	25.5 (HOVL) 8.6 (Gen.L)	16.9
off-peak direction	-1.3	
(c) CCF a.m. peak hour peak direction	3.2 (HOVL)	
Katy Transitway, Houston	8.0 (HOVL)	
I-5, Seattle peak hour	1.8-3.2 (HOVL)	1.8 a.m. 1.0 p.m.
Shirley Hwy., VA	15 to 20 (HOVL)	15 to 20
I-66, VA		12 to 15 (vs. other parallel routes)
I-93, Boston a.m. peak hour	1.0 (HOVL) -2.0(Gen.L)	4.0
Banfield Fwy., Portland a.m. peak hour	1.5 (HOVL)	1.0
Muanalua Fwy., Honolulu a.m. peak hour	3.0 (HOVL) -2.0 (Gen.L)	
Kalanianaole Hwy. Honolulu a.m. peak hour	4.0 (HOVL)	3 to 5

the corridor, as measured some years after HOV lane introduction. Only by removing the HOV prioritization from the added lane can we be certain of the lane's impact. In practice this is obviously an unwise approach to take, and so we must resort to simulation modeling of the problem, incorporating the potential for route switching and departure time changes, as well as modal shifts, as a result of returning a lane to general traffic use.

What these figures do show is the extent to which non-HOV lane users' travel times have deteriorated or improved since HOV lane inception. Where a serious worsening in traffic congestion has occurred due to growth in the number of commuters using the corridor it is only natural for some travelers to question the existence of a HOV lane, even if the lane is actually helping to keep the level of congestion in the corridor down. It is therefore worth keeping information of the sort presented in Tables 3.4 and 3.5 since public opinion, even when mistaken, can be a force in the decision making process, and may lead to the delay or abandonment of potentially beneficial planning projects. (Under such circumstances a campaign to inform commuters of the true situation might be worthwhile).

The second column of statistics in Table 3.5 shows those minutes saved by HOV lane users vis-a-vis general lane users, once prioritization has been established. Savings range from 1 minute to 18 or 20 minutes on a one way commute, with the San Bernardino, I-45N and Shirley Highway projects proving particularly beneficial to ridesharers and bus riders. That is, the longest lanes offer the greatest time savings.

Unfortunately, what is missing from the reported data is the percent of total commute time such savings represent for the various corridors studied. Since we can expect, say, a 7 minute savings to have different implications for commuter behavior on a 20 minute versus a 40 minute commute, it is difficult to judge just how effective HOV lane projects can be expected to be in inducing shifts to HOV modes. Clearly, we can expect a range of commuter travel distances and hence times along any given urban corridor and this range as well as the average commute time will affect the overall time saving benefits associated with a HOV lane.

A further note of caution is also offered when using such data as that reported in Table 3.4. Such speed data, as with the traffic volume data reported above, is usually obtained by monitoring traffic on only a small number of weekdays (sometimes a single day sample), at a limited number of points along the HOV lane section, and for specific time intervals within the peak hour/period. As shown in Table 3.6, for the Shirley Highway (April 1985) speeds can vary quite substantially at different times within the peak. This table also shows the significant difference in average speeds that are possible during the most congested operating times, as a result of including versus ignoring the delays caused all traffic, including to a large extent HOVs, at lane entry and (in particular) lane exit points. Finally it must be noted that little or no data seems to have been collected on the daily variance in HOV versus general traffic lane travel times. Significant delays to non-HOVs

Table 3.6. Average Travel Speeds on the Shirley Highway During HOV Lane Operation

Time of day	Average space mean speeds[a]		Average running speeds[b]	
	General lanes	HOV lanes	General lanes	HOV lanes
A.M. Peak				
6:40-7:50	19.2	46.9	22.9	52.8
8:05-9:17	24.5	34.8	31.0	44.5
P.M. Peak				
4:05-4:55	38.1	46.5	39.7	48.2
5:15-5:45	39.1	54.7	40.5	54.7
6:05-6:25	48.8	56.1	50.3	56.1

[a]Average speed including delays at lane terminal points.

[b]Average vehicle operating speeds during lane travel, excluding delays at entry/exit points.

Source: Virginia Department of Highways and Transportation.

Note: Data is from sample monitoring carried out on 24 and 25 April 1985, and is based on average across the results from 12 locations along the highway, including the two HOV lane end points.

on a regular basis may be a major reason for commuters to move to HOV use. Qualitative evidence of this situation is required.

3.3 IMPACTS ON THE GROWTH OF RIDESHARING

Two topics are covered in this section:

(1) The evidence for HOV lane projects' impacts on the growth of ridesharing.

(2) The effect on subsequent bus ridership of giving HOV lane access to vanpools and/or carpools.

The travel time savings referred to in Table 3.5 together with the monetary cost savings associated with ridesharing are the incentives required to make a HOV lane scheme work. Table 3.7 contains the reported number and resulting percent change in rideshare vehicle use and associated highway vehicle occupancies for those projects reporting such figures, and for which at least 6 months of HOV lane use elapsed before collection of the "after" figures shown. Only the I-95 in Miami (with its 50% violation rate) fails to reach well into three figures for % increase in HOVs.

Between 1973, the year before carpools were first allowed on the Shirley Highway HOV lanes, and 1981, HOV lane ridership (RS plus bus) increased by 221%: from approximately 13,500 HOV lane users to 43,320 [12] [37]. Since that time a significant drop in patronage has been observed, attributable in part to the opening of the I-66 lanes in 1984, and in part to alterations in bus routes connecting to the METRO rail line extension. Currently some 33,500 riders occupy the lanes, a growth of 148% in ridership since 1974.

Again, however, caution must be urged in taking such results on face value. Problems of evaluation arise for the following four reasons:

(1) Difficulties in separating HOV lane impacts from other supportive HOV facility use in the corridor

In the case of the Los Angeles and Seattle projects, where extensive use is made of ramp metering bypasses for HOVs, it is difficult to separate out the benefits of HOV lane benefits from those of pure bypass metering benefits. For Seattle's I-5 'FLOW' system, for example, it is estimated that some 3 to 8 minutes travel time savings result from the ramp metering and bypass lanes they have been using for over two years [5] [6] whereas the subsequent introduction of the median HOV lanes contributes the 1.0 to 1.8 minutes referred to in Table 3.5. Also contributing to the success of most HOV projects have been the introduction of express bus services and of park and ride lots.

Table 3.7. Growth of Ridesharing During HOV Lane Projects (results refer to a.m. peak period)

Project	Number of RS vehicles			Vehicle occupancy		
	Before	After	% Change	Before	After	% Change
San Bernardino, L.A. (1976-1985)	670	2,166	323%	1.20	1.35	12.5%
I-95, Miami (1976-1984)	2,185	2,714	24%	1.23	1.28	4.1%
I-45N, Houston (1979-1982)	70	267	281%	11.00	12.30	11.8%
Shirley Hwy., VA (1974-1982)	272	5,007	1,740%	1.35	4.42	227.4%
Shirley Hwy., VA (1974-1985)	272	3,723	1,269%	1.35	4.96	267.4%
I-93, Boston (1974-1980)	315	1,224	289%	1.35	1.48	9.6%
Banfield Fwy., Portland (1975-1977)	106	518	389%	1.22	1.26	3.2%
Moanalua Fwy., Honolulu (1974-77)	600	1,341	124%	1.70	1.95	14.7%
I-5, Seattle		see text				

The only recent, reliable and published evidence our survey could find on the separate impacts of HOV lane introduction versus (subsequent) improvements in express bus service (tied to park and ride lot openings) comes from the I-45N study of Houston's contraflow lane operation [1]. Based on close monitoring of bus ridership over the period August 1979 to May 1982 (the first 33 months of lane operation) by Houston METRO it was possible to observe sharp growth in bus patronage with such events as new park and ride lot openings and bus service capacity expansions [1, Chapter 6]. On the basis of this empirical evidence it was concluded that the contraflow lane per se led to bus ridership increases in the range 45.9% to 132.3% over a 33 month period. It was also estimated that 56.9% of those riding the bus would not have done so without the contraflow lane being present; while 35.4% of contraflow lane users required the improved express bus and park and ride lot service in order to use the lane. Whatever the actual figures the evidence does indicate a true synergistic effect between lane prioritization, remote parking provision and express bus service.

Perhaps the only reliable evidence for what effects such a lane opening has on HOV use must come from a commuter survey; such as that reported by [14] in 1978 for carpoolers using Los Angeles' San Bernardino HOV lane: with 57% of those who joined carpools indicating that the lane was necessary to their change of mode.

From the above evidence plus that summarized in [43] for other projects reported on in the seventies, it is concluded that (i) HOV lane projects can generate significant moves to HOV modes, but that (ii) we may need to recognize the necessity of providing additional remotely located (from the CBD) parking facilities and associated express bus services in evaluating the potential costs and benefits of any HOV lane project.

(2) Possible changes in the underlying demand for ridesharing

For example, in the case of Houston's I-45N corridor the above described growth in HOV use took place in the context of a rapidly growing demand for commuter transportation, both in the corridor and regionwide. In such cases we do not know with certainty just how much additional ridesharing would have resulted had no HOV lane been implemented.

One way to look at the problem of defining a suitable base for comparison is to look at other congested corridors in the same urban area, or at the comparative growth of ridesharing regionwide versus along a prioritized lane corridor: a necessarily somewhat biased comparison given the expectation of having selected the most appropriate corridors for HOV treatment in the first place.

For example, while the number of vanpools in the I-45N corridor of Houston had increased by 281% from HOV lane inception in August 1979 to May 1982 (= a ridership increase of 326%), a similar growth in vanpooling may have occurred throughout the Houston region over this period [1]. Complicating this evaluation, however, is the apparent competition between bus and vanpool services along the I-45N corridor, where express bus has been a major success. A clearer picture is presented by the carpool listings compiled by the Seattle/King County Commuter Pool. These figures indicate that the I-5 north Seattle HOV lane project increased that corridor's share of regional listings from 20% to 26% after 3 months of bus/carpool lane operation [5].

(3) Selection of an appropriate pre-project comparison date

A third difficulty with measuring the impacts of HOV lane use on ridesharing adoption results from the inception of the majority of these projects as a result of the energy crises of the 1970s. Hence, for example, the Banfield Freeway had only 106 carpools estimated to use it daily in April 1975 [33] but there was a rapid upsurge in use prior to HOV lane introduction in December of 1976. It is therefore difficult, given such statistics, to determine just how much the HOV lane actually contributed to carpool use, and how much was a response to the fuel shortage.

With such difficulties in mind it may still be concluded that 7 of the 8 HOV lane projects shown in Table 3.7 made significant impacts on bus/rideshare adoption for the journey to work and that the maintenance of constantly high levels of pooling right up to the current, low fuel price days of the mid-1980's, may be seen as evidence of a HOV lane project's continued benefit.

Turning now to the issue of shifts within HOV modes as a result of HOV lane operations, it is important to recognize the concern of transit authorities who fear a significant loss of bus ridership as a result of improved conditions for carpools and vanpools (or for privately operated buspools).

In the case of Houston's I-45N corridor some competition between the two modes clearly has been taking place, but with a favorable result for express bus useage. While such bus patronage has soared in the corridor the growth in vanpooling, while significant, has done little more in the first 33 months of operation than keep pace with vanpooling growth across the region as a whole: with decreases and increases in vanpooling adoption rates appearing to follow respectively the introduction of remote park and ride lots and the need for more spaces at such lots at which bus riders may leave their cars.

Where carpools are also a prioritized mode more concern may be voiced. According to [14] 32% of those carpoolers surveyed and riding on the San Bernardino Freeway in May 1978 indicated that they had previously used the bus, compared with 39% who had previously driven alone. More recently, the Spring 1984 closure of the US-1/South Dixie Highway HOV lane in Miami seems to have been due to concern that the lane would keep riders away from the new mass transit line opened along the same radial corridor (although no evidence could be obtained by our survey demonstrating that this was the only reason for lane closure).

Boston's I-93 as well as Virginia's Shirley Highway HOV lanes are well patronized by private bus companies. In the case of I-93, these private bus lines saw a 17% growth in patronage in the period 1974-1978, followed by a 55% increase 1978-1980 [23]. Over the same periods the Massachusetts Bay Transportation Authortity buses experienced 19.2 and 25.1% ridership increases respectively. From 1974 to 1980 carpools on the 1.4 mile long I-93 HOV lane saw only a 4.8% increase (from 580 to 608 vehicles). As in the case of Houston's I-45N lane, buses have managed to outperform carpool/vanpool modes in terms of lane usage.

What the above evidence, along with that summarized in [43] for the seventies' experiences, indicates, is that properly planned express bus service using appropriately located park and ride lots can compete effectively with ridesharing modes after lane prioritization, even when both of these HOV modes share the same HOV lane: and that from the viewpoint of providing the commuter with the widest choice of travel both modes should be made available where (i) sufficiently high and growing demand for travel exists within the corridor, and (ii) where currently high levels of traffic congestion require significant shifts from the drive alone mode.

3.4 IMPACTS ON ENERGY CONSUMPTION AND EMISSIONS

Only three projects were found to report HOV lane impacts on energy consumption:

(i) I-45N Houston CF lane [1]: 1,121,000 gallons/year (8.5% reduction claimed) for combined a.m. and p.m. peak periods.

(ii) I-5 Seattle [6]: 190,400 gallons/year for the combined a.m. and p.m. peak periods, based on changes in volumes and speeds on I-5 before and after bypass ramp metering as well as HOV lane use.

(iii) Banfield Freeway, Portland [33]: 72,277 gallons/year for the combined a.m. and p.m. peak hours, and 178,184 gallons/year for the combined peak periods. These savings are given for rideshare modes only (i.e. excludes bus use).

In all cases these estimates are as derived and reported in the project specific literatures, and are based upon the then current government (i.e. DOE and EPA) provided average estimates of fuel use and emissions production. Consistency across projects cannot be assumed, and the figures can be taken as rough approximations only, in all cases. In particular, none of these fuel consumption studies looked in detail at the effects of HOV lane introduction on departure time or traffic route shifts to other highways within a given corridor; nor were particularly detailed vehicle type breakdowns used in making the estimates of fuel consumed.

In Table 3.8 we give estimates of both the total annual fuel savings and the number of gallons of (assumed gasoline) fuel saved per year, per constructed HOV lane mile (c.l.m.), as a result of the number of vehicles removed from the highway daily through carpool and vanpool use. The data in Table 3.1 above on person throughput and vehicle occupancies is used to obtain the number of vehicles so removed. The 22 mile daily round trip commute is based on Bureau of Census estimates of average urban area commutes [9], and a 230 working day year is used, as is an average commuter fuel consumption of 15 mpg. Attempts to estimate the additional fuel saved by such projects as a result of before versus after HOV lane speed changes requires more detailed information than any made available to us. In particular, such estimates require information on the differences (sometimes significant) between the a.m. and p.m. peak period conditions, as well as data on the nature of traffic flow interruptions during the peak hours.

Attempts to use the FHWA's highway lane volume/capacity ratio versus speed relationships resulted in most cases in too large a discrepancy between the reported travel speeds given in Table 3.4 and the hypothetical values based on the traffic volume data contained in Table 3.1. A better understanding of local highway conditions is required before the appropriate formula adjustments can be made.

Evidence is also required on the nature and volumes of route diversions and/or departure time shifts brought about by HOV lane implementation. This is one further reason why the appropriate approach to effectively estimating fuel saved from HOV lane projects should be a combination of corridorwide network simulation modeling coupled with local knowledge of how to adjust the generic formulas typically applied in traffic flow studies.

No data could be obtained on the <u>estimated indirect energy savings</u> associated with HOV lane projects. That is, while the effect on highway surface life is likely to be minimal, automobile life may be extended significantly for the many vehicles left at home.

Only the I-45N Houston (1982) and Banfield (1977) studies were found to offer calculations of the <u>emissions savings</u> brought about through the operation of an HOV lane project. These studies report the following estimates:

(i) For Houston's I-45N contraflow lane, the following savings are estimated [1] <u>for the combined a.m. and p.m. peak periods</u>, and for savings attributable to HOV lane users only:

Hydrocarbons: 41.9 tons/yr (-4.2%) (=4.36 tons/yr/c.l.m)
Carbon Monoxide: 908.1 tons/yr (-7.3%) (=94.59 tons/yr/c.l.m)
Nitrogen Oxides: 40.5 tons/yr (-4.7%) (=4.22 tons/yr/c.l.m)

(ii) For Portland's Banfield Freeway CCF median lane, the following figures are for the combined a.m. and p.m. peak hours only [33], and were based on an assumed 'before' HOV lane condition.

Table 3.8. Estimated Number of Vehicles Removed from HOV Lane Highways and the Resulting Annual Fuel Savings

Project	No. of autos removed[a] on a daily basis		Annual fuel savings[b] in gallons of gasoline (gals. saved per HOV lane mile)	
	Peak hours	Peak periods	Peak hours	Peak periods
On Freeways				
Rt-101, Marin Co. CA (April 1984)	521	891	183,500 (49,600)	300,500 (81,200)
I-280, San Francisco, CA (May 1984)	NA	188	NA	63,400 (39,650)
Rt-237, Santa Clara Co., CA (Nov. 1984)	930	1,975	327,350 (72,750)	666,000 (144,800)
San Bernardino, Los Angeles, CA (1984)	1,434	3,462	504,700 (45,900)	1,167,800 (106,200)
I-95, Miami, FL (1984)	514	NA	181,000 (24,100)	NA
I-45N, Houston, TX (CF lane) (May 1982)	2,109	3,372	742,300 (77,300)	1,137,500 (111,900)
I-5, Seattle WA (Sept. 1983)	615	1,488	216,500 (18,200)	501,200 (42,150)
Shirley Hwy, VA (March 1985)	5,423	10,495	1,909,000 (79,500)	3,545,800 (147,750)
I-66, VA (Spring 1984)	1,748	2,316	615,300 (61,500)	781,000 (39,050)
I-93, Boston MA (1980)	NA	1,405	NA	474,000 (338,600)
Banfield Fwy., Portland, OR (1977)	248	414	87,400 (35,000)	145,700 (52,300)
On Non-Freeways				
US-1, Miami, FL (1984)	1,124	NA	379,150 (69,000)	NA
San Tomas Expressway, San Jose, CA (Spring 1985)	NA	1,208	NA	431,800 (54,000)

[a]Based on ridership and vehicle occupancies given in Table 3.1., i.e.

Autos Removed = [HOV Lane (RS) Users/Non-HOV Occupancy Rate] – [HOV Lane (RS) Users/HOV (RS) Occupancy Rate]

[b]Assuming average daily round trip commute of 22 miles, 230 working days a year and average automobile fuel rate of 15 mpg.

Where operational a.m. and p.m. HOV lane mileage differs, the average of the two is used (i.e. unweighted by ratio of a.m. to p.m. traffic volumes). Where two distinct lanes exist (rather than the usual reversible flow lanes) both a.m. and p.m. lane lengths are summed – as in the I-5 Seattle case).

NA – Data not available.

Route diversion to parallel arterial roads was, however, given some consideration in making these estimates:

Hydrocarbons: 3.26 tons/yr (-15.0%) (=0.65 tons/yr/c.l.m)
Carbon Monoxide: 35.14 tons/yr (-22.0%) (=7.03 tons/yr/c.l.m)
Nitrogen Oxides: 0.60 tons/yr (-4.0%) (=0.12 tons/yr/c.l.m)

The percentage figures in brackets in both cases represents the estimated percentage savings over the pre-HOV lane condition. Where the Banfield project is concerned, constructed lane miles (c.l.m) refers to two physically separate HOV lanes, whereas the Houston CF lane is reversible. Estimates of emissions production rates are based upon published U.S. Environmental Protection Agency figures, but the analyses were carried out at a quite crude level of spatial detail and using similarly crude vehicle type classifications.

3.5 CAPITAL AND OPERATING COSTS

Table 3.9 lists those capital and operating costs both for existing HOV lanes and for currently proposed or projected HOV lanes, based on data reported to our survey, or found via the associated literature review. The reader should pay attention to the brief comments accompanying each project description in this table. Capital costs per HOV lane mile constructed (given here in their original dollar values and therefore not discounted to a common base year where an existing lane is referenced) are clearly highest for the physically separated lanes that involve the construction of concrete barriers along the length of the lane: with cost at current (1985) prices on the order of 4.5 to 5.5 million dollars per lane mile. The other popular option, adding a median lane for HOV only use, currently appears to cost 1.0 to 4.5 million dollars per lane mile.

Very little current information is available on annual operation and maintenance costs; mainly law enforcement and repair costs. Given the similarly poor data on benefits associated with fuel savings (and by implication therefore on vehicle operating costs), as reported above, detailed quantitative evaluation of the actual net benefits from current HOV lane projects cannot be attempted from existing data without recourse to either further on site survey work or to detailed computer simulation modeling. Some rough estimates of benefit/cost ratios for 8 alternative Houston and 6 Dallas HOV lane proposals are provided however in a recent publication by the Texas Transportation Institute [12, page 47], with ratios from 3.3 for a 1 lane reversible project on the East R.L.Thornton Freeway in Dallas, to a ratio of 13.7 for a similar single lane project on Houston's West Loop. Benefits are given as travel time savings to highway users, in reduced fuel costs and in transit operating costs. (A 20 year period is used at 10% discounted costs, with $7 per hour value of time, $1.20 per gallon of fuel and $50 per hour bus operating costs).

Table 3.9. Reported Capital and Operating Costs for HOV Lanes

Projects	Capital (in millions of dollars) Total	Capital Per lane mile	Operating (in thousands of dollars) Annual	Operating Per lane mile	Comments
San Bernardino, L.A.	57.0	5.18	-	-	Barrier separated lane/ Opened 1/1973
San Bernardino Proposed Extension into downtown L.A.	20.0	20.0	-	-	Fully grade separated mile of hwy.
I-95, Miami	18.5	2.46	-	-	Median lane added (CCF). Opened 3/1976
I-45N, Houston CF and linked CCF lane	2.33	0.18	602.4	46.7	Existing lane used. Opened 8/1979
I-45N, Transitway, Houston	69.5 Note: In construction and partial operation	3.95	-	-	Projected cost estimate added barrier separated lane.
I-10, Katy Transitway, Houston	38.0 Note: In construction and partial operation	3.30	-	-	Projected cost estimate added barrier separated lane.
I-45 Gulf Transitway, Houston (Projected)	80.0	5.16	-	-	Projected cost estimate added barrier separated lane.
I-5, Seattle Extension (Projected)	10.13	1.03	-	-	Added median lanes.
I-405, Seattle (Projected)	10.16	0.82	-	-	Added median lane.
Shirley Hwy., VA	43.0	3.91			1970 dollars.
Shirley Hwy., Proposed I-95 Extension, VA	98.0	5.16			
Rt-50/301, Maryland (Projected)	10.0		55.0		Projected cost estimate (1981 constant dollars). Extra cost vs. best non-HOV lane alternative.
I-93, Boston					
Banfield Fwy., Portland	0.50	0.13	-	-	CCF lane added. Opened 12/1975
Muanalua Fwy., Honolulu	0.01	0.003	Zero	-	CCF lane added. Opened 10/1974
US-1, Miami	0.50	0.09	-	-	CCF lane added Opened 6/1976
Kalanianaole Hwy., Honolulu	0.34	0.14	37.2	14.9	Arterial Hwy. Opened 8/1973

Note: - Indicates data not available. Proposed project costs are in construction year dollars.

3.6 ACCIDENT RATES ASSOCIATED WITH HOV LANE USE

Table 3.10 contains the only recently reported accident data associated with HOV lane operations for which there is both before and after lane implementation data available. While limited in its coverage, and subject as with all such accident rate data to the problem of defining a sufficiently long observation period within which to smooth out the occurence of random clustering of accidents, there would seem to be no major increase in accidents as a result of HOV lane operations.

What can cause problems for public acceptance of the HOV lane concept is the occurence of one or more accidents during the early days of priority lane implementation. The I-4 HOV lane through Orlando, Florida experienced 3 such accidents in its early operational phases, when enforcement of the lane was being carried out. Problems with the lane include the need for lane widening (currently underway along a 30 to 35 mile stretch) and ramp entry and exit problems where HOVs must leave the freeway from the left hand lane: causing excessive traffic weaving. Adequate pre-operation publicity and well marked lane direction signs are necessary, as well as good sight distances for motorists approaching a HOV/non-HOV lane switching section of the freeway (i.e. on approaches to freeway access/egress ramps).

No evidence was obtained on the interrelationship, if one exists, between level of enforcement, lane geometrics, operational rules and the accident rate.

Table 3.10. Reported Accident Rates Associated With HOV Lane Projects

Rate = accidents per million vehicle miles (mvm) of travel along highway sections containing HOV lane(s)

Project	Rate before	Rate after
I-95, Miami	4.48	2.67
I-45N, Houston CF lane	2.4	2.1
I-45N, Houston CCF lane	1.1 a.m. 0.9 p.m	1.7 a.m. 0.9 p.m.
I-66, VA	0.6->1.0[a]	0.42

[a]Refers to range of rates on 1982-1983 Virginia interstate system, including I-66 section just west of HOV only section.

4. CHARACTERISTICS OF SUCCESSFUL HOV LANE PROJECTS

4.1 DEFINITION OF A SUCCESSFUL HOV LANE PROJECT

To measure the success of any HOV lane project requires that we understand the goals set for it. As stated in Chapter 1 and paraphrased here, the usual goal or goals are travel time and cost savings, energy savings, reduced pollution, reduced traffic congestion through increased bus ridership and ridesharing and reduced roadway maintenance and construction costs. Measuring success can prove difficult, however; since success must be evaluated on a corridorwide basis, or even on a regionwide basis in the case where, as in Houston, Seattle and the Washington D.C. region, more than one HOV lane corridor exists or is envisioned. That is, removing traffic congestion on a specific highway may cause problems elsewhere in the system. (Of particular interest here are situations where one HOV lane may impact directly the traffic on another such lane using a nearby freeway: as seems to have been the case with the drop in HOVs on Shirley Highway following the 1984 opening of Virginia's I-66 to dedicated HOV use [21]). It is also possible that changes in vehicle speeds both on and off the freeway containing the HOV lane, even where there is an average speed increase taken over all traffic, will lead to greater levels of some pollutants and possibly also in fuel use if these speed changes occur in the appropriate ranges.

With the above provisos in mind, and remembering that we are discussing here HOV mainline lane projects that rely in part, perhaps in large part, for their current success on the synergisms between lane dedication, park and ride lot provision, express bus service and active rideshare promtional programs, Table 4.1 is used to summarize our qualitative conclusions based on the evidence presented in Chapter 3. In this table projects are measured against 5 evaluation measures. Only 12 projects are listed, the first 11 being those for which we obtained sufficient and recent (i.e. post 1980) information and that have been in operation for a number of years. Of these 12, the I-5 project in Seattle is a marginal case in the sense that the most recent available data on the operation of its HOV lanes was based on only the first two months of operation. However, it is included because the other components of the I-5 'FLOW' project (ramp metering with HOV bypass in particular) provided evidence from 2 years of practice. The currently discontinued Banfield HOV lane in Portland is included despite its last available evidence being from 1977, because of the relatively comprehensive nature of that study [33] (second only to the excellent and subsequent job done on Houston's I-45N evaluation [1]).

Person Throughput is based on the evidence reported in Table 3.1, and a project receives a positive rating (indicated by an 'X') if the HOV lane carries more persons during the peak period than each of the adjacent general traffic lanes. All the schemes except the Banfield Freeway have, by the mid-eighties, managed to accomplish this. Lane Useage is based on the 'MCU' statistic presented in Table 3.3 but recognizing the impacts on this statistic of the number of violators using the HOV lane

Table 4.1. Qualitative Assessment of the Effectiveness of HOV Lane Projects

Project	Person throughout	Evaluation measures: Lane usage	Evaluation measures: Travel time saved	Evaluation measures: Growth in RS	Reduced fuel and emissions
Rt-101, Marin Co. (April 1984)[a]	X	X	NA	NA	NA
Rt-237, Santa Clara Co. (Nov. 1984)	X	X	NA	NA	NA
I-10, San Bernardino, L.A. (1984)	X	X	X	X	X
I-95, Miami (1984)	X	-	-	-	NA
I-45N, Houston (May 1982)	X	X	X	X	X
I-5, Seattle (Sept. 1983)	X	-	X	X	X
Shirley Hwy., VA (Sept. 1984)	X	X	X	X	X
I-66, VA (Sept. 1984)	X	X	-	NA	NA
I-93, Boston (1980)	X	X	-	X	NA
US-1/S, Dixie Miami (1984)	X	X	NA	NA	NA
San Tomas, San Jose (1985)	X	X	X	NA	NA
Banfield Fwy., Portland (1977)	-	-	-	X	X

[a]Dates show month/year for which data was made available to this study.

Note: (1) X indicates significant benefit appears to have been derived from the HOV lane project.
(2) - indicates no significant benefit apparent from HOV lane project.
(3) NA indicates information not available or not adequate for judgement to be made.

(see Table 3.2). Hence Miami's I-95 is not considered successful as yet under this measure (indicated by a '-' sign) since its MCU of 1.50 for the a.m. peak period owes a great deal to its 50% violation rate. Nine of the 12 projects are rated successful on this measure.

Travel Time Saved refers in Table 4.1 to the evidence for overall commuter time savings as a result of project implementation. A non-successful rating does not reflect negative time savings but rather insufficient savings per lane mile to warrant lane dedication on this criterion alone. That is, such savings are currently unlikely to encourage noticeable shifts to the HOV modes. For 4 of the projects sufficiently comprehensive data on this issue was not available (NA), at least from our survey. Of the remaining 8 projects 4 are considered successful in this regard. The Boston HOV lane is downrated because of its apparently adverse effects on non-HOV traffic in the adjacent freeway lanes, despite its obvious advantage for HOVs (recall the evidence in Tables 3.4 and 3.5). Virginia's I-66 is also a question mark at the current time, as trip departure time shifts have moved the a.m. peak hour to just after the HOV restrictions are lifted. Seattle's I-5 project receives its positive rating largely on the basis of the time saved by HOVs on the bypass ramps, with little gains at present on the mainline HOV lane (although traffic growth in the corridor over the next few years could change this latter situation).

Growth in HOVs is evaluated largely on the findings reported in Table 3.7, recognizing that only highway and not corridor analyses are the basis for this evidence to date. Six of the 7 projects for which recent data was made available are considered to be successful in this regard, generating significant increases in the use of bus or rideshare modes.

Finally, fuel savings and emissions reductions are successfully attributed to all 5 projects for which data was available (see Tables 3.8 and 3.9) or from which, on the basis of the other data reported in Chapter 3, such benefits could be computed on an approximate basis and the result inferred.

4.2 THE COMMUTING ENVIRONMENT

On the basis of the evidence reported in Chapter 3, an extensive literature review, and the many telephone conversations held during the survey, it is concluded that a successful HOV lane project must have the following characteristics:

(1) A significant and sustained growth in the number of commuters using the corridor containing the HOV lane, and hence a significant level of demand for additional highway capacity. In particular, success in attracting commuters to HOVs is more likely to occur when there is an influx of new residents.

(2) A noticeable deterioration in the average time taken by commuters to travel to work is a major benefit to HOV lane promotion. Average freeway speeds below 30 mph prior to HOV lane addition were reported by the more successful projects (see Table 3.5). This situation guarantees improved traffic flow once a new HOV lane is opened: perhaps offsetting immediate concern among some commuters that the new capacity is barred to them if they continue to drive alone.

(3) The ability of the road system to absorb the large traffic volumes leaving the freeway for their central area destinations is important if the benefits of freeway travel time savings to HOVs are not to be "cancelled out" by subsequent freeway exit queues and stop-go traffic conditions.

(4) A proper corridor traffic management plan is required, not one that focuses on the freeway traffic alone. Support for lane use needs to include an active rideshare promotional program, aimed both at the general public (highway signs, etc.) and focused on the corridors' employers; an adequate level of express bus service associated with careful selection and adequate supply of spaces at remote park and ride lots; ramp metered HOV bypasses and toll exemptions where appropriate.

(5) Well publicized lane access and egress instructions as part of a sufficiently early and prolonged mass media campaign announcing the opening of the lane (perhaps beginning 6 months in advance and building momentum). Added to this should be subsequent announcements of the benefits being gained from successful lane use.

(6) The engineering design of the lane is important for a number of reasons. To be most effective in terms of accident reduction due to reduced traffic interaction HOV lanes are probably better off if completely physically separated from other general traffic lanes throughout their length, by some fixed barrier such as a low concrete wall. Where complete separation is not possible the lane should have a number of relatively closely spaced pullover shoulders next to it: for both breakdown tow-offs and for more effective (including more visible) police surveillance. Good signing leading onto and off HOV lanes is also a necessity for success.

(7) An effective means of enforcing the HOV lane rules on appropriate usage is essential for proper operation of the project and accrual of the benefits of increased HOV use.

4.3 SYNERGISMS WITHIN HOV LANE PROJECTS

4.3.1 HOV Bypass Lanes on Metered Freeway Ramps

Both as an adjunct and as an alternative to mainline HOV lanes some freeways operate short HOV bypass lanes in conjunction with metering on freeway access ramps. In this report we are not concerned with the issue of ramp metering per se except as it affects the policy of giving preference to HOVs seeking access to the freeway. Since Detroit's first experiments with freeway control in 1959 many cities now have freeway ramp metering systems. A relatively small number of these systems make use of HOV bypass ramps. Such bypass lanes are reported to offer HOV users time savings of from 3 to 8 minutes per one way commute [6] [43] over travelers caught in queues formed at the metered access lanes. Very little new evidence was obtained by our survey on the costs and benefits of using such bypass lanes, with which to build upon the pre-1979 information in the 8 reports summarized in [43]. The major exception to this was the data from Seattle's recent I-5 experience, as reported by the Washington State Department of Transportation (WASHDOT) [5][6]. Also received was the January 1985 listing of bypass lanes in California, as compiled annually by the California State Department of Transportation (CALTRANS) [10].

Seattle's I-5 system provides a good example of effective ramp metering. In September 1981 WASHDOT implemented and currently controls 13 southbound metered on-ramps during the a.m. peak period (6 - 9 a.m.) and 5 northbound on-ramps during the p.m. peak period (3.30 - 6.30 p.m.). As with the majority of such schemes the objective of these ramps is to reduce traffic merging problems and hence freeway traffic speed changes, and with this the potential for accidents; by replacing "platoons" of vehicles entering the freeway with one-at-a-time vehicle entry. By using the ramp to "store" vehicles temporarily an effort is made to preserve smooth freeway flow. Metering on the I-5 ramps does not cover all of the peak period but is staggered according to peak congestion characteristics, beginning with earliest metering operation at the upstream entry ramps. Flexible on and off metering times allow the highway engineer to produce near optimal freeway operating conditions given the existing traffic pattern and volumes, while also paying attention to minimizing delays on the metered ramps themselves. After two years of operation the metered ramps along I-5 have been adjusted to impose delays in the range 3 to 8 minutes on non HOV bypass users, with very few violations of the metered signal rules taking place [6].

A 25% decrease in ramp volumes occured during the first year of operation, due it is claimed, to some route shifting by motorists wishing to avoid metered ramps with queues, to some mode switching to bus and rideshare modes, and to some commuters adjusting their departure times to miss peak period congestion [6]. The second full year of operation saw stable metered ramp volumes. At 6 of the a.m. peak period and at just 1 of the p.m. peak period metered ramps WASHDOT operates HOV bypass lanes for bus and +3CP. According to [6] 9% of vehicles (≈34% of riders) using these a.m. ramps are in the HOV bypass lane, while 48% of riders use the p.m. bypass option. These HOV users therefore avoid a 3 to 8 minute delay per one way commute. However about one third of all bypass users are violators of the +3CP rule, while 25% of the HOVs on the ramps have been observed not taking advantage of the bypass lanes.

In addition to freeway and traffic responsive metering, of which Seattle's I-5 system is one variant, both fixed time delays between successive vehicle releases, as well as gap acceptance metering schemes are currently in use. This last practice uses a ramp signal triggered by an upstream freeway surveillance device that identifies a gap in the approaching freeway traffic, thereby allowing a smooth merge.

Geographically, southern California has by far the largest number of metered freeway ramps and also of associated HOV bypass lanes. Of the 714 metered ramps throughout California, CALTRANS operates 224 with bus and carpool bypass lanes. 202 of these bypass lanes currently operate in District 7 based on Los Angeles. CALTRANS uses both fixed time metering based on historically determined rates of freeway traffic flow and traffic responsive meters linked to electronic surveillance devices. These latter are themselves one of two types: either responsive to local freeway traffic only, or linked to other metered ramps' operation via a centrally controlled computer system. A similarly computer controlled form of ramp metering was introduced to Virginia's Shirley Highway and to I-66 in June of 1985 (just as this report was being prepared). The I-66 ramps also meter HOVs accessing the 10 miles of what is a totally (2 lane) HOV highway from 7 to 9 a.m.: with the emphasis on controlling traffic backups prior to 7 a.m. when the HOV-only period begins.

While public acceptance of such metered ramp and bypass systems has been good in both Seattle and Los Angeles as well as on some corridors in Houston, San Francisco and Minneapolis, mixed response to ramp metering has occurred in Chicago and Dallas, with considerable hostility to the idea demonstrated in Atlanta. To succeed it would appear that a ramp metered HOV bypass scheme must as a minimum ensure the following [43]:

(1) Availability of alternative parallel and easily accessed arterials or frontage roads, to allow drivers wishing to avoid long at ramp queues to do so.

(2) Good, safe and trouble-free alternative routes running the length of the corridor for those drivers encouraged to change their routes by excessive ramp queueing.

A careful study of the road system adjacent to the freeway is therefore necessary, to determine how ramp metering will affect off-freeway congestion. Where significant increases in route circuity will result from avoidance of ramp metering delays and at the same time the HOV bypass and/or mainline lane is underutilized, VMT and hence energy consumption in the corridor as a whole may be increased.

4.3.2 Park and Ride Lots

An important ingredient for certain HOV lane project success would appear to be the provision of carefully sited park and ride lots, out of which a more appealing and effective express bus service can operate. These lots should be located at or near the upstream end of the HOV lane, at sites remote from the CBD into which the freeway is directed. Free parking at such lots is offered along with access to reduced fare express bus service. The lots may also be used as a rendezvous point for vanpools. Variants on this approach are operated by the Seattle, Houston, Miami, Californian and Virginian HOV lane corridors discussed above. Such lots may be local or state government owned or privately owned but public agency operated under various types of formal or informal agreement, the latter usually requiring the government agency to provide insurance coverage and maintenance (see [10] for a breakdown of CALTRANS' 270 park and ride lot facilities in January 1985).

In the case of Houston's I-45N contraflow lane project significant increases in bus patronage accompanied the opening of the Kuykendahl and North Shepherd lots, with close parallel growth of bus patronage and lot usage over the first two years of contraflow lane operation [1]. By encouraging bus ridership in this way such lots can do a good deal to ensure that person throughput (as well as visible evidence of lane use) is high on the HOV lane. This may prove particularly important to the continuation of a project in its early phases, when public acceptance is most important and when scrutiny is often at its keenest.

4.3.3 Toll Exemptions and Bypass for HOVs

Four examples of toll booth bypass, two of which have associated toll exemption for HOVs were turned up by our survey. These are the following projects:

(1) A 0.7 mile HOV bypass lane for +3CP at the a.m. peak (westward) direction entrance to the San Francisco - Oakland Bay Bridge Plaza began operation in February 1982. In conjunction with this lane are two 0.6 mile long bus only lanes, giving 3 HOV only lanes out of the 19 lane entries to the toll booths. The exemptions for HOVs apply from 6-9 a.m. and 3-6 p.m. weekdays.

(2) A short, 5 block length of +3CP and bus only lane west from the entry to the Holland Tunnel toll booths has been operated since the summer of 1984 in the leftmost lane, at the entry from New Jersey to New York City.

(3) In addition to its 2.5 mile exclusive bus lane, the Lincoln Tunnel linking New York City to New Jersey has a very short VP only lane situated on a limited access roadway to the south.

(4) Two short contraflow lane segments dedicated to bus,taxi and vanpools avoid pinch points and tolls on New York's Gowanus Expressway (a 6 lane highway).

A significant success in the generation of ridesharing appears to have been achieved by the San Francisco - Oakland Bay Bridge project. From 1970 to 1984 carpools and vanpools, given a toll exemption (and since February 1982 a bypass lane) have grown from 1,100 vehicles per 3 hour a.m. peak to 4,970 daily, an increase of 352%. Over the same period all traffic over the bridge grew by only 11%. In addition to not having to pay the now 75 cent toll, time savings for HOV users are currently as high as 20 to 30 minutes due to no delay at the toll booths. At the same time the phenomenon of "casual carpooling" has been observed in the a.m. period, with many people being picked up at bus stops by car drivers who then avoid the toll and delay. This activity may account, in part, for the decline in bus patronage and hence in bus traffic: from 550 vehicles in 1974 to 360 buses crossing the bridge between 6 to 9 daily in 1985. The difficulty in finding easy pick-up spots on the p.m. return trip also creates an imbalance in the demand for daily transit service.

Seattle's Route 520 HOV lane which also had toll exemption at the Evergreen Point Bridge in its early stages would also appear to have been a success, with increased traffic and public demand leading recently to the hours of its operation being extended from 6.30-9.00 a.m. to a full daily operation from 6.00 a.m. to 6.00 p.m. [50].

5. POTENTIAL FOR FURTHER HOV LANE PROJECTS

5.1 INTRODUCTION

As noted in the introduction to this report in Chapter 1 an aim of our survey was to find out what HOV lane project activity was planned or in the process of construction, as well as currently operational. Because of their length these findings are reported in the Appendix to this report under the title "Rideshare Supporting HOV Lanes Currently Proposed, Planned or In Construction". In Section 5.2 below we summarize the major conclusions to be drawn from this evidence. In Section 5.3 we then summarize the major conclusions to be drawn from our survey, including the evidence reported in Chapters 2 through 4, concerning reasons for HOV lane project rejection or abandonment. In this way we have tried to pull together the existing information relevant to an assessment of the potential for additional <u>and</u> successful HOV lane projects.

5.2 SURVEY OF PLANNED HOV LANE PROJECTS

As indicated by the list of planned HOV lane projects reported in the Appendix, and elaborated upon in many cases in the notes contained there, HOV lanes are either already planned or are being given serious consideration in a number of locations across the country; and most notably in the California counties of Alameda, Contra Costa, Marin and Santa Clara, in Denver (CO), Hartford (CT), Orlando, Fort Lauderdale and Miami (FL), New Orleans (LA), Minneapolis-St. Paul (MN), Newark (NJ), Pittsburgh (PA), Dallas and Houston (TX) and Seattle (WA).

These projects can be divided into two categories, (i) those projects scheduled to be implemented within the next three years (i.e. by 1989), and (ii) those of a more speculative nature, or with a completion date too far in the future to guarantee HOV prioritization will occur once the lane is built. Into this first category fall the 135 miles or so of scheduled HOV lanes shown in Table 5.1. Into the second category fall the longer range plans (10 years or so) for Hartford's I-91 HOV lane (10.2 miles), Dallas' LBJ Freeway HOV lane (20 miles), the regionwide plans by Seattle for some 60 miles of HOV lanes, and Florida's statewide HOV project plans, including an 11 mile extension to I-95. Details on these projects, plus a number of others reported via telephone interviews, are described in turn, by state, in Appendix A. The reader is encouraged to note the comments made on each project's current status - whether planned, being planned, in construction or merely proposed. In all, just under 300 additional miles of HOV lanes were reported to us as being under either construction or active consideration consideration at the time of our survey (April-June 1985).

Table 5.1. HOV Lanes to Begin Operation by 1989

Project[a]	Lane miles	Proposed HOV modes	Lane type	Proposed opening date
Hwy. 12/I-394, St. Paul-Minneapolis	11.0	Bus, CP	Median	1985
Katy Transitway Extension, Houston	6.5	Bus, +4CP	Median (separated)	1985-87
I-45N, Transitway, Houston	17.6	Bus, VP	Median (separated)	1985-87
I-45, Gulf Transitway, Houston	15.5	Bus, VP	Median (separated)	Oct. 1985-Aug. 1986
East Street Expressway, Pittsburgh	5.0	Bus, +3CP	Median	1987
Bridge No.2, New Orleans	2.0(x2)	Bus, +7VP	Median	1987
I-80/I-95, Newark	1.8	Bus, +3CP	Median	1987
I-84, Hartford	11.0	Bus, CP	Median	Dec. 1987
R. L. Thornton Fwy., Dallas	6.5	Bus, VP	Median CF lane	1987
I-95, Virginia Widening and Extension (to Shirley Hwy.)	19.0	Bus, +4CP	Median	July 1986
I-4, Orlando	31.0	Bus, CP	Median	1985-88

[a]Planned as reported April-June 1985: does not guarantee that lane will become HOV by 1989. These are considered by the authors to be the most likely projects to be completed, based upon evidence at time reported.

5.3 REASONS FOR REJECTION OF HOV LANE ALTERNATIVES

5.3.1 Introduction

In looking for the reasons for rejection of HOV lane alternatives two different sources of information readily suggest themselves: (i) comparative analysis of the costs and benefits of HOV lane versus other corridor traffic improvement schemes, as required of comprehensive Transportation System Management planning by state and city planning agencies seeking Federal funding through the Transportation Improvement Program (TIP) submissions process, and (ii) documentation of HOV lane project abandonments. This evidence is looked at below.

5.3.2 Rejection at the Planning Stage

In addition to the published reports referenced in Chapters 1 through 4 of this report, as a result of our survey we acquired a number of engineering feasibility studies, Environmental Impact Statements and Transportation Improvement Program reports containing consideration of HOV lane alternatives to urban freeway corridor traffic management that have either not as yet led to HOV lane selection, or will not lead to HOV lane implementation as a result of their findings (see references [3], [7], [8], [34], [36], [38], [40], [41], [46]). Considered together with past literature in this area and on the basis of our understanding of the Transportation Improvement Program (TIP) selection process as administered by the U.S. Department of Transportation, the following reasons appear to be the main ones for rejecting HOV lane projects along a specific freeway:

(1) Not enough current or projected traffic on the freeway or in the corridor as a whole to warrant lane prioritization. That is, if new highway capacity is going to be necessary, the feeling is that such capacity should be able to alleviate future congestion by being placed open to all users.

(2) Alternative HOV modes of transport are currently or soon to be supported in the same corridor: such as rail rapid transit.

(3) Bypass lanes for HOVs at metered entry ramps are considered sufficient incentive alone to encourage ridesharing growth, and to be much less costly to construct.

(4) Because of highway geometrics or other physical characteristics of the highway, HOV lane operation may be unadvisable. The following four situations are particularly relevant:

   (a) It may not be advisable to try to convert either an existing shoulder lane because the existing shoulder is too narrow and there is no room for expansion, or because there are too many bridge stantions taking away part of the shoulder at frequent intervals.

(b) Where reverse commuting is quite heavy, a contraflow lane may be considered a safety hazard.

(c) Where the lane is concurrent flow and non-physically separated, the absence of roadspace for frequent pull-over spots makes both enforcement and accident/breakdown clearance too difficult and costly.

(d) Where median lane use by HOVs leads to excessive traffic weaving problems as HOVs try to access and to leave the prioritized lanes by crossing through general traffic. In such instances neither physically separated access/egress or sufficiently long stretches of highway are deemed available to allow HOVs to clear the general traffic lanes.

(5) A belief, based on planning studies, that ridesharing volumes would not be raised to the point where lane dedication to HOVs would be justified on the basis of lane usage.

5.3.3 HOV Lane Project Abandonments

The two major project abandonments from the seventies, resulting in closure of the short-lived diamond lanes on the Santa Monica Freeway in Los Angeles and on Boston's Southeast Expressway, were both brought about by strong adverse public reaction to the removal of previously available highway capacity. Of the three HOV lane projects abandoned in the eighties, closure has occurred even though the HOV lane was implemented as an addition of new roadway capacity.

The US-1/South Dixie Highway project in Miami seems to have been dropped because of its potential to limit ridership on the newly opened rail rapid transit line serving the same urban corridor. The Dulles Access HOV lane was abandoned after one year of operation when commuter demand for more roadspace led to the opening of the 4 lane Dulles toll road. The Garden State Parkway lane was dropped in 1982 after 2 years of operation because of public reaction to initially low levels of lane use, fuelled by adverse media coverage.

It is worth noting however that in the case of South Dixie Highway in Miami the lane was apparently moving twice the number of commuters than the adjacent lanes during the a.m. peak hour (see Table 3.1), while the 10 mile section of Garden State Parkway on which the HOV lane was abandoned has once again reached overcongestion, in just four years (as it was predicted to do by the New Jersey Department of Transportation).

5.4 CONCLUSIONS: POTENTIAL FOR FUTURE HOV LANE PROJECTS

The evidence reported above leads us to conclude that the number of new HOV lanes introduced during the rest of this century will be quite limited, because:

(1) To ensure success future HOV lane projects will need to be limited to already heavily congested freeways serving as radial access to the major employment centers in our largest cities. Prioritizing newly constructed lanes on highways with insufficient congestion already present will lead to adverse public reaction to HOV lane introduction, even though new capacity is being added that will benefit all commuters using the corridor.

(2) The lack of available adjacent land will prevent the development of many otherwise possible HOV lane projects within our older, more densely organized cities. This results from the need for an effective HOV generating lane to be either (a) a relatively long lane, of at least 10 miles in length, or (b) a shorter lane operating as a bypass for a serious traffic bottleneck. Our older cities may lack the available right-of-way adjacent to the current highway, for the distances and specific sections of real estate required. HOV metered ramp bypass lanes may be an alternative solution here.

(3) The best chance for a successful HOV generating lane project is likely to be in already large and rapidly growing cities such as the "sun-belt" cities of southern California, Texas and Florida: where an influx of new, young residents offers a pool of potential riders with no pre-defined travel habits to overcome. These states are already among the leaders in HOV lane operation, and this raises the question of just how many additional highways are likely to generate enough demand to warrant HOV lane implementation in the near future. The Texas cities of Houston and Dallas are the most likely sites based on current evidence, while significant population growth will probably have to occur before other Florida cities follow Miami and Orlando's HOV lane experiments. In southern California San Diego's current average commute trip length is relatively short for such a modern city; a condition not conducive to HOV lane use.

(4) The positive attitude towards ridesharing demonstrated by the Connecticut State Department of Transportation, and the successes from that program [see 42], suggests that demonstrated success in HOV marketing may rub off onto the planning of HOV facilities.

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APPENDIX

RIDESHARE SUPPORTING HOV LANES CURRENTLY PROPOSED, BEING PLANNED OR IN CONSTRUCTION

Note: The following information is as received in April-May 1985, mainly via telephone interviews with some follow-up written documentation. Project status may change, and it cannot be assumed that HOV Lanes will result from any of those projects currently in the planned or proposed stages, or that if subsequently implemented will turn out to be successful. Projects listed are those which the authors were informed were under study or construction at the time of interview. The information may be seen as an overview of the current level of committment to HOV lane planning nationwide.

Project	Mileage (Approximate)	Status
California		
Rt-101, Marin Co.	3 (x2)	Under construction 2 median HOV lanes to serve San Rafael. Local support for project. +3CP proposed.
Rt-92, Alameda Co.	1	Approach to San Mateo/Hayward Bridge toll plaza. a.m. only. Right HOV lane proposed (construction 2-3 years away from start, if adopted). +3CP proposed.
Rt-17, Clara Co.	3	CP a.m. peak Santa median lane proposed in conjunction with downstream ramp metering project: as alternative to road widening. If

		adopted lane construction 4 years off. To serve cities of Los Gatos/ Campbell.
Rt-280, Santa Clara Co.	9(x2)	2 median lanes, one in each direction, proposed: making a currently 6 lane highway into 8 lanes. Construction start proposed for 1987. CP being suggested to FHWA. Estimated cost $30 million.
Rt-80/580, Alameda Co.	1 + 3	HOV lanes proposed on western approach to the Bay Bridge. 1 mile in a.m. on Rt-580 and 3 miles in p.m. on Rt-80. +3CP proposed but VP/Bus only a possibility.
Rt-24, Contra Costa Co.	4	Westbound approach to Caldecott Tunnel. Alternating HOV and mixed traffic sections of new right lane. Proposed only. May not get local support. +3CP.
Rt-80, Contra Costa Co.	6	+3CP median lane with buffer lane being considered for a.m. peak operation only. Project not scheduled as yet.

Lawrence Expressway		Shoulder lane HOV proposed for peak hours on limited access arterial. Currently in plan preparation stage.

Comments: CALTRANS (California State Department of Transportation) has the major responsibility for HOV lane planning on freeways. The policy is not to introduce HOV lane projects into areas unless local support for such projects is present. Only the Rt-101 Marin County project, the first one described in the above list, is currently beyond the proposal stage. The City of Santa Clara Transport Agency is responsible for preparing the plans for the Lawrence Expressway, as part of its County run HOV lane program.

Colorado

Santa Fe Drive/ US 85, Denver	5 to 6	A 4 lane arterial currently being widened to 6 lanes, with a proposal to have 1 HOV median lane in either direction. Projected opening summer/ fall 1986.
North I-25, Denver	11	Under study since 1981 by Regional transportation District and state DOT. Radial from CBD to north fringe of Denver. Currently in alternatives analysis and environmental impacts stage.

Connecticut

I-91, Hartford	10.2	Ready for construction bids, but court injunction threatened by town on route. Estimated 6-10 years away from operation. HOV lane intended.

I-84, Hartford	11.0	Currently in construction, with intended diamond lane. Estimated completion 12/87.

Comments: Positive attitude to ridesharing among state planners, but HOV lane potential may be limited outside Hartford region.

Florida

I-4/I-275, Tampa	10.0(part of 33 mile corridor	Planning study in progress. No completion date given.
I-10/I-95, Jacksonville	6.0	Planning study completed. No further progress reported.
I-95, Fort Lauderdale	27.0	Planning study completed and design study begun. Estimated study completion date 1990.
Dade/Metrorail Interconnection Miami	0.25	Planning study completed and design study in progress. Bus and carpool lane to rail rapid transit station. Estimated completion date 1990.
I-95 Extension and improvements	40.0	CCF HOV lanes. Planned to be operational about 1992. N. Dade Co. to Palm Beach Co.
I-4 Reconstruction Orlando	31.0	Reconstruction scheduled to be fully completed in 1988, but with HOV lane operation scheduled to resume

		1985-88. Delay caused by issue of lane safety (as a result of 3 accidents). Median lane with left lane entry/ exit ramps. Bus and CP. Express buses currently use lane.

Comments: All of the above with the exception of the last are planning projects only at this stage, with park and ride and express bus services proposed along with HOV lane prioritization. In addition, Florida DOT, Division of Public Transportation Operations, have identified an 11 mile corridor comprising the San Jose/Hendricks Boulevard sections of Jacksonville as a potential HOV lane corridor: along with 11 other locations across the state with HOV corridor planning or potential in terms of park and ride and express bus service (in Pensacola, Tallahassee, Orlando, Tampa, Miami and Ft. Lauderdale). None of the above projects are guaranteed to be implemented.

Louisiana

Bridge No.2, New Orleans	2.0(x2)	In construction, 2 new median lanes, one each way, added to existing four lanes. These new lanes are to be physically separated from other lanes, and for the use of +7CP, with exclusive on and off ramps accessing an 1/2 mile bridge linking the east and west banks of the Mississippi river.

Maryland

I-97, Baltimore	10.0	Bus and +3CP Lane under consideration.

Minnesota

Hwy.12/I-394, St. Paul-Minneapolis	11.0	HOV lane to be brought into operation during 5 year construction period, +2CP. Also bypass ramps. To begin 1985.
I-35, St.Paul-Minnesota	5.0	HOV lane to be designed. Physically separate lane. May allow CP/VP.

New Jersey

I80/I95, Newark	1.8	Upgrading of bus only lane to carry +3CP. Recently advertised for construction contract.

Comments: Agencies involved in HOV Lane planning are the Port Authority of New York/New Jersey and the New Jersey DOT. Port Authority is considering a $0.50 toll discount to +3CPs crossing George Washington Bridge. Estimated completion in 1986. Lack of physical capacity in existing roads is likely to restrict future HOV lane developments. N.J. DOT is developing an HOV screening process to aid their future planning efforts.

Pennsylvania

East Street Expressway, Pittsburgh	5.0	In construction, planned opening 1987 for +3CP.

Texas

R. L. Thornton Freeway, Dallas	6-7	Engineering work begun, east of downtown Dallas. Contraflow lane for buses and authorized (i.e. after driver training) 12-15 person vanpools is proposed.

LBJ Freeway Loop, Dallas	20.0	Longer range plan (over next six or so years) is currently giving consideration to (a) a 20 foot median HOV lane, or (b) adding a HOV lane that would be elevated for about 1/3 of its length, if there is insufficient room in existing median (bridge pillar problems). Little or no peripheral room now exists for extra lane. Loop road will give access to office complexes in North Dallas. Buses and VP only.

<u>Comments</u>: Safety questions may lead to exclusion of carpools from HOV lane. Physically separated lanes are preferred for CP use. 7 suburban and 2 downtown park and ride lots are currently served by express bus service. Rideshare promotional activities will shift to DART (Dallas Area Rapid Transit) within next two years.

I-10, Katy Fwy. Houston	6.5	The first 5 miles of a planned 11.5 mile median, barrier separated HOV lane have been operational since Nov. 1984. Rest under construction at present. Park and ride lots existing and more proposed, as part of corridor improvement program. +4CP experiment begun April 1985. Reversible for peak flow. Lane is 19.5 feet wide.

I-45N, Houston	17.6	Barrier separated 19.75 feet wide median HOV lane, to replace contraflow-cum-concurrent flow temporary HOV lane in use since 1979. Reversible for peak flow. Operations to begin in stages from 1985-1987. Buses and VP.
I-45 Gulf Fwy, Houston	15.5	Barrier separated 19.5 feet wide median, reversible flow HOV lane. Buses and VP. Scheduled to begin in phases, in Oct. 1985 - Aug. 1986.

Comments: The Houston system of Transitways or AVL's (Authorized Vehicle Lanes) are wide enough to accommodate a breakdown shoulder over much of their length. The rapid growth in office development and associated residential development in the region has encouraged the approach. A truly regional system of HOVs is possible here.

Virginia

I-95 Expansion	19	Widening and extension of I-95 (i.e. Shirley Hwy.) including HOV lanes from Springfield south to Quantico Creek is being considered for 1989-90 implementation. As an interim solution to traffic congestion a short term plan has been proposed that would strengthen the current shoulders of I-95 for mixed traffic use, with

		a +4HOV lane in the median between Woodbridge and Springfield. Construction is to begin August 1985, completion in July 1986.
Washington		
I-5N, Seattle	3.5	Extensions of the current I-5 HOV lane are planned (a) to the north into Snohomish county (by 1990) and to the south from Boeing Access Road to Mercer St. in downtown Seattle, and on south of the center for 15 or so miles. Additional ramp metering also to be added in near future.
SR-90, Seattle	1.5(x2)	Monitoring of traffic via one closed circuit television camera on the East Channel Bridge, to assess need for planned 1988 to 1992 opening of HOV lane for Buses and +3CP. East-West Fwy. feeds directly into Seattle CBD. Ramp metered bypasses would be used.
SR-405, Seattle	12.4	HOV lane planned for Buses and +3CP for phased opening 1985 to 1991.

SR-522, Seattle	3.3	Southbound (a.m.) traffic only. Planned opening in 1988.

Comments: The Washington State Department of Transportation has a truly regional HOV lane plan for the Seattle area, with some 60 miles of HOV lane treatment planned.

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