Evaluation of Seattle's South I-5 Interim High-Occupancy Vehicle Lanes

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The Washington State Transportation Center is developing a high-occupancy vehicle (HOV) monitoring and evaluation program for highways in the Seattle area. This paper represents a part of the transportation center's work in developing the program by evaluating one particular HOV facility on Interstate 5 in South King County. The study is both an evaluation of this facility's operation and a means of testing various measures that have been established and used in other research endeavors. Each of the following measures provided helpful information for evaluation of the facility: HOV lane volumes, congestion impacts, safety impacts, travel-time savings and reliability, average vehicle occupancy, violation rates, and public perception. The findings of this study give reason to believe that this facility has been relatively ineffective as a short-term application. Geometric improvements should be made in the facility to alleviate congestion and safety impacts caused by the HOV lanes. Following geometric improvements, the facility's occupancy requirement should be reduced from three to two persons per vehicle.

High-occupancy vehicle (HOV) lanes have become an integral part of regional transportation planning throughout the United States. Particularly in a city like Seattle, Washington, where there are no rapid transit and commuter rail lines, HOV lanes can play a valuable role in efforts to manage ever-increasing congestion. With new emphasis on transportation systems management (TSM), officials at the Washington State Department of Transportation (WSDOT) are interested in gaining a better understanding how effective its HOV facilities are. To gain this understanding, WSDOT has commissioned the Washington State Transportation Center (TRAC) to study the state's existing HOV facilities and to develop an HOV monitoring and evaluation program for facilities in the Puget Sound Region.

By evaluating the operation of each HOV facility against standard effectiveness measures, the research team can assess any apparent deficiencies and recommend improvements for more effective facility operation. Also, by using and testing the standard effectiveness measures, the research team can use the findings from each facility to help develop the long-term monitoring and evaluation program. Research findings from one HOV facility, on Interstate 5 in south King County, Washington, are discussed in this paper.

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BACKGROUND

The state of Washington regards priority treatment of HOVs as an effective means of maximizing highway travel capacity. WSDOT officials believe that HOV treatments can support efforts to reduce traffic congestion, dependency on fossil fuels, and automobile pollution. WSDOT takes an active role in promoting and coordinating the development of HOV facilities, transportation demand activities, and related TSM programs. This general policy approach to HOV facilities is intended to provide incentives for people to shift from single-occupant vehicles to ridesharing modes. Such efforts support the state's ultimate goal of protecting the environment while maintaining or improving each person's ability to travel (*1*).

The facility studied in this research is referred to as the South Corridor, and it consists of a pair of lanes on the Interstate 5 freeway in the southern part of King County (see Figures 1 and 2). There is one left lane in each direction, and each lane runs approximately 6.5 km (4 mi), adjacent to the freeway general-purpose lanes. Only vehicles carrying three or more people (3+ occupancy definition) are permitted on the HOV lanes. The South Corridor represents Phase I of the ultimate HOV facility, which will extend from downtown Seattle to south of Tacoma. This facility is part of the regionwide HOV system recommended by Washington's Interagency HOV Task Force.

Although originally planned for opening to traffic in the late 1990s, the South Corridor facility was opened in the summer of 1991. The accelerated construction of this facility was the WSDOT's short-term response to requests from the State Transportation Commission. The commission was acting on a request from Pierce County's Transit Board of Directors to install an HOV facility somewhere along I-5 between Federal Way and I-405. (Pierce County is south of King County, where I-5 continues to Tacoma). Pierce County's request resulted from many factors, including efforts to improve bus service from Pierce County to Seattle and reaction to a petition from one activist group demanding HOV lanes on I-5 (*2*).

METHOD

The overall method of this study includes the collection, analysis, and comparison of all data from within and across the South Corridor. The data were collected by field observations, detector systems, and questionnaire surveys. The Washington State Highway Patrol, WSDOT, the Municipality of Metropolitan Seattle (Metro), and Pierce Transit also provided relevant information.

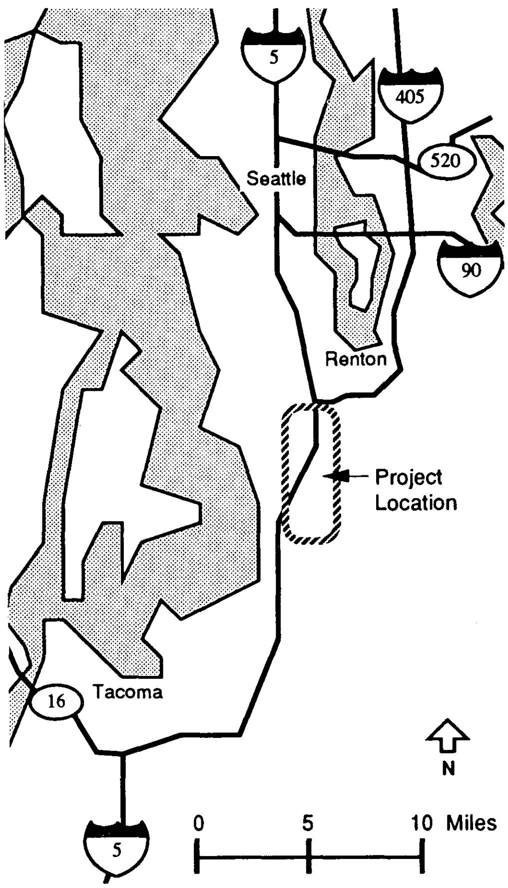

FIGURE 1 Location plan.

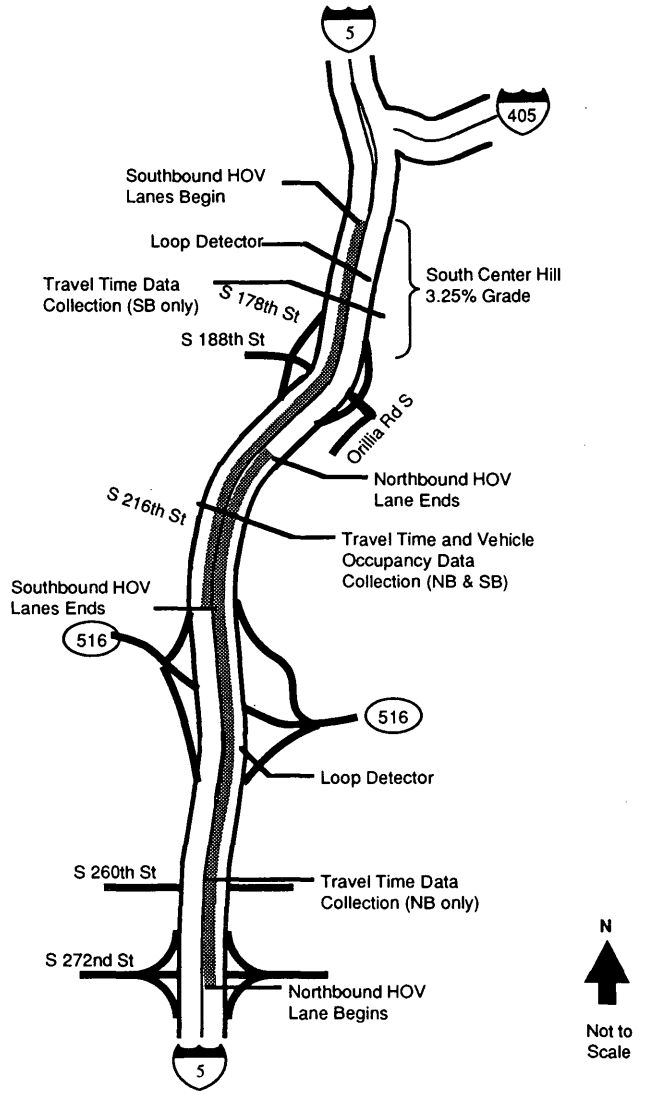

FIGURE 2 South Corridor plan.

Effectiveness Measures

The analysis included an application of the various data to a group of effectiveness measures. The effectiveness measures that the research team is testing for the evaluation and monitoring program have been developed by other research efforts and generally accepted as appropriate for evaluating HOV facilities. Accompanied by supporting objective statements, the following is a list of those measures, essentially derived from work by Turnbull (*3*), that were specifically chosen for the South Corridor evaluation:

- HOV lane volumes: the number of HOVs using the HOV lanes. The HOV facility should increase the per lane efficiency of the total freeway corridor. Of equal importance, the facility should maintain public support through a perception of adequate use.
- Congestion impacts: the impact of HOV lanes on the overall highway section. The HOV facility should not unduly impact the operation of the freeway mixed-flow lanes.
- Safety impacts: the effects of HOV lanes on highway safety. The HOV facility should be safe and should not unduly impact the safety of the mixed-flow lanes.
- Travel-time savings and reliability: the advantages provided by the HOV lanes. The HOV facility should provide travel-time savings and a more reliable trip time to HOVs using the facility. The facility should also increase the operating efficiency of bus service in the freeway corridor.
- Average vehicle occupancy (AVO): the average number of occupants per vehicle in all lanes of each highway section. The HOV facility should improve the capability of a congested freeway corridor to move more people by increasing the number of persons per vehicle.
- HOV enforcement: the number of vehicles violating the 3+ restriction. An HOV facility relies on enforcement to maintain the integrity of HOV travel benefits. Enforcement should also assist in maintaining public support by a perception of proper use.
- Public perception: public opinions, including traveler support of the HOV facility. It is imperative that the HOV facility have public support.

Each of these measures may also be applied to the following objectives provided by the *Washington State Freeway HOV System Policy* (*1*):

- Improve the capability of congested freeway corridors to move more people by increasing the number of persons per vehicle;

- Provide travel-time savings and a more reliable trip time to HOVs that use the facilities; and
- Provide safe travel options for HOVs without unduly affecting the safety of the freeway general-purpose mainlines.

Traffic Data

The following types of traffic data, which represent the peak periods of 6:00 to 9:00 a.m. (northbound) and 3:00 to 6:00 p.m. (southbound), were collected from the South Corridor:

- Lane volumes: number of vehicles traveling in each lane, applied to the measures of HOV lane volumes and congestion impacts;
- Accidents: number recorded by State Patrol before and after HOV lanes opened, applied to the measures of safety impacts and congestion impacts;
- Travel times: time for vehicles traveling in the corridor (HOV lanes versus regular lanes), applied to the measure of travel-time savings and reliability; and
- Persons per vehicle: number for each lane in the highway section, applied to the measures of AVO and HOV enforcement.

Lane volume data were collected both by roadway induction loop detectors and by visual field counts. Also, data on travel time and persons per vehicle were collected by traffic observers recording visual observations from field sites. For travel times, observers recorded (into laptop computers) the license plate numbers of vehicles in the appropriate lane at two sites within the corridor. The time difference and distance between the two recordings of each license plate were used to calculate travel times. For persons per vehicle, observers monitored and recorded the type of vehicle (or number of persons in each vehicle) into a laptop computer.

Because many unique traffic conditions or causes cannot be understood by traffic data analysis alone, many important discoveries about vehicle interaction were made in this study from the visual observations during data collection. The major limitation of this project, as with most HOV studies, is the lack of available data (AVO data are the exception), such as travel times or lane volumes, for any time period before the HOV lanes were opened to traffic in the summer of 1991.

Traveler Opinion Data

The research also includes responses to questionnaire surveys, distributed to travelers observed in the South Corridor. The travelers were distinguished by those who were observed using the HOV lanes versus those who were observed using the mixed-flow lanes. The questionnaire asked travelers for perceptions and opinions about HOV lane effects on safety, effects on travelers using both HOV and mixed-flow lanes, ways to improve each respective corridor, and HOV lane enforcement. In addition, the survey also asked for general demographic (personal) information, including typical mode choice for commuting, level of education, household size, and number of vehicles owned. The survey data were applied to the measure of public perception.

RESULTS AND DISCUSSION

HOV Lane Volumes

In general, analysis of the peak-period volume data indicates that the HOV lanes in the South Corridor were underused, in comparison with minimum volumes that are typically considered necessary for HOV lane effectiveness (see Table 1). A common criterion for minimum HOV lane volumes is based on developing and maintaining public perception that the facility is being adequately used. Fuhs provides the following insights on this issue: (*4*) "The perception of non-HOV drivers, and often the general public, is that the facility is not adequately used when they do not see vehicles in it. This may create what practitioners commonly refer to as "empty lane syndrome." This perception, whether correct or not, may create pressure to roll back occupancy restrictions . . . or terminate the project altogether. Such perceptions have been the single most critical issue in upholding the long-term viability of project operations in some locales . . . ."

Analysis of the HOV volume data also indicates a 33 percent drop in the volume of vehicles traveling in each HOV lane, within about 4 to 5 km (2 to 3 mi) downstream. It is unclear why there was a drop in HOV lane volumes. However one factor in the southbound direction could be that the southbound lane began at the base of the Southcenter Hill, which has a long, steep grade (see Figure 2). Buses entering the southbound HOV lanes would have to climb slowly because of the steep grade of the hill. To pass buses, drivers of HOV automobiles would often leave the HOV lane and travel in the general-purpose lanes, but only if traffic in the general-purpose lanes was traveling faster than the buses.

Perhaps more important, it was also discovered that carpools and buses tended to merge out of the HOV lanes well

TABLE 1 HOV Lane Peak-Hour Volumes

Direction/Data Collection Site	Peak Period Volumes (Vehicles per hour)
Northbound at Highway 516 (detector)	423
Northbound at S. 216th St. (manual)	257
Northbound Mean (combined data)	335
Southbound at S. 170th St. (detector)	404
Southbound at S. 216th/178th St. (man.)	261
Southbound Mean (combined data)	326
Literature Source	**Recommended Minimum (Vehicles per hour)**
Cal. Air Resources Board (5)	800
Nuworsoo & May (6)	1000
WSDOT (2)	200*
Parsons Brinckerhoff, et al. (7)	700**
Cechini (8)	800
Fuhs (4)	400

*For Seattle, otherwise 500
**For Orange/Riverside Counties, Cal.

in advance of the downstream lane endings to avoid bottlenecks created at the point where many other HOVs had to merge back into the regular traffic lanes at the end of the HOV lanes. There are also several exit ramps within the corridor, and some of the HOVs appeared to merge out of the HOV lanes to reach the appropriate exit ramp.

Congestion and Safety Impacts

The merge point bottleneck problem was particularly noticeable in the southbound direction at the south end of the HOV lanes. One symptom of this was an increase in accidents in the left-side general-purpose lanes since the installation of the HOV lanes (see Figure 3). The average number of accidents in the left lanes of the facility increased from 2 per month to 7 per month after the HOV lanes were installed. This increase in accidents is important for further investigation into safety and congestion impacts of the HOV lanes. Several survey respondents complained about added congestion near the downstream ends of the HOV lanes.

Two survey questions addressed concerns about the width of the HOV lanes and that those lanes use a part of the original highway shoulder. However the survey responses indicate that there was only marginal concern among travelers about such safety problems.

Because these HOV lanes were apparently contributing to increased highway congestion and accidents, they were not only ineffective in attracting HOVs, but they were also working against goals of increased mobility and welfare for all travelers (*9*).

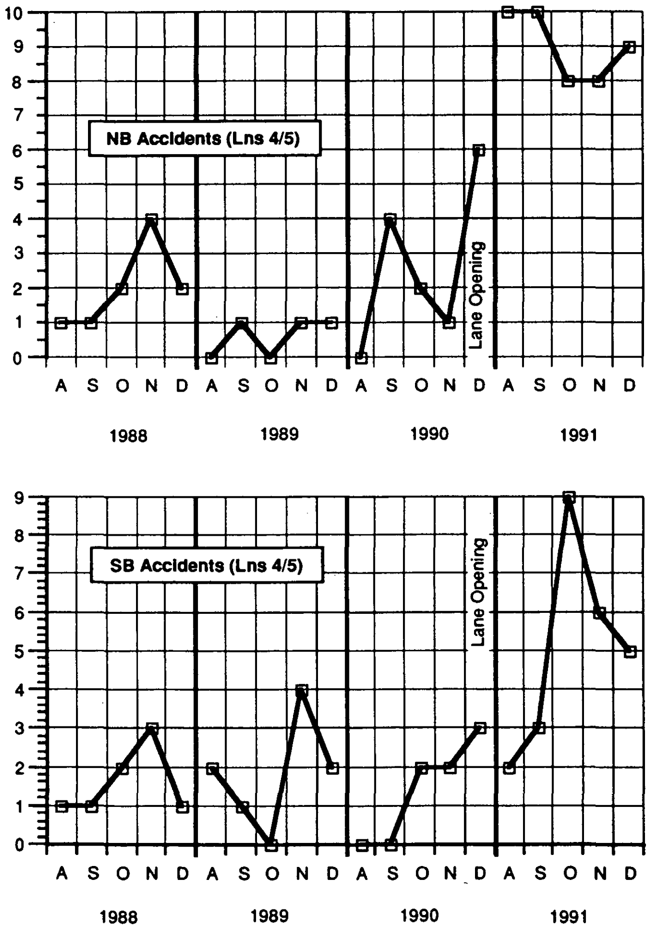

FIGURE 3 Monthly accidents, August–December, 1988–1991.

Travel-Time Savings and Reliability

The travel-time comparisons, presented in Table 2, indicate that there was a limited amount of travel-time savings provided to travelers who used the HOV lanes, in relation to a 1-min/mi level of travel-time savings that is typically considered necessary for HOV lane effectiveness (*6,8*). This is a key point addressed by a majority of the literature searched for this report. Travel-time savings are important in encouraging travelers to carpool. If the HOV lanes on a roadway do not provide such an advantage, the incentive for current carpoolers to use the lanes or for other travelers to begin carpooling is limited.

Through informal discussions with the researchers, managing representatives from Metro and Pierce Transit have expressed satisfaction with bus route operations on the South Corridor. They cited time savings and reliability as the assets provided by the HOV lanes. They have adjusted route schedules for shorter trip times because the lanes allow for faster and more reliable service. However, through a comparison of the travel-time data with the bus schedule changes, it is difficult to verify that the transit schedule changes actually reflect travel-time savings that may have been provided by the HOV lanes.

The travel-time analysis also indicates that, with the exception of the Friday afternoon peak, there is little advantage of day-to-day travel-time reliability (or consistency) provided by use of the HOV lanes (see Table 2). Although travel-time reliability is considered a valuable measure of HOV facilities, and even if higher levels of reliability were reflected in the data, the findings of this research do not provide a quantitative level for which travel-time reliability may be considered an effective incentive for mode shift. (This indicates the need for further study.)

Average Vehicle Occupancy

Before and after comparisons of persons per vehicle indicate there was only a marginal increase of AVO in the South

TABLE 2 Travel-Time Summaries

Direction	Lane	Day	Time of Day	Time Mean	St.Dev.	mph Mean
Overall am & pm						
PM/SB	HOV (n=151)	Mon — Fri	3:00-5:15	3:42	0:47	46
PM/SB	SOV(n=1186)	Mon — Fri	3:00-5:15	3:58	1:18	43
	(t = -2.41, 2-tail p = 0.16)		Difference	0:16	0:31	-3
AM/NB	SOV (n=28)	Wednesday	7:30-8:15	3:17	1:05	45
AM/NB	HOV(n=204)	Wednesday	7:30-8:15	3:32	1:08	43
	(t = -1.07, 2-tail p = 0.29)		Difference	0:15	0:03	-2

Corridor since the HOV lanes were installed (see Table 3). A minimal change (1 to 2 percent) of AVO in the South Corridor implies that the HOV lanes were relatively ineffective in providing an incentive for an increasing number of travelers to carpool. "A related question is how much the existence of an HOV lane will trigger and sustain mode shift in favor of carpool formation and/or transit ridership" (*6*). The actual mode shift impact caused by HOV lanes may further be diminished by the fact that new policies for HOV incentives have been implemented for the Seattle area within the past few years.

The vehicle occupancy analysis shows that carpools of 3 or more persons increased by more than 100 vehicles per hour in the morning peak period. However the increase in carpools is only about 50 vehicles per hour in the afternoon peak period. The analysis also indicates that only 50 to 60 percent of the vehicles that qualified to use the South Corridor HOV lanes were actually found to be traveling in those lanes (see Table 3). Therefore the analysis indicates that some new carpools were attracted to the facility (either by change in mode or change is route), but the actual attractiveness of the HOV lanes is questionable because of the low percentage of carpools that were actually found in those lanes.

Note that in Table 3 each transit bus occupancy was counted as 40. This is an average consistent with transit buses throughout the region. Also note that at the time of this study, Metro and Pierce Transit reported essentially no increase in ridership attributed to opening of the HOV lanes. Also, the state's HOV system policy indicates that HOV lanes are appropriate improvements when "evidence exists that during peak hours of operation, the HOV lane will move more people than the per lane average of the adjacent general purpose lanes" (*1*). The vehicle occupancy and lane (vehicle) volume data for this corridor show that the HOV lanes were each moving approximately 1,900 persons per hour during the peak, versus an average of 2,500 persons per hour in the adjacent lanes.

HOV Enforcement

Further vehicle occupancy analysis indicates that the HOV lane violation rate is 26 percent in the South Corridor, which is a high rate in comparison with rates typically considered acceptable for an effective HOV facility. "A recommended goal in enforcing HOV lane restrictions is to keep violations at or below 10 percent" (*6*). Enforcement is quite difficult in this corridor because the highway shoulders are narrow and there is little access for police to observe and ticket violators. It is also arguable that the high violation rates are another symptom of the general ineffectiveness of this facility. The combination of underuse and a high violation rate could easily stimulate a negative public attitude toward HOV facilities, which clearly presents a concern in the South Corridor. Responses from the traveler surveys demonstrate much concern about the high number of violators seen traveling in the HOV lanes.

Traveler Perception of HOV Lanes

Several of the survey questions addressed traveler support for HOV lanes. A summary of the responses is shown in Figure 4. The results indicate that even most of the respondents who said they normally drive alone are supportive of HOV lanes.

The survey also asked for respondents to choose among alternative facility improvements, which would make the HOV lanes more attractive for carpooling and bus riding in the corridor. The most popular choice was that the HOV lanes should be extended farther in each direction. Eighty-four per-

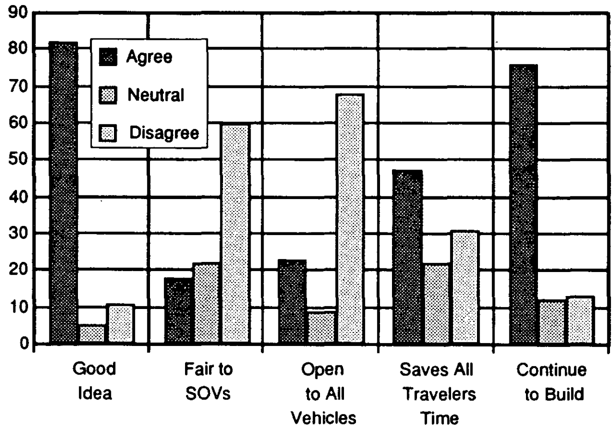

FIGURE 4 General traveler support for HOV lanes.

TABLE 3 Vehicle Occupancy Summary

South Corridor Dir	Year	Start	End	1	2	3	4	Van	Tbus	Bus	Strk	Btrk	MC	Sum	AVO	% Viol	%3+ in HOV	%3+ Ovral	%2+ Ovral
				Averages for each category over all lanes															
AM	92	7:00	9:00	6424	780	156	40	8	28	8	116	248	12	7820	**1.32**	**25**	**49**	**4**	14
				82%	10%	**2%**	**1%**	.10%	.36%	.10%	1%	3%	0%	100%					
AM	90	6:00	9:00	6202	746	66	18	8	26	2	104	272	38	7482	**1.29**	NA	NA	**2**	12
				83%	10%	**1%**	**0%**	.11%	.35%	.03%	1%	4%	1%	100%					
PM	92	3:00	5:00	4416	871	144	58	18	16	4	56	156	8	5747	**1.38**	**27**	**59**	4	19
				77%	15%	**3%**	1%	.31%	.28%	.07%	1%	3%	0%	100%					
PM	90	3:00	6:00	5368	1071	136	50	14	18	6	70	190	16	6939	**1.35**	NA	NA	4	19
				77%	15%	**2%**	1%	.20%	.26%	.09%	1%	3%	0%	100%					

Ln — Lane Number
1 — Single Occupant Vehicle(counted as 1 for AVO)
2 — 2 Occupant Vehicle(counted as 2 for AVO)
3 — 3 Occupant Vehicle(counted as 3 for AVO)
4 — 4 Occupant Vehicle(counted as 4.1 for AVO)
Van — Designated Vanpool(Counted as 10 for AVO)
Tbus — Transit Bus(counted as 40 for AVO)
Bus — all other buses
Strk — Double Axle Truck
Btrk — Triple Axle Truck
MC — Motorcycle

cent of the respondents chose this alternative. The results are consistent with another survey question that asks for agreement on whether or not more people would carpool if the lanes were extended farther (43 percent agreed, 21 percent disagreed). The relevance of this traveler support is also consistent with a general approach to HOV lane applications around the country. "The continuity of HOV lanes along a given corridor and/or connecting with other corridors is a significant factor contributing to the overall effectiveness of a high-occupancy vehicle lane system" (*8*).

Left Versus Right Side of Freeway

The survey listed another alternative improvement: moving the HOV lanes from the left to the right side of the highway in each direction (see Figure 2). The responses indicate low support for such a change. This lack of support tends to demonstrate that travelers perceive the use of HOV lanes on the right side as a hindrance to traffic, particularly when there are a high number of on- and off-ramps within each corridor (see Figure 2). This lack of support is also an indication that the HOV lanes would be even less attractive to travelers if they were located on the right side if each direction of the South Corridor.

Park-and-Ride Lots

Another alternative is for more park-and-ride lots to be located in the vicinity of the South Corridor. The responses show lack of support for such an improvement, which indicates that added park-and-ride lots would not particularly improve existing attractiveness of the HOV lanes. The research team found that park-and-ride lots were in good strategic locations for support of the HOV facility.

Occupancy Definition

The survey responses show an extremely strong preference (more than 75 percent agree) for an occupancy definition of two or more people per vehicle versus three or more. There are probably two main reasons for this response. First, it is much easier for travelers to form two-person carpools than three-person carpools. Second, travelers understand that if the definition is changed to two or more people per vehicle, it is likely that more vehicles will use the HOV lanes. In general, if travelers see more cars in the HOV lanes, then they perceive that the lanes are better used.

Because there is such strong support for a 2+ occupancy definition for the HOV lanes, it is reasonable to believe that the existing 3+ requirement is the cause for underuse in the South Corridor. However, because there is already new congestion on the highway at the merging ends of the HOV lanes, a change to the 2+ definition would likely create too much of an increase in HOV lane volumes, and an even larger bottleneck could occur at the merge locations. Therefore geometrics at the lane terminations must be addressed before a definition change would be feasible. It is also arguable that a change to the 2+ occupancy requirement as a short-term solution may work against the long-term goals of the state (*1,3*).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Installation of the South Corridor HOV lanes was accelerated to provide a short-term solution to highway congestion-related problems in southern King County. However the findings of this research indicate that the HOV lanes were not an effective short-term application. An apparent lack of travel-time savings and low traveler use of HOV lanes were the most noticeable deficiencies. The merge alignment at the ends of each HOV lane created additional highway congestion, which also magnifies the facility's short length and contributes to the lack of traveler incentive to use the lanes.

By the application of various traffic and public opinion data to the measures established for this study, the South Corridor showed deficiencies in several other areas: significant congestion and safety impacts to the mixed-flow traffic, a low level of improvement in the peak-period person movement on the basis of vehicle occupancy counts, and a relatively high HOV lane violation rate. The vehicle occupancy data also indicated that, of the vehicles traveling in the corridor, only about half of the 3+ qualifiers were found to be using the HOV lanes.

Traveler responses to applicable survey questions indicated that nearly all travelers, independent of mode, were supportive of HOV facilities. However the survey responses, traffic data, and field observations also indicate a need for improvement of the facility. This point is particularly important, because effective performance and healthy public perception are critical to long-term acceptance and development of HOV facilities.

A positive aspect of the research is that representatives from Metro and Pierce Transit expressed satisfaction with the facility in providing improved service for those buses that travel through the South Corridor. The park-and-ride lots in the South Corridor also provided an advantage to HOV travelers, particularly for those who use the transit buses.

As this facility is developed toward long-term application from Tacoma to Seattle, performance should improve with permanent construction and extension of the lanes and with WSDOT (and local agencies) providing future HOV support programs and other connecting HOV facilities. Improved performance will also depend on how well the regional community will adapt to a general HOV approach to transportation.

Recommendations

Geometric Improvements

It is recommended that appropriate geometric changes be made in the facility to alleviate the bottlenecks for the particular intention of improving effectiveness and public perception of the HOV lanes.

First, the lanes should be extended downstream in each direction. The northbound lanes should be extended to I-405.

This recommendation is supported by WSDOT's final report for the South Corridor: "In order to avoid this potential bottleneck, the HOV lane should be extended past these ramps to Southcenter and I-405. Therefore, the section between S. 200th Street and I-405 becomes a top priority" (*2*).

Second, geometric improvement should also be made to the HOV lanes. The lane striping should be modified at the HOV lane endings in each direction, so that the HOV lanes extend and become mixed-flow lanes (see Figure 5). For WSDOT to maintain the same number of mixed-flow lanes downstream, the far right lane would have to be changed to an exit-only lane at the appropriate exit.

This type of lane configuration was proposed as an alternative (Plan B), as presented in a White Paper from Parsons Brinckerhoff for WSDOT (*10*). By this plan, it was recommended that the operation of the southbound HOV and mixed-flow lanes would be improved for both safety and congestion impacts. Current traffic volume exiting to SR 516 in the southbound is sufficient (~1,200 vehicles per hour in the peak) to justify an exit-only lane, with no negative impact to mainline traffic. The traffic volume exiting at South 200th in the northbound is not as easily justifiable for an exit-only lane (~400 vehicles per hour in the peak). Therefore in the context of current HOV volumes under the 3+ definition, it is recommended that the exit-only configuration be developed in the northbound lanes and that the HOV be extended lane to I-405.

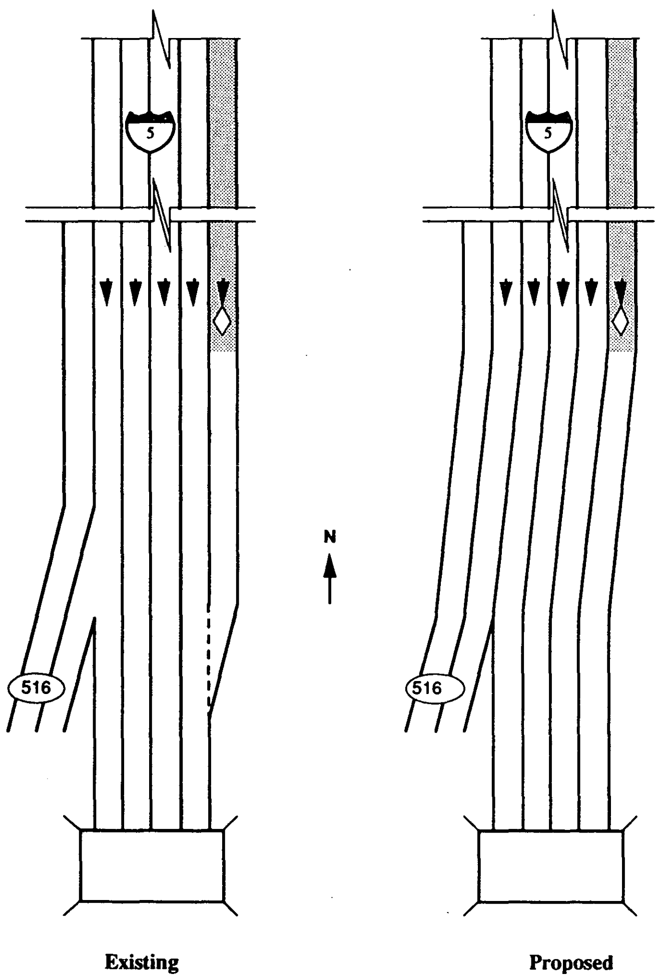

FIGURE 5 I-5 southbound HOV transition at SR 516 (schematic).

2+ Demonstration

A new evaluation should be done for this facility after the recommended geometric improvements are made. This evaluation should reflect operational improvements in the corridor on the basis of the measures presented here. With speculation by the researchers that HOV use will be satisfactory for efficient use, it is also recommended that, following the appropriate geometric changes, a demonstration should be conducted for the feasibility of a 2+ occupancy definition. The 2+ demonstration should be conducted similar to the 2+ demonstration conducted in another HOV facility on I-5 in north King County (*11*).

Because bottleneck problems exist at the HOV termination points under the 3+ definition, excessive impacts to the mixed-flow traffic is likely with an increase in volumes under a 2+ definition. Therefore it is essential that a change to 2+ be made as a demonstration only, and only after the recommended (minimum) geometric improvements have been made and evaluated.

SUGGESTIONS FOR FURTHER RESEARCH

It appears that each of the HOV effectiveness measures provided helpful information for evaluation of this HOV facility. However the research team discovered that there is a relative rank of productiveness provided by the measures, according to available resources. The most effective evaluation measurements came from the opinion surveys and the vehicle occupancy data. Analysis of both of these data types revealed how travelers in the corridor perceived and reacted to existence of the HOV lanes, perhaps the most critical elements in the evaluation of HOV facilities.

The least effective measurements came from travel-time data. With the efforts of the research team to collect comprehensive data, many limitations were discovered. For travel-time data to be completely effective, it should be comprehensive, representing all days over the entire length of the facility and over the entire peak period. This is an expensive and time-consuming process, particularly with the incorporation of traffic observers recording license plates. However if other techniques, such as automobile detector or video applications could be made, the feasibility daily peak-period collection could improve.

Travel-time data would also become much more beneficial if a reasonable means were developed for determining the quantitative (threshold) significance of travel-time reliability to HOV travelers. WSDOT has developed a new policy on travel-time reliability that should help to address this issue in future evaluation studies. It is also important that all types of data be collected from highway corridors for which HOV lanes have been planned before the HOV lanes are opened.

Frequent observation of vehicle interaction, beyond simply collecting and analyzing data, cannot be sufficiently emphasized. The process of training and incorporating observers is expensive and time-consuming, but because each highway corridor is unique, particularly in short-term application, field observations are probably the most important part of the HOV monitoring and evaluation process.

New evaluation should begin immediately, particularly following each of the suggested geometric and operational improvements. Whether or not the improvements are made, the data limitations discussed here should be addressed by data collection that represents all seasons and accounts for the entire peak period. The opinion surveys should include questions related to mode shift and perhaps be directed to travelers who changed modes after the HOV lanes opened. Data collection could also include automobile occupancy at entrance and exit ramps within the corridor. Methods should also be developed for more observation and data collection at the HOV lane termination points.

Perhaps the most beneficial research for this corridor will occur over time as the region begins to realize more impacts from transportation and land use policy changes. Evaluation of this corridor should be continuous over time and should be incorporated into the regionwide HOV monitoring program. This should include more concentrated evaluation efforts by researchers as the South Corridor improvements and extensions are made toward the ultimate facility plan of Seattle to Tacoma.

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