Research Report
Agreement T4118, Task 24
HOV Action Plan

HOV ACTION PLAN

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16. ABSTRACT

Despite the fact that travel speed and reliability on numerous segments of the high-occupancy vehicle (HOV) lanes of the central Puget Sound freeway network are not meeting the adopted state performance standard, trends suggest that HOV travel demand is expected to increase. This study was conducted to evaluate the performance of Interstate 5 HOV lanes between Federal Way and Everett, Washington, focusing on congestion; to identify congestion bottleneck segments and potential causes; and to develop a range of potential short-term (0 to 5 years) enhancements to improve HOV traffic flow at bottlenecks.

A review of estimated speeds and vehicle volumes for 2007 determined that the I-5 HOV corridor as a whole does not meet the state standard during the peak travel periods in the dominant direction of traffic (inbound to Seattle from the south and north in the AM peak, outbound from Seattle in the PM peak). Eight HOV lane segments were specifically identified as bottleneck locations of heavy congestion.

The report details possible causes of congestion in these areas: heavy usage of the HOV lane, roadway geometry, lane friction, merging conflicts, slow vehicles, and incidents. The report also discusses short-term options for addressing congestion at these locations: implementing general purpose on-ramp metering, implementing inside HOV on-ramp metering, moving the HOV lane endpoint approach the northbound express lane entrance, strengthening the incident response program, introducing buffer separation, reconfiguring express lane ingress/egress, introducing active traffic management, reserving HOV lanes for bus transit only, and changing the occupancy requirement from 2+ to 3+. The advantages, disadvantages, and other issues related to these options are also discussed.

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INTRODUCTION

Performance data indicate that travel speed and reliability in the high-occupancy vehicle (HOV) lanes of the central Puget Sound freeway network are not meeting the adopted state performance standard on an increasing number of segments. Furthermore, trends suggest that HOV travel demand is expected to increase. Therefore, as part of the Washington State Department of Transportation's ongoing efforts to improve highway system efficiency, it conducted a research study to analyze the performance of the HOV lane network on freeways in the Seattle area and develop an action plan of potential congestion mitigation strategies. This effort had the following components:

- Evaluate the existing performance of Seattle-area HOV lanes, focusing on congestion.
- Identify congestion bottleneck segments and potential causes.
- Develop a range of potential short-term (0 to 5 years) enhancements to improve HOV traffic flow at bottlenecks.

This document summarizes the results of analyses, begun in July 2007, on the HOV lane network on Interstate 5 between Federal Way and Everett.

INTERSTATE 5 HOV LANE USAGE

An evaluation of 2007 vehicle usage on Interstate 5 in the Seattle area showed that the HOV lanes carry significant vehicle volumes throughout the corridor during the peak periods, with some segments carrying 1500 or more vehicles per hour in the peak hour. HOV lane person volumes are also high. At peak locations during the peak periods, the HOV lane moves more people in fewer vehicles than the adjacent non-HOV lanes. For example, at Northgate during the AM peak period, the southbound HOV lane carries 44 percent of the persons traveling on all lanes of Interstate 5, in only 21 percent of the vehicles. Figures 1 and 2 show the peak-hour volume profile in the HOV lane along the I-5 corridor.

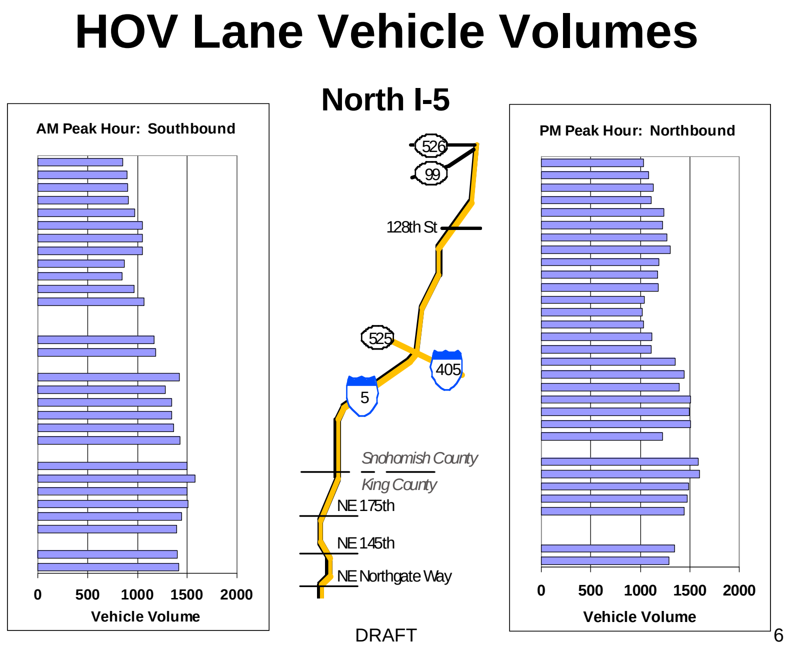

Figure 1. HOV Lane Vehicle Volumes North I-5

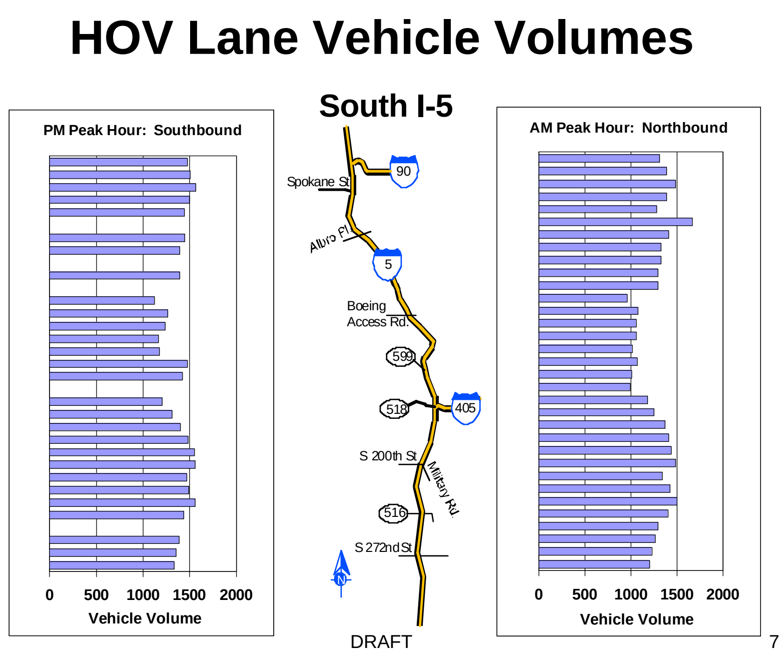

Figure 2. HOV Lane Vehicle Volumes South I-5

INTERSTATE 5 HOV LANE PERFORMANCE

The Washington state HOV performance standard states that vehicles in the HOV lane should be able to maintain an average speed of 45 mph or higher, at least 90 percent of the time, during the peak hour of travel.

With this in mind, the HOV lane network in the Seattle area was evaluated to identify congested segments of the Interstate 5 HOV lane corridor that do not meet the state standard. A review of estimated speeds and vehicle volumes for 2007 determined that the I-5 HOV corridor as a whole does not meet the state standard during the peak travel periods in the dominant direction of traffic (inbound to Seattle from the south and north in the AM peak, outbound from Seattle in the PM peak). Specifically, eight HOV lane segments were identified as bottleneck locations of heavy congestion. Figures 3 and 4 illustrate the locations of those segments, as well as the estimated extent and severity of peak period congestion at each segment.

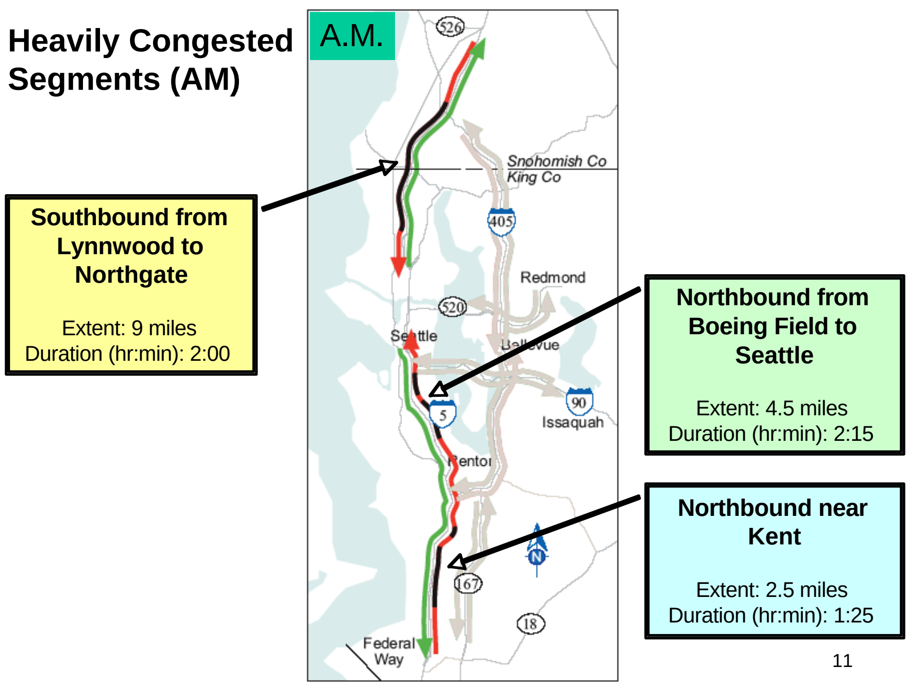

Figure 3. AM Peak Period Congestion

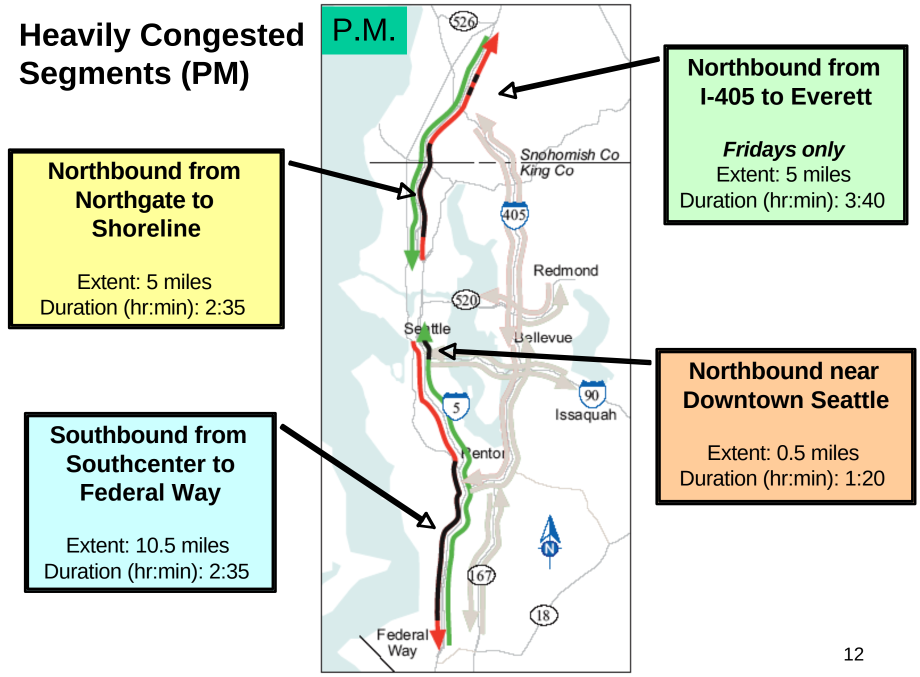

Figure 4. PM Peak Period Congestion

POSSIBLE CAUSES OF CONGESTION ON THE INTERSTATE 5 HOV LANE NETWORK

Congestion in the HOV lane can be caused by one or more of the following:

Heavy Usage of the HOV Lane

Heavy vehicle volumes on the HOV lane produce congestion and slow traffic conditions. Typical areas where HOV lane vehicle volumes are high include popular commuting routes, such as travel toward downtown Seattle in the AM peak period (from the south and the north) and away from Seattle in the return PM peak period. In addition, heavy use of the HOV lanes can occur at some locations as a result of special events, such as downtown Seattle concerts or sporting events, or because of recreational travel, such as the traffic on routes leaving Seattle just before the weekends.

Roadway Geometry

The geometry of the HOV lane can also affect traffic by introducing a disruption in the smooth flow of vehicles. Examples include locations where the HOV lane ends at the edges of the HOV network (or approaches the gap in the HOV network in downtown

Seattle); at these locations high-occupancy vehicles must exit the HOV lane and merge into (potentially) slower general traffic. For HOVs traveling on more than one corridor (e.g., from Interstate 5 to Interstate 405), the gap in the HOV lane at a freeway interchange requires HOVs to merge back into general traffic temporarily, potentially causing slowing and congestion. Unusual general purpose exit locations, such as an inside (left side) off-ramp, forces exiting vehicles to temporarily mix with HOVs that are on the inside HOV lane, causing potential slowing. In some cases, unusual road curvature or banking can cause drivers unfamiliar with the area to slow in response.

Lane Friction

"Lane friction" refers to the slowing of vehicles in the HOV lane because of the presence of slow vehicles in the adjacent general purpose lane. The speed differential between the HOV lane and the adjacent lane can cause travelers in the HOV lane to decelerate in anticipation of slow-moving vehicles suddenly merging into the HOV lane. It can also cause vehicles in the HOV lane to slow as they prepare to change lanes into the slow-moving adjacent traffic in order to access exit ramps on the right side of the freeway.

The effect of friction is reduced when there is less expectation that vehicles will change lanes into the HOV lane, and when easier merge opportunities exist for leaving the HOV lane. For example, the friction effect is lower in the middle of a traditional commute route, where vehicles tend to stay in their lanes as part of their commute routine. Also, a corridor with fewer on- and off-ramps (and therefore fewer vehicles moving to and from those ramps) will have fewer lane changes and therefore a limited friction effect.

Merging Conflicts

More generally, any type of merging into a well-used HOV lane can cause slowing and congestion. For example, a direct access ramp that provides a connection from a nearby park-and-ride directly to the inside HOV lane can cause slowing at the merge point. Also, closely spaced on-ramps can introduce HOV traffic to the general purpose lanes that will eventually want to merge into the HOV lane.

Slow Vehicles

The presence of a slow vehicle in the HOV lane can cause a "moving bottleneck," particularly when the adjacent general purpose lane is congested. In such a case, there is limited ability to pass on the right (because of slow adjacent traffic) and no ability to legally pass on the left (the shoulder). The resulting platoon of backed-up vehicles can cause congestion. The slow vehicle can take the form of a slow-moving car or bus that is staying in the HOV lane, a slowing vehicle in the HOV lane preparing to merge into an adjacent congested lane, a vehicle affected by lane friction, or a vehicle still accelerating after entering the freeway from a left-hand direct access ramp. Given the constrained ability to pass slower vehicles in an HOV lane, it only takes one such vehicle to cause spot slowing or congestion.

Incidents

Just as with general purpose lanes, the HOV lane can be affected by incidents, not only in the HOV lane but also in adjacent lanes. Blocking incidents in the HOV lane will, of course, produce congestion, but incidents in the GP lanes or the far right shoulder can also cause GP lane congestion and thus associated lane friction for the HOV lane. Incidents also produce "rubber necking" from drivers in the HOV lane, causing vehicle speeds to slow in the HOV lane. Incidents on the left shoulder can also introduce friction effects.

Figure 5 illustrates how these causes of HOV lane congestion are associated with the bottleneck segments identified previously. Note the widespread nature of many of these causes, suggesting that it is unlikely that any one mitigation strategy can fully address all congestion issues at a given location.

	Location	Heavy Volumes	Roadway Geometry	Friction with Slower Vehicles	Merging Conflicts	Slow Vehicles	Incidents
1A	I-5 Southbound AM approaching Northgate	●	●	●	●	●	●
1B	I-5 Southbound AM near Lynnwood	●	●	●	●	●	●
2	I-5 Northbound AM near Federal Way	●		●	●	●	●
3	I-5 Northbound AM approaching Seattle CBD	●	●	●	●	●	●
4	I-5 Northbound PM near the County Line	●		●	●	●	●
5	I-5 Northbound PM north of Swamp Creek	●		●		●	●
6	I-5 Southbound PM south of Southcenter	●	●	●		●	●
7	I-5 Northbound PM approaching Seattle CBD	●	●	●		●	●

Figure 5. Bottleneck Locations and Possible Causes

SHORT-TERM OPTIONS TO ADDRESS CONGESTION AT HOV LANE BOTTLENECKS

A range of potential short-term options to address congestion on HOV lanes has been identified. These options are grouped into operational changes, capital projects, and changes to HOV policy. These options are summarized in Figure 6.

	Heavy Volumes	Roadway Geometry	Lane Friction	Merging Conflicts	Slow Vehicles	Incidents
Operational Strategies						
Meter NE 145th southbound I-5 Ramp	●		●	●		●
Meter Direct Access Ramps		●		●	●	●
Meter South Area I-5 Ramps	●		●	●		●
Move HOV Lane Restriction	●	●		●	●	●
Expand Incident Response	●			●		●
Capital Projects						
HOV Buffer			●	●		●
Distributed Express Lane Access and Exit	●	●		●		●
Active Traffic Management	●		●			●
Policy Changes						
Change Occupancy Requirement	●			●		●
Reserve HOV Lane for Transit	●	●	●	●	●	●

Figure 6. Possible options

Options 1 and 2 (operational change): Implement General Purpose On-Ramp Metering

These options would implement metering on non-metered general purpose on-ramps. The goal would be to reduce conflicts and congestion associated with merging and to distribute incoming vehicles that might otherwise produce congestion, lane friction, and merging congestion. Possible metering locations include the NE 145th southbound on-ramp (option 1), as well as northbound and southbound on-ramps between Federal Way and S. 188th (option 2). These locations are all within I-5 segments with congested HOV lanes.

Option 3 (operational change): Implement Inside HOV On-Ramp Metering

This option would implement metering on inside lane on-ramps (direct access ramps) that feed directly into the HOV lane. The goal would be to reduce conflicts and spot slowing associated with vehicles merging directly into the HOV lane. Possible locations include the direct access ramps at Lynnwood and Federal Way. While peak volumes from those ramps are not high (200 vehicles per peak hour at Lynnwood, 120 per peak hour at Federal Way), individual vehicles can still produce spot slowing near the merge point. This slowing can be exacerbated by vehicles that travel more slowly or that have slower acceleration characteristics, such as transit buses. Although the lower volumes might limit the cumulative significance of any resulting spot slowing, this option does point out the importance of following a strategic approach to direct access ramp implementation, with a placement approach that takes into account possible effects such as spot slowing.

Option 4 (operational change): Move the HOV Lane Endpoint Approaching the Northbound Express Lane Entrance

This option would end the northbound HOV lane (south of Seattle) farther upstream (south). In the existing configuration, the northbound HOV lane continues to just before downtown Seattle. At that point, the HOV-only designation ends, and the lane becomes the on-ramp to the express lanes. Furthermore, the lane to its right becomes the off-ramp to Seneca Street. Vehicles in the right lane that wish to enter the express lane but are not HOVs must wait until the end of the HOV lane to access the express lane entrance. The goal of this option would be to reduce conflicts and spot slowing by extending the segment in which merging can take place, thereby reducing the concentrated merge and lane changing that occurs at the existing end of the HOV lane.

Option 5 (operational change): Strengthen the Incident Response Programs

This option would put continued emphasis on incident response efforts to attend to and clear blocking incidents in both general purpose and HOV lanes in order to reduce their effects on congestion.

Option 6 (capital project): Introduce Buffer Separation

This option would explore the use of a 2-foot to 4-foot buffer to separate the HOV lane from the other lanes and to possibly act as a no-cross zone as well. The goal of this buffer would be to reduce the effects of friction and merging (in the case of no-crossing zones).

Option 7 (capital project): Reconfigure Express Lane Ingress/Egress

This option would address the concentrated merging and exiting that occur at the north exit from the express lanes near Northgate. At that point, the HOV express lane becomes the mainline HOV lane heading northbound, which means that HOVs already in the mainline that wish to enter the HOV lane must weave through vehicles exiting from the express lanes. The goal of this option would be to provide an additional **HOV ingress point** to the express lanes that would give mainline HOV traffic another location at which to enter the HOV lane, as well as an additional **GP egress point** from the express lanes to provide general purpose vehicles with another opportunity to exit. By distributing vehicles at several different locations, the concentrated conflicts at the north express lane exit could be reduced.

Option 8 (capital project): Introduce Active Traffic Management

This option would use detector, signage, and communications technology to flexibly manage traffic systems. The objective would be to use information about changing traffic conditions to dynamically manage both HOV and GP freeway performance more efficiently. Examples of HOV lane management include variable time of day HOV lane use, variable HOV occupancy requirements, or HOT lane operation.

Option 9 (policy): Reserve HOV Lanes for Bus Transit Only

This option would manage HOV lane volumes by restricting use to transit. An example application could restrict southbound HOV lanes approaching Seattle to bus rapid transit serving Northgate, the University District, and downtown Seattle.

Option 10 (policy): Change the Occupancy Requirement from 2+ to 3+

This option would manage HOV lane volumes by restricting HOV lane use to 3+ person carpools. Given that about 70 percent of vehicles in I-5 HOV lanes in the Seattle area are 2-person carpools, a 3+ requirement would likely reduce HOV lane volumes significantly, even given that some 2-person carpools might re-form as 3+ carpools.

SUMMARY OF FINDINGS

The I-5 corridor features heavy peak period vehicle volumes in the HOV lane (at many locations near or above 1500 vehicles per hour during the peak hour), with significant volumes during the shoulders of the peak periods as well. At those volumes the I-5 HOV lanes are subject to the congestion-causing factors common to a general purpose, heavy volume roadway. Such peak volumes are approaching the maximum volume throughput that one can anticipate in an HOV lane; data from the Seattle area and other regions are consistent with the view that HOV lanes have a lower maximum volume limit than adjacent general purpose lanes, in part because of the constraints imposed by lane friction and the inability of faster moving HOVs to pass slower moving HOVs.

At the same time, while heavy vehicle volumes in the HOV lane (and the adjacent GP lanes) are often a significant factor in HOV lane congestion, there are instances at specific bottlenecks where other factors also have an effect. Because volume management strategies that focus on either volume reduction via restricted HOV lane access or capacity expansion at the identified bottlenecks would be difficult to implement in the short term, it is important to analyze the potential usefulness of options that will provide strategic improvements in the short term even when the HOV lane is operating at existing volume levels.

Congestion at HOV lane bottlenecks is typically associated with more than one cause. A review of the eight bottleneck segments identified in this analysis showed that every bottleneck was influenced to some extent by at least four of the six potential causes of HOV lane congestion analyzed in this project. This suggests that no one strategy is likely to be sufficient in mitigating HOV lane congestion throughout the network.

While a range of policy strategies is available that could improve specific bottlenecks and restore their performance to the state standard, such options might face significant public and/or political consequences. Policy changes that restricted use of the HOV lane (e.g., bus rapid transit only, 3+ only) might run counter to many users' expectations about the goals and accessibility of the HOV lane system and provoke significant negative reactions. It is uncertain whether such options are politically feasible, at least in the short term.

Some of the short-term strategies could involve a significant monetary cost. Capital projects (buffer separation, express lane ingress/egress reconfiguration, ATM) all have potentially significant costs that might affect their feasibility as a short-term strategy.

Some of the short-term strategies would remove bottlenecks and restore performance to the state standard but with significant tradeoffs. Policy strategies that attempted to manage volume-driven congestion by imposing stricter eligibility requirements for the HOV lane could improve HOV speed and reliability to meet the state standard, but the cost might be lower overall freeway performance in the form of lower vehicle and person throughput as vehicles are diverted into already congested general purpose lanes.

While a number of the short-term strategies described above might improve HOV congestion at bottleneck segments, they would not likely be sufficient to bring the entire I-5 HOV lane corridor into full compliance with the state speed and reliability standard, in part because of the constraints imposed by lane friction. The widespread presence of significant and long-lasting general purpose lane congestion throughout the network means that even if a number of the individual short-term treatments described here were implemented, their effect could be constrained as long as lane friction continued to impose a restriction on HOV lane performance.

Given the likelihood that general purpose lane congestion will not be resolved in the short term, short-term strategies that address friction issues, such as buffer treatments and possibly limited access points, may be useful ways to combat HOV lane performance issues. Additional research of these options and their feasibility along the I-5 corridor would be helpful.