Evaluation of the Seattle I-5 North High-Occupancy Vehicle Lane 2+ Occupancy Requirement Demonstration

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High-occupancy vehicle (HOV) facilities allow for a great deal of operational flexibility. This flexibility has often been noted as one of the advantages of HOV lanes. The ability to change the vehicle occupancy level required for use of the HOV facility reflects this flexibility. Increasing or decreasing the occupancy requirement provides one approach to managing the demand on the facility and thus the number of vehicles and people using the facility. The impact of increasing and decreasing vehicle occupancy requirements has been a topic of discussion at recent national HOV conferences and other meetings. Although a few areas, most noticeably Houston, have documented the impact of changes in HOV lane vehicle occupancy levels, more information is needed to fully understand the consequences of these changes. This paper summarizes the impact of one such change: the demonstration project in which the minimum vehicle occupancy requirement on the I-5 North HOV lanes in Seattle was lowered from three or more persons per vehicle to two or more persons per vehicle. The impact of this change on the I-5 North HOV lanes and the general-purpose lanes is documented in this paper. The information presented assists in enriching the understanding of the consequences of changing HOV lane vehicle occupancy requirements.

On July 29, 1991, the Washington State Department of Transportation (WSDOT) initiated a 6-month demonstration project in which the minimum vehicle occupancy requirement on the I-5 North high-occupancy vehicle (HOV) lanes was lowered from three or more persons per vehicle (3+) to two or more persons per vehicle (2+). The demonstration was undertaken to determine the impacts of reducing the occupancy requirement from 3+ to 2+ on the operation of the HOV lanes and the freeway general-purpose lanes.

The results of this demonstration, as presented in this paper, should be of interest to transportation planners and engineers, transit personnel, and others. The operational flexibility associated with HOV lanes, including the ability to change the vehicle occupancy level required to use the facility, represents an often-noted advantage of HOV facilities (*1*,*2*). Advantages of increasing and decreasing HOV occupancy requirements have been discussed at recent HOV conferences and other meetings (*3*). Few quantifiable data exist outside of Houston (*4*) on the impact of changes in vehicle occupancy requirements on the HOV lane and the general-purpose lanes. An evaluation program, conducted by the University of Washington and the Texas Transportation Institute (TTI) under contract to WSDOT, was undertaken to examine these impacts (*5*). The results from this evaluation are summarized here. By providing additional insights into these impacts on the basis of the I-5 North demonstration, this paper enhances the current level of understanding and enriches the available information on the impacts of changes in vehicle occupancy requirements on HOV lanes.

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PURPOSE OF DEMONSTRATION AND EVALUATION

The demonstration was initiated to determine the impacts reducing the occupancy requirement from 3+ to 2+ persons per vehicle would have on the operation of the I-5 North HOV lanes and the freeway general-purpose lanes. The location of the I-5 North concurrent flow HOV lanes is shown in Figure 1. The southbound HOV lane is 7.7 mi long, and the northbound HOV lane is 6.2 mi long. The HOV lanes were first opened in 1983.

Specifically, the demonstration was intended to determine whether the change in occupancy requirement maintained or contributed to meeting the objectives of the Washington State HOV program (*6*). The I-5 North Demonstration Project Steering Committee, composed of representatives from WSDOT, Seattle Metro, Community Transit, Pierce Transit, the City of Seattle, Washington State Patrol, and FHWA, provided guidance for the evaluation.

The evaluation was focused on the impact the change in the vehicle occupancy requirement on the I-5 North HOV lanes had on achieving the objectives established by WSDOT for the freeway HOV lane system. The objectives and measures of effectiveness developed by WSDOT, as identified in the following paragraphs, were used to guide the evaluation (*6*):

Preamble:
By satisfying the following overall objectives the HOV system is successfully providing mobility choices consistent with the mission of the Washington State Department of Transportation and the goals of recent growth management, commute trip reduction, and air quality legislation. Critical to the success of the HOV system is public support. These objectives and all decisions regarding the system must reinforce public acceptability of and support for HOV facility development.

The overall objectives of the HOV system are to accomplish the following:

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

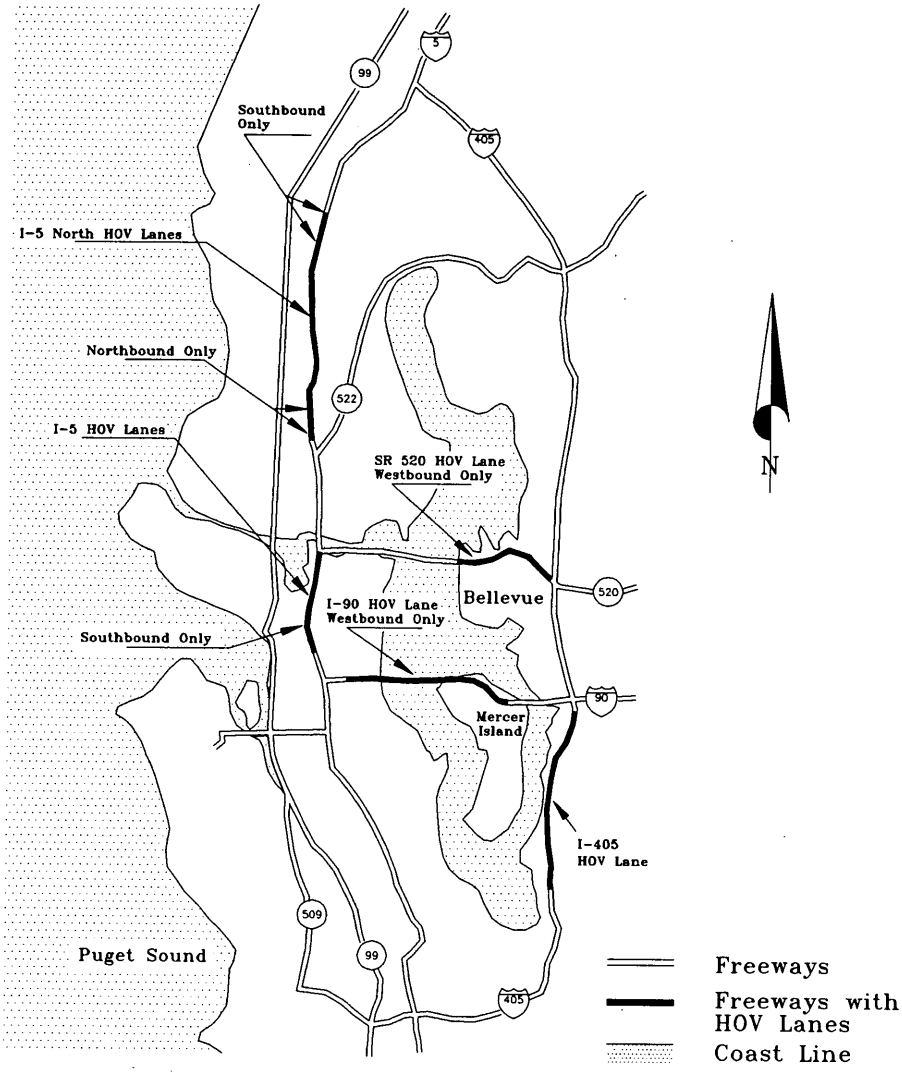

FIGURE 1 Location of I-5 North HOV lanes.

- Provide travel time savings and a more reliable trip time to high-occupancy vehicles utilizing the facilities.
- Provide safe travel options for high-occupancy vehicles without unduly affecting the safety of the freeway general-purpose mainlanes.

Measures of effectiveness used to determine the impact of the HOV system include the following:

- Person throughput,
- Vehicle occupancy,
- Comparative and absolute general-purpose and HOV lane travel times,
- Travel time reliability, and
- Accident rates.

First, the impact of the occupancy requirement change on the HOV lanes was examined. This included an analysis of changes in use levels, travel times, travel-time reliability, and bus ridership levels. The impacts on the general-purpose lanes and the total freeway were also examined. Changes in vehicle volumes in the general-purpose lanes were examined, along with travel time and accident data. The changes in average vehicle occupancy levels and person throughput were also analyzed. Public perception of the change and the HOV lanes in general was also measured through surveys of bus riders, carpoolers, and motorists.

A variety of data collection activities was conducted to support the analysis. Travel-time surveys, using the license plate methodology, were taken of vehicles using both the HOV and general-purpose lanes. Use levels and lane vehicle volumes were obtained from loop detector data gathered as part of the ongoing WSDOT monitoring program. Accident data were obtained from the State Patrol. Bus ridership levels and park-and-ride lot use rates were provided by Community Transit. Special surveys were conducted of Community Transit riders, carpoolers, and motorists to provide additional information on the impact of the change in the vehicle occupancy requirement and general attitudes toward the HOV lanes.

It is important to note that the change in the I-5 North HOV lane occupancy requirement did not occur in a vacuum. Thus, there are a number of limitations with evaluation. First, many factors other than the change in the HOV occupancy requirement may have influenced travel in the corridor during

the demonstration. Identifying and evaluating the impact of these confounding variables, such as the introduction of the U-Pass program at the University of Washington, was difficult. Second, individuals' travel habits change over time, and changes in modes, travel times, and routes could be expected in any corridor. However, while individuals' travel habits change, it takes time to establish new routines and patterns. Thus, changes in travel characteristics may not emerge immediately after the implementation of a demonstration. The analysis was further limited by the availability of data, especially for the period immediately preceding the start of the demonstration.

Even with these limitations, the evaluation provides an indication of the general trends and impacts of the reduction in the I-5 North HOV lane occupancy requirement on the HOV and general-purpose lanes. Thus, results of this analysis should be of interest to other areas considering changing the vehicle occupancy requirements on HOV lanes. Further, the results enrich the general understanding of the impact changes in occupancy levels have on the operation of the HOV and general-purpose lanes, overall vehicle occupancy levels, and other factors.

ORGANIZATION OF PAPER

The remainder of this paper presents the results from the 6-month evaluation of the demonstration project in which the minimum vehicle occupancy requirement on the I-5 North HOV lanes was lowered from 3+ to 2+ persons per vehicle. To accomplish this, the remainder of the paper is divided into two major sections. The next section provides an overview of the data collection activities undertaken as part of the evaluation, discusses some of the limitations associated with the evaluation, and presents a summary of the major results. The paper concludes with a discussion of how these results may be of use on a national level and ideas for improving future evaluations.

EVALUATION RESULTS

This section presents a summary of the results from the evaluation of the reduction in the vehicle occupancy requirement on the I-5 North HOV lanes. The information used in the analysis was obtained through special surveys and from ongoing WSDOT monitoring efforts. The availability of data from these different sources varies. The WSDOT lane volumes were available in computerized format for recent years. However, data older than 1990 were available only on microfiche, making it more difficult to obtain and analyze. Due to the quick implementation of the demonstration, travel-time surveys and vehicle occupancy counts were conducted for only 4 days in July before the change was made. Thus, the ability to fully analyze many impacts during the evaluation was limited by the available data.

The major focus of the analysis was on the impact the change in the vehicle occupancy requirement had on traffic levels and traffic conditions during the morning and afternoon peak hours and peak periods. For the purposes of the evaluation, the morning peak hour was defined as 7:00 a.m. to 8:00 a.m.; the morning peak period was defined as the 3-hr period from 6:00 a.m. to 9:00 a.m.; the afternoon peak hour was defined as 5:00 p.m. to 6:00 p.m.; and the afternoon peak period was defined as the 3-hr period from 3:30 p.m. to 6:30 p.m. These times correspond to the periods when the greatest demands, and thus the greatest vehicle volumes, are typically placed on the general-purpose freeway and HOV lanes.

The major results from the evaluation are summarized in Table 1 and discussed in more detail next. Information is presented first on the impact the change had on the I-5 North HOV lanes. This includes a discussion of changes in use levels, travel times, travel-time reliability, and bus ridership levels. This is followed by a discussion of the impact on vehicle volumes, travel times, and travel-time reliability for the general-purpose lanes. The changes in overall vehicle occupancy levels and person movement are discussed next. This is followed by a brief review of available information on accident rates. This section concludes with a summary of the public perception concerning the change.

Impact on I-5 North HOV lanes

HOV Lane Use Levels

Data on the HOV lane use levels were obtained from the WSDOT ongoing monitoring program on the I-5 North freeway. Loop detectors located in the pavement at selected sites along the HOV and general-purpose lanes record the number of vehicles passing over the detectors. Data from 1990 to the present were available through the WSDOT computer system. However, data from before 1990 were stored on microfiche, making it harder to compile and analyze those data. For the purpose of the analysis, HOV lane use trends in 1990 and 1991 at the 3+ vehicle occupancy level were compared with those during the 6-month demonstration period when the 2+ occupancy requirement was in effect. HOV lane volumes were examined for three southbound and two northbound data stations.

In general, the peak-hour and peak-period volumes in the HOV lanes recorded at each of the three station more than doubled after the change to the 2+ vehicle occupancy requirement. However, slightly different trends emerged in the morning and afternoon periods. In the morning peak hour–peak direction, HOV volumes increased significantly with the change to the 2+ requirement and continued to increase during the demonstration period. HOV volumes increased from approximately 500 vehicles an hour to between 1,200 and 1,400 vehicles an hour. This trend may be seen by the information from one data station, shown in Figure 2. Further, the number of vehicles using the HOV lane continued to increase during the demonstration. The vehicle volumes in August and September, immediately after the change, averaged between 950 and 1,100 vehicles during the morning peak hour. However, the peak-hour HOV volumes continued to increase steadily, averaging between 1,300 and 1,400 vehicles in November and December. Similar trends were reflected in the morning peak-period volumes, which more than doubled initially and continued to increase during the demonstration.

The afternoon volumes in the HOV lane also more than doubled for both the peak hour and the peak period. The

TABLE 1 Summary of General Trends Associated with I-5 North 2+ HOV Lane Demonstration

Measures of Effectiveness and Related Policies	General Trends in Change from 3+ Persons per Vehicle to 2+ Persons per Vehicle
Person Throughput	
HOV Lane Vehicle Volumes	Significant increase in peak hour volumes from approximately 400-500 vehicles to 1,200 to 1,400 vehicles or approximately 200%.
HOV Lane Person Volumes	Peak hour person volumes increased by approximately 1,200 or 35%.
General-Purpose Lane Vehicle Volumes	Remained approximately the same.
General-Purpose Lane Person Volumes	Remained approximately the same.
Bus Ridership Levels	Community Transit ridership to the University has increased. This appears to be result of the U-Pass Program. Ridership to downtown Seattle was stable or slightly declining.
Total Person Throughput	Increased during demonstration period by approximately 12%.
Vehicle Occupancy	
HOV Lane	Declined, due to more 2 person carpools and fewer 3 person carpools.
HOV and General-Purpose Lanes	Vehicle occupancy levels for the combined HOV and general-purpose lanes increased after the start of the demonstration, but have declined since to about the same level (1.2 persons per vehicle) as in 1989-1990.
Travel-Times and Travel-Time Reliability	
HOV Lane Travel Times	Morning peak hour travel times have remained about the same, while afternoon peak hour travel times have increased.
General-Purpose Travel Times	Morning peak hour travel times have decreased and afternoon peak hour travel times have increased.
HOV Lane Time Savings over General Purpose Lanes	HOV lane travel time savings decreased in the morning peak hour, but increased in the afternoon peak hour. These changes are due primarily to changes in travel speeds in the general-purpose lanes.
HOV Lane Travel Time Reliability	HOV travel time reliability has declined, especially in the afternoon peak hour.
General-Purpose Lanes Travel Time Reliability	Travel time reliability in the general-purpose lanes has remained about the same in the morning, but appears to have declined slightly in the afternoon peak hour.
Bus Service On-Time Performance	On-time performance appears to have declined slightly in the afternoon.

(*continued on next page*)

volumes in November and December averaged between 1,300 and 1,550 vehicles. This represented a significant increase from the average of 400 to 600 vehicles recorded in March through June, 1991, before the demonstration. In general, the afternoon peak-hour HOV lane volumes were higher than those recorded during the morning peak hour. However, contrary to the morning trend of increasing growth in vehicle volumes, the afternoon data indicated a slightly different trend. Some of the highest volumes were recorded in August, immediately after the change to the 2+ occupancy requirement. From September to December, the HOV lane volumes were more erratic, and a clear picture of increasing volumes, such as noted in the morning, did not emerge. This trend may have been caused by initially higher afternoon volumes with little capacity for additional vehicles.

Travel Times

Travel times for vehicles using the HOV lane were measured by recording the license plate numbers of vehicles in the lane at two locations in the corridor. The license plate information was recorded using a microcomputer that also recorded the time at locations close to the beginning and end of the HOV

TABLE 1 (*continued*)

Measures of Effectiveness and Related Policies	General Trends in Change from 3+ Persons per Vehicle to 2+ Persons per Vehicle
Accident Rates	
HOV and General-Purpose Lanes Accident Rates	No discernible trends were identified associated directly with the change. However, the areas downstream from both the northbound and southbound HOV lane reflect an increasing accident rate, which started before the implementation of the demonstration.
Public Perception	Surveys of bus riders, carpoolers, and motorists indicate that all three groups think the I-5 HOV lane is a good transportation improvement and between 59% to 74% think it is sufficiently utilized. 39% of the bus riders, 83% of the carpoolers, and 89% of the motorists survey felt permitting 2+ carpools to use the I-5 North HOV lane was a good move. 47% of the bus riders and 23% of the carpools indicated that travel times seem longer with the 2+ requirement, 23% said buses are not on schedule, and 5% reported missing connections. 23% of the carpoolers reported longer travel times and 21% reported problems entering or exiting the lane.
Other Federal, State, and Local Policies	
Transportation Policy Plan for Washington State	This plan emphasizes the movement of people rather than vehicles and advocates the provision of cost-effective alternatives to one-person vehicles, including transit and ridesharing. To the extent that the 2+ demonstration has resulted in more vehicles on the facility and lowered the overall occupancy vehicle rate, the results are counter to this plan.
Clean Air Act and Commute Trip Reduction Act	To the extent that more vehicles are moving through the I-5 corridor, due to the reduction in 3+ carpools, and to the extent that a degradation in the travel times and travel time reliability for HOVs have occurred, the demonstration is less supportive of these acts than the 3+ requirement.
Growth Management Act and PSCOG's Vision 2020	The demonstration evaluation did not examine possible land use or growth management impacts of the change, which would occur over a long time period. The impact on the Growth Management Act and other policies should be examined more closely.

lanes. The license plate numbers were then matched by computer and the travel time computed. Because of the short time period before the demonstration project was implemented, only 4 days of "before" data were available for July 1991.

Overall, the travel times in the segment of the HOV lane included in the survey during the morning peak hour did not change significantly with the 2+ requirement. The average travel time was 5.82 min before the demonstration and 5.80 min after, even with the increase in the number of vehicles in the lane. During the afternoon peak hour, the travel time in the HOV lane increased from 7.50 min before the demonstration to 7.98 after.

The travel-time savings for HOVs during the morning peak hour decreased during the demonstration. This decline was due primarily to a decrease in travel times for vehicles in the general-purpose lanes. Thus, while the travel times for vehicles in the HOV lane remained relatively constant, the travel times in the general-purpose lanes decreased, resulting in less difference between travel times for vehicles in the HOV and general-purpose lanes.

The travel-time savings for HOVs during the afternoon peak hour were greater during the demonstration period than those experienced when the 3+ occupancy requirement was in effect. On Mondays through Thursdays, the travel-time savings increased from 1.58 min to 3.44 min, and on Fridays the increase was from 6.12 min to 9.66 min. Because the travel times in the HOV lane during the afternoon peak hour did not decrease significantly, the increased travel-time savings resulted primarily from longer travel times in the general-purpose lanes, which occurred during the demonstration.

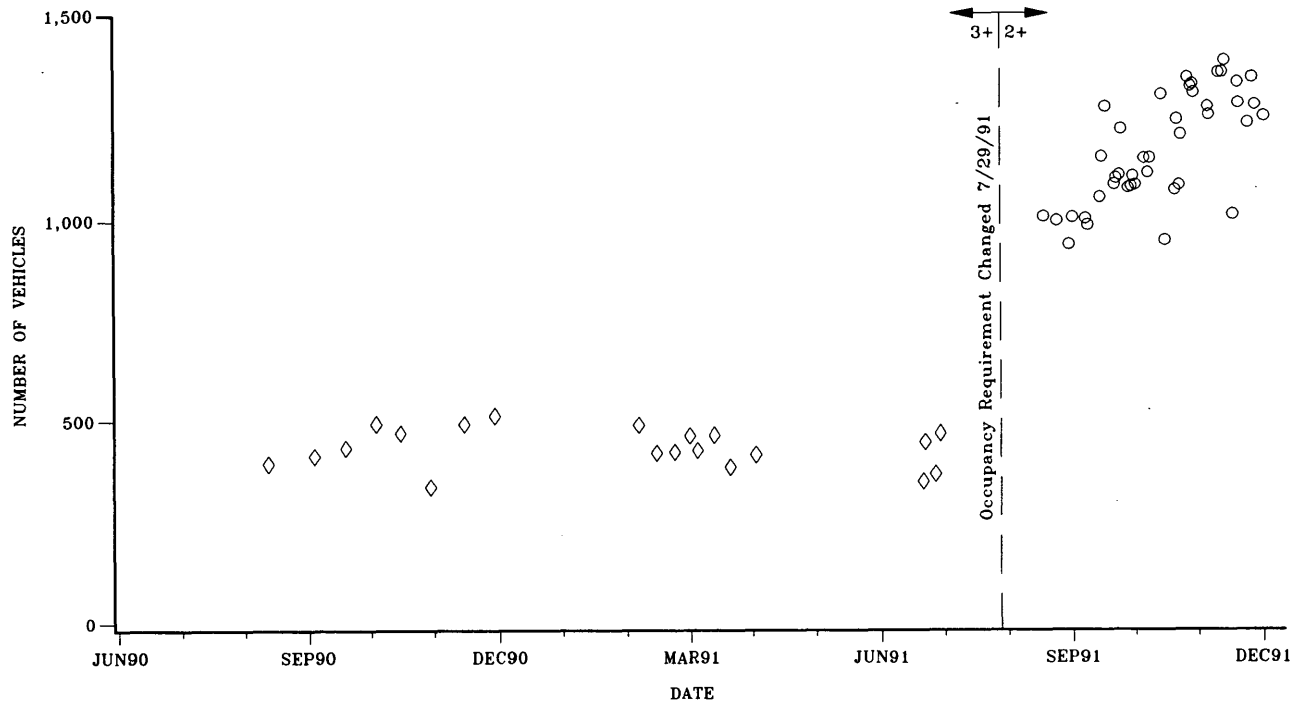

FIGURE 2 Morning peak-hour HOV volumes, 145th Street.

Travel-time Reliability

Another important factor influencing the use of HOV lanes is the travel-time reliability offered by these facilities. Thus, not only is the actual shorter travel time important to HOV lane users, the ongoing reliability of these savings is also important. The influence of the change in the vehicle occupancy requirement on travel-time reliability was measured by calculating the standard deviation of speeds in the HOV lanes before and after the change. This measure provided an indication of the reliability of travel times for HOVs.

The analysis indicated that travel times were more reliable in the morning than in the afternoon. However, the increase in the standard deviation experienced in both time periods indicated that travel-time reliability suffered during the demonstration. Thus, travel times in the HOV lanes were not as reliable with the 2+ occupancy requirement as they were with the 3+ requirement. The analysis indicated that this change was strong and statistically significant.

Bus Ridership Levels

Bus service in the I-5 North corridor is provided by both Seattle Metro and Community Transit. However, because of the location of the HOV lanes and the orientation of service, only Community Transit buses use the I-5 North HOV lanes in the study area on a regular basis. Information on the number of buses using the lane, ridership levels, and use of park-and-ride lot was obtained from Community Transit. In addition to the examination of trends in bus use on I-5 North, comparisons were also made of bus volumes and ridership levels associated with HOV facilities in other metropolitan areas in North America.

Community Transit operates a total of 19 weekday routes in the I-5 North Corridor. Of these, 14 routes are oriented toward downtown Seattle, 4 routes are oriented toward the University of Washington, and 1 route provides service to the North Seattle Community College. A total of approximately 109 inbound and 116 outbound buses provide weekday service to downtown Seattle, whereas 48 inbound and 44 outbound buses serve the university. One inbound and one outbound bus serves the Community College. Of these, approximately 59 buses operate during the morning peak hour, and 40 operate during the afternoon peak hour. Service is oriented from both neighborhood areas and park-and-ride lots located in Snohomish County. In addition, connections are provided to both the Edmonds and Mukilteo ferry service.

This represents a significant level of bus service for an HOV facility. The bus volumes on the I-5 North HOV lane rank first in a comparison with other concurrent flow HOV lanes in the United States. Further, the bus volumes are higher than a number of the exclusive freeway HOV facilities. Thus, buses represent a significant component in the vehicle mix on the I-5 North HOV lane.

Overall, approximately 10,000 daily riders were carried to downtown Seattle and the University of Washington on Community Transit buses using the I-5 North HOV lane. During the morning peak hour, some 2,500 riders were carried on buses using the HOV lane. The morning peak-hour bus passenger volumes on the I-5 North HOV lane compare favorably with levels on other HOV lanes in North America. The I-5 facility carries the second largest number of bus riders in the morning peak hour of the concurrent flow HOV lanes and records higher bus passenger volumes than some of the exclusive freeway HOV lanes.

Ridership on the Community Transit systems has grown dramatically during the past 5 years. In 1986, the daily average

ridership on the commuter routes to downtown Seattle was approximately 3,400 passengers. By 1990, this figure had increased to some 7,400 passengers. During 1991, ridership leveled off, however. The ridership trends for the months of August 1991 through January 1992 were examined for routes oriented toward downtown Seattle. While ridership remained constant with the levels from the previous year in August and December, ridership in September, October, November, and January was slightly below the levels for the same months the previous year.

It appears that this stabilization and slight decline may be attributable to a number of factors. First, most runs are at capacity with little room for new riders. Second, the general slowdown in the economy may have resulted in fewer bus riders in the corridor. Third, some bus riders may have changed to carpooling with the lower occupancy requirement. Given all these factors, it is difficult to determine the exact impact the occupancy requirement change had on bus ridership levels on service to downtown Seattle.

Community Transit service to the University of Washington experienced significant ridership increases during fall 1992. The average daily ridership during the school year increased from 1,593 passengers in February to 2,739 passengers in October. This trend, which was also experienced on Seattle Metro service to the university, appears to be the result of the new U-Pass Program. To accommodate the increased ridership, articulated buses replaced regular buses on some routes.

Impact on I-5 North General-Purpose

Vehicle Volumes

Vehicle volumes for the I-5 North general-purpose lanes were obtained from the WSDOT ongoing monitoring program on the I-5 North freeway described previously. The examination of the vehicle volumes in the general-purpose lanes before and during the demonstration indicated a good deal of variability between days. Vehicle volumes for the three-lane section of the facility averaged between 4,000 and 5,000 vehicles for the morning peak hour, with slightly higher volumes during the afternoon peak hour. The vehicle volumes were generally similar during the complete time period, however, and no significant changes were discernible during the demonstration.

Travel Times

Travel times were estimated for vehicles in the general-purpose lanes using the same methodology described previously. The results of this analysis indicated that on average, travel times declined during the morning peak hour and increased during the afternoon peak hour during the demonstration. During the morning peak hour, travel speeds for vehicles in the general-purpose lanes decreased by almost 2 min. During the afternoon, however, travel times increased by 2 to 3 min. Field observations indicated that the increase in the afternoon travel time appears to be caused in part by traffic congestion resulting from the lane drop and merging occurring at the north end of the HOV lane.

Changes in Vehicle Occupancy Levels

The changes in personal vehicle occupancy levels on the I-5 North HOV facility were also examined. This analysis did not include bus ridership, which was examined separately. Personal vehicle occupancy levels on the I-5 facility were measured in 1989 and 1990 as part of the WSDOT Vehicle Occupancy Monitoring Project. Vehicle occupancy information was also collected for 4 days in July 1991, before the start of the demonstration. Similar surveys were conducted during the first 5 months of the demonstration.

Overall, the percentage of two-person carpools was higher in the afternoon peak period. This relates to the fact that there are more nonwork trips, which tend to have higher occupancy levels, in the afternoon. The results of the analysis further indicated that there was as increase in two person vehicles from 1989 to July 1991. After the initiation of the 2+ demonstration, two-person carpools increased from some 10.5 percent to 16.5 percent during the morning peak period. A similar, although smaller, increase also occurred during the afternoon peak period. The number of two-person carpools declined during the October to December time period, however, returning to approximately the same percentage as the period before the demonstration.

A different trend was found in three-person carpools. The percentage of three-person carpools on the I-5 North facility has historically averaged about 4 percent. During August and September, the first 2 months of the demonstration, the percentage of three-person carpools remained about the same. The percentage of three-person carpools dropped off considerably from October through December, however. In December, three-person carpools accounted for approximately 1 percent of the morning peak-period volumes.

Trends in the percentage of single-occupant vehicles (SOVs) on the I-5 North freeway were also examined. SOVs represented the largest percentage of vehicles using the facility both before and during the demonstration. The percentage of SOVs in the morning peak hour decreased slightly after the start of the demonstration, reflecting the increase in two-person carpools noted earlier. However, reflecting the mirror image of the trends described earlier, the percentage of SOVs increased again after October to a level slightly below the previous high in 1989 and 1990. The average vehicle occupancy level during the morning peak period in December was approximately 1.2 persons per vehicle, the same level as in 1989 and 1990.

Person Movement

The change in the vehicle occupancy requirement influenced not only the number of vehicles using the HOV lane, but also the number of people using the facility. On the basis of the Community Transit ridership information, it appears that ridership to downtown Seattle was slightly lower than the previous year, whereas ridership to the University of Washington increased significantly. In order to determine the impact the change in the occupancy requirement had on the person-movement levels in the I-5 North HOV lanes and the general-purpose lanes, a number of factors were examined. These factors included the increase in vehicles using the lane,

changes in the observed vehicle occupancy levels, and the results from the surveys of bus riders, carpoolers, and motorists.

The results of this analysis indicated that the person throughput for the total facility was greater during the demonstration period. A slight decline in the person throughput was noted during the demonstration period, however. Thus, in general, more people were being moved on the facility with the 2+ occupancy requirement than on the one with the 3+ occupancy requirement.

Accident and Safety Impacts

One of the objectives of the WSDOT freeway HOV system policy states that the HOV lanes should provide safe travel options for HOVs without unduly affecting the safety of the freeway general-purpose lanes. The intent of the safety analysis was to determine whether the reduction in the vehicle occupancy requirement altered the safety levels on the segment of I-5 North under study. Information from the WSDOT accident data base and accident reports from the Washington State Patrol were used for the analysis, which focused on identifying changes in safety conditions on both the HOV and general-purpose lanes in the study area and examining possible causes if any changes were found. The analysis of the accident information did not identify any specific trends or variations in the previous patterns that could be associated with the reduction in the vehicle occupancy requirement on the I-5 North HOV lanes.

Public Perception

The preamble to the freeway HOV system objectives outlined by WSDOT notes that public support is critical to the success of the HOV system. Previous surveys (*7*) conducted by WSDOT and Seattle Metro have indicated that the HOV lanes have been received positively by users, nonusers, and the general public in the Seattle area. Surveys of bus riders, carpoolers, and motorists in the I-5 North corridor were conducted to obtain additional information on the perceptions of these user groups concerning the change in the occupancy requirement.

A survey of Community Transit bus riders was conducted on Thursday, November 21, 1991. Approximately 1,300 surveys were distributed; 925 were returned, yielding a response rate of about 71 percent. License plates were recorded in November of carpools in the HOV lane and motorists in the general-purpose lanes. Surveys were then mailed to those two groups. A total of 534 surveys was mailed to motorists; 160 were returned, yielding a response rate of 30 percent. Six hundred surveys were mailed to carpoolers; 57 completed forms were returned, a response rate of 10 percent. The low response rate for the carpool and motorist surveys may be due to the holidays. As a result of the low response rate, it was not possible to draw statistically significant conclusions from the carpool and motorist surveys. However, the results were used to identify general trends.

The results of the surveys of Community Transit bus riders, carpoolers, and motorists indicated a general support for the HOV lanes, but showed a mixed response to the reduction in the occupancy requirement on the I-5 North HOV lanes. More than 90 percent of the bus riders and carpoolers and 82 percent of the motorists surveyed believed that the I-5 HOV lanes were good transportation improvements. A lower percentage, ranging from 42 percent to 74 percent, indicated that they felt the lanes were currently being sufficiently used. Slightly more than 50 percent of the motorists surveyed believed that traffic conditions in the general-purpose lanes had improved since the change in the occupancy requirement was made, and only 15 percent reported encountering problems in the general traffic lanes that may have resulted from the lower occupancy requirement. Almost 50 percent of the carpool respondents indicated that they had not encountered any difficulties with the HOV lanes since the change.

Some 23 percent of the carpoolers responding to the questions indicated that travel times appeared longer, however, and 21 percent reported problems entering or exiting the lane. An even larger number of bus riders reported problems after the occupancy change was made. Some 47 percent indicated that travel times appeared longer, 23 percent reported buses were not always on schedule, and 5 percent noted they had missed connections. More problems were noted by bus riders for afternoon trips than morning trips. Finally, the response to the question on whether permitting 2+ carpools was a good move varied by user group. Approximately 92 percent of the motorists and 83 percent of the carpoolers surveyed indicated strong support for the change, whereas only 39 percent of the bus respondents favored the change.

Many of the respondents to all three surveys provided additional comments. A number of bus riders indicated problems with slower travel times and many strongly supported a return to the 3+ occupancy requirement. These concerns were also reflected in a petition received by Community Transit in September and telephone calls from bus riders complaining about the negative impacts on bus service since the change. A number of comments on all three surveys strongly supported extending the HOV lanes further in the northbound direction.

CONCLUSIONS

A number of observations may be made concerning the 6-month evaluation of the 2+ demonstration project on the I-5 North HOV lanes. These observations are related to both the demonstration and the evaluation process and the results of the 6-month evaluation. These observations, which are discussed briefly in this section, should be of interest on both a local and national level.

First, the evaluation of the I-5 North 2+ demonstration was limited by data availability because the demonstration was implemented on short notice. Consequently, few "before" data were collected, which limited the ability for meaningful comparisons to be made with the data collected during the demonstration. The importance of adequate "before" and "after" data has been stressed in other studies (*4,8*). The I-5 North evaluation further supports this need.

Additional data-related problems were encountered during the study. Although historical data on vehicle volumes, ac-

cidents, and other information needed in the evaluation have been maintained, obtaining it was often difficult. This further supports the importance of maintaining ongoing transportation data bases with easy access. The WSDOT monitoring system is one of the better systems in the United States, and improvements are being made to facilitate access to the data. This will benefit future evaluations and studies.

The results of the 2+ demonstration indicated ambiguous evidence concerning the relationship between the 2+ carpool definition and the WSDOT HOV System Policy objectives and other related policies. This was due to the limitations of the evaluation just noted, the short time period covered by the evaluation, and the ambiguity of some of the HOV System Policy objects and the lack of specific measures of effectiveness. The difficulty in drawing conclusions on some of the objectives is discussed here briefly.

The first objective of the HOV System Policy is to "improve the capability of congested freeway corridors to move more people by increasing the number of persons per vehicle." The demonstration results indicated that more people were traveling on the I-5 facility during the peak period during the demonstration. However, the number of persons per vehicle was lower during the October to December period than it was in the week before the demonstration started. The percentage of SOVs increased, and the percentage of 3+ carpools decreased. The percentage of two-person carpools increased initially, but went back down to predemonstration levels. Data also indicated that on a monthly basis Community Transit ridership levels to the downtown during the demonstration were approximately the same or slightly lower than those of the previous year.

A number of questions arise concerning these data, however. The decrease in 3+ person carpools may be attributable to the change in the occupancy requirement. However, the increase in SOVs may come from several sources, including shifts from parallel arterials, shifts from earlier and later time periods, and latent demand filling the additional capacity. Ridership on Community Transit increased to the university at a level comparable to the increase experienced by Metro Transit that was attributable to the U-Pass. The lower ridership levels from the previous year to downtown Seattle may have been partially attributable to the lack of increase in service, the general downturn in the economy, and poor weather conditions in the previous year, which resulted in some of the highest ridership levels recorded by Community Transit. However, survey data and other responses from bus riders show that they did notice a decline in the service reliability for buses using the I-5 HOV lanes.

The second objective in the HOV System Policy is to "provide travel time savings and a more reliable trip time to high-occupancy vehicles utilizing the facilities." During the demonstration, HOVs still saved time, on the average, by using the HOV lanes. However, the travel-time savings in the morning decreased, and the increase in travel-time savings in the afternoon from a decrease in speed in the general-purpose lanes. Furthermore, reliability of travel time was degraded.

During the demonstration, conditions in the morning and afternoon peak periods were quite different. During the morning peak hour, travel times for HOVs did not change significantly. Travel times in the general-purpose lanes actually decreased during a season when increased congestion is normal. This improvement in general-purpose travel times may have been due to a combination of an increase in transit usage to the university, resulting from the U-Pass, and the ability of two-person carpools to use the HOV lanes.

For the afternoon, the results were different, with travel times in both the HOV lanes and the general-purpose lanes increasing. The major difference in the two time periods is partially a result of an existing bottleneck at the north end of the corridor, in the northbound direction. At this point, the HOV lane ends, a general-purpose lane drops, and the resulting merging often causes traffic to back up. The impact of this bottleneck was exacerbated during the demonstration by the large volumes of vehicles in the HOV lane. The increase in volume may be due partially to increased demand historically experienced in the fall. Unfortunately, comparable travel-time information was not available from previous years to compare the change to the normal seasonal change in congestion.

Travel-time reliability for HOVs declined during the demonstration. The standard deviation for travel speed doubled in the morning and increased by approximately 50 percent in the afternoon. On-time performance for Community Transit buses declined compared with the first part of the year. Bus riders responding to the surveys noted that travel-time reliability, especially in the afternoon, was worse during the demonstration, and additional complaints have been received by Community Transit.

It appears that travel-time reliability declined even when the average travel time did not change significantly. The reason for this was that with a 3+ carpool definition and vehicle volumes no higher than 500 to 600 in the peak hour, vehicles in the HOV lane have virtually always enjoyed free-flow conditions. With the additional vehicles in the HOV lane resulting from the change to the 2+ definition, traffic volumes reached levels at which the flow occasionally broke down.

The information presented in this paper should be of benefit on both a local and a national level. At the local level, the results of the 6-month demonstration provide useful data for making future decisions on to the vehicle occupancy levels for the I-5 North HOV lanes and for other HOV facilities in the Seattle area. On a national level, the information provides an enriched understanding of the consequences of changing HOV lane vehicle occupancy requirements. As such, this paper further enhances the common body of knowledge on the use and impacts of HOV facilities.

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