HIGH-OCCUPANCY VEHICLE FACILITIES: GENERAL CHARACTERISTICS AND FUEL SAVINGS POTENTIAL

Monica C. Burke

American Council for an Energy-Efficient Economy
1001 Connecticut Avenue NW, Suite #801
Washington, DC 20036

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INTRODUCTION

When analyzing the advantages and drawbacks of implementing high-occupancy vehicle (HOV) priority facilities, few commentators seriously address the fuel savings which may result from the creation of HOV lanes and related programs such as ridesharing. After years of low oil prices, emphasis has shifted to the need to deal with choking traffic congestion. Yet these programs save fuel, primarily by reducing vehicle miles of travel (VMT). Unfortunately, despite their utility in addressing transportation problems in a given corridor, the evidence suggests that widespread application of HOV priority treatments would produce a measurable but small reduction in national VMT and fuel consumption.

The usefulness of HOV facilities in dealing with ever-increasing congestion may insure their use in a number of additional corridors, however. As new freeway construction slows because of fiscal and environmental constraints, traffic engineers and politicians have begun to practice a kind of mobility triage; high-occupancy vehicles (HOVs) are given preferential treatment in order to minimize congestion for at least those who share the ride. Steve Keefe, Chair of the Metropolitan Council of Twin Cities, reviewing his area's experience with HOV facilities, notes, "Access means different things to different people ... What we are finding is that we cannot guarantee perfect access for single-occupant automobiles. We cannot build eight- and ten-lane freeways, which are counterproductive to the other things we are trying to accomplish."[1]

Because HOV facilities are justified primarily as a traffic management measure, there is a dearth of studies on the fuel savings which may result from them. If an HOV project is cost-justified on the sole basis of time savings, what fuel savings do occur could be considered to have little if any marginal cost. On the other hand, rideshare initiatives often justify their implementation on the basis of fuel savings alone, reducing fuel use at a cost ranging from 20 to 50 cents per gallon (for large-scale projects).

This paper focuses primarily on four areas and the HOV facilities and rideshare programs found there: Los Angeles/Orange County, specifically Routes 10 (also known as the San Bernadino freeway), 91 and 55; Seattle, Washington, mainly I-5; Houston, Texas, notably the Katy, North, Northwest and Gulf transitways; and the Shirley Highway and Route I-66 of Washington D.C.'s Virginia suburbs. In order to place the discussion of fuel savings in context, a brief account of conditions which favor the implementation of HOV facilities and a review of some commonly held beliefs about HOV lanes and rideshare programs is provided. Following the discussion of fuel savings, the policy implications of these findings are discussed.

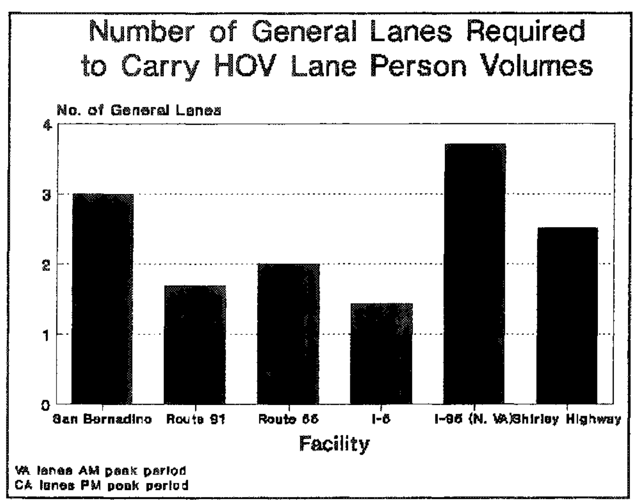
GENERAL HOV LANE CHARACTERISTICS

Severe and increasing congestion is the most commonly cited reason for implementing an HOV facility.[2] Indeed, large amounts of time and fuel are wasted by traffic problems. Lindley (1986) estimates that in 1984 time lost due to recurring delay -- excluding delay caused by incidents -- equalled 485 million vehicle hours, and excess fuel consumption was about 531.6 million gallons. Including the delay caused by incidents, which are more frequent on congested roadways, the time lost was 1251.8 million vehicle hours and fuel wasted about 1377.5 million gallons.[3] The costs of such delay and waste are significant. Using a time value of \$5.00 per hour and a fuel cost of \$1.15 per gallon, the cost for the incident inclusive total was more than \$7.8 billion.

All indications are that the problem will get worse before, if ever, getting better. Several factors complicate the search for solutions, not the least of which is a lack of money. Along with other infrastructure funding, that for highways has diminished precipitously in past years. The American Public Transit Association notes that "doubling federal transportation investment to \$40-45 billion annually would restore U.S. DOT spending, as a percent of Gross National Product, to levels that existed in the mid-1960s."[4]

Such an increase will probably not take place, but even if it did, new highway construction would be unlikely to reach the levels of the 1960s. The interstate system, construction of which was at full throttle 20 years ago, is nearly complete, and the advisability of building new highways is questioned by the public generally and more stridently when the construction is proposed nearby. Neighborhoods impacted by proposed new highways are increasingly vocal in opposing them, resulting in changes in plans for new facilities and even cancellation of some projects.

HOV lanes seem to be a reasonable response to traffic problems in the face of the challenges of low funding and public opposition to new construction. In building an HOV facility, emphasis is placed on increasing the person capacity of the roadway rather than the vehicle capacity. A well-designed HOV lane with adequate support services, including active ridesharing programs, can carry the same number of people as 1.5 to 4 general purpose lanes (Graph 1).



Graph 1

A variety of other measures can be used to measure HOV facility effectiveness. One is the percentage of persons carried in the HOV lane in relation to the percentage of vehicles in the lane. On Interstate 5 in Seattle, for example, a well-utilized HOV lane carries 26% of the people in only 5% of the vehicles.[5] Similar statistics for the Shirley Highway show that 21% of the vehicles carry 56% of the passengers.[6] One of the measures of effectiveness to which Christiansen refers is an increase in the overall vehicle occupancy of the facility (combined figure including HOV and general use lanes) of at least 10 but hopefully more than 15%.[7] As shown in Table 1, such increases have occurred across many areas studied. The implications which increased occupancy has for reduced VMT and fuel use will be addressed below.

Table 1
PRE- AND POST-PROJECT OCCUPANCY RATES

Facility	Pre-proj. occupancy	Post-proj. occupancy	Percent change
San Bernadino	1.26 (unknown)	1.69 (PM per)	34
Rte. 55	1.22 (PM)	1.34 (PM per)	10
Katy	1.26 (AM hr)	1.55 (AM hr)	23
North	1.28 (AM hr)	1.60 (AM hr)	25
Northwest	1.14 (AM hr)	1.26 (AM hr)	10

Note: Time of day and length of measurement are in parentheses (all peak).

Sources: San Bernadino pre-proj. data, Wagner; Rte. 55 pre-proj. data, Klusza; LA post-proj. data, CalTrans; Houston data, Christiansen

SUPPORT PROGRAMS

If merely painting a diamond symbol on a stretch of freeway guaranteed a measurable increase in the person-carrying capacity of the facility, HOV lanes would be the rule and not the exception on roads across the country. However, constructing the lane itself is often the easiest part of the process of increasing the effectiveness of the facility. To reap the benefits described above, a range of services must be provided.

Ridesharing. The first component is a rideshare program.

While the time savings users experience encourage utilization of the HOV lane and the formation of carpools, an active rideshare service can help match potential car- or vanpoolers to each other.

One way for rideshare programs to increase their effectiveness is to work closely with employers. Many programs offer services such as providing matchlists and personal follow-up to major employers within their jurisdiction. A 1987 overview of numerous rideshare programs noted that "rideshare organizations may be filling a gap that more traditional transportation providers have been unable to fill -- that of a mediator and negotiator between public and private sectors."[8]

Several reasons for a new emphasis on employer-based programs are evident. One is the changing nature of commute patterns. Whereas most transit and highway programs were developed to serve the commuter travelling from a suburb to a central business district (CBD), commutes are increasingly taking place between suburbs. As early as 1982, "27 million workers commuted between suburbs in contrast to half that number who commuted from the suburban rings to the central cities."[9] When journey to work trips are thus diffused, focusing on the employer may be the only way to reach numerous people with the same destination.

Orange County, California, is a case in point. Lacking a single CBD, the county instead hosts ten "activity centers" which together represented 116,539 workers in 1980.[10] The local rideshare program, Commuter Network, has focused much attention on the employers in these activity centers, and with positive results. Michelle Kirkoff of the Orange County Transit District, the parent organization of Commuter Network, notes that as of late June OCTD had matched only 77 people through call- or write-in requests to rideshare, but had placed about 6,000 people in rideshare arrangements in conjunction with employers. Table 2 suggests one reason for the difference in success rates. When working with a "group survey," which would include employers, significantly more names per matchlist are produced, thus increasing the likelihood of a successful match.

Orange County also emphasizes employer-oriented programs because employers of 200 or more people in the region are

Table 2
NAMES PER MATCHLIST

Quarter Ending	GROUP SURVEY Average Names/Matchlist	INDIVIDUAL REQUEST Average Names/Matchlist
3/31/84	8.15	6.60
6/30/84	8.03	6.85
9/30/84	8.50	5.57
12/31/84	9.21	7.75
3/31/85	8.60	6.60
6/30/85	7.60	6.90
9/30/85	12.30	13.40
12/31/85	10.60	11.70
3/31/86	11.90	8.80
6/30/86	17.10	7.40
9/30/86	13.10	8.10
12/31/86	13.70	11.70

Source: Orange County Transit District

currently required by the South Coast Air Quality Management

District (SCAQMD) to submit a trip reduction plan under Regulation 15, part of the Air Quality Management Plan. Similar ordinances are in force from Maryland to Washington State, usually affecting developers rather than established employers. The city of Bellevue, Washington, for example, has adopted various measures to combat single-occupancy vehicle (SOV) use including zoning laws which allow developers to provide less parking per square foot of office space when trip reduction measures are taken and requiring a transportation coordinator to encourage non-SOV modes at new developments, among others. Such programs can produce results; 36% of office employees in Bellevue now use non-SOV modes[11] compared to 27% in neighboring King County.[12] Other innovative measures are being developed by rideshare coordinators which address common concerns of commuters. One example is the guaranteed ride home program, developed in Seattle and in use or under consideration in other cities. Operated and paid for by the city of Bellevue and Seattle Metro, the program allots 60 miles per year of taxi service for $1.00 to commuters along the I-90 corridor, eliminating the common fear of being trapped at work in case of emergency at home.[13] Other issues, such as what services people require at their place of employment if they are to give up their cars, are also under discussion in Orange County and elsewhere.

Fuel Savings Potential. Many area-wide rideshare programs are cost-justified on the basis of fuel savings alone, despite their slight effect on areawide VMT.

Three rideshare programs in two areas of this study collect and evaluate data on a regular basis. These programs are located in Los Angeles and Orange counties and the Washington, D.C., area. Table 3 presents the budgets and fuel savings

Table 3
COST OF FUEL SAVED BY RIDESHARING PROGRAMS

Program	Period	Budget (millions)	Fuel Saved (gallons)	Cost/ Gallon
Commuter Network (OC)	1986	$1.75	3,825,036	$0.45
Commuter Computer (LA)	88-89	$6.18	31,130,900	$0.20
Ride Finders (DC/VA/MD)	1987	$0.69	1,676,250	$0.41

Sources: OC data, OCTD; LA data, Commuter Computer; DC data, MWCOG

characteristic of each project. Note that the programs do not consider fuel to have been saved unless the person placed in a ridesharing arrangement previously drove alone or did not make the trip. Therefore, the 40 to 50% reduction applied when considering HOV lane VMT reduction/fuel savings does not apply.

Perhaps the most striking information in Table 10 is that the program with the highest budget saved fuel at the cheapest rate. To further explore this phenomenon, data for two years of rising operating budgets for Commuter Network in Orange County were analyzed. In 1985, the operating cost of the program was $610,571, rising to $922,671 for 1986. So much more fuel was saved in 1986, however, that the cost per gallon saved went from $0.58/gallon to $0.24/gallon.[14] (The $0.45 figure in Table 10 includes money received from the Orange County Transit District for expenses beyond salaries and benefits.)

These economical fuel savings result despite the fact that the areawide VMT reduction from such programs is very limited. In the case of the Ride Finders Network, which serves Washington DC, Northern Virginia and parts of Maryland, 1987 VMT savings equalled 30,009,250, a 0.14% gross reduction of the nearly 22 billion VMT regionwide.[15]

One rideshare strategy that was closely evaluated in the Bellevue, Washington area is the use of transportation system management (TSM) strategies, including the work of transportation coordinators (TCs) at the workplace, preferential parking for ridesharers and other tactics. As noted above, such measures are being mandated with increasing regularity by municipalities concerned about congestion levels. Data from the 1988 TC projects show, however, that from a fuel savings perspective these programs are very expensive, saving gasoline at a cost of between $3.20 and $5.07 per gallon. Including the value of time savings, on the other hand, Seattle Metro estimated a benefit/cost ratio of 1.44 to 2.29, and adding estimated savings due to reduced highway construction pushed the ratio to 5.91 to 9.37.[16]

It is clear from our data that rideshare programs, especially those that extend over a fairly large area and offer a variety of services, are cost-effective ways to save fuel. Since small programs seem to provide too little fuel savings to justify even their modest costs, from an energy-saving standpoint larger, well-funded programs should be pursued instead.

Other support efforts. Apart from ridesharing, another key contribution to the success of an HOV lane is adequate attention to public relations. Several projects have died very public deaths that have adversely impacted later attempts to implement HOV facilities. The most publicized such failure was that of the Santa Monica diamond lane in Los Angeles in the mid-1970s, which contributed to a 9 year lapse of HOV lane construction in the LA basin. The foremost problem with the Santa Monica project was that it converted a general lane into an HOV lane, restricting use to carpools of 3 or more people. Only 3% of the traffic stream qualified to use the lane; the capacity of the facility was reduced, public outcry ensued and a citizens' committee eventually filed suit to end the project. By that time, HOV lane person movement had surpassed that of adjoining general lanes, but the program was discontinued by a federal judge.[17]

The Santa Monica experience led to a general consensus that lanes should never be taken away in order to create an HOV lane. Beyond the intense public criticism they inspire, HOV lanes that are created by taking a lane have also been found to save much less fuel than those established through new construction.[18]

However, HOV lanes are not safe from controversy even if they do result from adding lanes. For example, in 1985 plans to designate a lane under construction northwest of Los Angeles as limited to HOVs were thwarted by pressure from motorists who accused the California Dept. of Transportation of attempting "social engineering."[19] Studies have shown that even when HOV lanes are well-utilized from a technical perspective, public perception may still be that the lane is underutilized. In Houston, the Katy Transitway recently raised its occupancy requirement from vehicles with 2 or more occupants (HOV-2) to HOV-3 because the volumes on the lane were threatening to congest it. Still, just before the requirement change, only 44% of non-HOV drivers responded positively when asked "Is the transitway sufficiently utilized?"[20] The public obviously errs on the side of disapproval when appraising HOV lane utilization, a reaction which underscores the need for aggressive public and media relations work in HOV promotion.

Lax enforcement also contributes to public frustration and undermines the effectiveness of the lanes. One method to both combat violation rates and vent frustration was, again, devised in Seattle and is currently in use in Seattle and Virginia. The "Hero" program provides a posted telephone number which citizens use to give information on violations they have witnessed. Thus far the program in both areas has avoided a "big brother" reputation and has contributed to a noticeable reduction in violation rates. In May, 1988, prior to implementing the Hero program, the violation rate on the Shirley Highway during the a.m. peak period was 16%; in May 1989, 5 months after the program began, violations have declined to 14%.[21] On I-5 in Seattle the change has been more marked. The average mainline violation rate pre-Hero was 28.3%, a figure which dropped to 19.1% after implementation.[22]

Benefits of HOV Facilities

Assuming that adequate support services exist, HOV lanes can deliver significant benefits. Mentioned above are the increases in vehicle occupancy which ultimately result from greater ridesharing. One way to be certain that it is indeed the HOV lane which is causing the increase in vehicle occupancy is to compare the facility with an HOV lane to a comparable roadway without one, as Christiansen did in his study of Houston's transitways. He found that while vehicle occupancies on affected freeways had increased by 10 to 25%, occupancy on a control freeway, the Southwest, had declined 9%.[23] One might also compare occupancy rates in general and HOV lanes to look for the factor driving up overall occupancy on the facility. Table 4

Table 4
GENERAL VS. HOV LANE OCCUPANCIES

Facility	Date	HOV Lane Occupancy	Genl Lane Occupancy	Percentage Difference
San Bernadino	10/88	4.87	1.21	301%
Rte. 91	10/88	2.18	1.08	101%
Rte. 55	11/88	2.12	1.08	97%
I-5	unknown	7.02	1.20	485%
Katy	12/88	4.14	1.55	167%
North	12/88	24.7	1.60	1543%
Northwest	12/88	2.73	1.26	117%
I-95	4/89	3.77	1.16	225%
Shirley Hwy	5/89	5.85	1.20	387%

Sources: LA data, CalTrans; I-5 data, WSDOT; Houston data, Christiansen; VA data, VDOT.

presents these occupancies for all four areas of study. Given the greater occupancy measurements of the HOV lanes, it is clear that these lanes contribute significantly to overall occupancy increases.

Both of these methods of comparison are somewhat flawed in that HOV lanes attract carpools from other lanes or freeways and thus cause their occupancy ratings to drop. On Route 55 in Orange County, for example, institution of an HOV lane led to a drop in mixed-use lane occupancy of about .12 persons/vehicle.[24]

If the occupancy of HOV lanes rises, however, one might assume that new carpools are being encouraged by the lanes' existence. The data here are mixed. Looking first at the Los Angeles area project data (Table 5), it appears that minor fluctuations have occurred in the last few years with respect to overall occupancy and that the dominant trend in HOV lane

Table 5
OCCUPANCY TRENDS FOR LA/ORANGE COUNTY FREEWAYS WITH HOV LANES

FACILITY	10/86	10/87	10/88
Overall Freeway Occupancy			
Rte. 10	1.63	1.64	1.69
Rte. 91	1.28	1.27	1.28
Rte. 55	1.34	1.32	1.34
HOV Lane Occupancy			
Rte. 10	5.39	5.65	4.87
Rte. 91	2.42	2.21	2.18
Rte. 55	2.20	2.15	2.12
General Lane Occupancy			
Rte. 10	1.20	1.22	1.21
Rte. 91	1.08	1.11	1.08
Rte. 55	1.09	1.08	1.08

Source: "HOV Lane Comparisons," CalTrans, 1986, 1987 and 1988

Table 6
EVOLUTION OF SAN BERNADINO FREEWAY OCCUPANCY

Date	Occupancy	AM/PM peak Hour/Period
pre-project	1.27	unknown
pre-1980	1.49	unknown
Oct. 1986	1.63	PM per
Oct. 1987	1.64	PM per
Oct. 1988	1.69	PM per

Note: San Bernadino HOV lane implemented 1973.

Sources: pre-1980 data, Wagner; 1986-88 data, CalTrans.

occupancy has been downward. However, for at least one project, the San Bernadino freeway, overall occupancy rates have climbed over the years, indicating that over time HOV lanes can become more effective (Table 6).

One project worthy of special mention in this context is the Shirley Highway. One of the oldest and most successful HOV

Table 7
EVOLUTION OF SHIRLEY HIGHWAY OCCUPANCY

Date	Occupancy	AM/PM peak Period/Hour
1973*	2.43	AM per
1979	2.88	AM per
March 1985	2.35	unknown
August 1987	2.19	AM per
May 1988	2.19	AM per
May 1989	2.16	AM per

*Data gathered just prior to opening the lane to carpools.

Sources: 1973-79, Wagner; 1985 data, Southworth; 1987-89 data VDOT

projects, the Shirley Highway Express Lanes move more people during the peak hour than any transportation corridor in the country except for a subway line in lower Manhattan.[25] Nevertheless, vehicle occupancy on the Shirley has steadilydecreased over time, except for the initial post-project increase and a marginal upswing in 1987 (Table 7). The evolution of the occupancy requirements on the facility may account in large part for this development. The requirements have decreased from buses and emergency vehicles only in 1971-73 to HOV-4 in 1973-89 and finally to HOV-3 in January 1989.

Declining occupancy requirements reflect the need to accommodate technically optimum measures with political reality. Despite the evident success of the Shirley Highway, attempts have been made to open the HOV lane to motorcycles and vehicles carrying the elderly, seeing eye dogs and critically ill children.[26] Such variances would be difficult to enforce and would decrease the effectiveness of the lane, but politically their implementation is appealing. Considering the ramifications of negative public opinion, decisions may have to be made based on a "lesser of two evils" criteria, reflecting the need to maintain the image of the lane to keep public criticism from doing away with it altogether. Such factors may partially explain why increasing occupancy is sometimes foregone in the interest of increasing utilization. Whatever the specific justification, a review of data does not necessarily support the contention that HOV lanes will continue to pull up overall vehicle occupancy rates on a facility over time, or even that their own will continue to rise.

Other measures of effectiveness also may be used. Providing congestion-free conditions for HOV lane users at a minimum and general lane users at best is usually a central goal of HOV facility implementation. Time savings for lane users are usually all but guaranteed, but travel times and average speeds for general lane drivers tend to be only marginally better.

Table 8 shows travel time savings of HOV lane users over general lane drivers for select projects. Of particular interest is the measurement of minutes per mile saved. A common criterion used to measure effectiveness of an HOV lane is said to be a time savings of 1 minute per mile; only one project shown attains this level, yet nearly all the projects are considered successful by transit and highway authorities. Perhaps the minute-per-mile criterion should be reevaluated.

Table 8
TRAVEL TIME SAVINGS FOR HOV LANE USERS

Facility	Length of Test (mi.)	HOV time savings (min.)	Min/Mi
I-5	5.6	3.8	0.68
Katy	11.5	13.8	1.20
North	9.1	6.2	0.68
Northwest	9.5	4.3	0.45
Gulf	6.5	5.3	0.82

Sources: I-5 data, "6-Year FLOW Evaluation," WSDOT, p. 16; Houston data, Christiansen p. 16.

Shorter travel times for three projects that added lanes to the facility were measured by Wagner in his 1980 study: I-95 in Miami, the Banfield Freeway in Portland, Oregon, and the Kolanianole Highway in Honolulu. None of these facilities are the focus of this study and one (Banfield) has since been discontinued. The savings found were in any case not remarkable, ranging from 0.2 to 4 minutes.[27]

Changes in highway speeds also reflect the effect of HOV lanes on general traffic flow. Table 9 notes increases in speed in Seattle and Houston, as well as Miami. These increases are

Table 9
HIGHWAY SPEED IMPACTS OF HOV IMPLEMENTATION

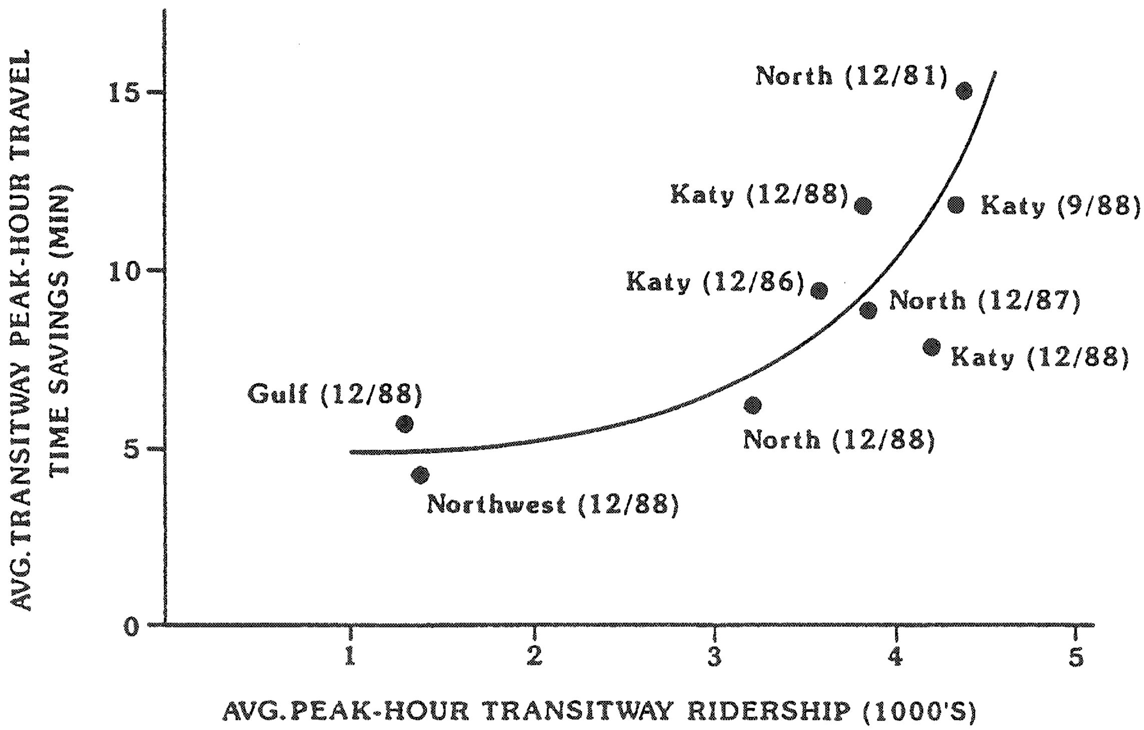
Facility	Pre-project (avg all lanes)	Post-project (avg genl lanes)	AM/PM peak hour/period
I-5	30.0	47.6	AM hr
Katy	22.0	22.0	AM hr
North	22 to 26	29.0	AM hr
North	16 to 17	21.0	PM hr
I-95 (Miami)	31.5	38.1	AM hr

Source: Southworth, p. 3-11.

notable for their effect not only on congestion levels but also fuel use, since in this velocity range increases in speed lead to decreases in fuel consumption.

Increasing highway speed may be a two-edged sword, however. It is well-recognized that time savings are the primary reason people use HOV lanes. Christiansen has plotted travel time savings against lane utilization and found that the greater the time savings, the higher the lane usage (Graph 2). Time savings on an HOV lane may decrease if the HOV lane nears capacity, such as on the Katy freeway prior to the occupancy requirement change. In addition, if general lane speeds increase, the time savings for HOV (transitway) users also become less significant. Because

Graph 2
TIME SAVINGS AND HOV RIDERSHIP



Note: The HOV lanes on the Katy, North, Northwest and Gulf freeways are known as Transitways.

Source: Christiansen

of the relationship between time savings and lane use, HOV lanes are considered "congestion-dependent" -- that is, they can never cure congestion because they rely on it for their appeal.

In presenting the case for an HOV lane to the public, therefore, the lane should not be touted as a "remedy" for congestion. Such a tactic cannot but backfire. A more accurate assertion might be similar to that put forth in Seattle: "Indeed, no matter what we do, congestion will continue to increase. Our hope lies in slowing that increase."[28] While such a message is unlikely to encourage cheers of enthusiasm, it is nonetheless more accurate than more optimistic prognoses.

FUEL SAVINGS

This section estimates the amount of fuel that can be saved in metropolitan areas in the U.S. if HOV lanes were widely implemented on arterial freeways serving CBDs.

Generally, an increase in the vehicle occupancy of a facility indicates a decrease in VMT. Pre-and post-project

Table 10
PRE- AND POST-PROJECT OCCUPANCY RATES

Facility	Pre-proj. veh/pers	Post-proj. veh/pers	Percent change
San Bernadino	.79 (unknown)	.59 (PM per)	25
Rte. 55	.82 (PM)	.75 (PM per)	9
Katy	.79 (AM hr)	.65 (AM hr)	18
North	.78 (AM hr)	.62 (AM hr)	21
Northwest	.88 (AM hr)	.79 (AM hr)	13

Note: Time of day and length of measurement are in parentheses (all peak).

Sources: San Bernadino pre-proj. data, Wagner; Rte. 55 pre-proj. data, Klusza; LA post-proj. data, CalTrans; Houston data, Christiansen

vehicle occupancies (Table 10) are the base for the analysis. In a 1980 paper that closely examined fuel savings possibilities from HOV lanes, Wagner used both reduction in VMT and vehicle hours of travel (VHT) to calculate possible areawide fuel savings. Using new data and a similar methodology, our analysis produced more encouraging results.

Effect on VMT. Wagner found a decrease in vehicles per person of about 1 to 18% on the 6 projects he studied.[29]

Analysis of only 2 of the 4 areas studied here was possible due to a lack of reliable pre-project occupancy data for Seattle and Northern Virginia. The results for the 5 freeways with adequate data reflect a decrease in number of vehicles per person of 9 to 25%.

The percentage reduction in vehicles per person, however, does not translate into an equal percentage reduction in VMT. First, the estimate must be altered because of factors which minimize the VMT reduction itself. In Wagner's analysis, he mentions specific concerns such as:

> -- A portion of the persons shifted to buses make automobile trips to park-ride lots, thereby reducing the apparent gross reduction in vehicle trips and vehicle-miles.
> -- A portion of persons shifted to carpools drive and park at pre-arranged pickup points.
> -- Carpool trips involve some circuitous travel to pick up passengers, making the trip longer than it would be if the driver traveled alone.
> -- Some carpools are attracted to the priority facility because of the travel time advantage from more direct, shorter distance routes to their destinations.[30]

Wagner hypothesizes that such factors reduce savings of VMT by 35 to 45%.

Unfortunately, it is unclear whether Wagner included in his estimate the issue of the tendency of HOV lanes to draw carpools from other streets as well as cause new ones to form. Reduction in VMT should not be accredited to an HOV lane if the decrease in vehicles per person is primarily a result of old carpools using the facility rather than new rideshare arrangements being formed. Data from three Houston transitways (Katy, Northwest and Gulf) show that 44 to 65% of drivers then carpooling previously car- or vanpooled or rode the bus.[31] The VMT reduced through these rideshare arrangements cannot be ascribed to the existence of the HOV lane. It seems likely that Wagner would have indicated had he included the issue of new carpool formation, but adding his and Christiansen's figures would equal more than a 100% reduction to the initial estimate of VMT reduction. Thus, a decision to use an adjustment factor of 40 to 50% to provide low and high estimates was made. Using our data, then, a project-level reduction of VMT of 4.5 to 15% would be expected following these adjustments.

To determine what the area-wide effect of HOV lanes would be, other reductions of this estimate are necessary because only 15 to 20% of work-related travel is oriented toward a CBD, where HOV lanes are most likely to be found. Further, only 30% of area-wide VMT is journey-to-work travel.[32] Therefore:

Area-wide VMT reduction = (4.5%)(.15)(.3) = 0.20% (low)

Area-wide VMT reduction = (15%)(.2)(.3) = 0.90% (high)

Thus, a reduction of 0.20 to 0.90% of total areawide daily VMT would be possible. This estimate compares with Wagner's findings of 0.3 to 0.45%.

<u>Effect on VHT.</u> The second component in estimating fuel saving is the reduction of VHT which results from HOV implementation. Because cars are more efficient at moderately high speeds than they are at a crawl or in stop-and-go conditions, reduction of VHT increases the efficiency of the automobiles. VHT reduction measurement is based on travel time

savings to the general user following the implementation of an HOV lane.

Some commentators have speculated that time savings to general lane users will be marginal and disappear quickly due to latent travel demand in a region. Wagner documented gross VHT reduction of only 2% on three lanes added projects he studied in 1980.[33] In terms of the four areas under consideration here, only 2 freeways -- I-5 in Seattle and Rte. 55 in Orange County -- had reliable enough data to attempt the calculations necessary to determine VHT reduction.

As noted in Table 11, travel time savings noticed by general lane users were much more marked than speculation or Wagner's data would prepare one for. As a percentage of an assumed average 30-minute commute, gross reductions in travel time ranged from 15.2% during the a.m. period to 32.9% during the afternoon. A distinction between a.m. and p.m. travel time savings was noticeable; therefore, they were analyzed separately.

The gross reduction in travel time percentage must be diminished for the same reasons that VMT reductions are altered: 15-20% of all work-related travel is CBD-oriented and 30% of daily trips are work-related. Therefore:

15.2% (.15)(.3) = .68 (low)
32.9% (.2)(.3) = 1.97 (high).

<u>Total Fuel Savings.</u> Using these estimates for reduction in VMT and VHT, total fuel savings can be computed using the equation:

TFS = gals/mi(VMT) + [gals/mi(VMT- VMT)](.4)(VHT/VHT)

Total fuel savings can be found by adding the reduction in fuel use due to VMT reduction to that due to VHT reduction. Our

Table 11
TRAVEL TIME SAVINGS (MINUTES)

	I-5		Rte. 55		Avg AM/	% of 30
	post 1	post 2	post 1	post 2	PM svgs	min. comm.
7:00 am	3.08	2.5	5.5	6.5	4.56	15.2
7:30 am	3.16	4.0	9.5	1.0		
4:30 pm	1.83	2.66	12.8	18.0	9.87	32.9
5:00 pm	1.42	1.25	24.0	17.0		

Sources: Seattle data, Washington State DOT; OC data, Klusza.

assumptions include a reduction of .4% in fuel consumed per mile percent reduction in travel time[34], 18 average mpg, and 27.8 average mph.[35]

Change in VMT and VHT can be found by multiplying the percentage change in these variables by total VMT and VHT figures. In 1989, light vehicle VMT was approximately 1.9 trillion.[36] Divided by the U.S. population, 248 million, this produces a VMT per capita figure of 7585. Approximately 63% of these are urban miles. Using a city mpg figure of 18 mpg, per capita urban gasoline consumption amounts to about 265 gallons annually. The average urban speed of 27.8 mph suggests an urban VHT total of 172 hours per person per year. The range of percentage changes in VMT computed above was .2 to .9%. Therefore, VMT savings range from 9.5 to 43.0 per year. VHT reduction percentages were figured to be .68 to 1.97%, resulting in an annual VHT savings of 1.17 to 3.34.

Introducing these figures into the equation results in, on the low end:

$$TFS = .055(9.5) + .055(4768)(.4)(.0068)$$

$$= .5 + .7 = 1.2 \text{ gallons per person per year}$$

to

$$TFS = .055(43) + .055(4735)(.4)(.0197)$$

$$= 2.4 + 2.0 = 4.4 \text{ gallons per person per year}$$

as a high estimate. These savings would apply to individuals living in areas likely to be served by HOV lanes, that is, cities of 500,000 or more. 140 million people lived in such areas in 1986,[37] making the total national savings estimate between .17 to .62 billion gallons per year, which is from .2 to .6% of U.S. annual gasoline consumption.

This estimate may be considered conservative for some reasons, extravagant for others. On the one hand, some factors suggest the above estimate may be rather conservative. The calculations are constructed to provide an estimate of fuel savings assuming HOV lanes across the country provided results similar to those found on the subject freeways. However, if HOV lanes were present on all freeways in a metropolitan area, the increased occupancy and time savings for users would probably be greater than those upon which these calculations are based. In addition, we assume here that HOV lanes are applicable only to journey-to-work travel related to a CBD. While this has been the case to date, a wider network of HOV lanes might encourage people to share the ride even on non-work trips, and the Orange County experience demonstrates that even when there is no CBD to speak of HOV lanes can be moderately successful.

On the other hand, this estimate is optimistic in assuming that all roads in large metropolitan areas leading to a CBD might be considered for HOV lane construction. This is not the case. The four areas considered in this paper are among the most dedicated to the HOV concept. We cannot expect all communities to adopt similar measures.

Per-project fuel savings. The above analysis estimated how much fuel might be saved in urban areas with aggressive HOV lane promotion. Estimating the per-project fuel savings of individual lanes might also be of interest.

VMT reduction. To estimate the VMT reduction caused by a single project, one might count the people served by the facility and estimate how many vehicles were removed from the road through higher vehicle occupancies. Using Wagner's figures for pre- and immediately post-project occupancies and person volumes on the Shirley Highway, for example, roughly 4000 vehicles were removed by this project. However, as noted above, a reduction of 40 to 50% is necessary since some of this reduction should not be ascribed to the lane making the number of vehicles removed about 2200. Assuming a 15 mile trip (11 miles on the highway and 2 miles at each end), 18 mpg average fuel consumption, 250 working days and equal savings in both directions, a savings of .92 million gallons per year is possible.

VHT reduction. Our data suggest a reduction in VHT of

15 to 30%. Since previous data, including that on which the above analysis was based, indicated a 6% reduction in VHT, we chose to use our low estimate of 15% VHT reduction. Wagner estimates that for each 1% reduction in average time, a 0.4% reduction in fuel consumption occurs; a 6% reduction in fuel consumption is thus assumed. With the same assumptions as those used for VMT reduction estimation and assuming 29,500 affected vehicles,[38] 0.74 million gallons per year would be saved through VHT reduction, for a total annual fuel savings of 1.66 million gallons. At $1.15/gallon, the monetary savings from fuel use reduction is $1.91 million per year.

POLICY IMPLICATIONS

Clearly, if the primary objective is fuel savings, other far more effective strategies than HOV facility implementation are available. For example, raising the average fuel economy of new cars to 45 mpg and that of new light trucks to 35 mpg through a combination of higher fuel economy standards, gas-guzzler taxes, and gas-sipper rebates would save an estimated 17 billion gallons annually by the year 2000.[39] This is obviously a much greater savings than even the high end of our HOV estimate, .62 billion gallons per year.

However, usually the issue is not whether to pursue auto efficiency or HOV lanes, but whether to institute a mixed-use or HOV lane. From a fuel savings perspective, one would clearly prefer an HOV lane to a general lane on the basis of effect on VMT. While HOV lanes have the small but measurable effect of decreasing VMT, we can assume that a new mixed-use lane would at best hold VMT constant or, more likely, encourage increases in VMT. Despite the positive effects of HOV lanes relative to general lanes, slightly less than 1% of target freeways in the U.S. have HOV lanes; out of a 1984 total of 15,335 miles of urban freeways,[40] only about 150 miles carried HOV lanes in 1989.[41]

Our data suggests that a large, well-funded rideshare program can save fuel at an inexpensive rate, especially through close coordination with employers in the area. Smaller programs, such as employer- or developer-based TSM organizations required by some local regulations, tend to be less cost-effective on the basis of fuel savings. If regulations specify a certain area as "reserved" for employer-based efforts only, as some do, these programs may backfire in that the efforts of a larger, more efficient regional operation may be foregone.

Both HOV lanes and rideshare programs could enjoy greater utilization if the issue of free parking were addressed. Currently, most zoning codes encourage SOV use by permitting and even requiring copious on-site parking. Tax laws also encourage SOV use. For example, transit subsidies for employees are considered taxable benefits if they exceed $15 per month, while no tax is imposed on an employer-provided parking space which may be worth far more. One bill before the U.S. House of Representatives (H.R. 2265) would raise the level of tax-free transit subsidies to $60 per month, bringing it more in line with what it actually costs to commute via transit. On the issue of parking more generally, four steps of increasing severity might be taken to encourage HOV use: (1) preferential parking for HOVs, (2) reducing the overall number of parking places available (or required by zoning laws), (3) taxing parking as an employee benefit and (4) charging for parking and allowing ridesharers to park for free. It is unlikely that severe enough penalties can be enacted to shift the primary incentive to use an HOV lane from time to money savings, but as congestion continues to provide time savings for HOV users, adding monetary incentives can only augment ridesharing.

CONCLUSION

HOV lanes and rideshare programs are among the few known ways to decrease VMT along a given corridor. Many efforts to reduce VMT have had limited or adverse effects on the problem. Telecommunications may lead to VMT reduction, but has yet to. Suburbanization of jobs has led to growth in VMT. Slow-growth initiatives drive up the price of housing and force people to live further away from their jobs, lengthening commutes and increasing VMT. In light of all the forces pushing VMT up, we should take notice of anything that pushes it down. HOV facilities are just such programs.

Increasing transportation efficiency and decreasing fuel use will require not only that we make the vehicles travelling on the road more efficient, but that we make the roads themselves more efficient as well by increasing their person-carrying capacity. We have seen that although overall mpg of the U.S. passenger vehicle fleet has increased, gasoline consumption is on the rise because of VMT growth; gasoline use rose 11.5% during 1980-88, despite the fact that new car fuel economy improved 21% during the same time period. This phenomenon illustrates how difficult it is to reduce transportation fuel use through vehicle fuel economy alone; measures to reduce vehicle use should also be pursued.

In order to choose intelligently between these options, we must be sure that the efforts undertaken are serving the purposes for which they were created. This requires adequate data collection and evaluation, which in the case of HOV lanes and ridesharing programs has occurred only in fits and starts for the last decade. Closely examining whether programs are working as they should provides clues of how to do things better, yet such examinations are few, far between and sometimes self-serving.

Changing people's behavior patterns is not easy. It is often simpler to invest a great deal of money to find ways to do what we have always done, only better. It may be, however, that environmental and technical constraints are at such a level that reducing VMT is a necessity in order to face the challenges of congestion, air pollution and global warming. HOV facilities, including rideshare programs, have provided modest but measurable results in this area, and they should therefore be supported and extended despite their less-than-spectacular effect on fuel consumption.

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