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HOV Monitoring V

# HOV LANE PERFORMANCE MONITORING: 2000 REPORT

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16. ABSTRACT

High occupancy vehicle (HOV) lanes, also known are carpool lanes and diamond lanes, are designated for use by carpoolers, transit riders, ridesharers, and motorcyclists that meet the occupancy requirement. By restricting access, the HOV lanes benefit users by allowing them to travel the freeway system at a faster speed, thus saving time and experiencing greater travel time reliability in comparison to motorists on general purpose (GP) lanes. To accurately evaluate the system's effectiveness, a state policy requires an annual HOV system report to document system performance, examining the HOV lanes' person-carrying capability, travel time savings, and trip reliability benefits in comparison to adjacent GP lanes, as well as the lanes' violation rates.

This report describes the results of an extensive monitoring effort of HOV lane use and performance in the Puget Sound area in 2000. It presents an analysis of data collected to describe the number of people and vehicles that use those lanes, the reliability of the HOV lanes, travel time savings in comparison to general purpose lanes, violation rates, and public perceptions. This information is intended to serve as reliable input for transportation decision makers and planners in evaluating the impact and adequacy of the existing HOV lane system in the Puget Sound area and in planning of other HOV facilities.

Descriptions of the tool set and methodology for analyzing HOV facility usage and performance in terms of vehicle and person throughput, travel time, and speed reliability measures are provided in a separate report, *Evaluation Tools for HOV Lanes Performance Monitoring*.

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# CHAPTER 1.
# INTRODUCTION

High occupancy vehicle (HOV) lanes, also known as carpool lanes and diamond lanes, are designated for use by carpoolers, transit riders, ridesharers, and motorcyclists who meet the occupancy requirement. By restricting access in this way, the HOV lane benefits users by allowing them to travel the freeway system at a faster speed, thus saving time and experiencing greater travel time reliability in comparison to motorists on general purpose (GP) lanes. As indicated in the *1992 Washington State Freeway HOV System Policy* report, the objectives of the HOV facilities are threefold:

- Improve the capability of congested freeway corridors to move more people by increasing the number of people per vehicle
- Provide travel time savings and a more reliable trip time to high occupancy vehicles that use the facilities
- Provide safe travel options for high occupancy vehicles without unduly affecting the safety of freeway general-purpose mainlines

To ensure that these incentives for HOV users provide benefit, a state policy related to speed and reliability standards has been established. It states that any HOV facility "should maintain or exceed an average speed of 45 mph or greater at least 90 percent of the time" during the peak hour. To accurately evaluate the system's effectiveness, the policy also requires an annual HOV system report to document system performance, examining the HOV lanes' person-carrying capability, travel time savings, and trip reliability benefits in comparison to adjacent GP lanes, as well as the lanes' violation rates.

## REPORT OBJECTIVE

The objective of this report is to illustrate the performance of the HOV facilities in the Puget Sound area by using an advanced set of performance measures and tools. These results can help guide transportation decision makers and planners in evaluating the impact and adequacy of the existing HOV lane system in the Puget Sound area and in planning for other HOV facilities.

Descriptions of the tool set and methodology for analyzing HOV facility usage and performance in terms of vehicle and person throughput, travel time, and speed and reliability measures are provided in a separate report titled *Evaluation Tools for HOV Lanes Performance Monitoring*.[1] The raw vehicle occupancy data collected as part of this report can be obtained from an Internet Web site at the following URL:

http://depts.washington.edu/trac/hov/

Users should note, however, that this Web site is still experimental and may not always be functional.

## STUDIED CORRIDORS

HOV lanes exist in major corridors around the Puget Sound area. Virtually all HOV lanes are available 24 hours a day, 7 days a week for vehicles that meet the occupancy requirement. The occupancy requirement for HOV lanes on limited access freeways is two or more persons, with the exception of the SR 520 westbound lanes, which have a 3+ passenger requirement. Other exceptions to the occupancy requirement include motorcyclists, who may travel on any HOV lane, and SOVs traveling on the I-90

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[1] Nee, Jennifer, et. al., *Evaluation Tools for HOV Lanes Performance Monitoring*, for the Washington State Department of Transportation, WA-RD 473.2, August 1999

reversible lanes between Mercer Island and Seattle. Operational specifications for each of the studied HOV facilities are provided in Table 1-1.

This report presents corridor-wide and location specific HOV performance results for the following corridors: I-5, I-405, I-90, SR 520, and SR 167. Analysis on other corridors and locations (i.e., SR 16, SR 410, and SR 512) were not feasible because of limited data availability. Transit services offered on the measured corridors include Community Transit, Metro Transit, Pierce Transit, and Sound Transit, which provide express service to several downtown locations and across Lake Washington. As of late 1998, all HOV lanes have operated along the freeway median, with the exception of the HOV lane on SR 520, which is located along the shoulder. The outside to inside HOV lane conversion for I-405 north of the I-90 interchange was completed in autumn 1998.

**Table 1-1. HOV System in Washington State**

| *HOV Corridors* | *Geometric* | *Direction* | *Number of Lanes* | *Operating Hours* | *Occupancy Requirement* |
|---|---|---|---|---|---|
| I-5 | Concurrent Flow<br><br>Barrier Separated Express Lane Reversible Flow | NB, SB<br><br>SB (AM only) | 1 each direction | 24-hr | 2+ HOVs |
| I-405 | Concurrent Flow | NB, SB | 1 each direction | 24-hr | 2+ HOVs |
| I-90 | Concurrent Flow<br><br>Barrier Separated Reversible Flow | WB, EB<br><br>WB (AM only)<br>EB (PM only) | 1 each direction<br><br>2 reversible | 24-hr | 2+ HOVs |
| SR 520 | Concurrent Flow | WB | 1 (WB only) | 24-hr | 3+ HOVs |
| SR 167 | Concurrent Flow | NB, SB | 1 each direction | 24-hr | 2+ HOVs |

## MEASURES OF EFFECTIVENESS

The measures of effectiveness (MOEs) for this project provide a valid basis for evaluating the performance of the current HOV lane system. In addition to their usefulness in decision-making concerning lane configuration, occupancy requirement policies, and general purpose lane conversion, the MOEs also serve WSDOT's needs for information to help determine where and when to construct new HOV facilities. As stated by the WSDOT's *HOV Lane Minimum Threshold Policy*, four preconditions for HOV lane construction must exist:

1. facility demand exceeds capacity for more than one hour each day
2. evidence exists that an HOV lane will move more people per hour during peak periods than the per-lane average of the adjacent general purpose lanes
3. there is local support for HOV lane construction
4. the HOV lane segment will improve continuity by linking other HOV lane corridors identified in the *Year 2000 HOV Core Lane System* report

The impact of the HOV system is reflected by primary measures of effectiveness such as person throughput, vehicle occupancy, travel time, speed, and reliability. The ability of the HOV facility to carry more people is reflected by measures of vehicle and person throughput, as well as by vehicle occupancy. Travel time speed and trip reliability illustrate the performance of the HOV facility. Secondary performance measures include enforcement and violation rates along the HOV lane system. In addition to the analysis supported by the quantitative data, it is also important to assess how the public perceives the performance of the HOV facility. A brief description of the primary and secondary measures on which the data collection efforts focused is provided below.

**Primary Measures**

- **Vehicle Volume**—Number of vehicles recorded passing a given freeway location during weekday morning and evening peak commute periods, as well as over an average 24-hour weekday.

- **Person Volume**—Number of passengers measured at a given freeway location during weekday morning and evening peak commute periods.

- **Average Vehicle Occupancy**—Average number of occupants in a vehicle, which includes persons in cars, vanpools, and transit buses, at a given freeway location during weekday morning and evening peak commute periods.

- **Speed and Trip Reliability**—Average vehicle speeds based on the average travel time for a given trip. Trip reliability refers to the percentage of time that the vehicle travels less than 45 mph.

- **Travel Time**—Average time in hours and minutes required to complete a trip from point A to point B based on trip start time, throughout an average weekday.

This report deals primarily with ***peak period***, not peak hour, statistics for HOV use. The peak periods are defined as 6:00 AM to 9:00 AM and 3:00 PM to 7:00 PM on weekdays. Peak period is used in place of peak hour because it does a more complete job of explaining facility performance during the busiest parts of the day, and it includes the majority of commute trips. Because of the expansion of the peak travel periods beyond a single hour, peak hour statistics do a poor job of explaining both growth in facility use and the length and duration of congestion associated with facility use.

**Secondary Measures**

- **HOV Violations**—Because restrictions along the Puget Sound freeway HOV system apply 24 hours a day, the only violation to enforce is when motorists don't meet the minimum occupancy requirement. Indicators for HOV violations include violations observed on area highways by traffic observers, tickets and warnings issued by law enforcement officers, activity levels on the region's violation reporting hotline (764-HERO), and the support of the judicial system when tickets are contested in the courts.

- **Public Opinion—**Public opinion data indicate the HOV program's perceived importance and effectiveness, as well as ways it may be modified to appeal to more of the region's drivers. This report presents public opinion data that rank various options to improve the HOV system and that indicate differences in opinion between ridesharers and SOV commuters regarding HOV related issues.

## REPORT ORGANIZATION

This report provides the results of an analysis of HOV system performance. Chapter 2 illustrates HOV lanes' success at moving people and vehicles. Speed and reliability for HOV lanes and travel time comparisons between GP and HOV lanes are in Chapter 3. HOV violation information is discussed in Chapter 4. Chapter 5 includes the results of the last major public opinion survey that WSDOT performed concerning HOV lanes.

# CHAPTER 2.
# THROUGHPUT

To investigate the effectiveness of the HOV system, person and vehicle volumes were analyzed at specific sites along major HOV corridors. The results were then compared with those of GP lanes for morning and afternoon peak periods (e.g., 6:00 AM-9:00 AM, 3:00 PM-7:00 PM) in the direction of heaviest traffic flow (directional flow). The purposes of these measures are to determine (1) whether the HOV lane is enhancing the person-carrying capacity of the system, and (2) to what extent an HOV lane is being used. Various types of HOV performance are reflected in the following sections:

- **General Results**

  General comparison of HOV vs. GP person throughput on a per-lane basis is provided for the representative sites over the defined peak periods. HOV person-carrying ability is described by the rate of average vehicle occupancy (AVO). Mode split and bus ridership in HOV lanes are also presented.

- **HOV Volume Flow**

  To examine more closely the extent and variation of changes in vehicle volumes observed along HOV corridors, HOV volumes along HOV corridors are depicted geographically during the peak periods for average weekdays. These graphics help identify directional patterns as well as locations with high and low HOV usage.

- **GP vs. HOV 24-hour Volume Profile**

  A 24-hour average daily traffic volume profile for each combination of lane type and traffic direction is presented for each of the representative sites. For each location, the 24-hour GP and HOV volumes are expressed as volume per lane per hour (vplph) for both directions.

- **GP vs. HOV Throughput Comparison**

  Person and vehicle volumes for HOV and GP lanes are compared by lane type (i.e., GP, HOV) and by per-lane unit for both morning and afternoon peak periods for each representative site. The average vehicle occupancy rate is also presented. The per-lane comparison allows a true comparison between HOV and GP lane vehicle- and person-carrying abilities.

Eleven representative sites were selected in the major corridors (I-5, I-405, I-90, SR 167 and SR 520) for detailed usage analysis (see Figure 2-1). Selection was based on points of interest and the availability and usability of input data in 2000 (Table 2-1).

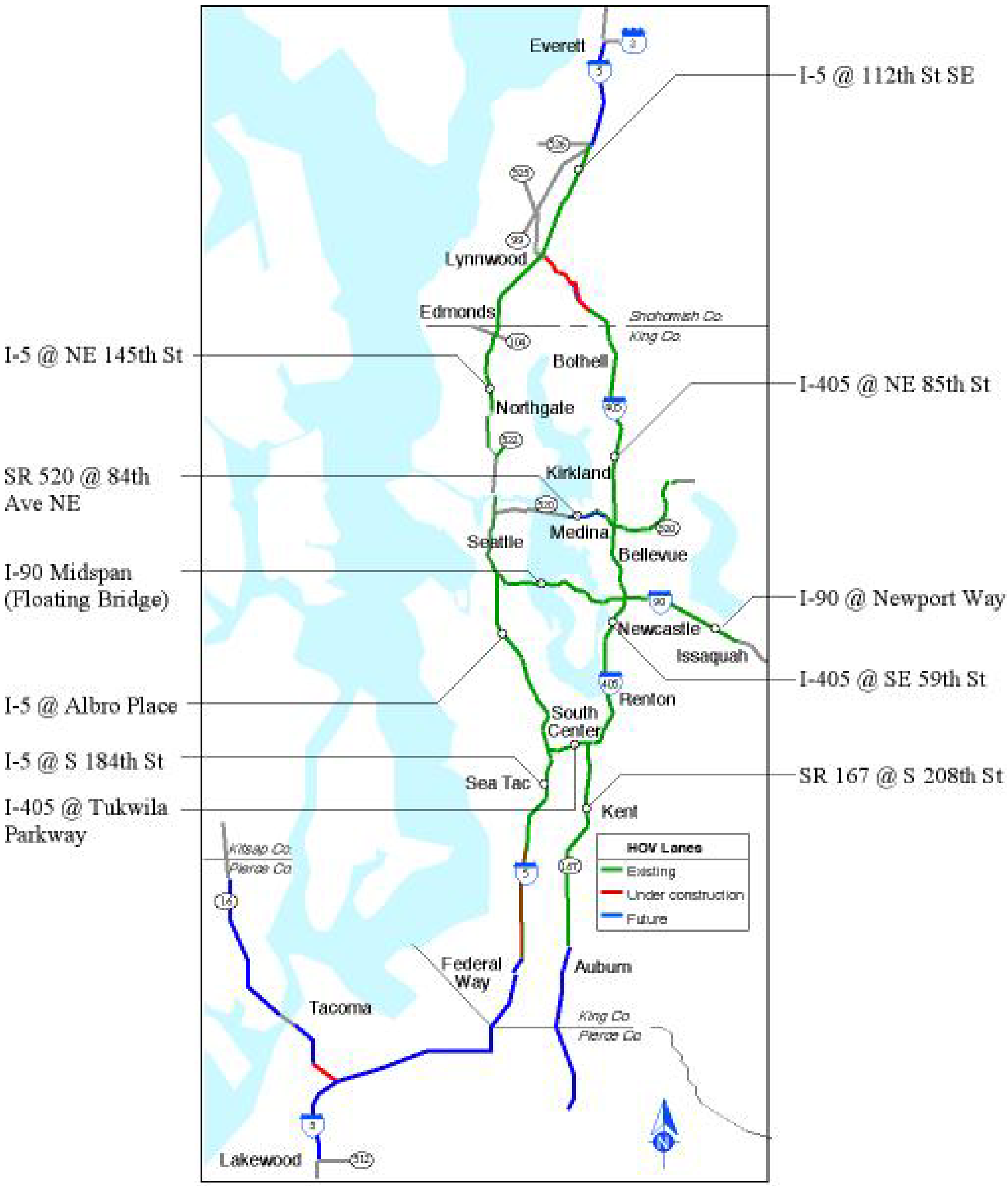



**Figure 2-1. Selected HOV Analysis Sites**

**Table 2-1. Eleven HOV Sites Selected for Analysis**

| Corridor | Locations |
|---|---|
| **I-5 North of the Seattle CBD** | I-5 @ 112$^{th}$ SE – Everett (near Everett)<br>I-5 @ NE 145$^{th}$ St. (near Northgate) |
| **I-5 South of the Seattle CBD** | I-5 @ Albro Place (south of Seattle Downtown)<br>I-5 @ S 184$^{th}$ St. (south of Southcenter) |
| **I-405 North of I-90** | I-405 @NE 85th St. (near Kirkland)<br>I-405 @ SE 59th St. (near Newcastle) |
| **I-405 South of I-90** | I-405 @ Tukwila Parkway (near Southcenter) |
| **I-90** | I-90 @ Midspan (Floating Bridge)<br>I-90 @ Newport Way (near Issaquah) |
| **SR 520** | SR 520 @ 84$^{th}$ Ave. NE (near Medina) |
| **SR 167** | SR 167 @ S 208$^{th}$ Ave. S (near Kent) |

## GENERAL RESULTS

Typically, the major freeway corridors have one HOV lane and two to four GP lanes in each direction (except I-90, which has two non-exclusive HOV lanes from Mercer Island through the Mt. Baker tunnel to Seattle). Figures 2-2 and 2-3 show person volume, vehicle volume, and AVO for each of the eleven representative sites during the morning and evening peak periods. In addition, these figures also indicate whether the HOV lane carried more or fewer people during these periods than the adjacent GP lane.

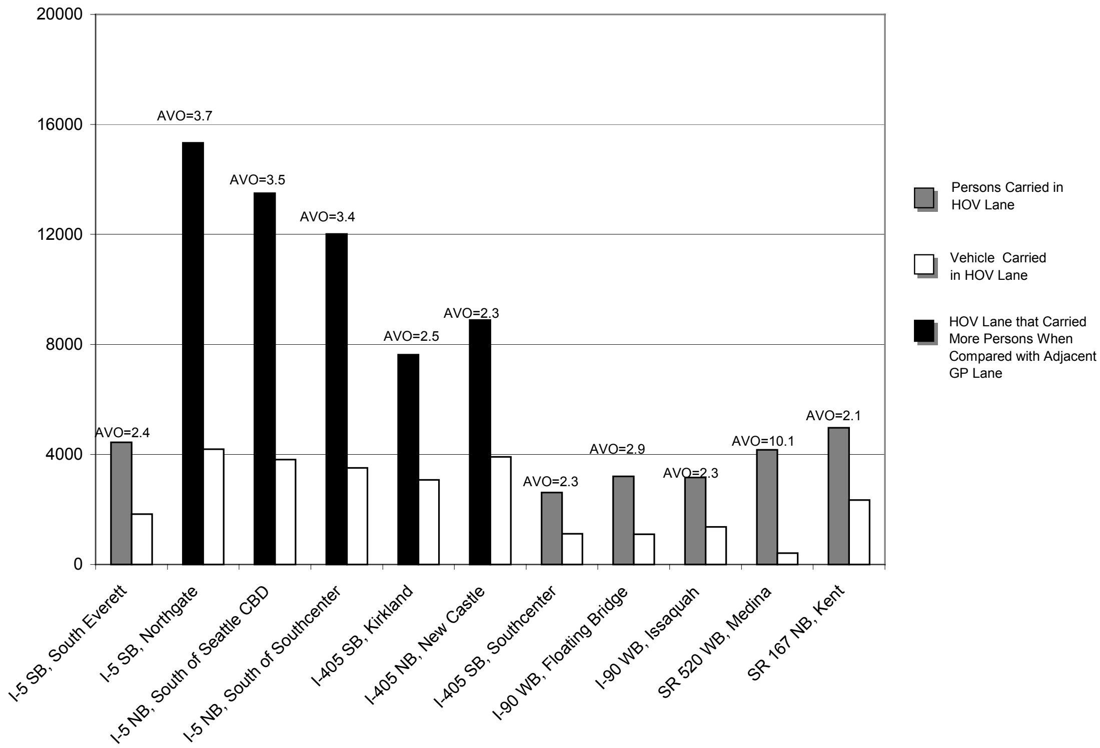



**Figure 2-2. HOV Lane Usage During AM Peak Period (2000)**

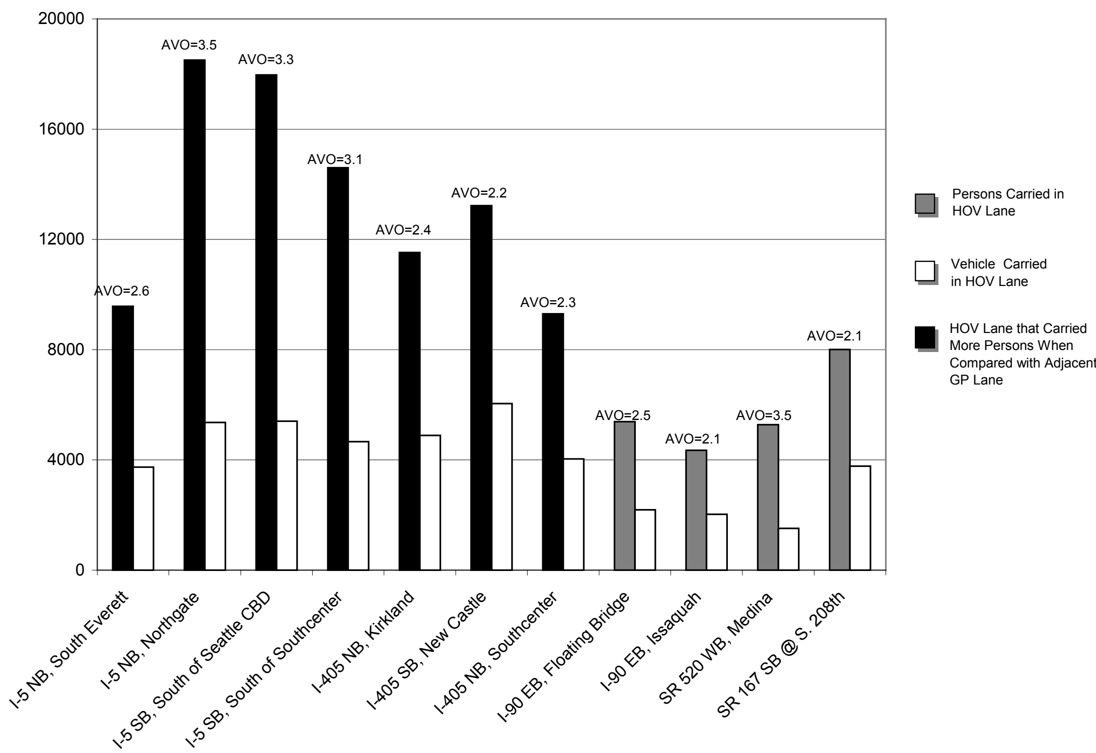



**Figure 2-3. HOV Lane Usage During PM Peak Period (2000)**

Both vehicle and person volumes in the HOV lanes were high on I-5 near Northgate and south of downtown Seattle, and on I-405 near Kirkland and Newcastle during the peak periods. For example, the HOV lane on I-5 near Northgate carried over twice as many people in about 23 percent fewer vehicles than an average adjoining GP lane (refer to Figure 2-31 for details).

Figure 2-4 shows the percentages of people carried by buses, cars, and vans in HOV lanes during the peak periods. The high person volumes observed on I-5 were due in large part to high bus ridership: between 30 to 44 percent of the people in the HOV lanes at the selected sites on I-5 was carried by buses. Significant use of transit buses allowed the HOV lane to move considerably more people than the adjacent GP lanes. More specific throughput comparisons between HOV and GP lanes are provided later in this chapter.

In contrast, the I-90 and SR 520 HOV facilities carried fewer people in comparison to the adjacent GP lane during the peak periods. However, these levels of performance are lower for different reasons. I-90 has relatively low congestion levels in comparison to other major freeway corridors in the Puget Sound area. In addition, HOV volumes are split between two lanes on the I-90 midspan, and person throughput is only partly enhanced by the presence of SOVs bound to Mercer Island. On the other hand, SR 520 is among the most congested facilities in the state. Nonetheless, it is harder for motorists to form and maintain carpools to satisfy the 3+ occupancy requirement that currently applies (for safety and operational reasons) to this HOV facility. This limits use of the shoulder HOV facility.

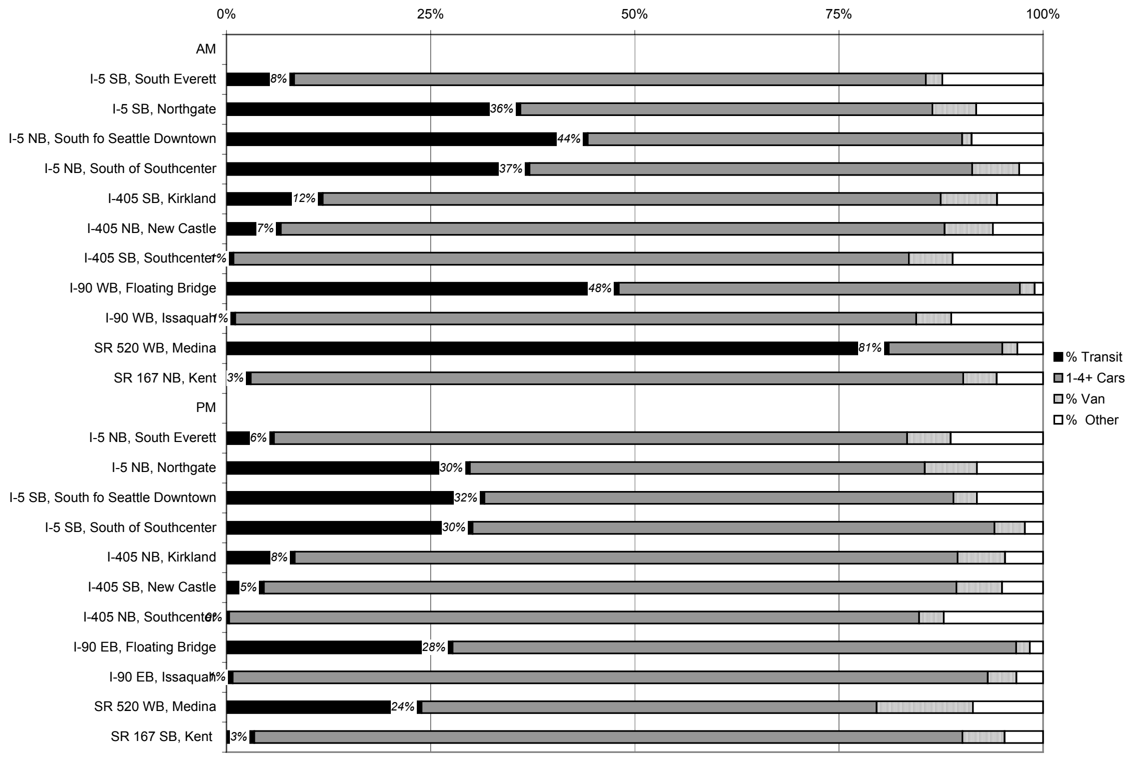



**Figure 2-4. Percentage of People Carried in HOV Lanes by Mode of Travel During Peak Periods (2000)**

Interestingly, although the vehicle volume on the westbound SR 520 HOV lane near Medina was relatively low, the AM peak period AVO was 10.1, whereas the typical AVO value ranged between 2.1 and 3.7 at other studied sites. This is because transit buses frequently use this HOV facility. Figure 2-5 shows the vehicle classification percentages in HOV lanes based on field measurements for the selected sites during morning and afternoon peak periods. On westbound SR 520 during the morning commute period, buses comprised 34 percent of the inbound traffic, carrying 84 percent of all HOV lane travelers (see Figure 2-4). High percentages of HOV users, from 28 to 48 percent, were also observed commuting by transit bus in the HOV lanes on I-5 near Northgate, Boeing Field, and in the reversible HOV lanes on I-90.

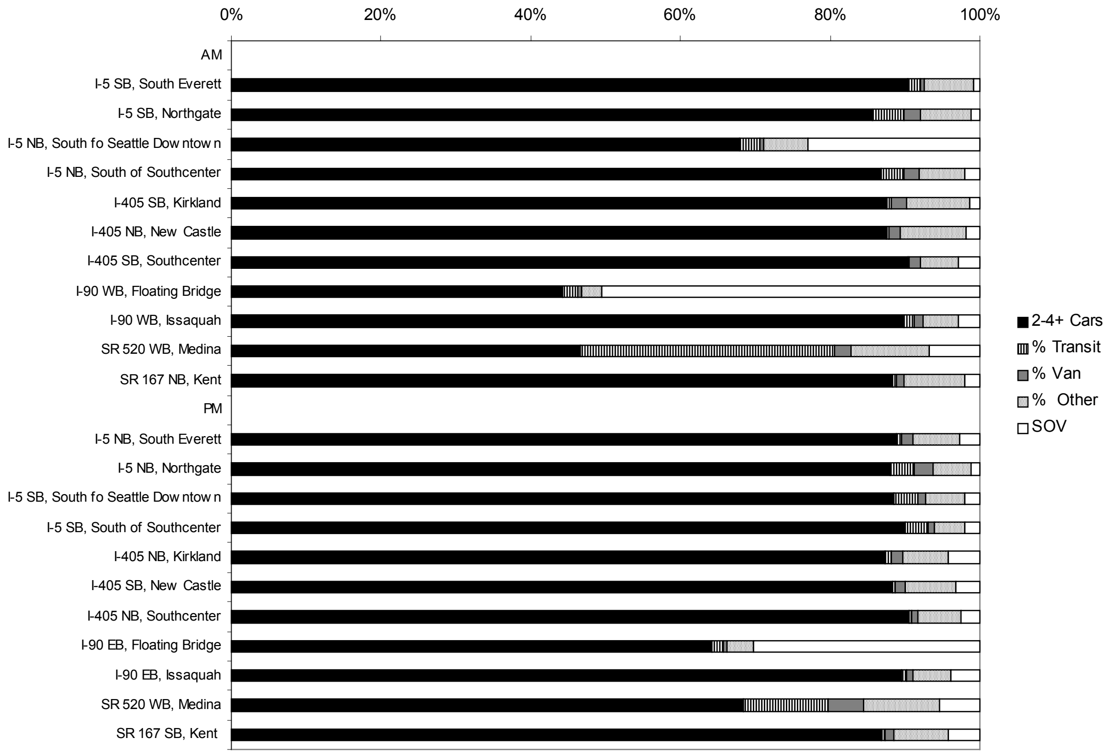



**Figure 2-5. Mode Split in HOV Lanes (2000)**

Note that HOV volumes are not necessarily evenly distributed during the hours within the peak periods, and that HOV volumes become higher during the peak commute hour. Thus the HOV lane performs even better during the peak ***hour*** than suggested by its peak ***period*** performance described in this chapter. The timing of the true peak hour of HOV lane volume varies from location to location (e.g., 7:35 AM to 8:35 AM or 7:50 AM to 8:50 AM), depending on the nature of travel demand at that location. Figure 2-6 shows that peak hour volumes can increase from 9 percent to as high as 49 percent over the average hourly volume during the peak period.

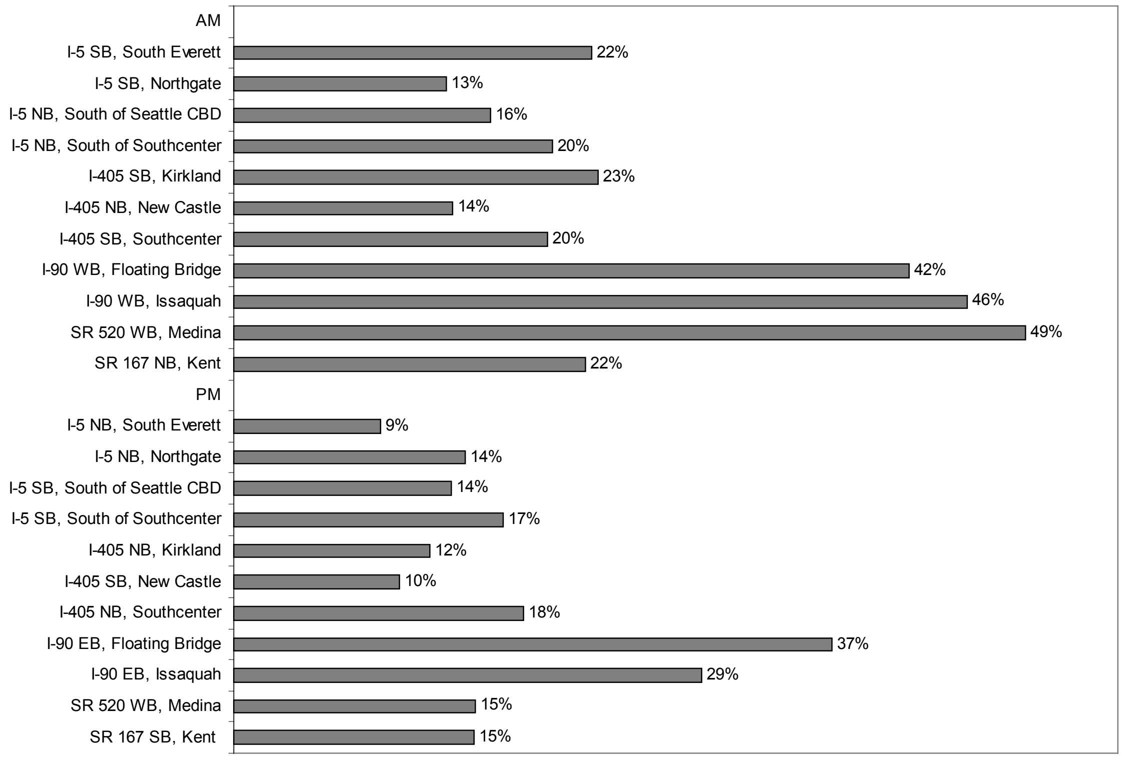



**Figure 2-6. Percentage of Increase in HOV Volumes: Peak Hour Volume vs. Peak Period Average Hourly Volume (2000)**

## HOV VOLUME FLOW

Figures 2-7 through 2-18 examine more closely the extent and variation of change in vehicle volumes observed along HOV corridors during the average weekdays. In general, HOV volumes increased when the lanes were closer to dense employment centers and decreased on the suburban ends of HOV facilities. Lower usage rates were also expected at the endpoints of HOV facilities where HOV traffic merges with GP traffic. As explained in the previous section, the low HOV volumes on I-90 and SR 520 were largely due to the combination of having two lanes of travel and lower congestion levels on I-90 and the more restrictive 3+ occupancy requirement on SR 520.

**I-5 North of the Seattle Central Business District (CBD) (see figures 2-7, 2-8)**

On I-5 between Alderwood and SR 526, HOV volumes were significant southbound during the AM peak period (> 3,000 vehicles) and northbound during the PM peak period (> 4,000 vehicles). This HOV corridor presents a strong directional pattern, with high southbound volumes traveling toward the University District and downtown Seattle in the morning, and high northbound volumes traveling away from downtown Seattle in the evening.

**I-5 South of the Seattle CBD (see figures 2-9, 2-10)**

On I-5 between the I-90 interchange and the I-405 interchange, HOV traffic during the AM peak period exhibited a typical in-bound commute flow, with northbound peak period volumes sometimes exceeding 3,000 vehicles. HOV volumes were significant in both directions during the PM peak period, with the southbound HOV lane carrying over 4,000 vehicles and the northbound HOV lane topping out at over 3,000 vehicles.

**I-405 North of I-90 (see figures 2-11, 2-12)**

This corridor exhibited classic directional commute characteristics in the morning, with HOV users traveling toward downtown Bellevue and the cross-lake bridges from surrounding rural areas and reversing flow during the evening commute. The northbound HOV volumes were concentrated between downtown Bellevue and the Bothell area, carrying as many as 5,000 vehicles. The highest southbound HOV volumes were between Totem Lake and Kirkland, carrying more than 3,000 vehicles during the afternoon peak period.

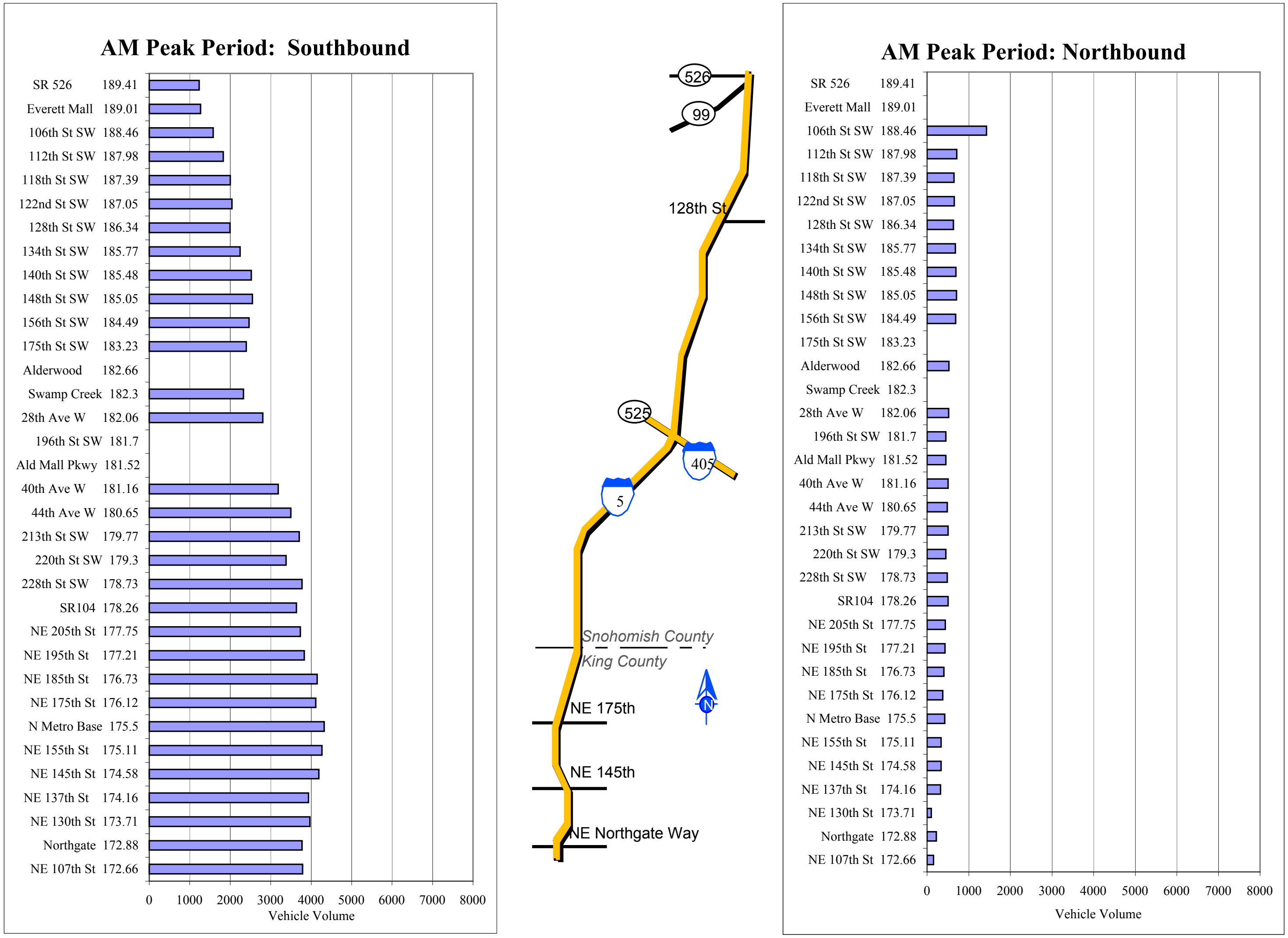



**Figure 2-7. HOV Traffic Flow Profile (2000): I-5 North of the Seattle CBD During the AM Peak Period**

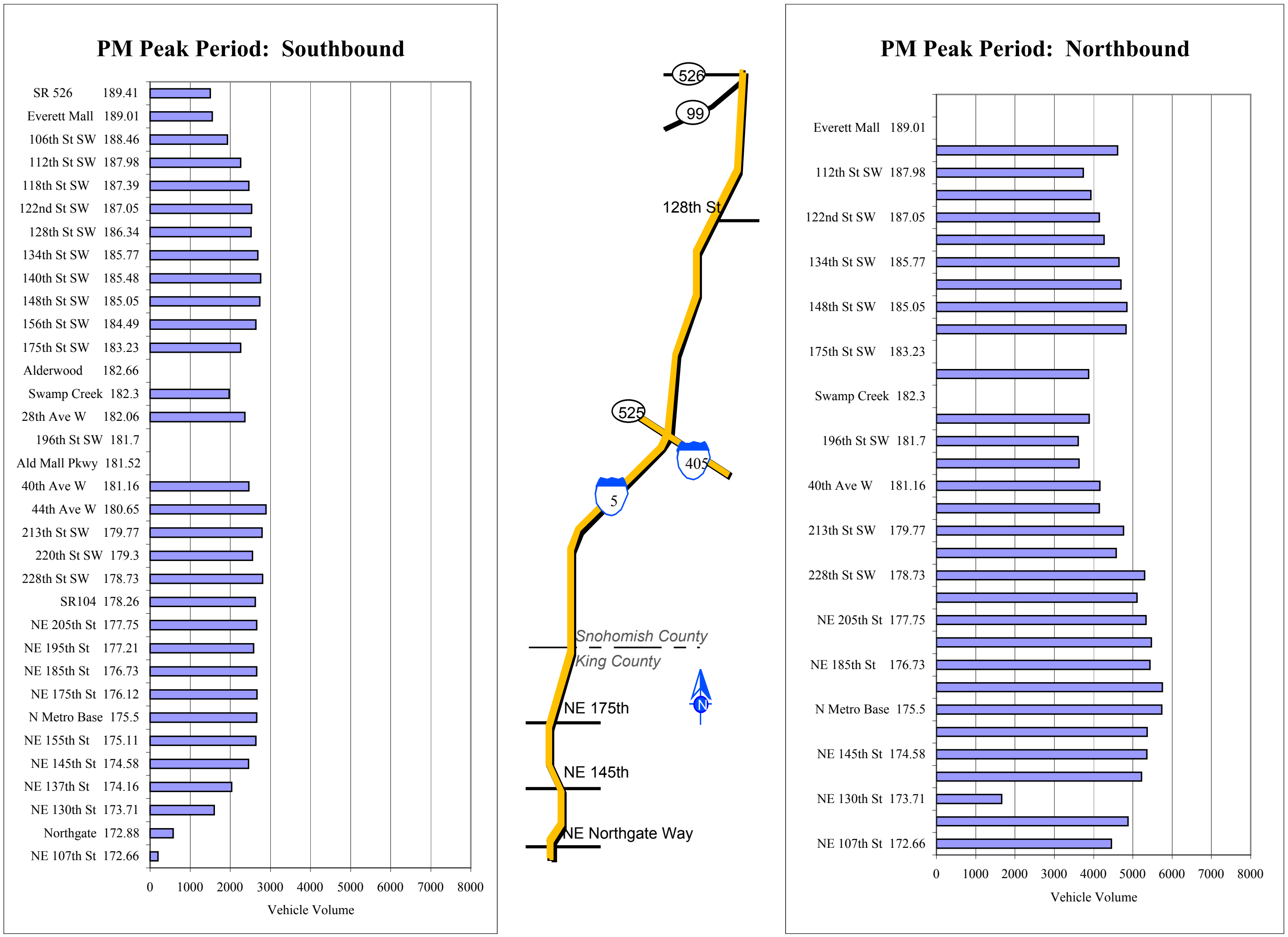



**Figure 2-8. HOV Traffic Flow Profile (2000): I-5 North of the Seattle CBD During the PM Peak Period**

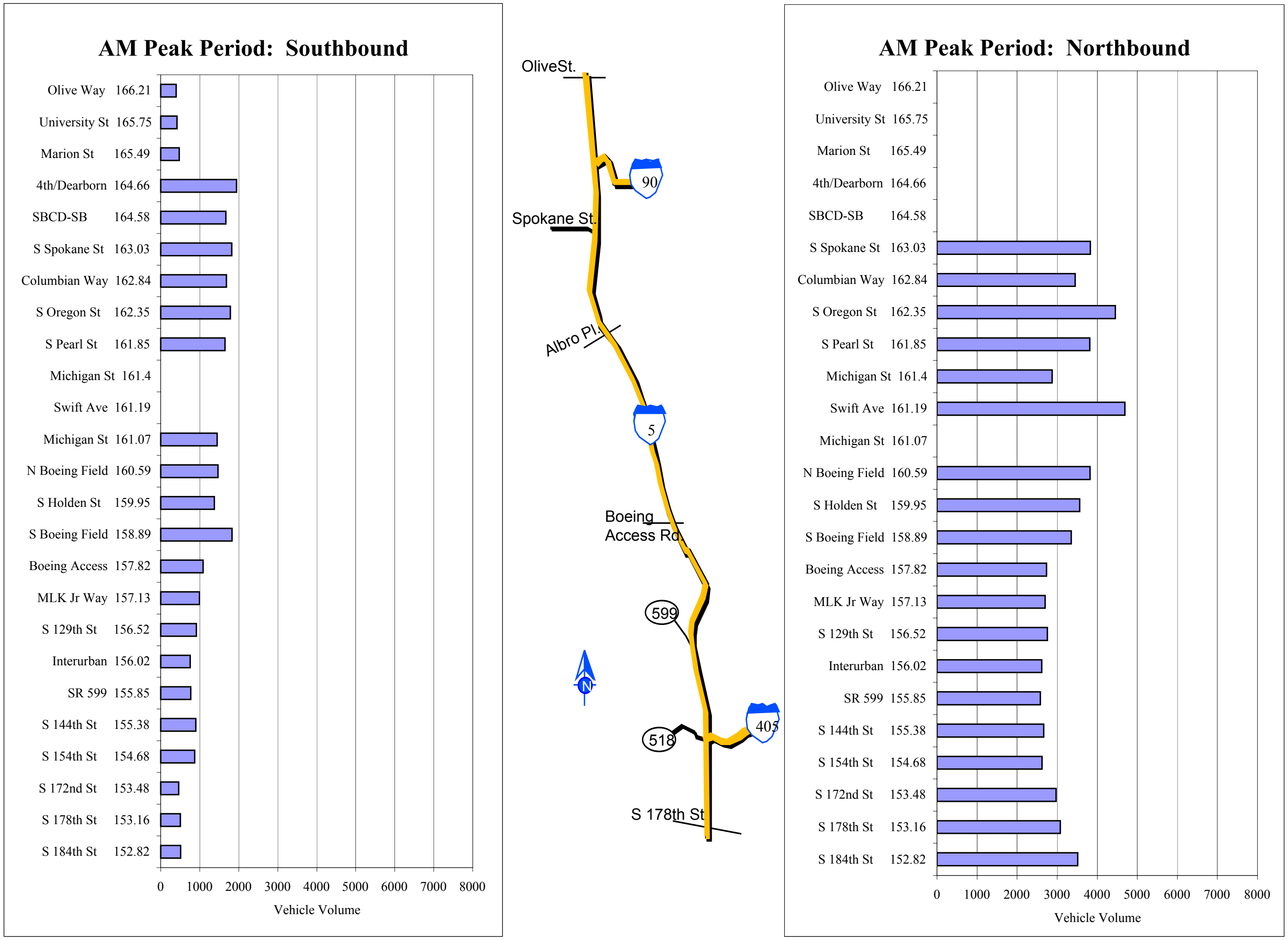



**Figure 2-9. HOV Traffic Flow Profile (2000): I-5 South of the Seattle CBD During the AM Peak Period**

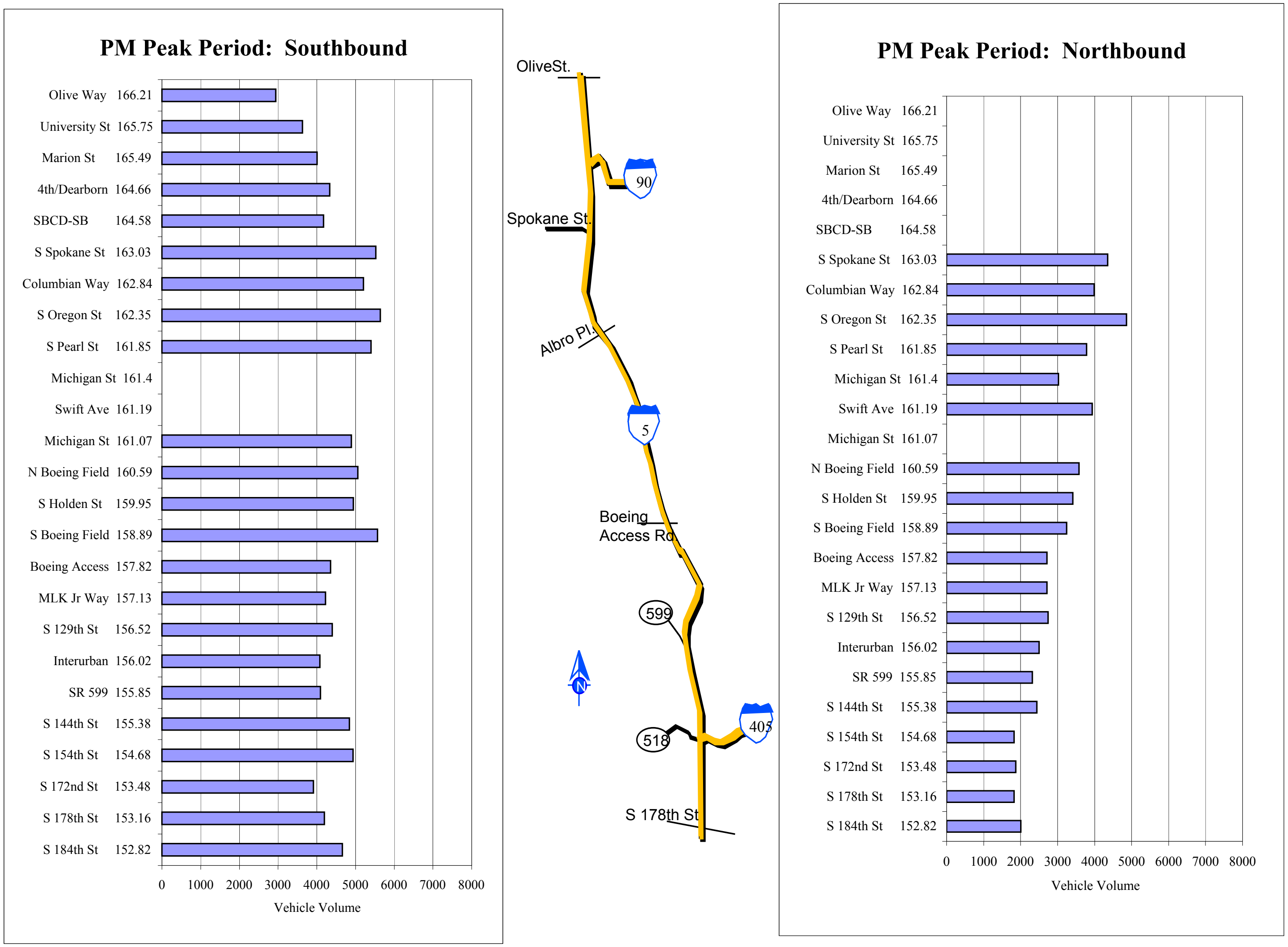



**Figure 2-10. HOV Traffic Flow Profile (2000): I-5 South of the Seattle CBD During the PM Peak Period**

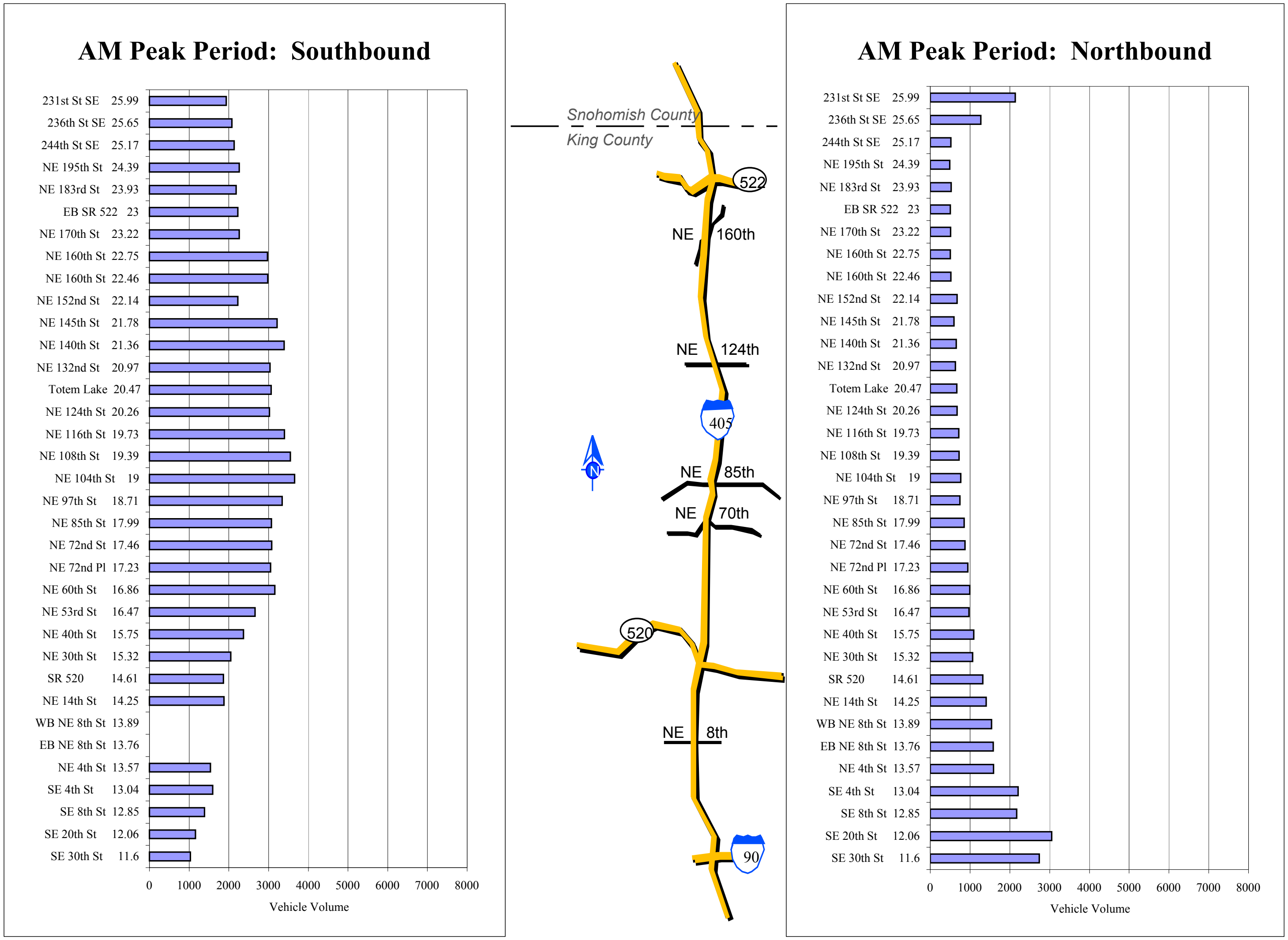



**Figure 2-11. HOV Traffic Flow Profile (2000): I-405 North of I-90 Interchange During the AM Peak Period**

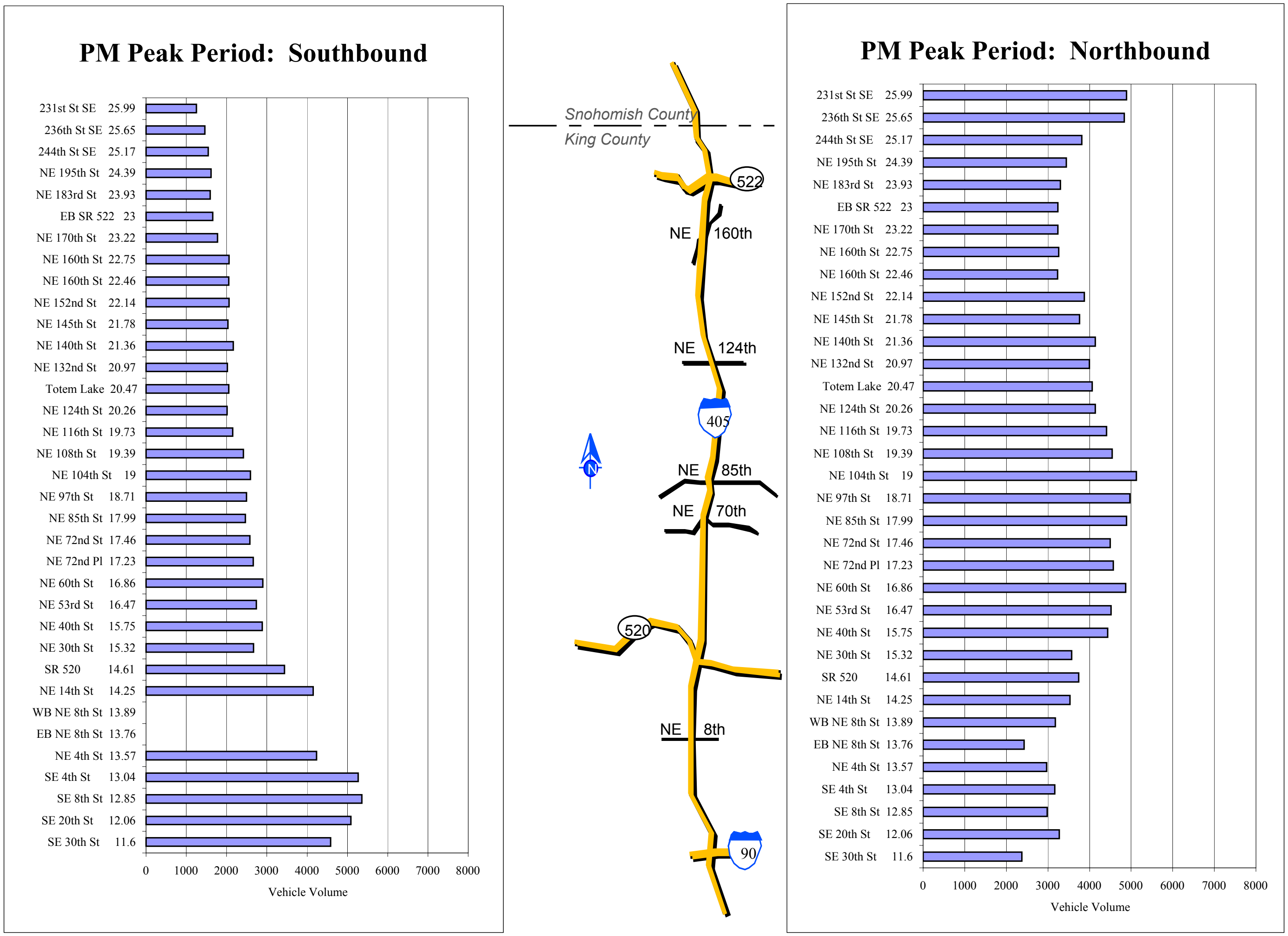



**Figure 2-12. HOV Traffic Flow Profile (2000): I-405 North of I-90 Interchange During the PM Peak Period**

**I-405 South of I-90 (see figures 2-13, 2-14)**

Northbound in the morning and southbound in the evening, HOV vehicle volumes in the I-405 corridor south of the I-90 interchange but north of the SR 167 interchange were among the highest in the region. However, person volumes on this facility were not equal to those found on I-5 because of a much lower level of transit service and use. Northbound AM peak period volumes sometimes exceeded 4,000 vehicles. The southbound HOV volumes were highest during the PM peak period, carrying as many as 6,000 vehicles. Southbound volumes dropped significantly at the SR 167 interchange. Relatively few HOVs used this facility southbound through Tukwila.

**I-90 (see Figure 2-15)**

The main area of interest along this corridor was the section containing the I-90 reversible express lanes. Note that the reversible lanes between Mercer Island and the Mt. Baker Tunnel include mixed-flow traffic comprising both HOV traffic and Mercer Island GP traffic. Thus HOV volumes were higher in the reversible lanes than at locations between the I-405 interchange and Issaquah.

**SR 520 (see Figure 2-16)**

Comparatively, SR 520 carried the least amount of HOV vehicular traffic because of its 3+ occupancy requirement. HOV volumes were highest during the PM peak period partly because westbound PM transit service is not as good as the AM westbound service. One note of interest is that the design of this HOV lane was intended to improve transit service by allowing buses to pass the queue of cars.

**SR 167 (see figures 2-17, 2-18)**

Like north I-405, this corridor exhibited classic directional commute characteristics. HOV volumes were highest in the northbound direction during the AM

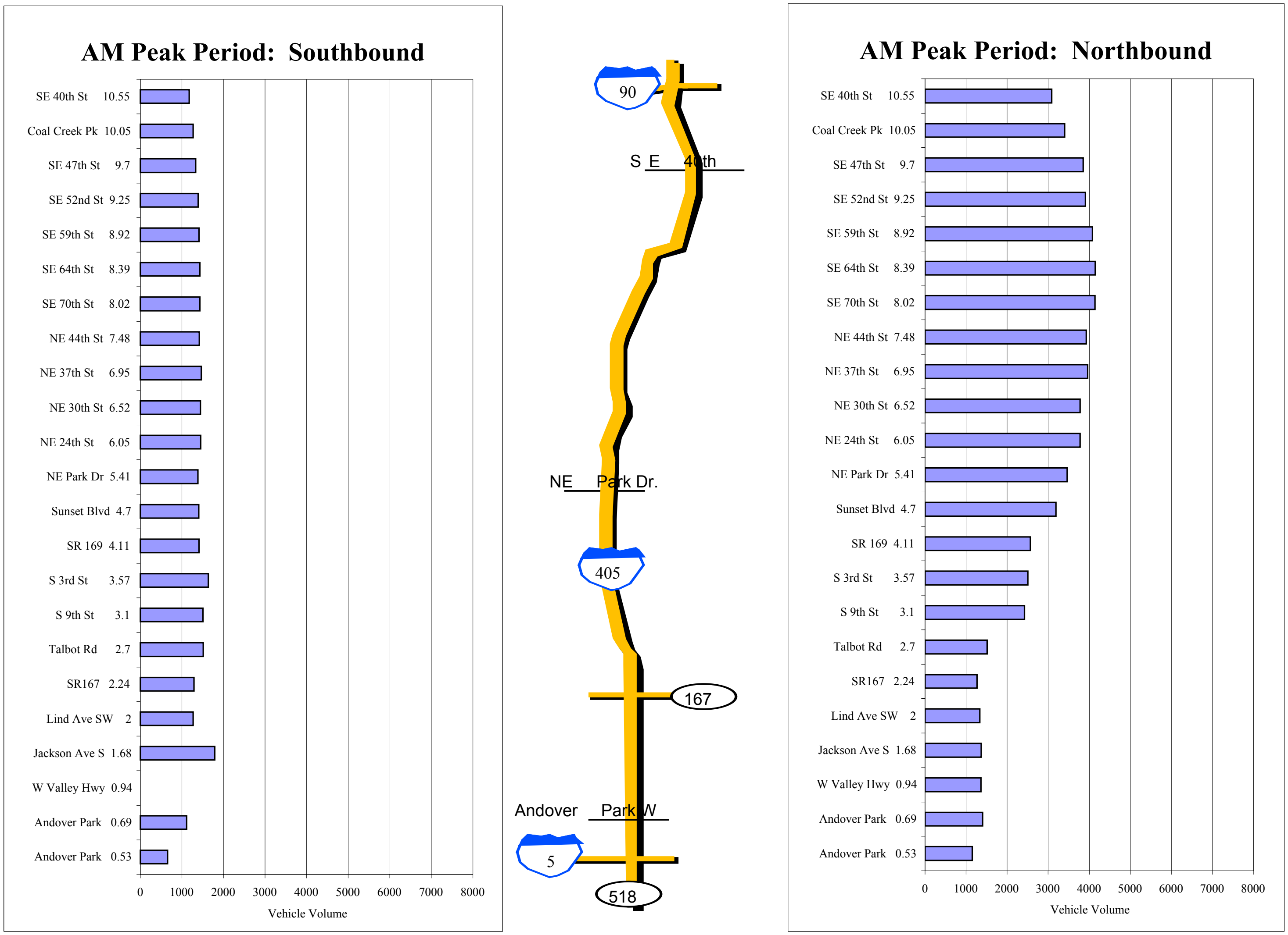



**Figure 2-13. HOV Traffic Flow Profile (2000): I-405 South of I-90 Interchange During the AM Peak Period**

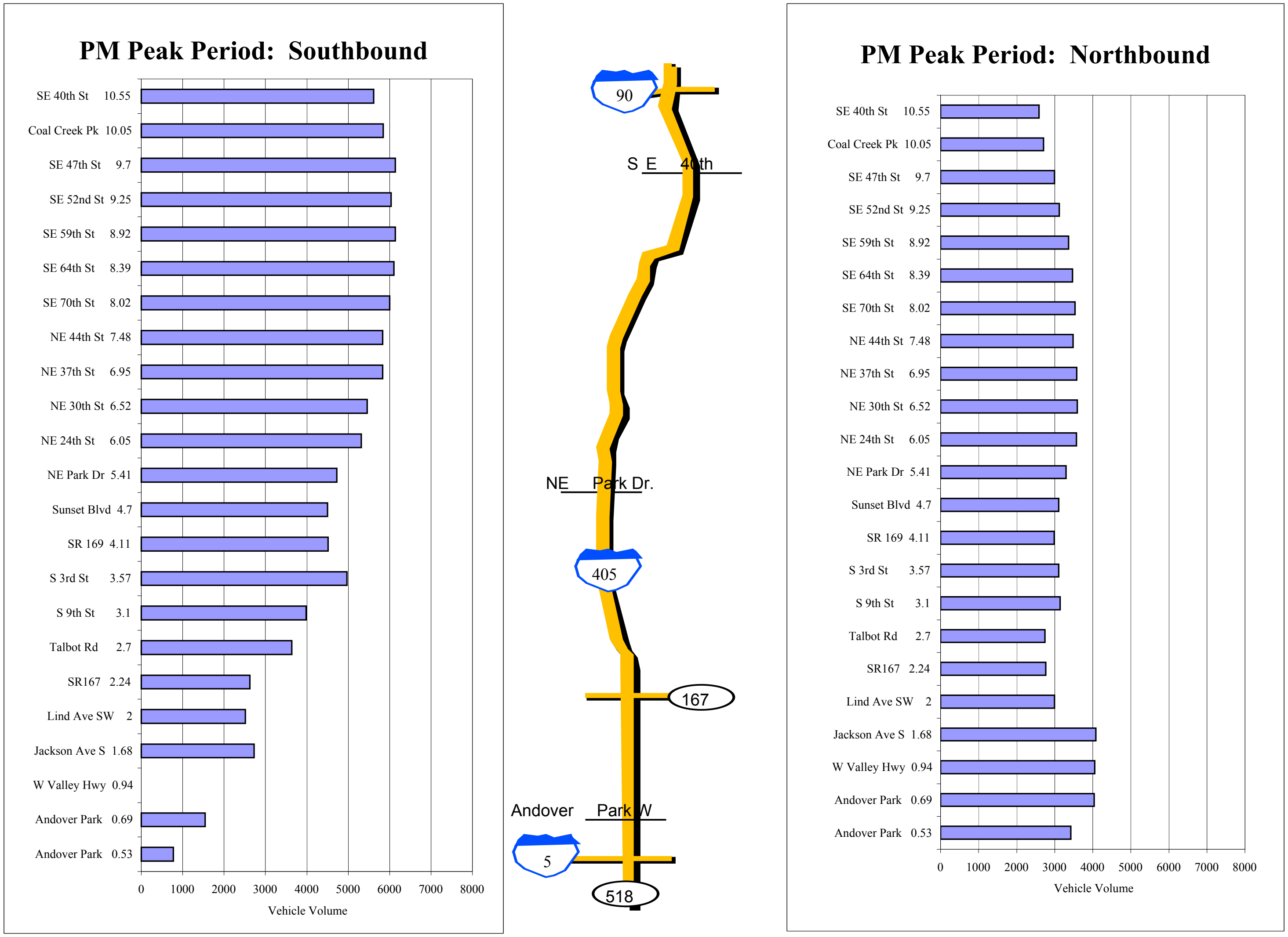



**Figure 2-14. HOV Traffic Flow Profile (2000):  I-405 South of I-90 Interchange During the PM Peak Period**

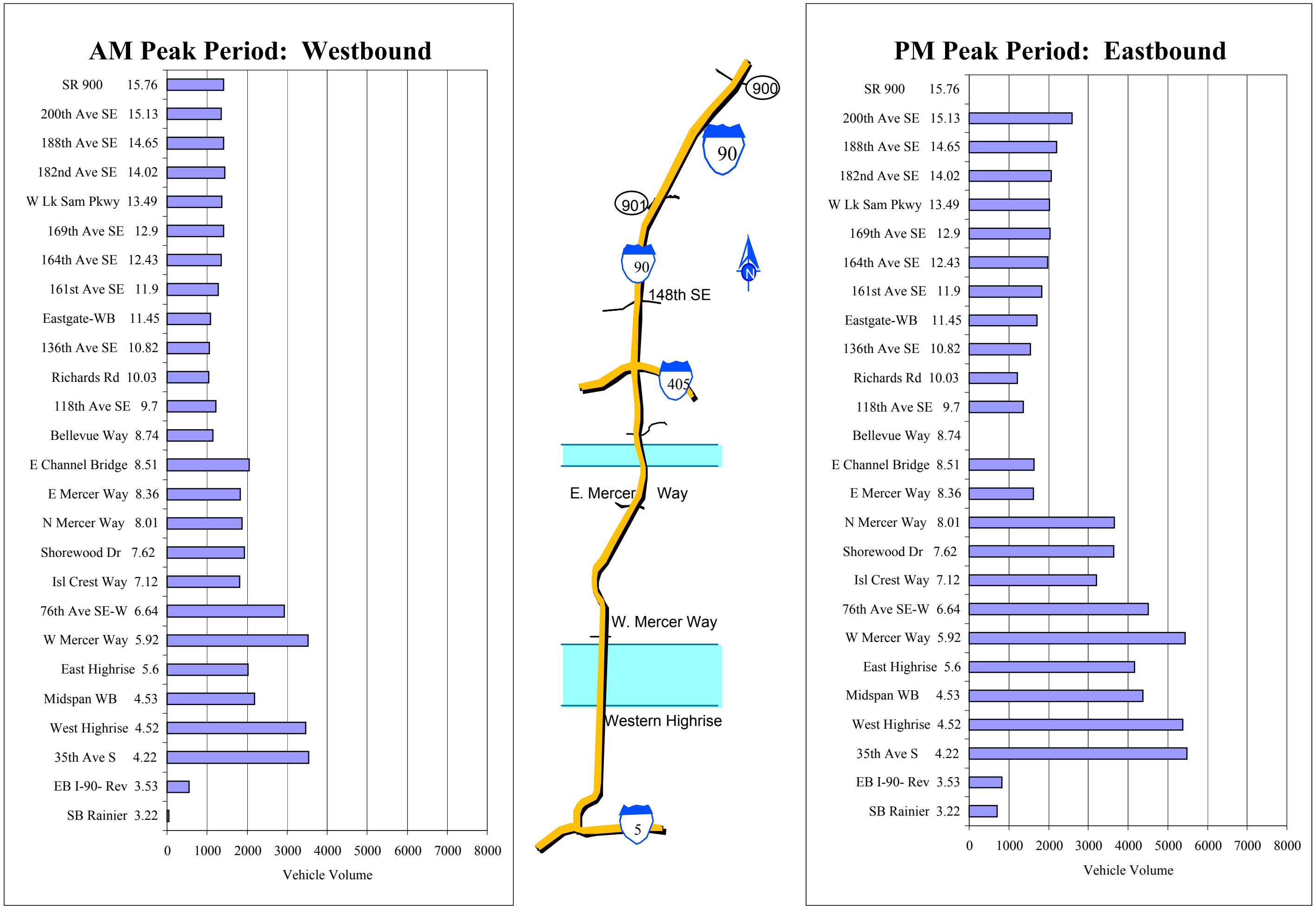



**Figure 2-15. HOV Traffic Flow Profile (2000): I-90 During Peak Periods**

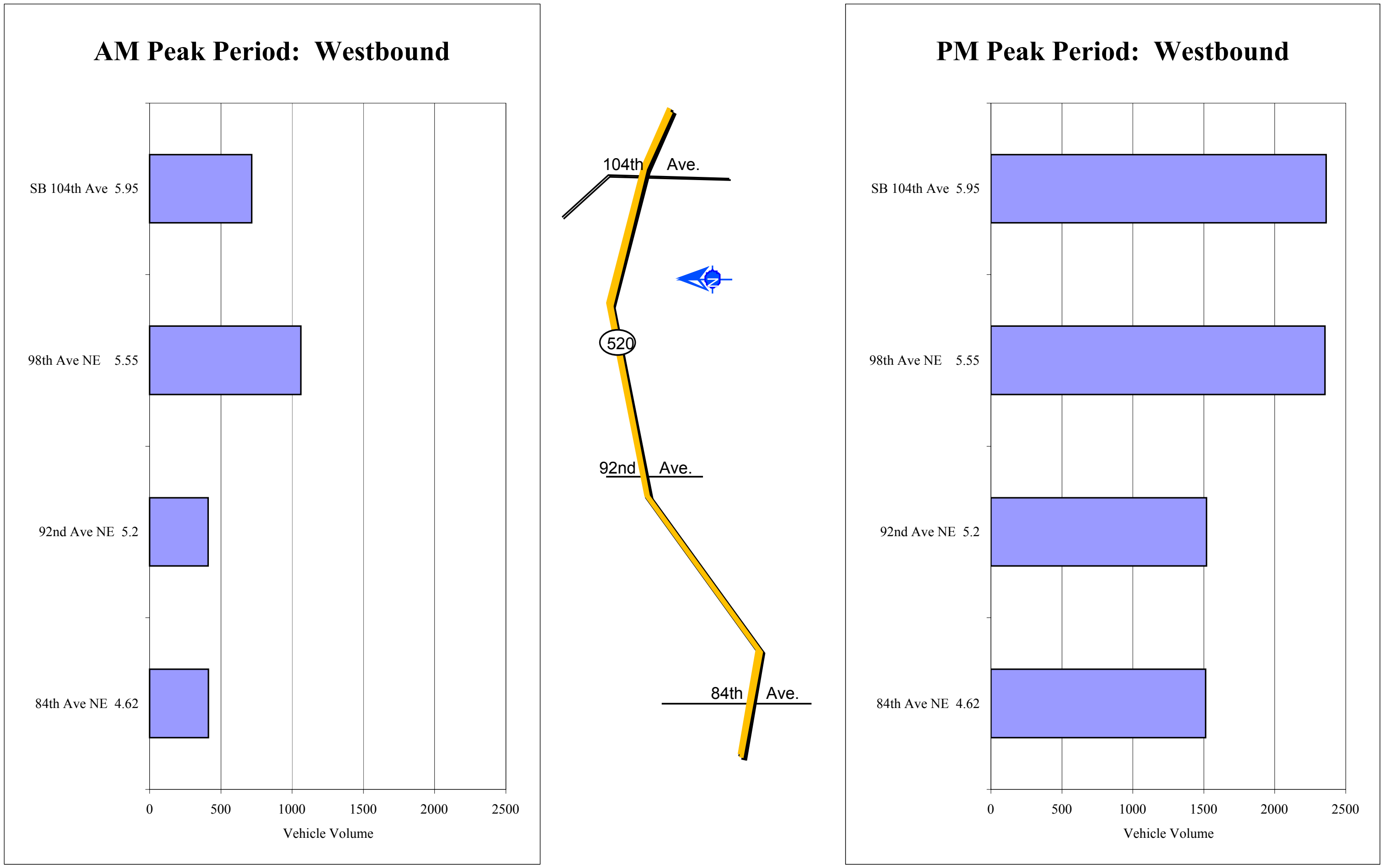



**Figure 2-16. HOV Traffic Flow Profile (2000): SR 520 During Peak Periods**

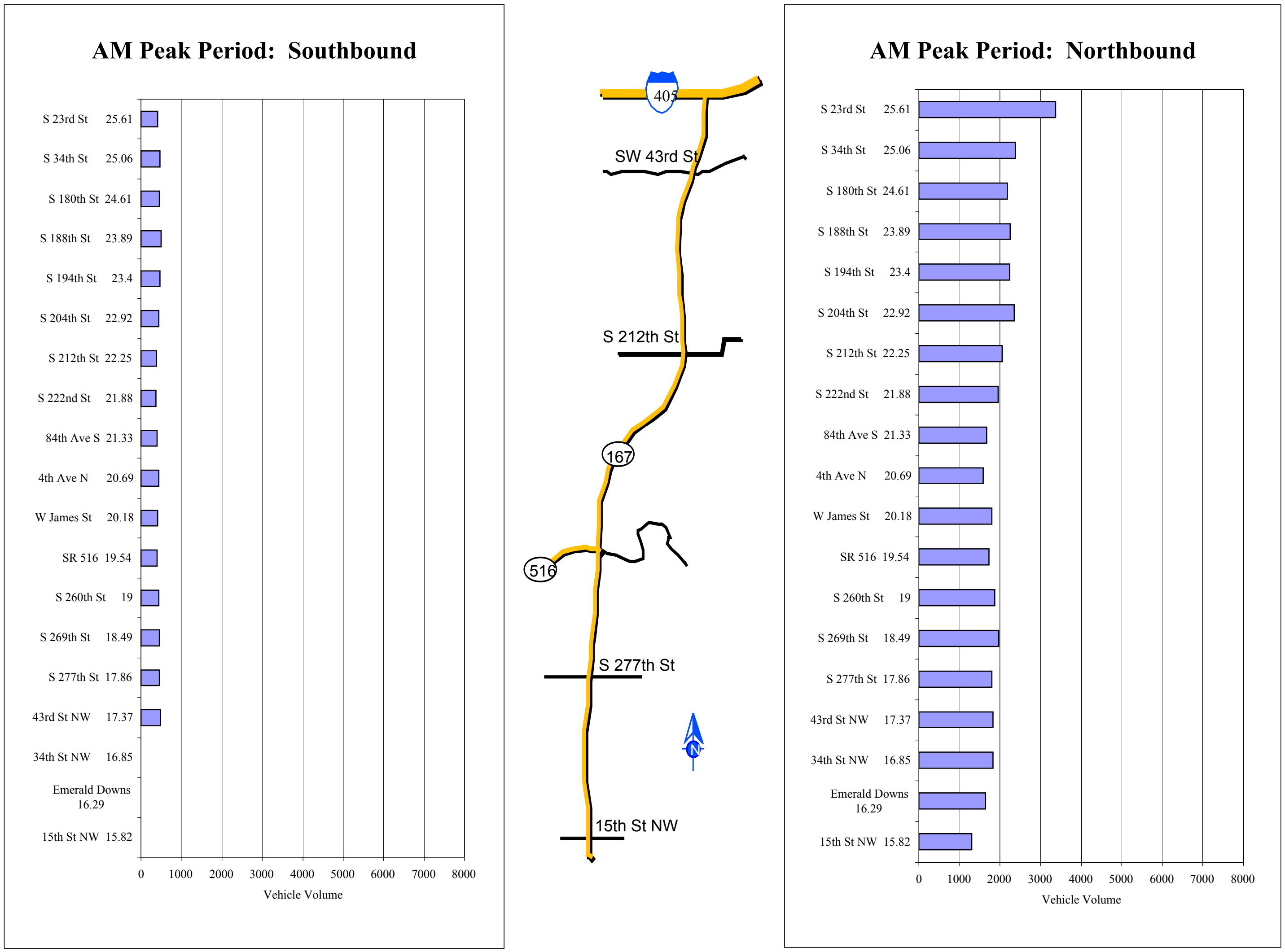



**Figure 2-17. HOV Traffic Flow Profile (2000): SR 167 During the AM Peak Period**

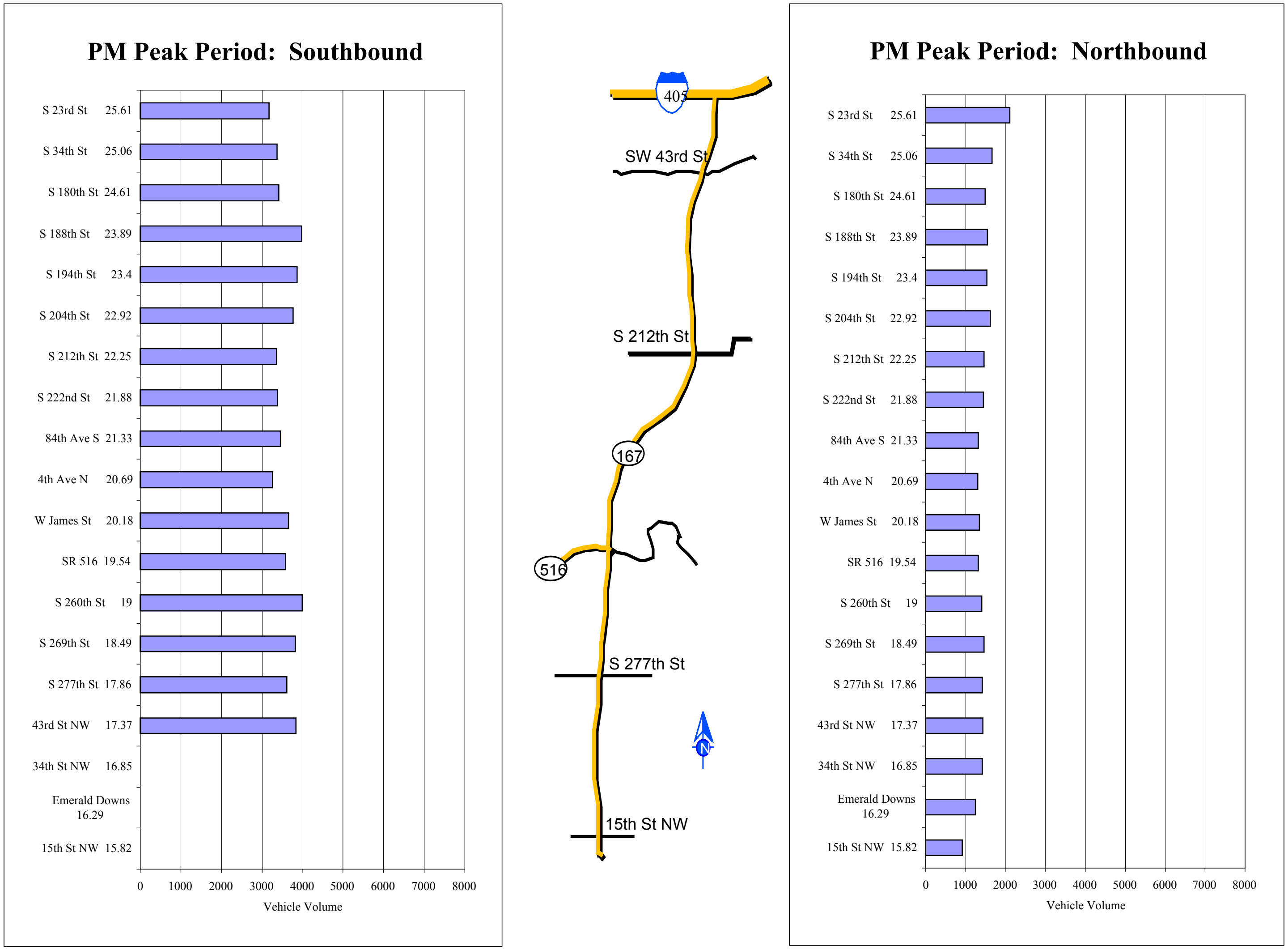



**Figure 2-18. HOV Traffic Flow Profile (2000): SR 167 During the PM Peak Period**

peak period between 15th St. NW and S. 23rd St. and during the reverse flow of the PM peak period. HOV volumes were significant in the southbound direction during the PM peak period, with as many as 4,000 vehicles. This section of the HOV system opened in September 1998.

## GP VS. HOV 24-HOUR VOLUME PROFILE

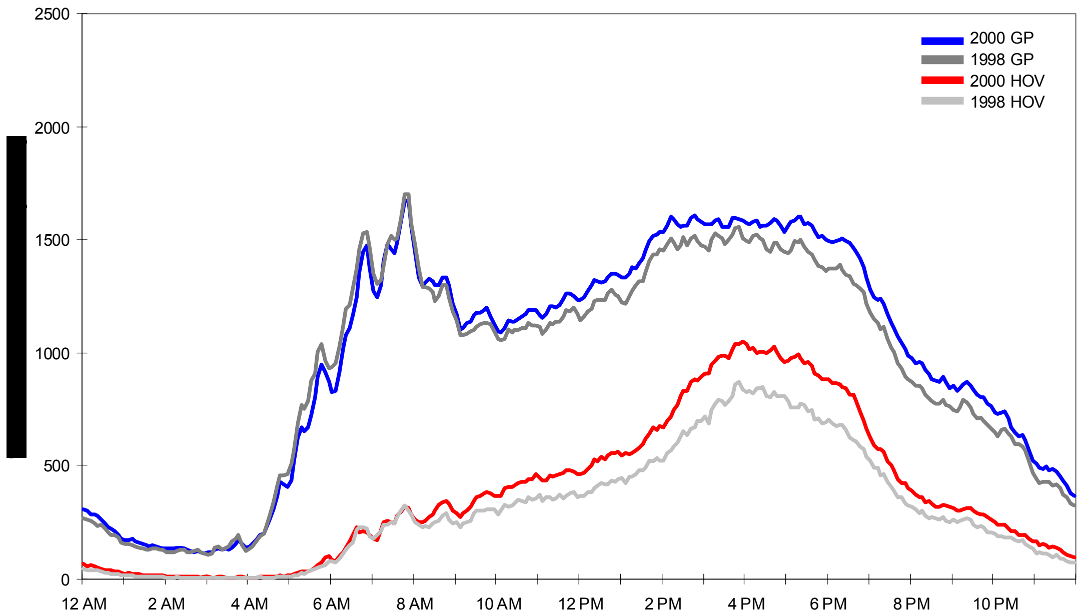
Figures 2-19 to 2-29 illustrate the variation of HOV volumes throughout the day and the relationship between HOV traffic and GP traffic at selected locations. Like GP lanes, traffic volumes on HOV lanes vary by time of day and location. High HOV use typically coincides with high levels of travel demand and with locations that routinely experience elevated congestion levels in adjoining GP lanes. This largely occurs sometime during the traditional peak commute periods.

On a per-lane basis, HOV lanes can carry a significant number of vehicles in comparison to their GP counterparts. For example, traffic volumes in the HOV lanes approach 1500 vehicles per hour at various locations during peak-use times (i.e., near Northgate, south of Seattle downtown, and at Newcastle); this is a high rate even for GP lanes. In fact, at some locations and times of day HOV volumes actually match or even exceed GP volumes on a per-lane basis (see Figure 2-24, SE 59th St. on I-405) as a result of severe congestion within the GP lanes. Additional performance information on HOV volumes in relation to speed and congestion frequency is presented in Chapter 3.

### I-5 near South Everett (see Figure 2-19)

On a per-lane basis, the northbound HOV volumes were approximately 60 percent of northbound GP volumes during the afternoon peak period. The southbound HOV lane could approach 40 percent of corresponding GP volumes during both peak periods.

**I-5 @ 112th St SE, Northbound**




**I-5 @ 112th St SE, Southbound**

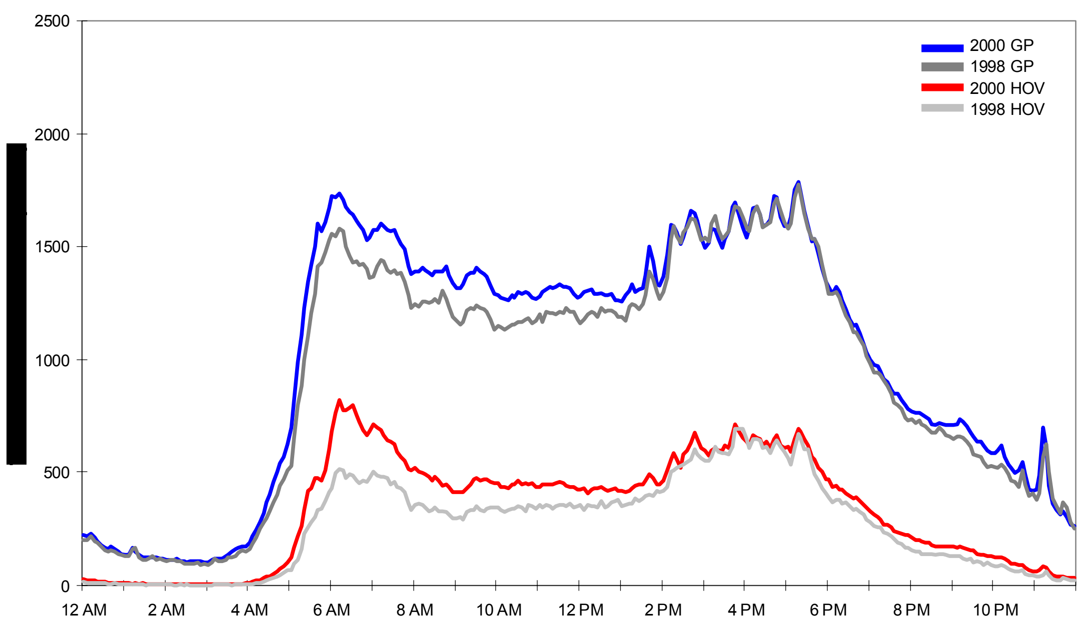



**Figure 2-19. Average Weekday GP and HOV Volume Profile (2000): I-5 @ 112th St SE**

Since 1998, HOV volumes have increased approximately 25 percent in the northbound direction during the afternoon peak period, and as much as 40 percent in the southbound direction during the morning peak period. Mid-day volumes have increased about 20 percent in both directions.

**I-5 near Northgate. (see Figure 2-20)**

HOV volumes were extremely high during the commute periods. The northbound HOV volumes during the afternoon peak period and the southbound HOV volumes during the morning peak period could reach 1,500 vplph, that is, nearly 80 to 90 percent of GP per lane volumes. The southbound HOV volumes have increased moderately (10 to 30 percent) throughout the day since 1998.

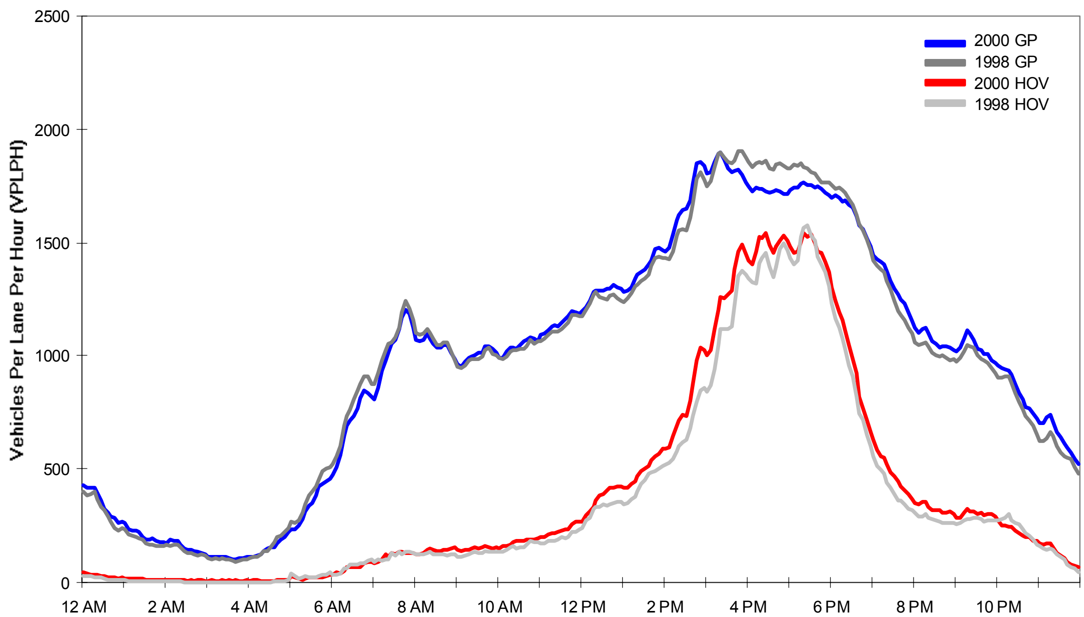
**I-5 South of the Seattle CBD (see Figure 2-21)**

HOV volumes were significant in comparison to GP volumes, particularly on northbound I-5 during the morning peak period and southbound during the afternoon peak period. Peak period HOV volumes approached 1,500 vplph, 80 to 90 percent of GP lane volumes. Mid-day HOV volumes for both directions have increased as much as 20 percent.

**I-5 South of Southcenter (see Figure 2-22)**

HOV volumes were significant during the commute periods. Peak period HOV volumes approached 1,500 vplph. The northbound HOV volumes approached 70 percent of the corresponding GP volumes during the morning peak period. The southbound HOV carried about the same number of vehicles (~1,300 vplph) as the adjoining GP lanes on a per-lane basis between 3:45 PM and 5:30 PM. HOV volumes have increased moderately throughout the day in the northbound direction but have not changed significantly southbound.

## I-5 @ NE 137th St, Northbound




## I-5 @ NE 137th St, Southbound

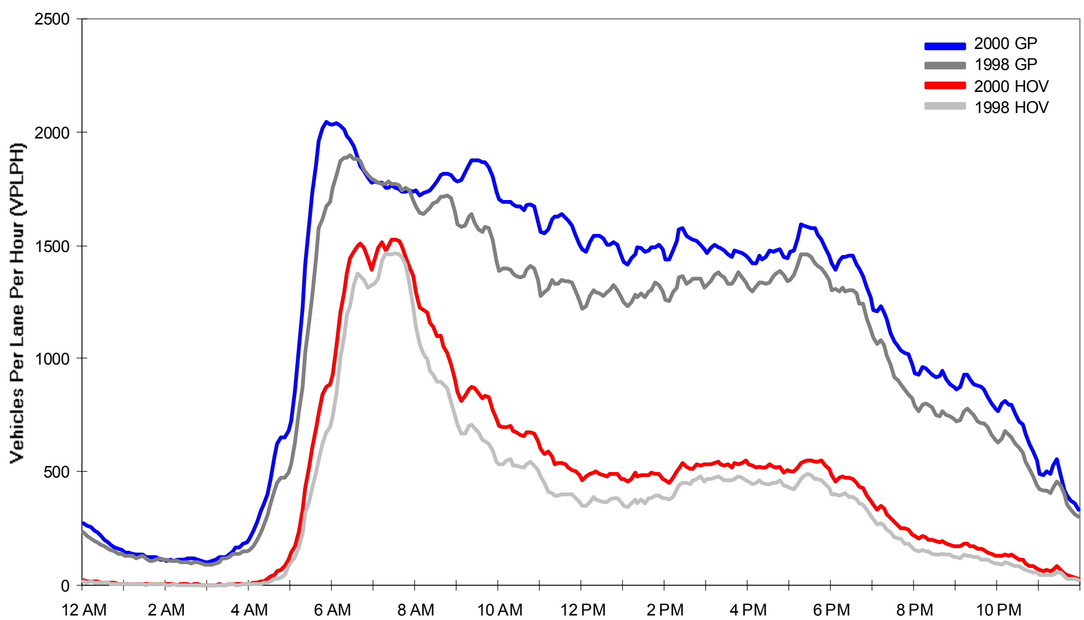
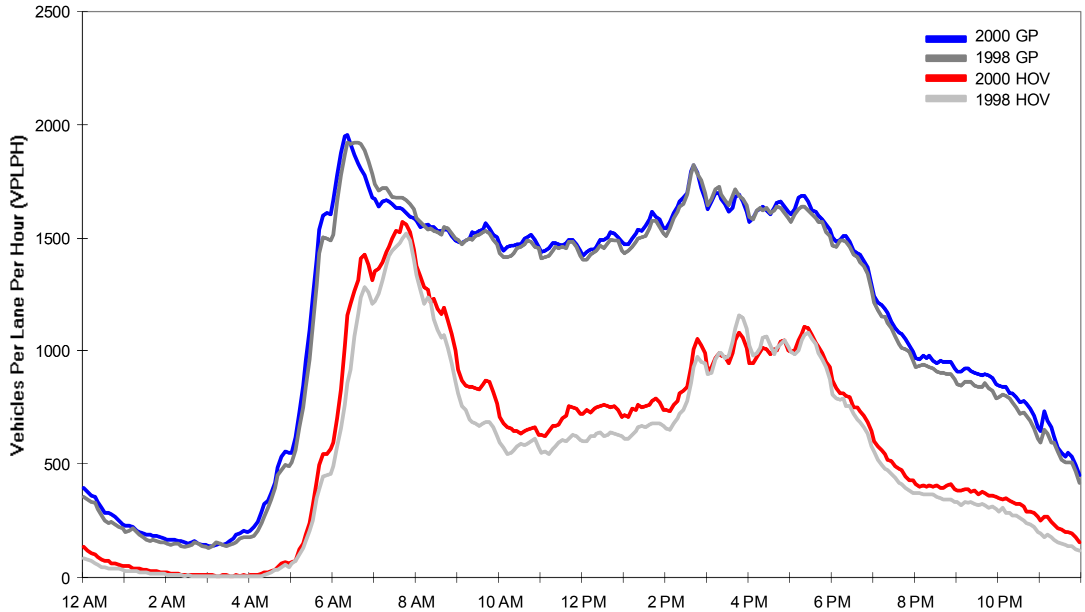



**Figure 2-20. Average Weekday GP and HOV Volume Profile (2000): I-5 @ NE 145th St**

## I-5 @ Albro Place, Northbound




## I-5 @ Albro Place, Southbound

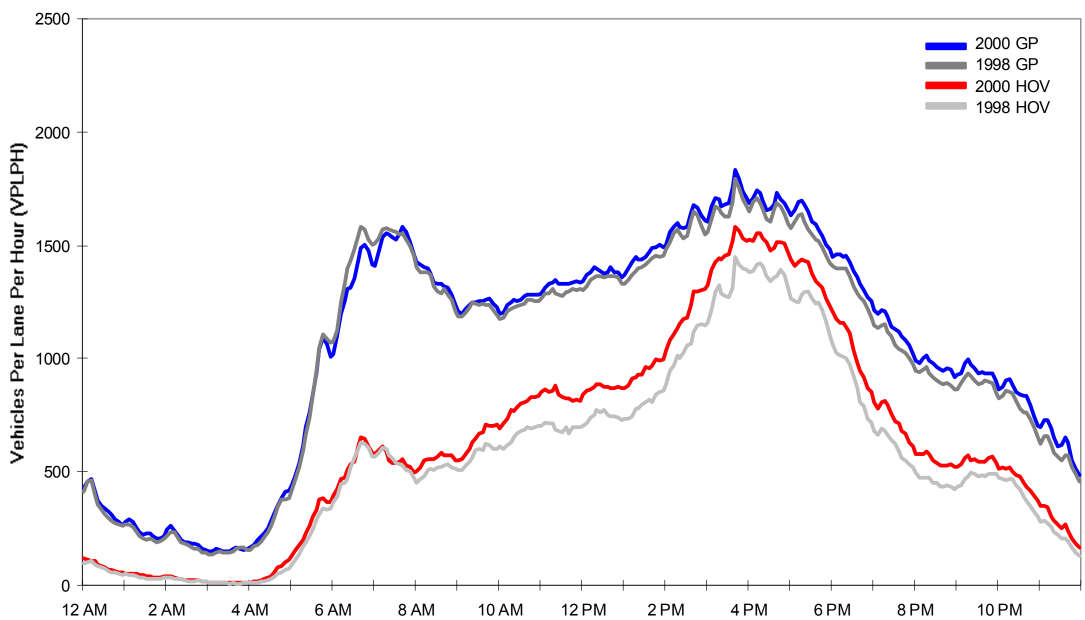
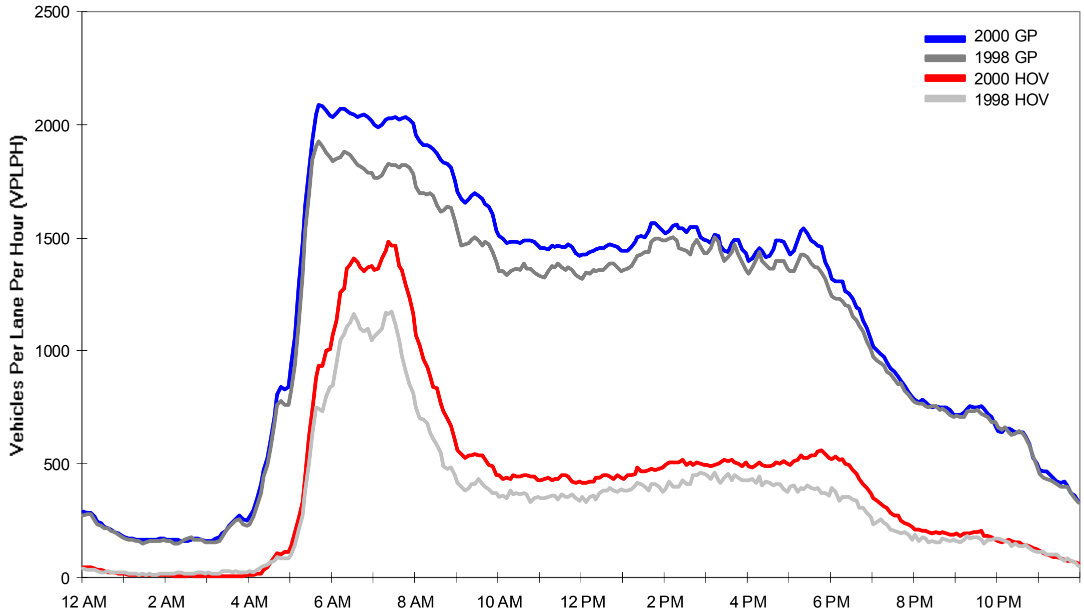



**Figure 2-21. Average Weekday GP and HOV Volume Profile (2000): I-5 @ Albro Place**

I-5 @ S 184th St, Northbound




I-5 @ S 184th St, Southbound

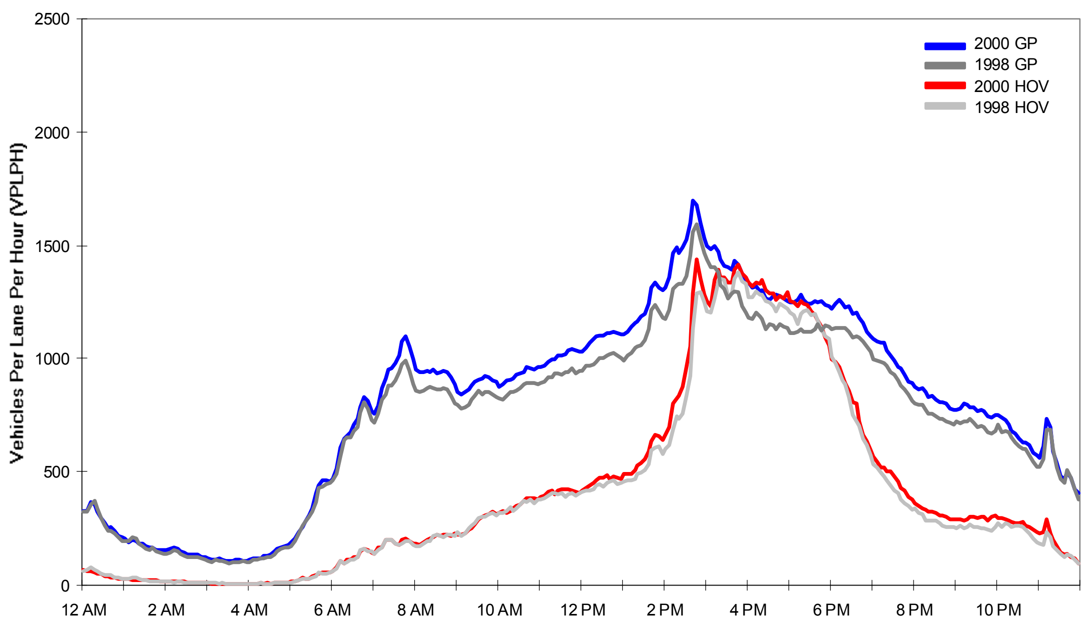



**Figure 2-22. Average Weekday GP and HOV Volume Profile (2000): I-5 @ S 184th St**

**I-405 near Kirkland (see Figure 2-23)**

Peak period HOV volumes ranged between 1,000 and 1,400 vplph. The northbound HOV lane carried approximately 80 to 90 percent of the volume of an adjacent GP lane during the afternoon peak period. Southbound HOV volumes served roughly 80 percent of southbound GP per-lane volumes during the morning peak period. HOV volumes in both directions have increased moderately throughout the day, with significant growth during the peak periods.

**I-405 near Newcastle (see Figure 2-24)**

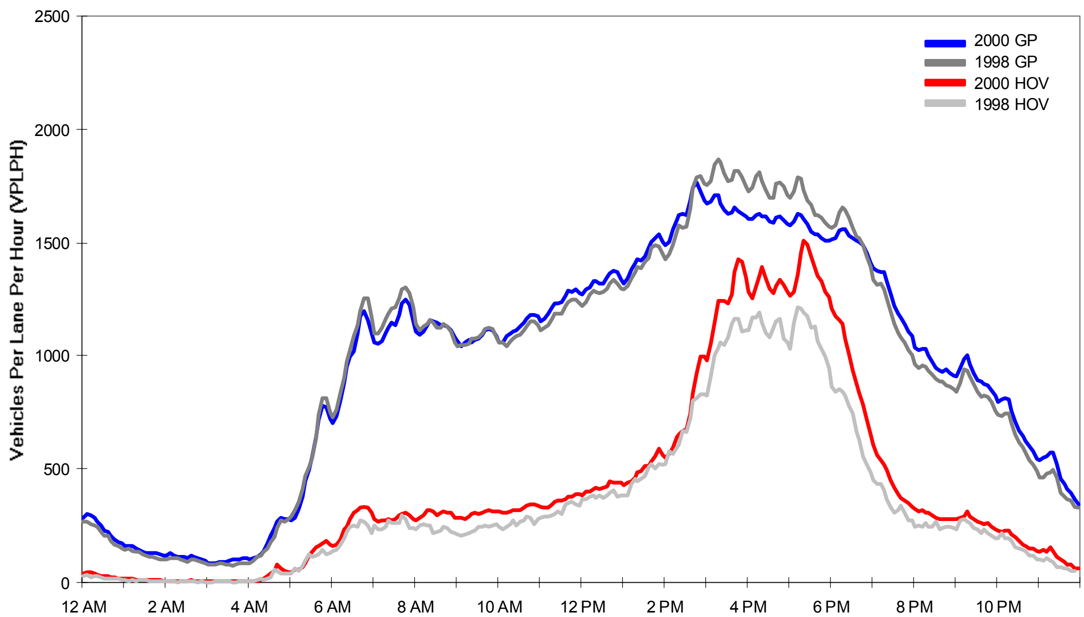
In 1998, HOV vehicular volumes (~1,500 vplph) at this location exceeded GP volumes (~1,400 vplph) in the northbound direction between 7:30 AM and 8:00 AM. (This was partly the result of a reduction in GP lane capacity caused by high congestion levels at this location.) In 2000, this pattern had lengthened from 7:00 AM to 8:00 AM with no change in GP volumes but more HOV volumes (over 1,500 vplph). An increase in southbound HOV volumes during the afternoon peak period was observed in comparison to the 1998 data. Afternoon peak period HOV southbound volumes approached as high as 95 percent of adjoining general traffic volumes on a per-lane basis.

Note that little opportunity exists for GP volume growth on this segment of freeway. Thus, a large proportion of all growth on this facility is HOV traffic. Anecdotal evidence suggests that people traveling in this corridor go out of their way to create carpools to take advantage of the trip reliability offered by the HOV lane.

**I-405 near Southcenter (see Figure 2-25)**

HOV volumes were significant during the afternoon peak period for both directions. Northbound HOV volumes approached 80 percent of adjacent per-lane GP volumes. Southbound HOV volumes only approached 30 percent of the corresponding

## I-405 @ NE 85th St, Northbound




## I-405 @ NE 85th St, Southbound

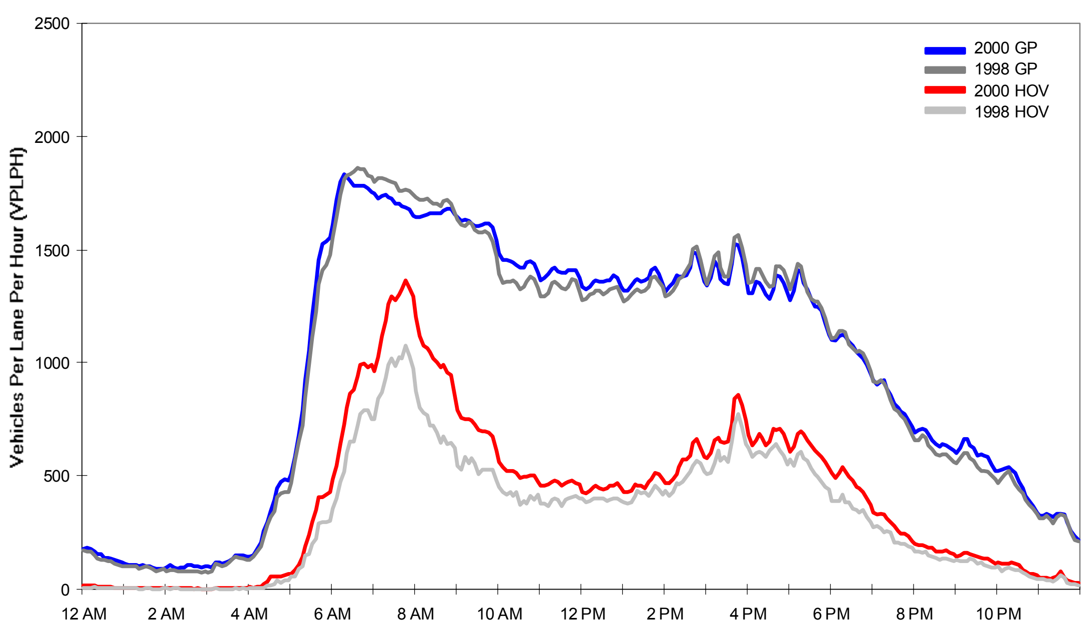
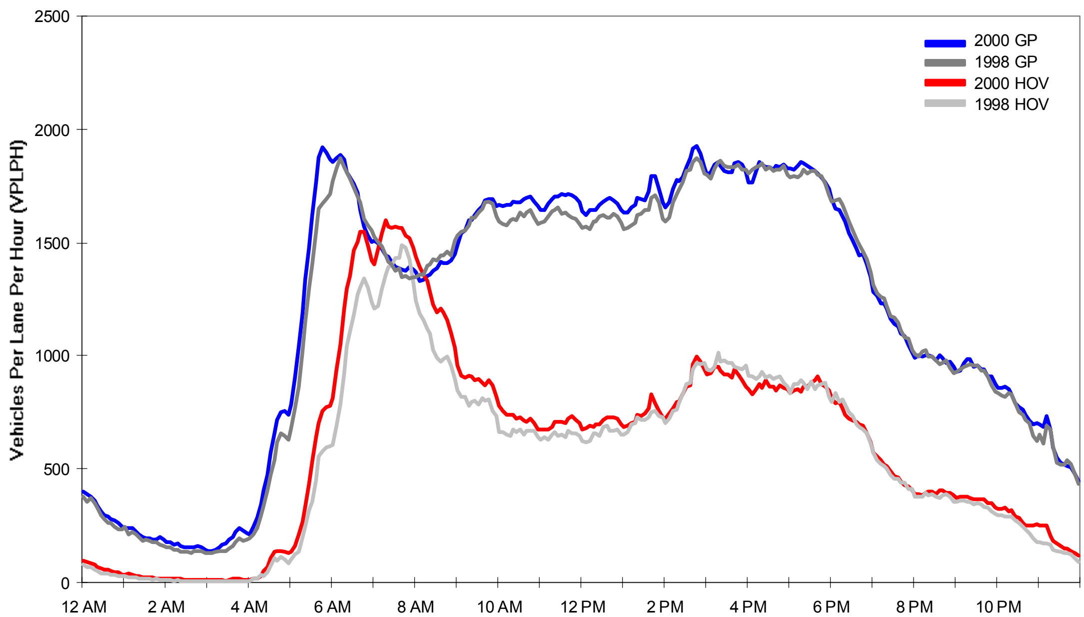



**Figure 2-23. Average Weekday GP and HOV Volume Profile (2000): I-405 @ NE 85th St**

## I-405 @ SE 59th St, Northbound




## I-405 @ SE 59th St, Southbound

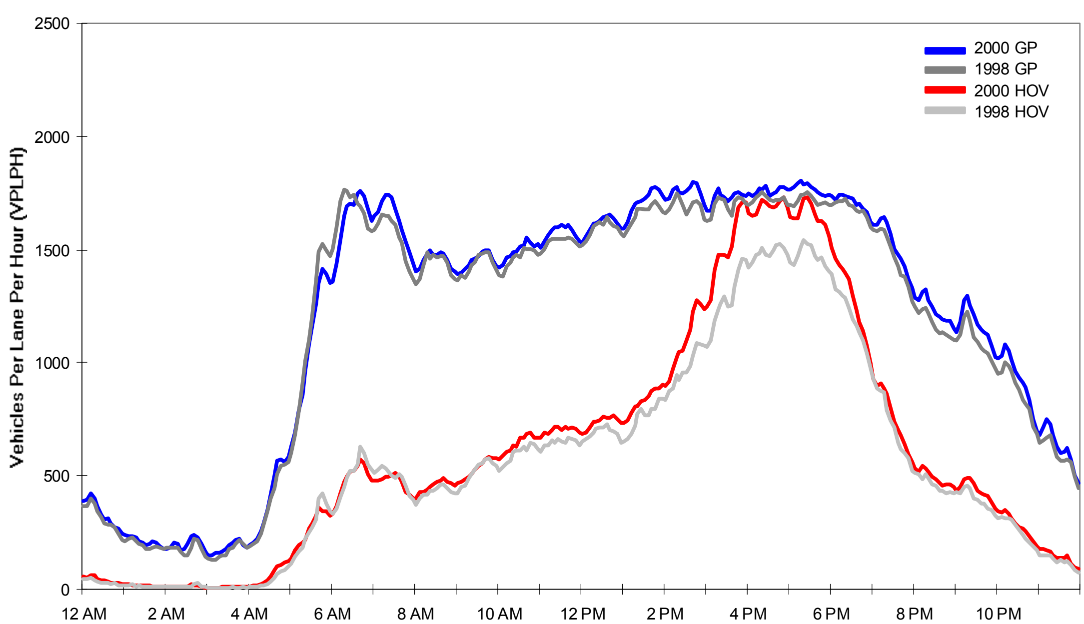
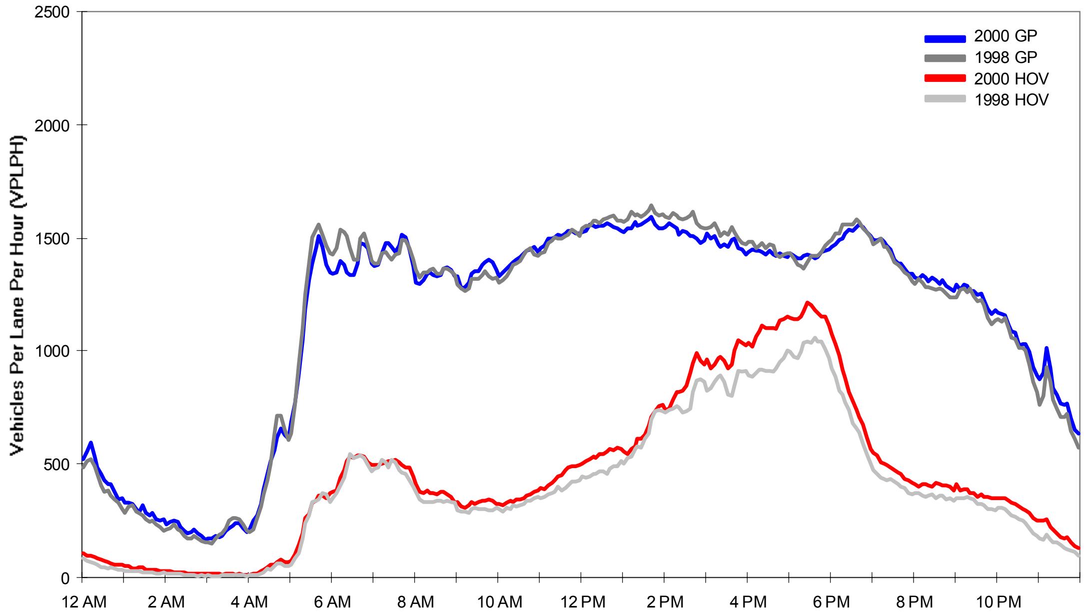



**Figure 2-24. Average Weekday GP and HOV Volume Profile (2000): I-405 @ SE 59th St**

## I-405 @ Tukwila Parkway, Northbound




## I-405 @ Tukwila Parkway, Southbound

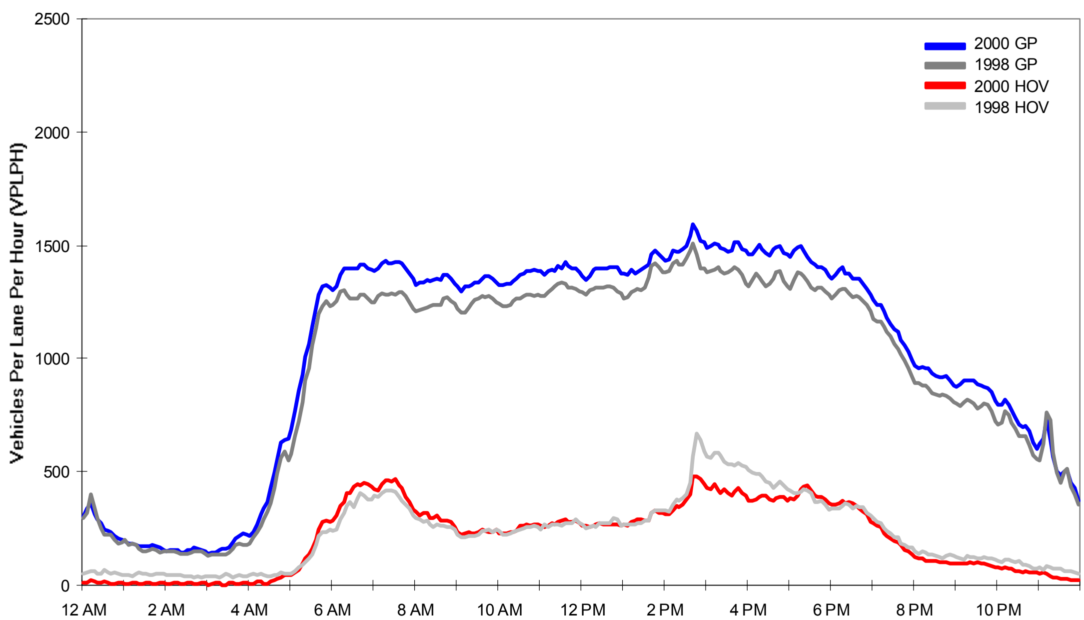



**Figure 2-25. Average Weekday GP and HOV Volume Profile (2000): I-405 @ Tukwila Parkway**

GP volumes during the afternoon peak period. A moderate increase in HOV volumes was observed in both directions during the afternoon peak period. Data at this recording location were biased by the design characteristics of the SR 167 interchange.

**I-90 Floating Bridge (see Figure 2-26)**

The reversible facility volumes were very high during the peak periods. Peak period volumes approached 30 to 45 percent of adjoining general traffic volumes on a per-lane basis. Note, however, that the reversible lanes at this point contain mixed-flow traffic comprising both HOV traffic and Mercer Island GP traffic. Reversible lane volumes remained basically unchanged from 1998.

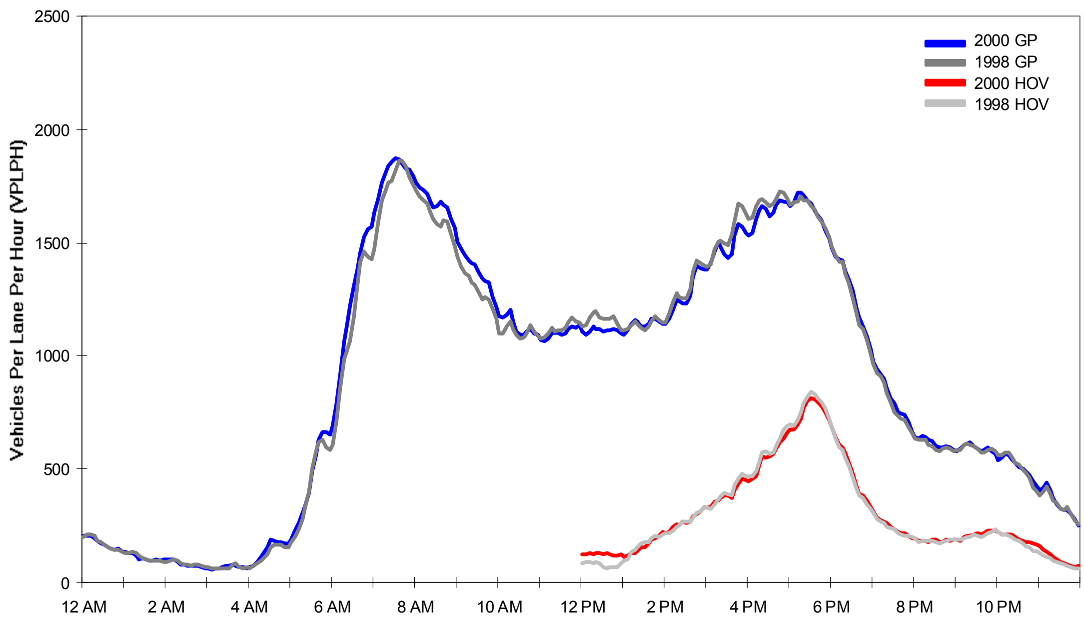
**I-90 near Issaquah (see Figure 2-27)**

HOV volumes exceeded 500 vplph heading eastbound during the afternoon peak period and westbound during the morning peak period. HOV volumes peaked around 40 percent of corresponding GP volumes during the peak periods. Congestion was virtually non-existent along this HOV segment. Modest volume increases have occurred since 1998 during each peak period.

**SR 520 near Medina (see Figure 2-28)**

HOV volumes were relatively low at this location (~400 vplph). PM peak HOV volumes exceeded AM peak volumes in part because AM transit service is much better than PM service. This results in a much higher level of carpool formation in the evening, thus higher volumes in the HOV lanes. A strict occupancy requirement (3+ occupants per vehicle) applies to this converted shoulder HOV facility. The main purpose of this segment is to allow transit vehicles to pass the queue of cars. There was no significant volume change in comparison to the 1998 data in the AM peak, but a modest increase

I-90 @ Midspan, Eastbound




I-90 @ Midspan, Westbound

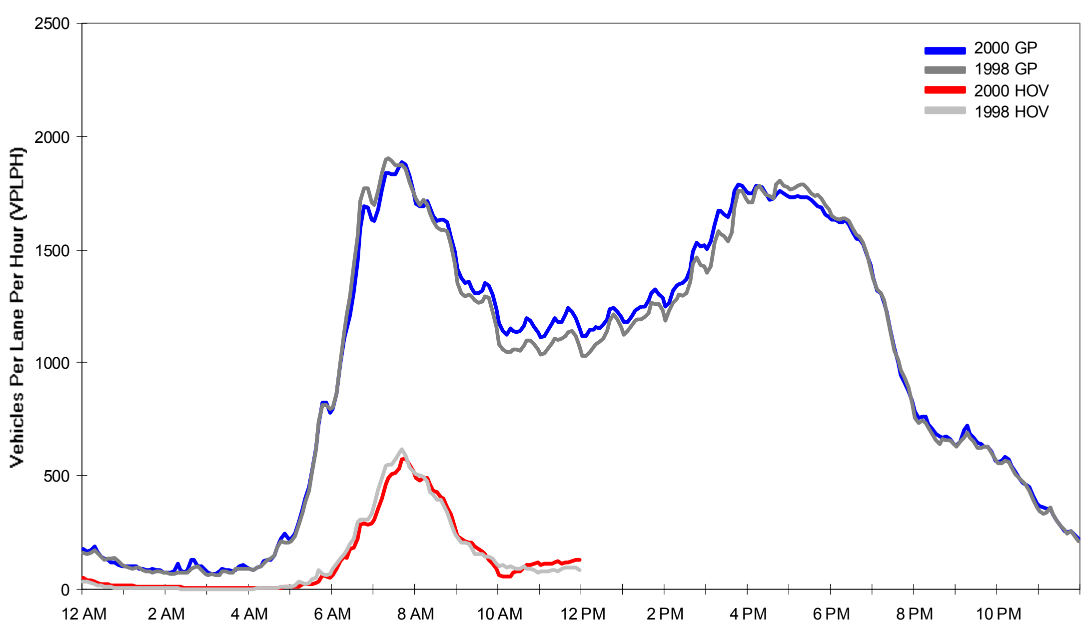
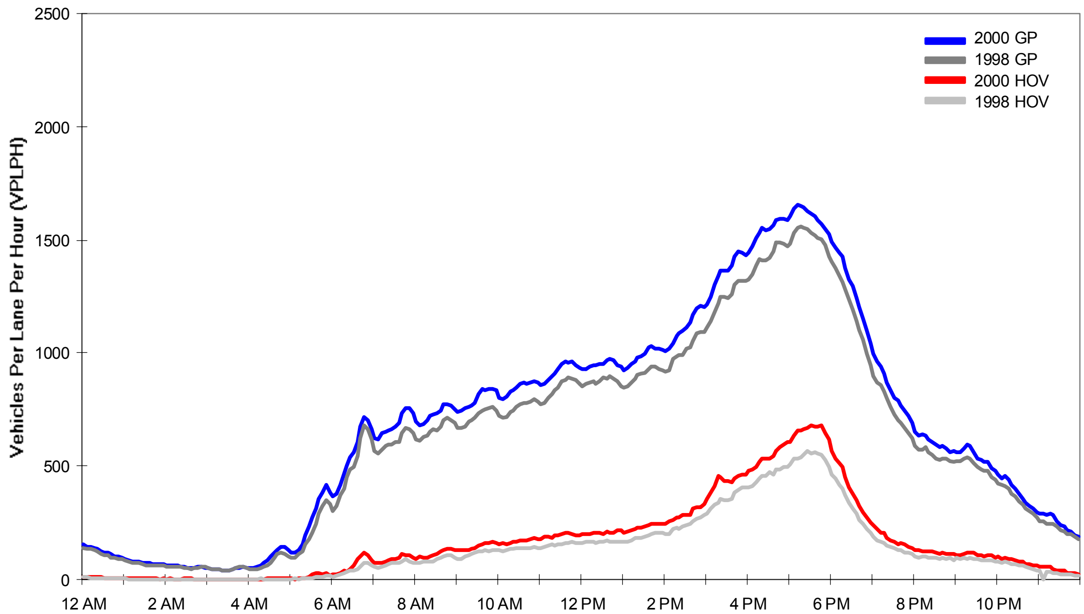



**Figure 2-26. Average Weekday GP and HOV Volume Profile (2000): I-90 @ Midspan**

## I-90 @ Newport Way, Eastbound




## I-90 @ Newport Way, Westbound

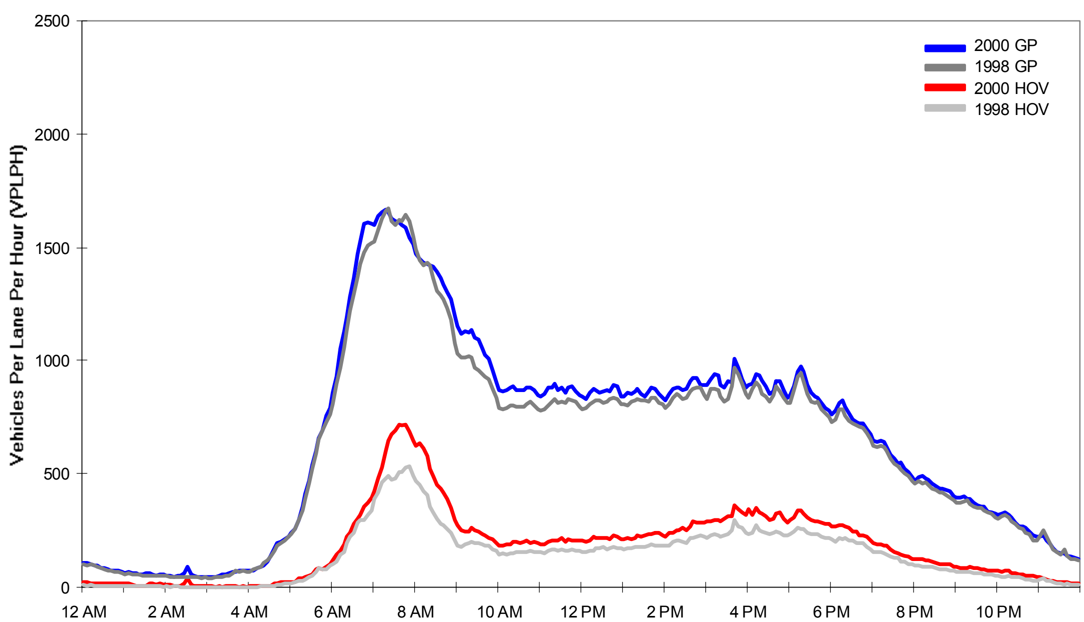



**Figure 2-27. Average Weekday GP and HOV Volume Profile (2000): I-90 @ Newport Way**

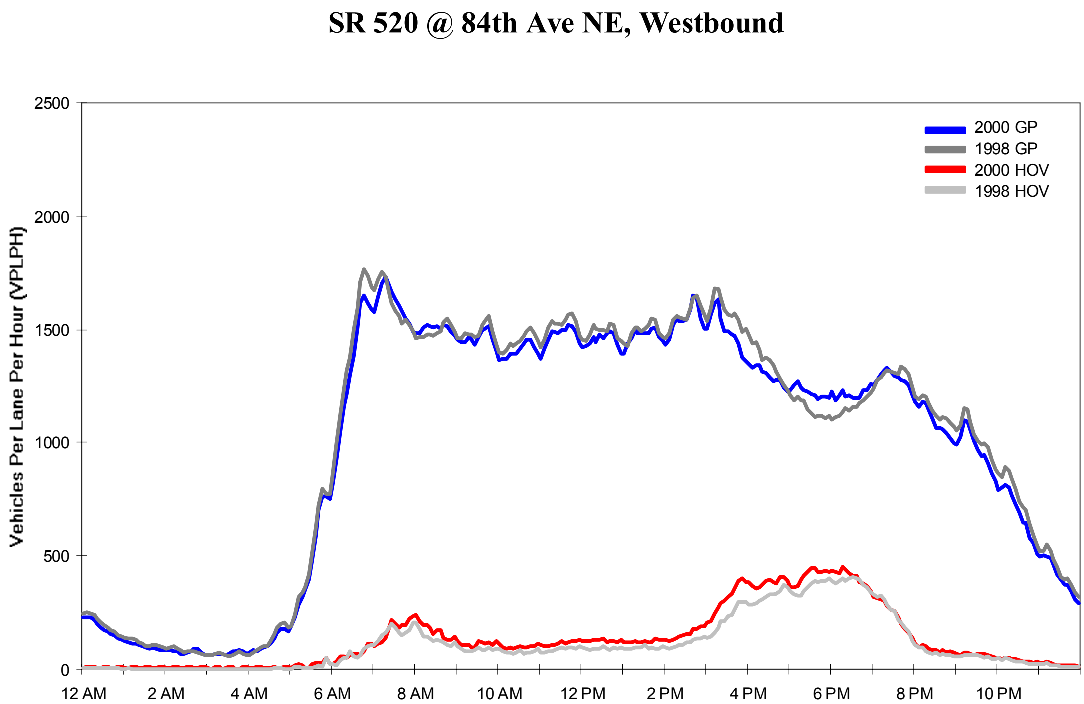



**Figure 2-28. Average Weekday GP and HOV Volume Profile (2000): SR 520 @ 84th Ave NE**

early in the PM peak occurred. This may be due to increased congestion on the GP lanes early in the evening commute period.

**SR 167 near Kent (see Figure 2-29)**

Classic directional commute characteristics exist along this corridor. The southbound HOV volumes approached 1,000 vplph during the afternoon peak period, which was nearly 70 percent of the adjacent GP lane's volume. In comparison to 1998, the 2000 southbound HOV volumes increased about 30 percent during the afternoon peak period. The northbound HOV volumes remained relatively unchanged from 1998, about 600 vplph during the morning peak period. Of interest on this route is the midday HOV volume increases, which while modest, tend to equal or exceed GP increases (per lane).

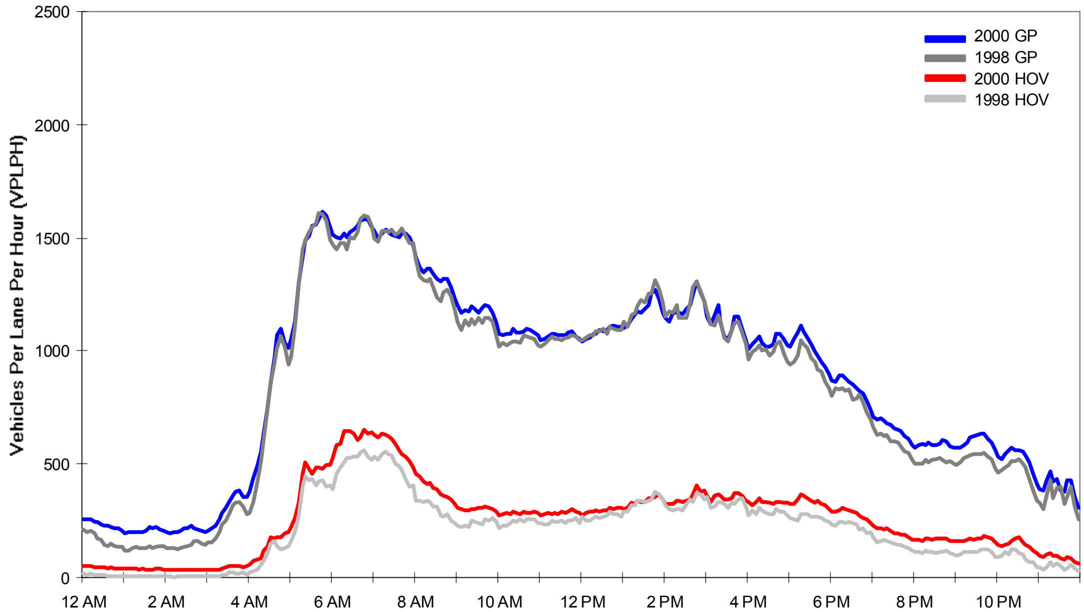
## GP VS. HOV PERSON THROUGHPUT COMPARISON

To what extent is an HOV lane being used? A complete answer to this question requires an analysis of both person and vehicle throughput. Figures 2-30 through 2-40 break down person and vehicle volumes within GP and HOV lanes during the peak times and directions. Several pieces of throughput information are depicted for each representative site. The vehicle and person throughput data for GP and HOV lanes are presented as both overall and per-lane statistics. This allows the determination of what proportion of total throughput the HOV facility provides, while also allowing a fairer comparison of how much throughput the HOV lane is providing in comparison to a single GP lane.

**I-5 near South Everett (see Figure 2-30)**

**AM Peak Period**. The southbound HOV lane carried 20 percent of all people in 12 percent of all cars, resulting in an average vehicle occupancy that was nearly two

**SR 167 @ S 208th St, Northbound**




**SR 167 @ S 208th St, Southbound**

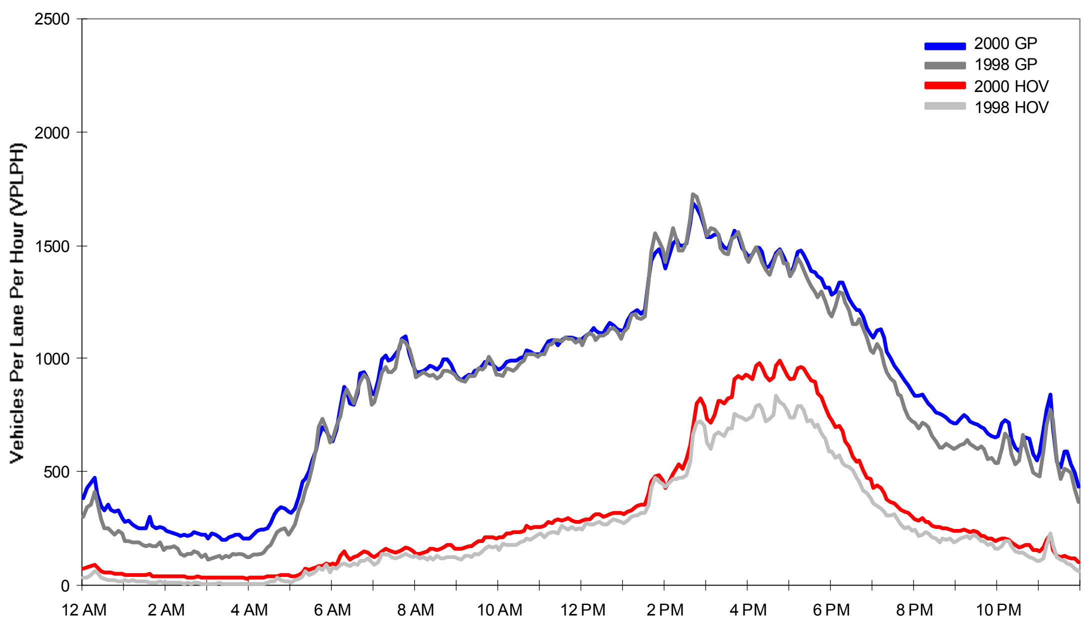



**Figure 2-29. Average Weekday GP and HOV Volume Profile (2000): SR 167 @ S 208th St**

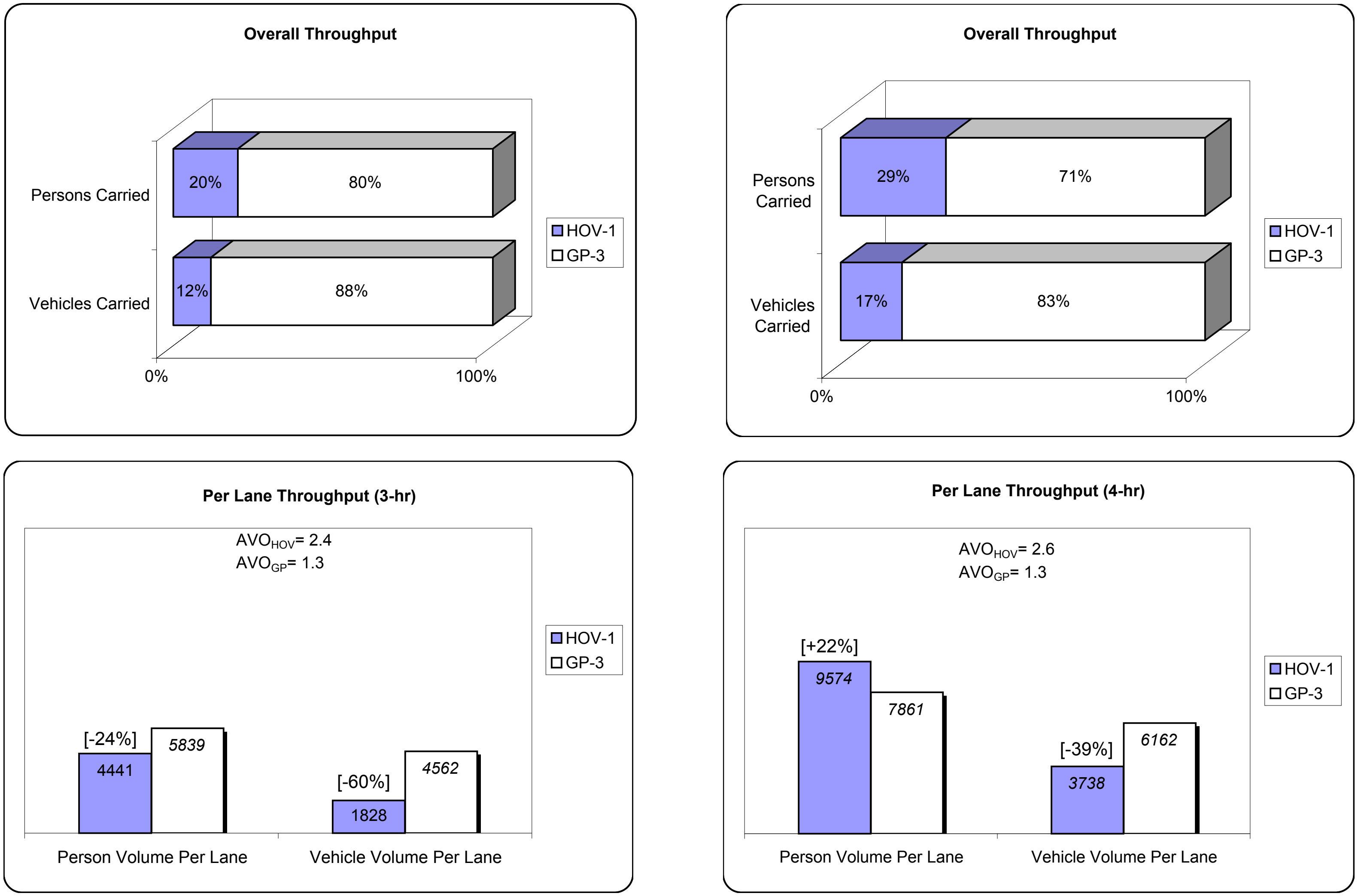



**Figure 2-30. GP vs. HOV Throughput Comparison (2000): I-5 near South Everett**

times that of the adjacent GP lane (2.4 people per vehicle versus 1.3 people per vehicle). Transit riders made up just under 10 percent of HOV lane users. On a per-lane basis, the southbound HOV lane carried 24 percent fewer people and 60 percent fewer vehicles than the adjacent GP lane.

**PM Peak Period**. The northbound HOV lane carried 29 percent of all people in 17 percent of all cars, with an AVO of 2.6. On a per-lane basis, the HOV lane carried 22 percent more people in 39 percent fewer vehicles than the adjacent GP lane.

**I-5 near Northgate (see Figure 2-31)**

**AM Peak Period**. About 60 percent of the people traveling southbound toward the University of Washington and downtown Seattle were carried by four GP lanes; and the single southbound HOV lane carried the remaining 40 percent of all travelers in 16 percent of the vehicles in the forms of carpools, vanpools, and buses. About 36 percent of total people carried in the HOV lane were bus riders (refer to Figure 2-4), resulting in an average vehicle occupancy of 3.7. On a per-lane basis, the HOV lane carried 144 percent more people in 23 percent fewer vehicles than the adjacent GP lane.

**PM Peak Period.** In the evening peak period, the HOV lane carried 35 percent of all people and 16 percent of all vehicles. On average, 3.5 people were in each vehicle in the HOV lane. About one third of all people traveling in the HOV lane used transit services. The HOV lane carried more than twice as many people in 23 percent fewer vehicles than the adjacent GP lane.

**I-5 South of the Seattle CBD (see Figure 2-32)**

**AM Peak Period**. About one third of all people traveling northbound in the peak period used the HOV lane and were carried in 16 percent of the vehicles. Unlike other inside HOV lanes, the northbound HOV lane at this location is also an exit lane, so it

**AM Peak Period: Southbound** **PM Peak Period: Northbound**

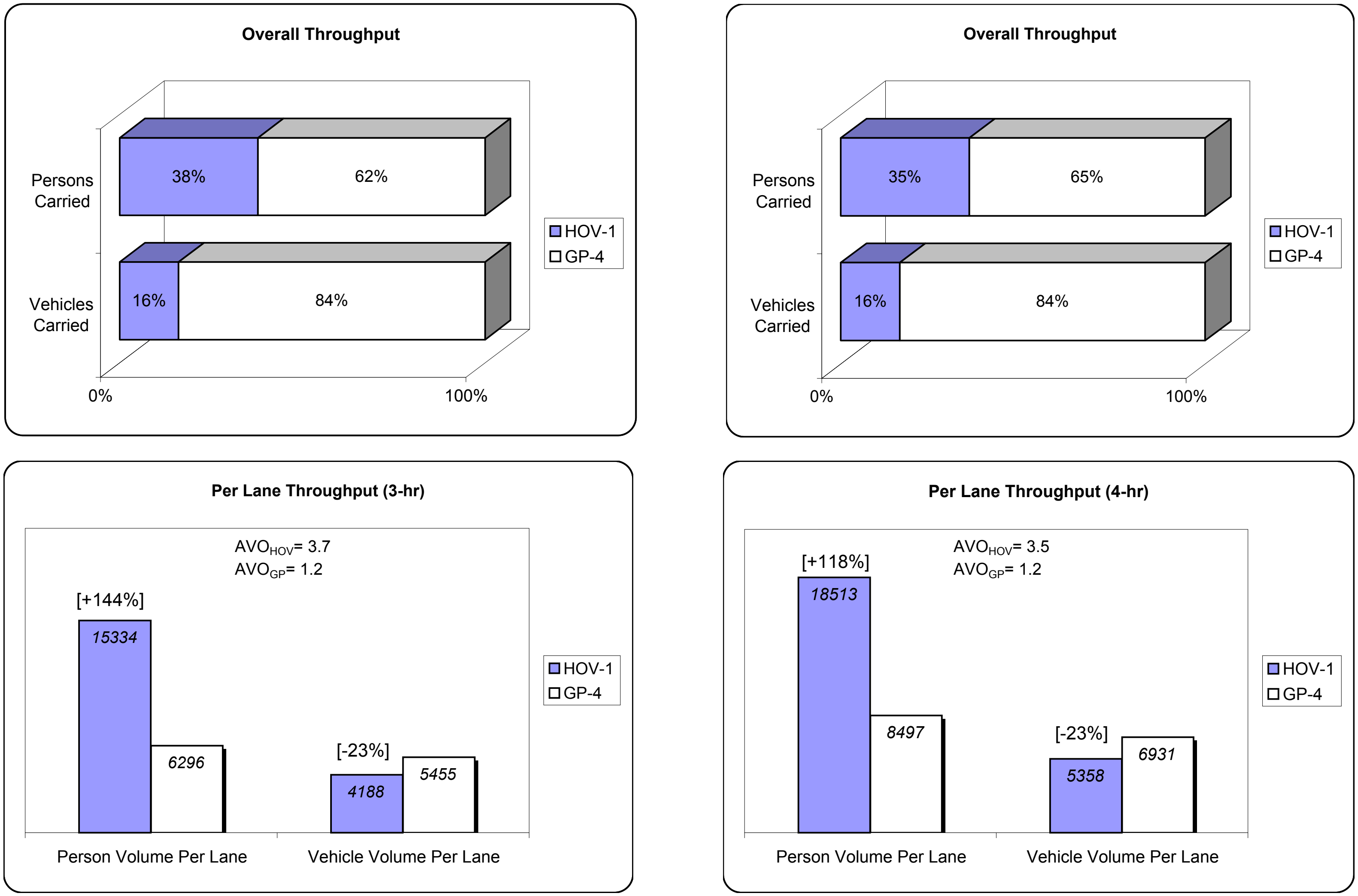



**Figure 2-31. GP vs. HOV Throughput Comparison (2000): I-5 near Northgate**

**AM Peak Period: Northbound** **PM Peak Period: Southbound**

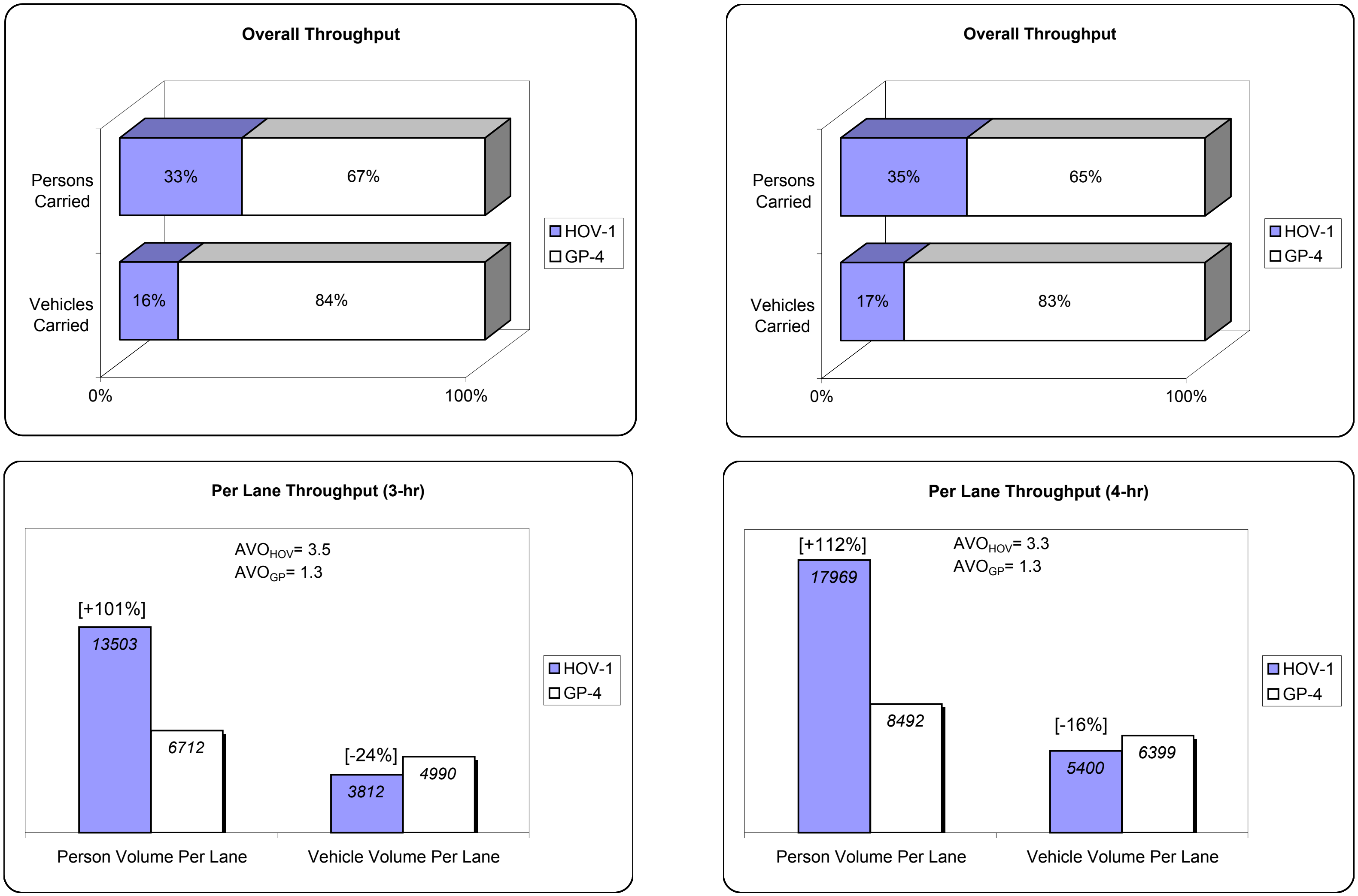



**Figure 2-32. GP vs. HOV Throughput Comparison (2000): I-5 South of Seattle CBD**

includes a mixture of SOV and HOV traffic. This slightly lowered the average vehicle occupancy rate. Almost half (44 percent) of people carried in the HOV lane were bus riders. The HOV lane carried 13,503 people in 3,812 vehicles, or twice as many people in 24 percent fewer vehicles than the adjacent GP lane.

**PM Peak Period**. The southbound HOV lane carried 35 percent of all people in the evening peak period in 17 percent of the vehicles, equivalent to an AVO of 3.3 people in each vehicle. About one-third of all people traveling in the HOV lane used transit services. The HOV lane carried 112 percent more people in 16 percent fewer vehicles than the adjacent GP lane.

**I-5 South of Southcenter (see Figure 2-33)**

**AM Peak Period**. Nearly 30 percent of all people traveling northbound used the HOV lane and were carried in 13 percent of the vehicles. About 37 percent of the HOV lane users were bus riders. The HOV lane carried 12,020 people in 3,515 vehicles, or 67 percent more people in 41 percent fewer vehicles than the adjacent GP lane.

**PM Peak Period**. In the evening peak period, the southbound HOV lane carried 28 percent of all people and 13 percent of all vehicles. On average, 3.1 people were in each vehicle in the HOV lane. About 30 percent of all people traveling in the HOV lane used transit services. The HOV lane carried twice as people in 25 percent fewer vehicles than the adjacent GP lane.

**I-405 near Kirkland (see Figure 2-34)**

**AM Peak Period.** The southbound HOV lane carried 30 percent of all people in 17 percent of all vehicles, or 6,855 people in 2,805 vehicles, resulting in an AVO of 2.4 people per vehicle. The HOV lane carried 26 percent more people in 40 percent fewer

**AM Peak Period: Northbound** **PM Peak Period: Southbound**

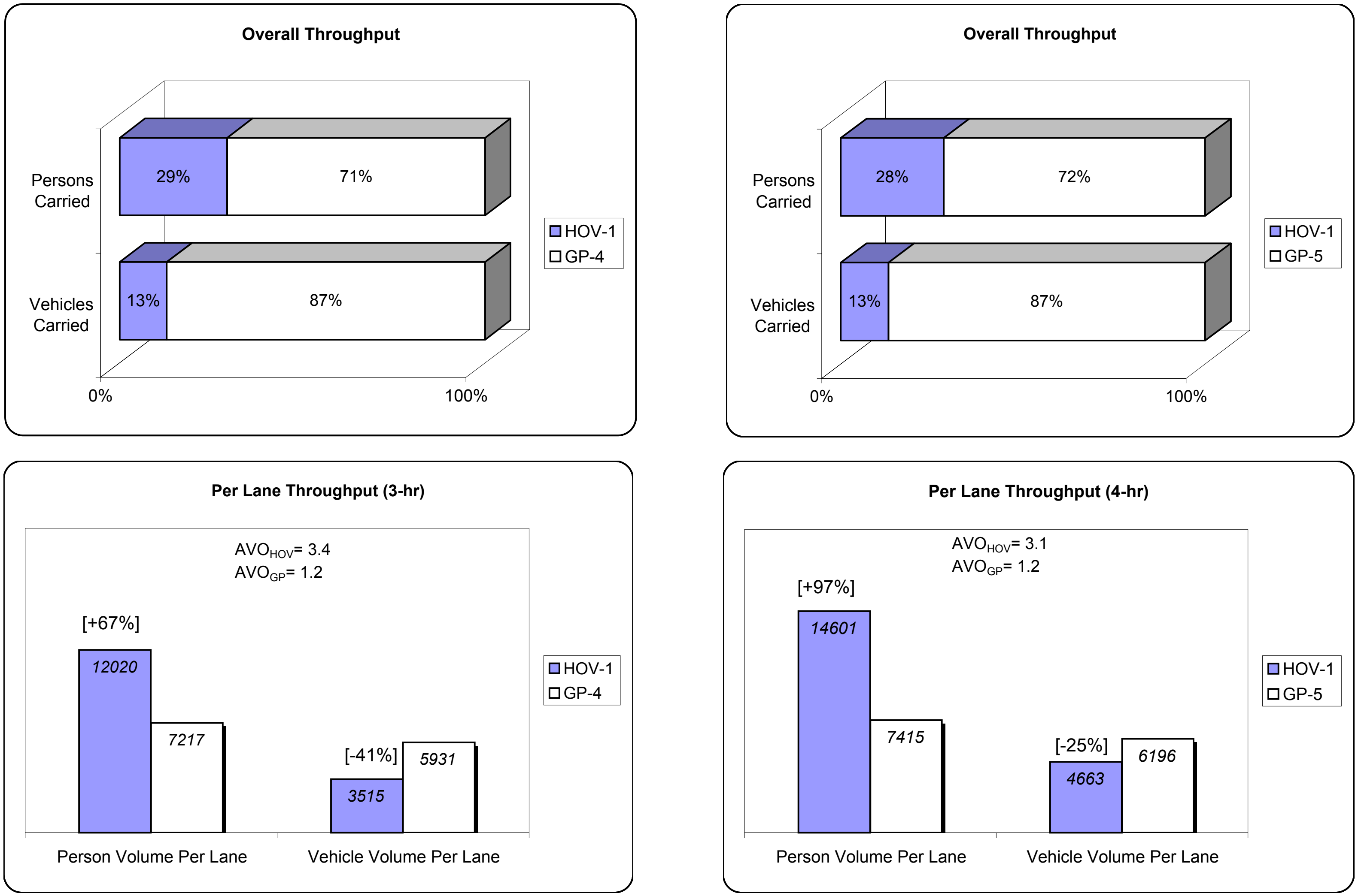



**Figure 2-33. GP vs. HOV Throughput Comparison (2000): I-5 South of Southcenter**

**AM Peak Period: Southbound** | **PM Peak Period: Northbound**

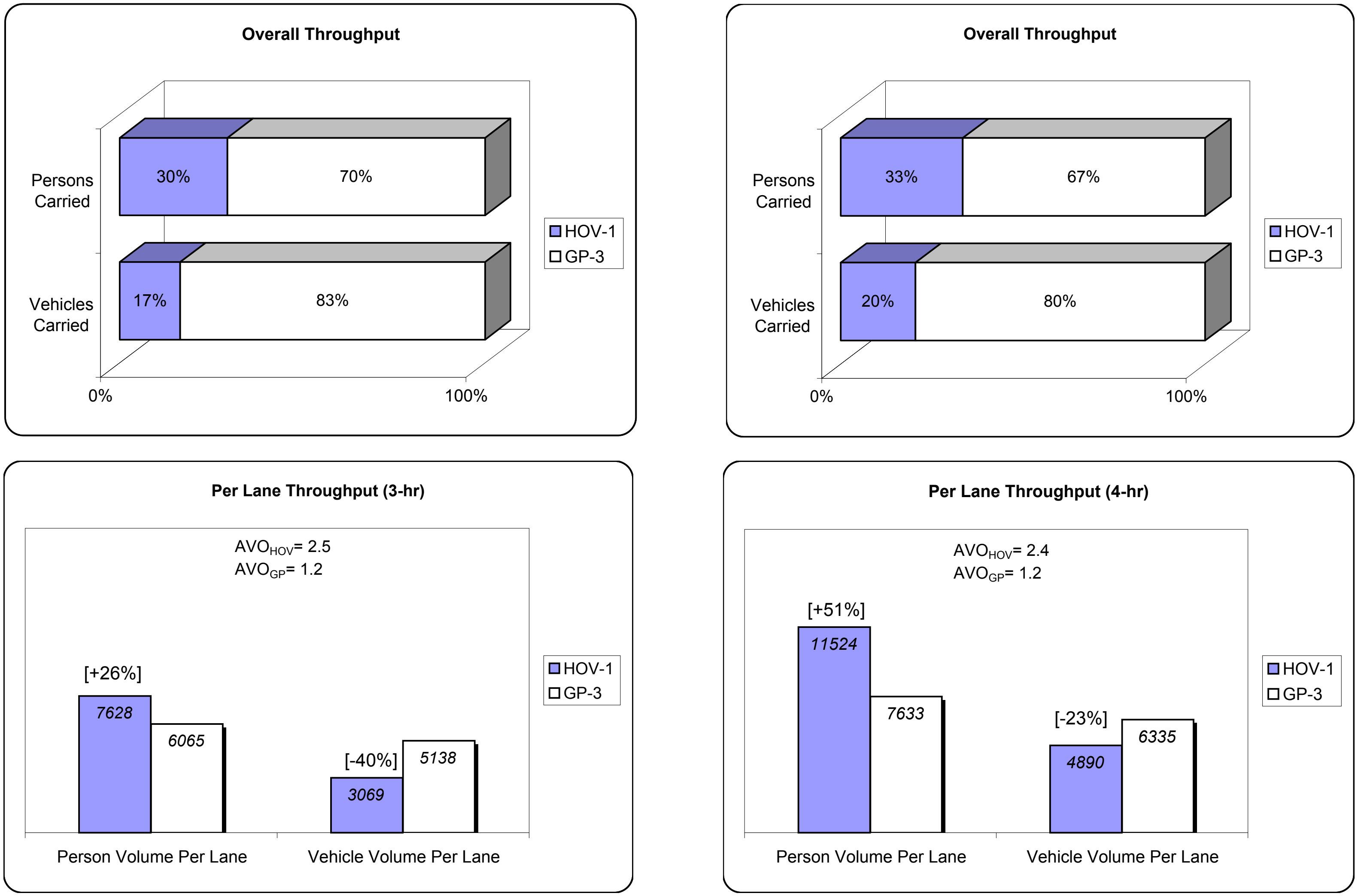



**Figure 2-34. GP vs. HOV Throughput Comparison (2000): I-405 near Kirkland**

vehicles than the adjacent GP lane. Roughly 12 percent of travelers in the HOV lane were in transit vehicles.

**PM Peak Period.** The northbound HOV lane carried one third of all people in 20 percent of all vehicles with an average of 2.4 people in each vehicle. The HOV lane carried 51 percent more people in about 23 percent fewer vehicles than the adjacent GP lane.

**I-405 near Newcastle (see Figure 2-35)**

**AM Peak Period**. The northbound HOV usage during the morning peak period was relatively high, although transit patronage at this location was modest. The HOV lane carried almost half of the people in 30 percent of the vehicles, an average of 2.3 people in each vehicle. The vast majority of HOV lane users were in carpools, with only 5 to 7 percent using transit on this portion of I-405. In comparison to the adjacent GP lane, the HOV lane carried 60 percent more people in about 16 percent fewer vehicles.

**PM Peak Period**. The HOV usage during the evening peak period was also high. About 45 percent of the people using I-405 southbound were carried in the HOV lane in 31 percent of the vehicles, with an average of 2.2 people in each vehicle. This is roughly 67 percent more people in about 11 percent fewer vehicles than in the adjacent GP lane.

**I-405 near Southcenter (see Figure 2-36)**

**AM Peak Period**. HOV lane use at this location was moderate in comparison to the adjacent GP lane during the morning commute. GP person and vehicle throughput per lane both exceed HOV lane throughput on this section of roadway.

**PM Peak Period**. Unlike the morning peak in the southbound direction for this location, the northbound HOV lane outperformed the adjacent GP lanes during the

**AM Peak Period: Northbound** | **PM Peak Period: Southbound**

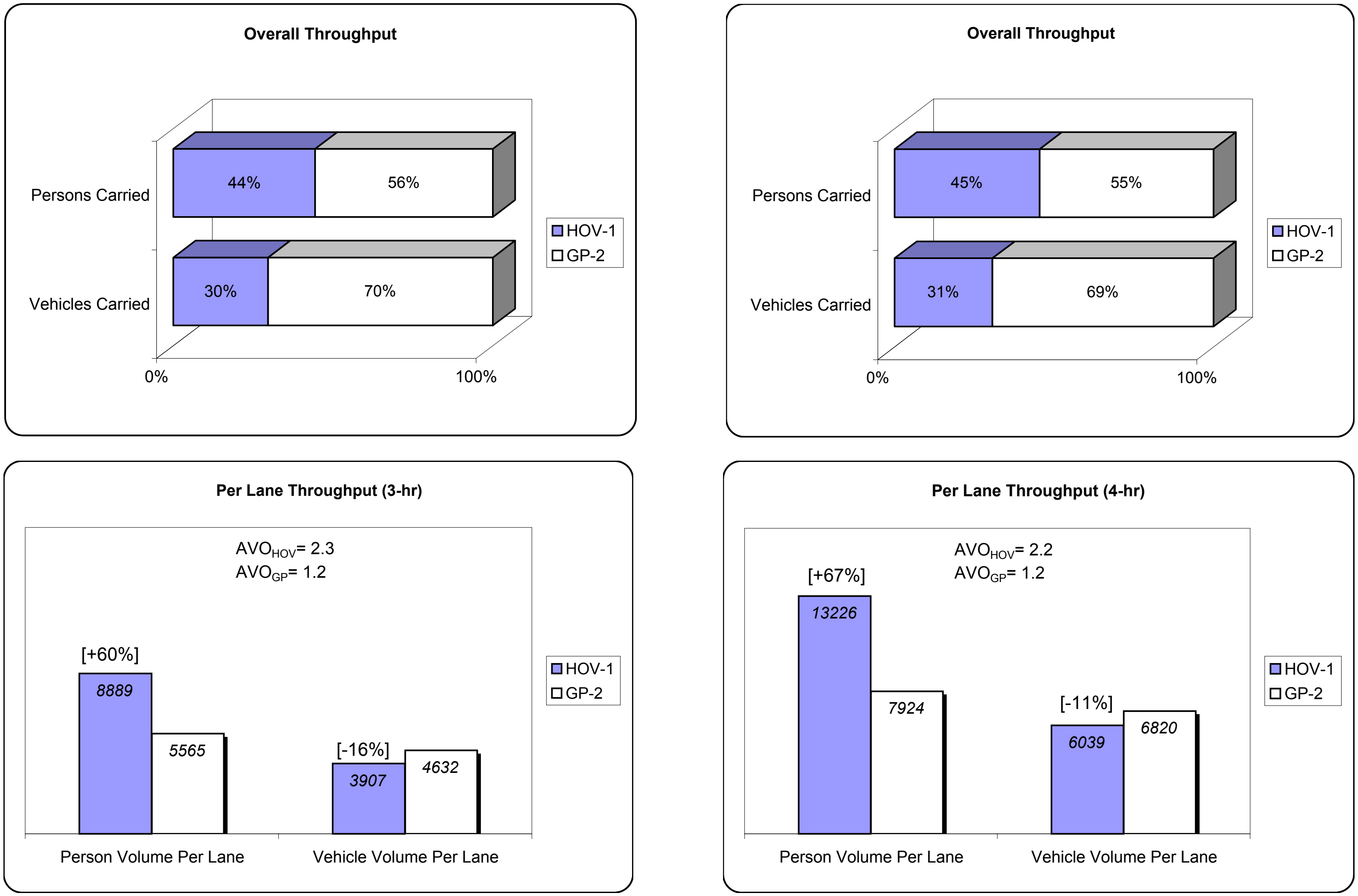



**Figure 3-35. GP vs. HOV Throughput Comparison (2000): I-405 near Newcastle**

**AM Peak Period: Southbound** **PM Peak Period: Northbound**

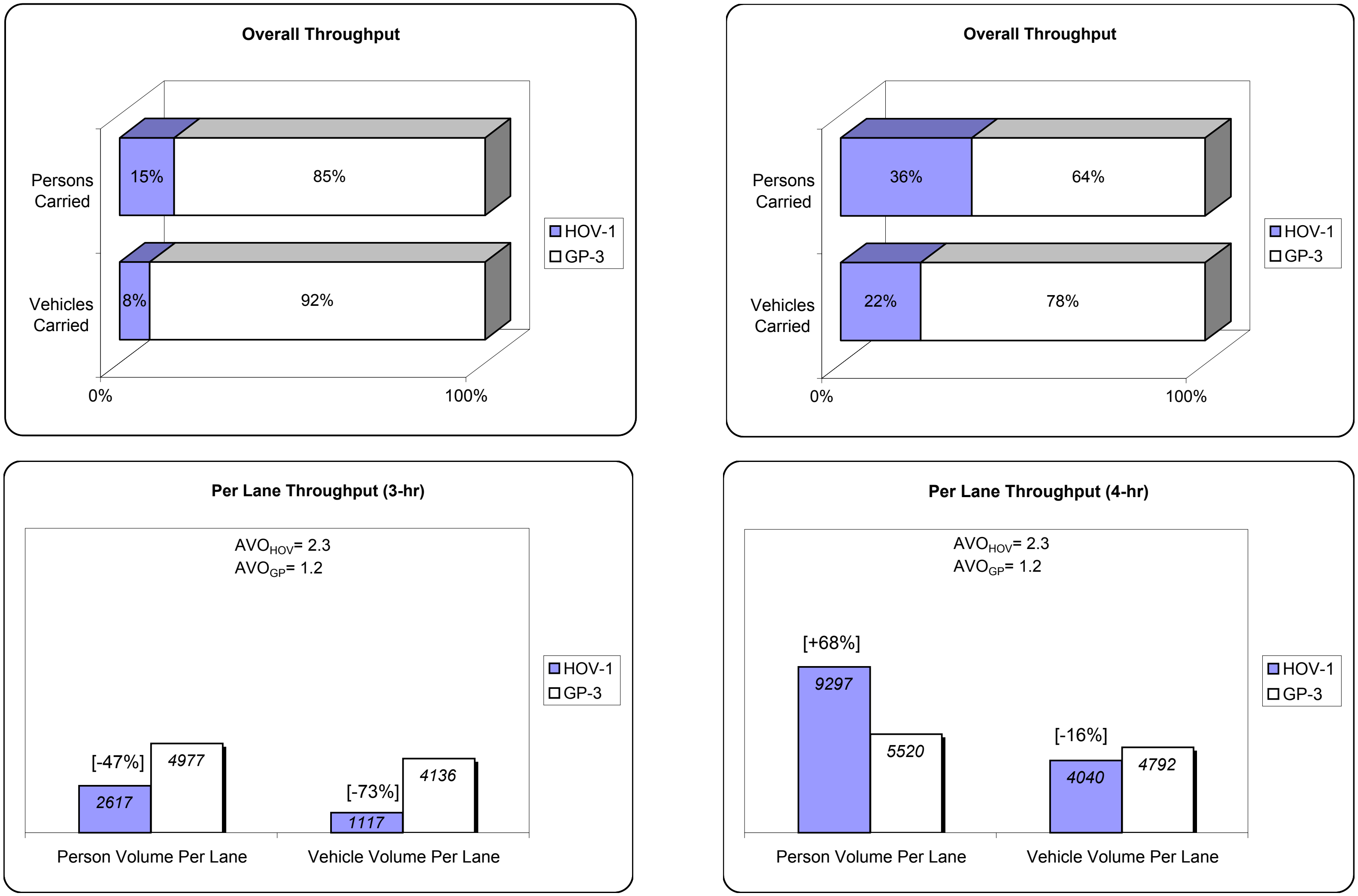



**Figure 2-36. GP vs. HOV Throughput Comparison (2000): I-405 near Southcenter**

evening peak period. It carried 68 percent more people in 16 percent fewer vehicles than the adjacent GP lane during the afternoon peak period.

**I-90 Floating Bridge (see Figure 2-37)**

**AM Peak Period**. Almost one third of the westbound commuters utilized the center roadway, traveling in a mixture of transit, carpools, vanpools, and GP vehicles. Traffic volumes along the center roadway at this time of day represented 13 percent of all vehicles on I-90. On a per-lane basis, each HOV lane carried 40 percent fewer people and 77 percent fewer vehicles than an adjacent GP lane.

**PM Peak Period**. In the evening peak period, 34 percent of the people traveling eastbound used the center lanes in 19 percent of all vehicles traveling on the I-90 bridge. Each HOV lane carried 23 percent fewer people in 64 percent fewer vehicles than an adjacent GP lane.

**I-90 near Issaquah (see Figure 2-38)**

HOV usage during both the commute periods was moderate. Overall, the HOV lane carried about 18 percent of all people in 10 percent of all vehicles. On a per-lane basis, the HOV lane carried fewer people and vehicles than the adjacent GP lanes. This moderate usage of the HOV facility was primarily due to the low congestion level on I-90; however, note that HOV volumes in the AM are growing much more quickly than GP volumes as congestion in the GP lanes increases (see Figure 2-27, presented earlier).

**SR 520 near Medina (see Figure 2-39)**

**AM Peak Period**. The westbound HOV lane on SR 520 (the only freeway HOV lane in Puget Sound that requires three or more occupants) carried 28 percent of all people in only 4 percent of all vehicles. Eighty-one percent of the people carried in the HOV lane were in buses.

**AM Peak Period: Westbound** **PM Peak Period: Eastbound**

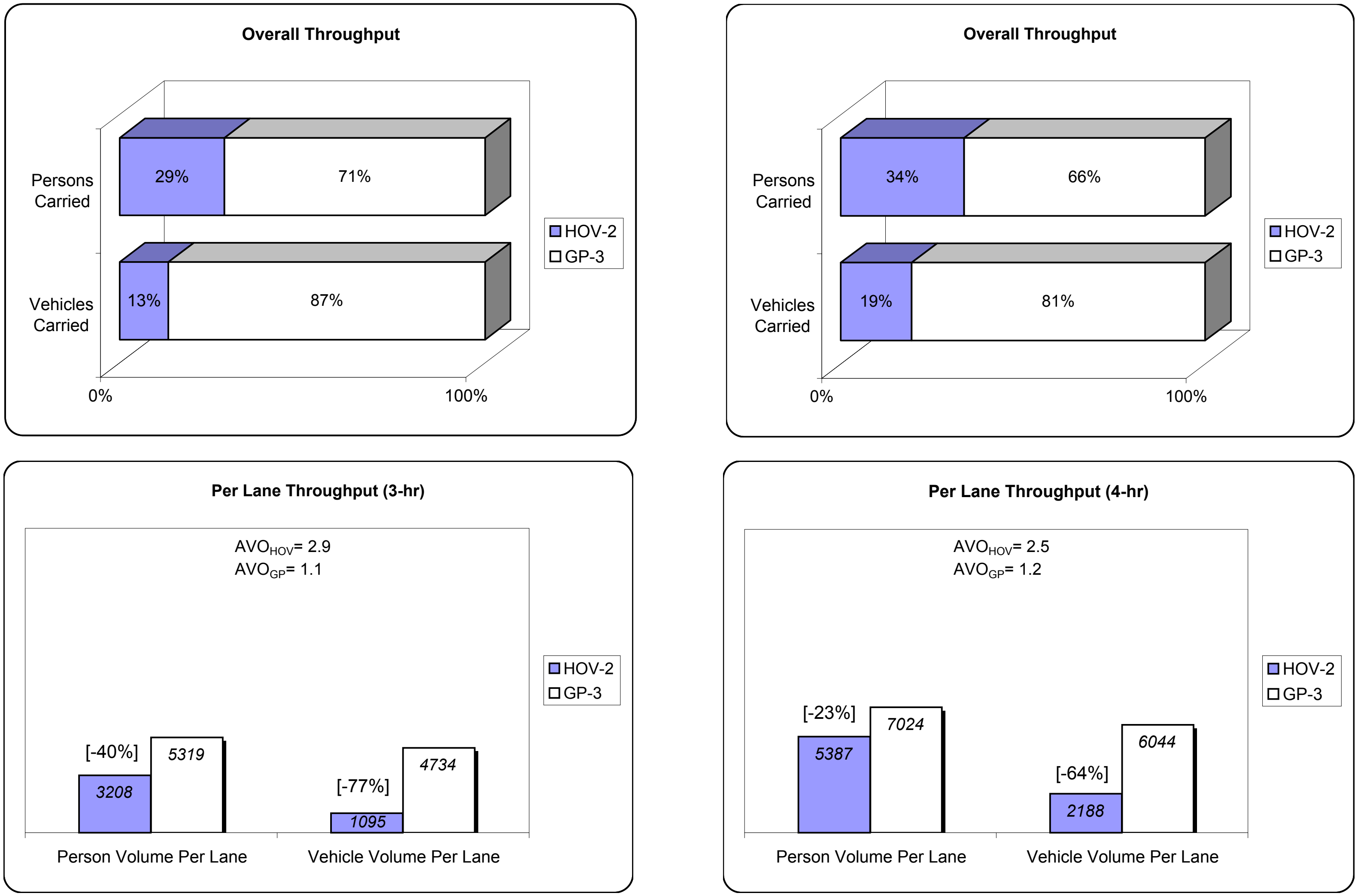



**Figure 2-37. GP vs. HOV Throughput Comparison (2000): I-90 Floating Bridge**

**AM Peak Period: Westbound** | **PM Peak Period: Eastbound**

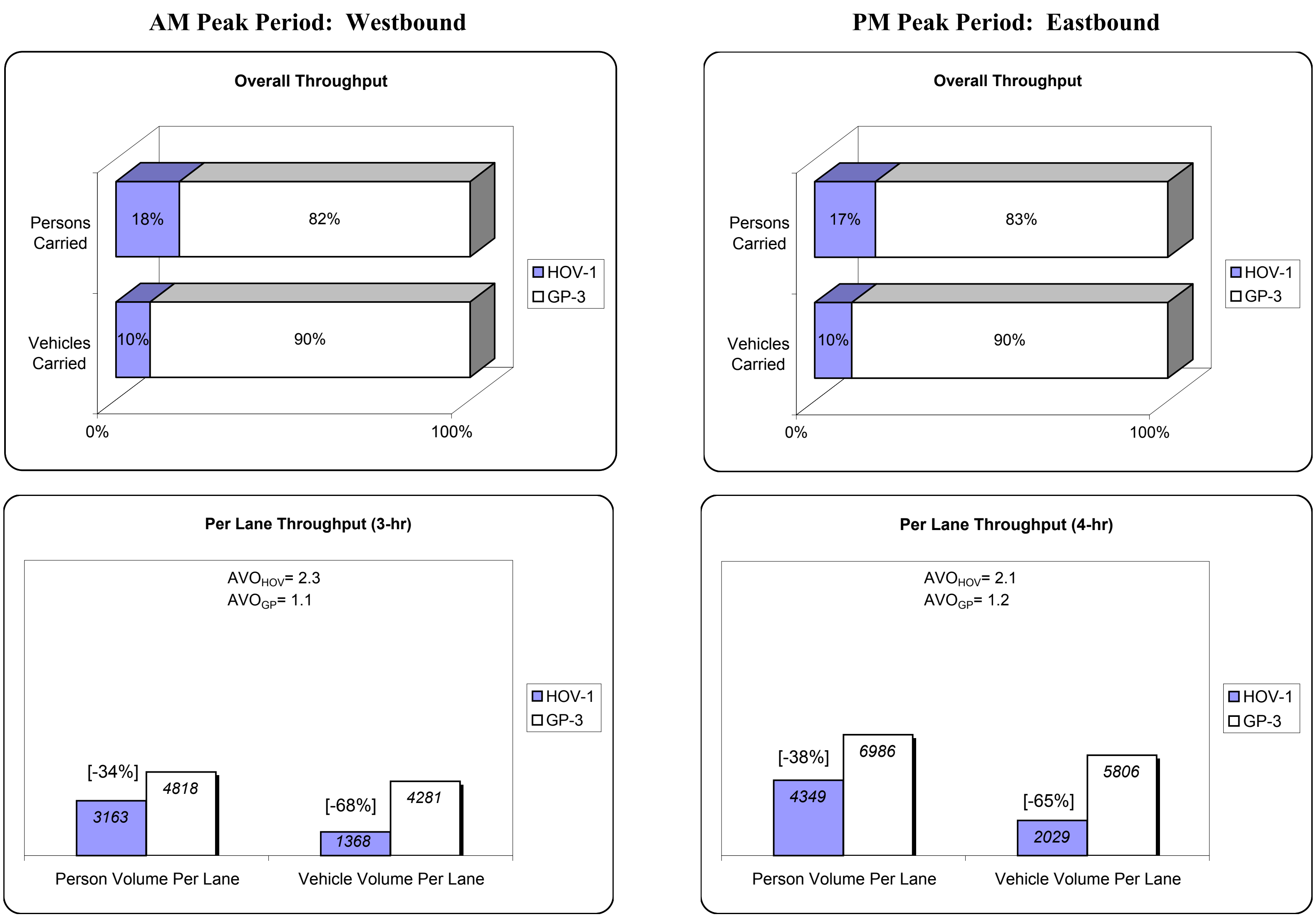



**Figure 2-38. GP vs. HOV Throughput Comparison (2000): I-90 near Issaquah**

**AM Peak Period: Westbound** **PM Peak Periodm: Westbound**

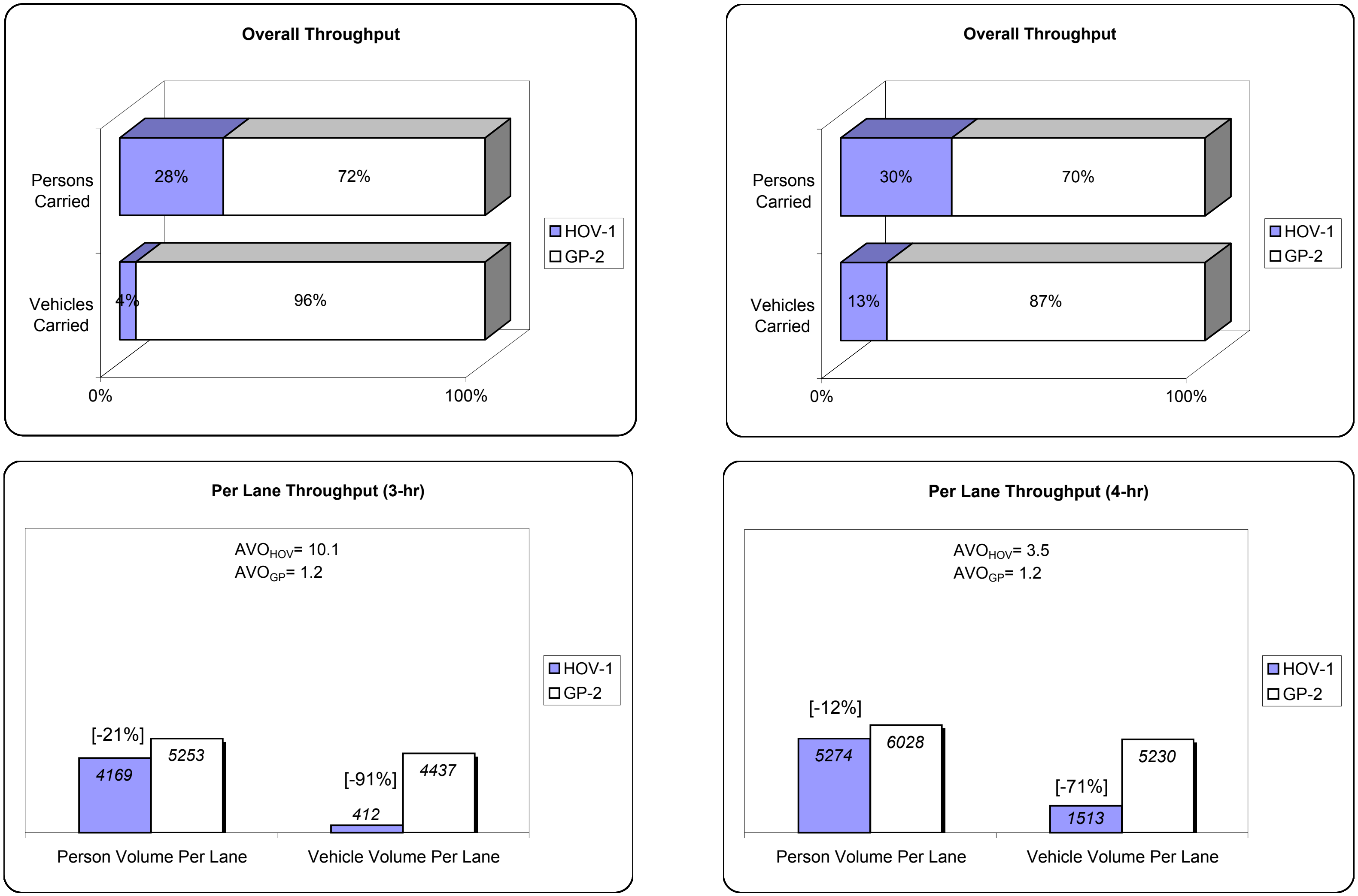



**Figure 2-39. GP vs. HOV Throughput Comparison (2000): SR 520 near Medina**

**PM Peak Period**. Despite lower levels of transit service in the PM, the westbound HOV lane carried one third of all people heading across Lake Washington in only 13 percent of the vehicles. Per lane, the HOV lane carried about the same number of people but in 71 percent fewer vehicles than either of the GP lanes adjacent to it.

**SR 167 near Kent (see Figure 2-40)**

**AM Peak Period**. HOV usage during the morning peak period was relatively low. (Peak HOV use occurs farther north near the interchange with I-405.) On a per-lane basis, the HOV lane carried fewer people and vehicles than the adjacent GP lanes.

**PM Peak Period**. The southbound HOV usage during the afternoon peak period was slightly better than in the morning. About 33 percent of all people were carried in 22 percent of all vehicles, with an average of 2.1 people in each vehicle. Person throughput per lane was roughly equal for the GP and HOV lanes at this location, but the HOV lane served only about half the vehicle volume.

**AM Peak Period: Northbound** **PM Peak Period: Southbound**

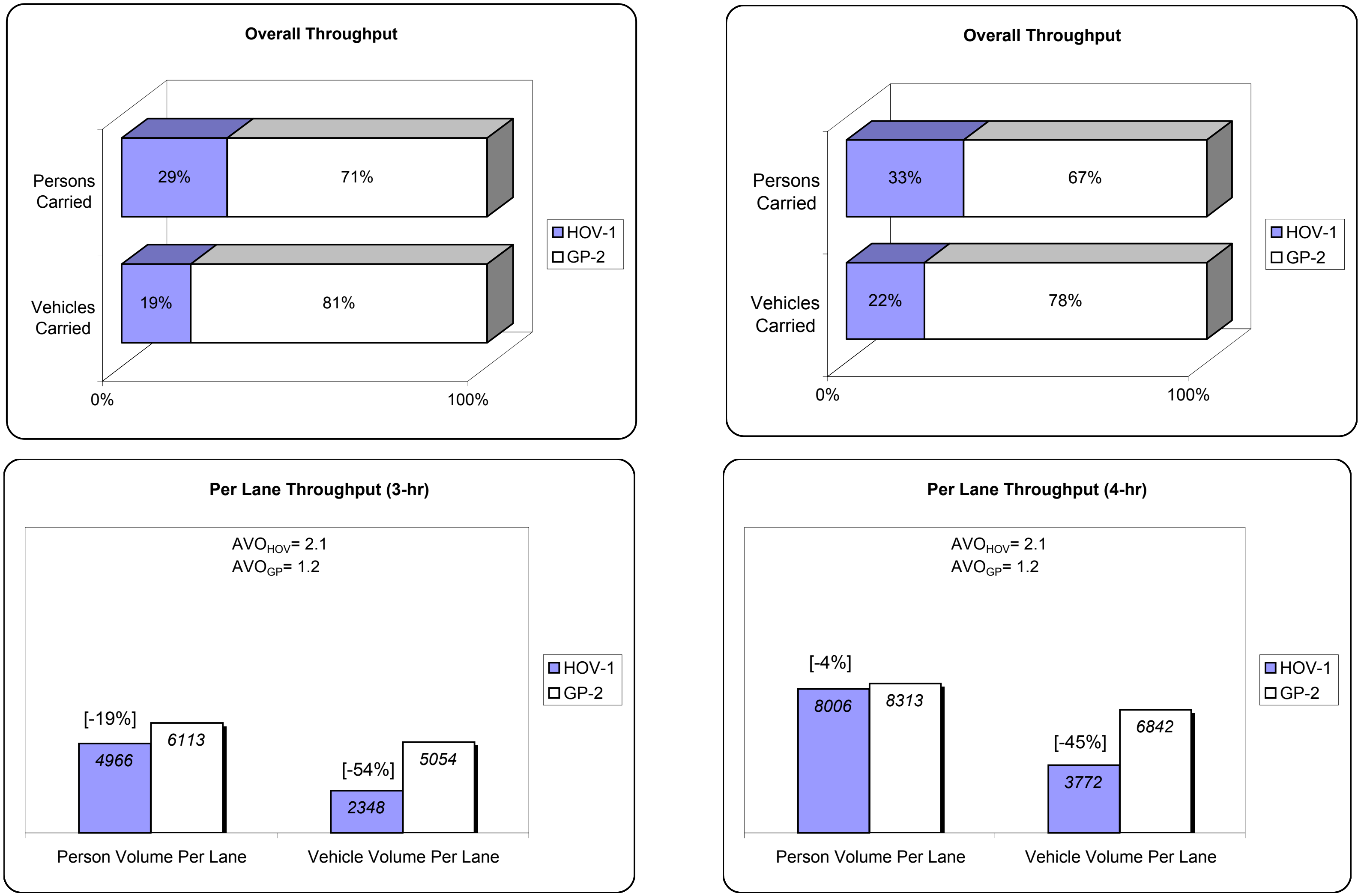



**Figure 2-40. GP vs. HOV Throughput Comparison (2000): SR 167 near Kent**

# CHAPTER 3.
# SPEED RELIABILITY AND TRAVEL

This chapter presents the corridor-wide and site-specific operational performance of HOV facilities. The WSDOT HOV system policy states that "HOV lane vehicles should maintain or exceed an average speed of 45 mph or greater at least 90 percent of the time they use that lane during the peak hour (measured for a consecutive six-month period)." To best gauge whether HOV facilities are offering users faster travel speed and a more reliable trip than the GP lanes, HOV operational performance was measured in these terms:

- speed
- reliability
- congestion pattern
- travel time

The purpose of these measures is to describe the following:

- the HOV lane travel speeds that can be expected for a range of trip start times throughout the day
- the likelihood of the average trip in the HOV lane becoming congested (with a speed of less than 45 mph)
- how traffic conditions change from location to location along an HOV corridor throughout the day
- how HOV and GP travel times compare
- the travel time savings realized when the HOV lane is used

The results of the operational performance analysis allow us to identify "problems" that can then be examined in more detail. When problems occur it is important to understand why a particular corridor is not meeting the criteria set by the

HOV policy before making operational changes. In many cases, the cause of the deficiency may not be easily fixed. For instance, when stop-and-go congestion occurs in the GP lanes, HOV traffic often slows down because drivers are uncomfortable with traveling at 55 mph so close to stopped traffic. This is called “lane friction.” The friction between vehicles with only a lane line separating them is too substantial. The fact that HOV vehicles slow down under these conditions improves safety as well as driver comfort, and should not necessarily be viewed as a “bad” outcome, even if that means the HOV lanes operate below the 45 mph standard. In addition, the geometric improvements required to limit “fiction” slow downs are very expensive and create their own operational difficulties.

Another concern is how incidents affect HOV lane operations. This requires determining whether incidents physically block the HOV lane or are simply nearby, and how these incidents cause delays. Other factors, such as adverse weather and the geometric constraints of roadways, can also affect HOV lane operation. Geometric constraints such as hills and curves have a pronounced effect on vehicle speeds, particularly when steep grades prevent buses from maintaining desired speeds. Last, congestion often occurs where HOV facilities merge with GP lanes as GP traffic merges into the HOV lane, or where vehicles exit the HOV lane by weaving through congested GP lanes. Examples of merge related congestion are on I-405 near SR 522 and on I-405 at SR 167, although this phenomenon happens to a greater or lesser extent on all major HOV lanes in the region.

## CORRIDOR-WIDE OPERATIONAL PERFORMANCE

This section describes the performance measures used to evaluate the operational characteristics of the region's HOV facilities. Each HOV corridor is discussed independently. Operational performance was assessed with the following measures: speed, speed reliability, level of traffic congestion, and travel time savings. Each of these measures is defined below:

- **90th Percentile Average Speed, by Trip Start Time**. Because the state policy standard for HOV lane performance requires an average speed of 45 mph or better, 90 percent of the time during the peak hour, the 90$^{th}$ percentile weekday HOV lane speeds were estimated for a range of trip start times throughout an average 24-hour weekday. This measurement indicates that nine times out of ten (i.e., 90 percent of the time) a vehicle will travel at a particular speed or faster.

- **Trip Reliability, by Trip Start Time**. In contrast to the 90$^{th}$ percentile average travel speed, this measurement indicates the likelihood (percentage of weekdays) that the average trip speed will be below 45 mph for a given trip start time. This measure indicates how frequently an HOV lane fails the 45 mph standard adopted for Puget Sound freeways.

- **Average Traffic Congestion Levels**. To better understand how traffic conditions change as vehicles travel from one location to another on the HOV system, the researchers measured HOV lane congestion patterns at different points (mileposts) along the corridor. The data presented are the average of conditions (average annual weekday lane occupancy data from WSDOT's loop detectors) measured for all weekdays during the year. The result is an image of the " routine" conditions in each HOV lane corridor for all 24 hours of the average weekday.

- **Average Travel Time Savings**. Travel times are another measure of corridor-wide freeway performance. This measure is particularly useful for conveying corridor congestion because it is in a form that is readily understood by the public. It allows individual travelers to compare their own experiences against the reported statistics. It is also useful for tracking changes in facility performance over time and for comparing GP and HOV lane performance. For this report, travel times were estimated for a range of start times for trips that traverse the length of particular GP and HOV lanes in the analysis. For a range of start times for each trip, the project estimated the average of GP and HOV lane travel times measured for the weekdays during the year.

Table 3-1 lists the corridors for which operational performance was measured.

**Reading the Speed and Reliability Graphs**

The speed and reliability measures described on the previous page are illustrated on the same set of figures in this report. For the corridor trips listed in Table 3-1, specific graphs were created to plot the 90$^{th}$ percentile average speed and the 45 mph speed reliability (that is, the frequency at which the average vehicle speed falls below 45 mph during trips for a given trip start time). The following instructions are intended to help the reader understand how to interpret these graphics.

Figure 3-1 is an 8-hour slice of a speed and reliability graph for the northbound HOV lane on I-5 near Northgate. Both of these measures depend on the time of day the traveler leaves. The starting time of a trip is shown along the horizontal axis from midnight to midnight (only the hours from 1:00 PM to 9:00 PM are shown). The line graph (near the top of the figure) represents the 90th percentile average speed for HOVs using I-5 from Northgate to Alderwood. It is measured with the left vertical axis. It indicates that HOV lane vehicles travel at a speed below 45 mph between 4:00 PM and 5:20 PM.

The column graph at the bottom of the figure is measured with the right vertical axis. It illustrates the reliability of this HOV trip. It shows the percentage of time travel speed for this trip (leaving at the time indicated) averages less than 45 mph. In this example, between 4:00 and 5:00 PM, the reliability of this trip is about 10 percent. This can be interpreted as a “a carpool on this route will average less than 45 mph once every two weeks when making this trip in the evening rush hour.”

**Table 3-1. HOV Corridors Measured for Operational Performance**

| Corridors | Dir | From | To | Length (miles) |
|---|---|---|---|---|
| **I-5 North of the Seattle CBD** | NB | Northgate | 112th St SE | 15.1 |
| | SB | 106th St SE | Northgate | 15.6 |
| **I-5 South of the Seattle CBD** | NB | S 184th St | Columbian Way | 10.3 |
| | SB | S Spokane St | S 184th St | 10.2 |
| **I-405 North of I-90** | NB | I-90 Interchange | 236th St SE | 14.5 |
| | SB | 231st St SE | I-90 Interchange | 15.8 |
| **I-405 South of I-90** | NB | W Valley Hwy | I-90 Interchange | 10.3 |
| | SB | I-90 Interchange | Andover Park E | 10.5 |
| **I-90** | EB | 23rd Ave S | 188th Ave SE | 11.1 |
| | WB | 188th Ave SE | 23rd Ave S | 11.1 |
| **SR 520** | WB | 104th Ave NE | 84th Ave NE | 1.4 |
| **SR 167** | NB | 43rd St NW | S 23rd St | 8.2 |
| | SB | S 23rd St | 43rd St NW | 8.2 |

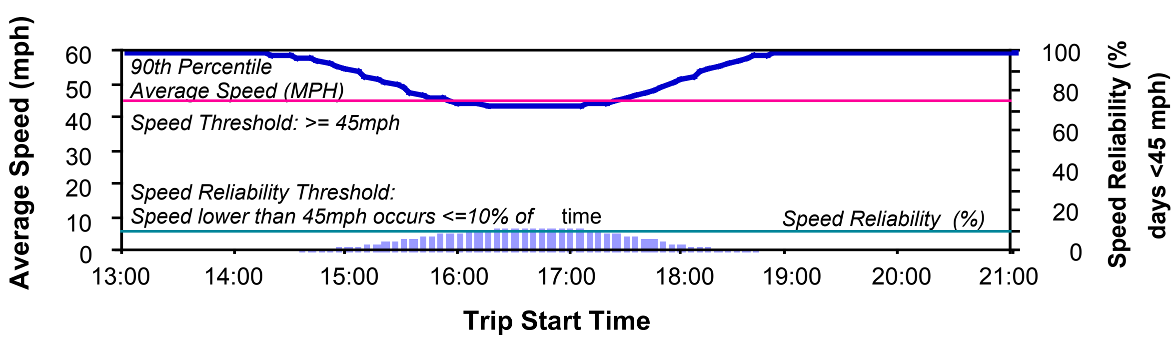



**Figure 3-1. Average Weekday HOV Speed and Reliability Graph: I-5 North of the Seattle CBD, Northbound from NE 130th St. to Alderwood**

## Reading the Contour Graphs (Average Congestion Conditions)

The second set of graphics shown in this chapter illustrates the geographic and temporal extent of congestion in the HOV lanes. These graphics were developed to help the reader better understand how traffic conditions change as vehicles travel from one location to another on the HOV network.

Each map shows one HOV corridor and is presented in a contour format similar to that of a topographic or elevation map. Various colors indicate the relative levels of congestion a commuter may experience as a function of time of day and location (milepost) along the corridor. Figure 3-2 shows a slice of one of these contour graphs for the northbound HOV lane on I-5 near Northgate. The conditions illustrated represent the average condition for all 261 weekdays of 1998. Vertically, the graph represents the geographic extent of the corridor (in this case between mileposts 174 and 177). Horizontally, the graph shows a 24-hour day, from midnight to midnight (although in Figure 3-2 only the hours from 1:00 PM to 9:00 PM are shown). The colors on the profile represent congestion, measured in units of level of service, as follows:

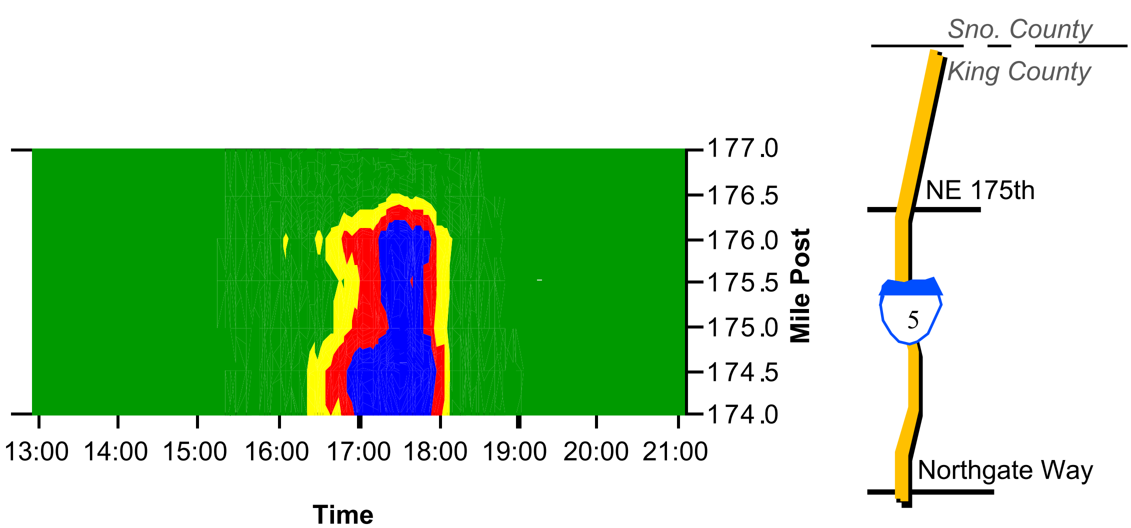



**Figure 3-2. Corridor Contour Graph: I-5 North of Seattle CBD, Northbound from NE 137th St. to Alderwood**

- green means that traffic generally moves at or near the speed limit under free-flow conditions
- yellow means that travelers encounter borderline traffic conditions with more restricted movements, but still travel near the speed limit
- red is congested traffic traveling perhaps between 45 and 55 mph
- blue denotes an extremely congested situation, with unstable traffic ranging from stop and go to 45 mph. For the HOV facilities, this usually means "free flow" conditions, but with speeds of 35 mph or lower.

Beside each graph is a map of the freeway corridor and major cross-streets to provide a means of reference to the freeway milepost locations.

Studying the portrait of the HOV segment in Figure 3-2 shows that, on average, vehicles in the HOV lane experience heavy congestion from milepost 174 to almost 176.5 from approximately 5:00 PM to 6:00 PM. Traffic is free flowing for the rest of the day.

## SPEED AND RELIABILITY RESULTS BY CORRIDOR

Statistics and graphics produced in this section are based on data collected by WSDOT throughout 2000. In most cases, the data presented are based on all weekdays within a given year. Note that current conditions may be different than those described below, particularly when new sections of HOV facility open or where major changes in operational procedures take place. In addition, note that many of the statistics presented are for "average" conditions. Thus, on any given day, conditions can be much better or much worse than those depicted and discussed below.

### I-5 North of the Seattle CBD

#### Northbound

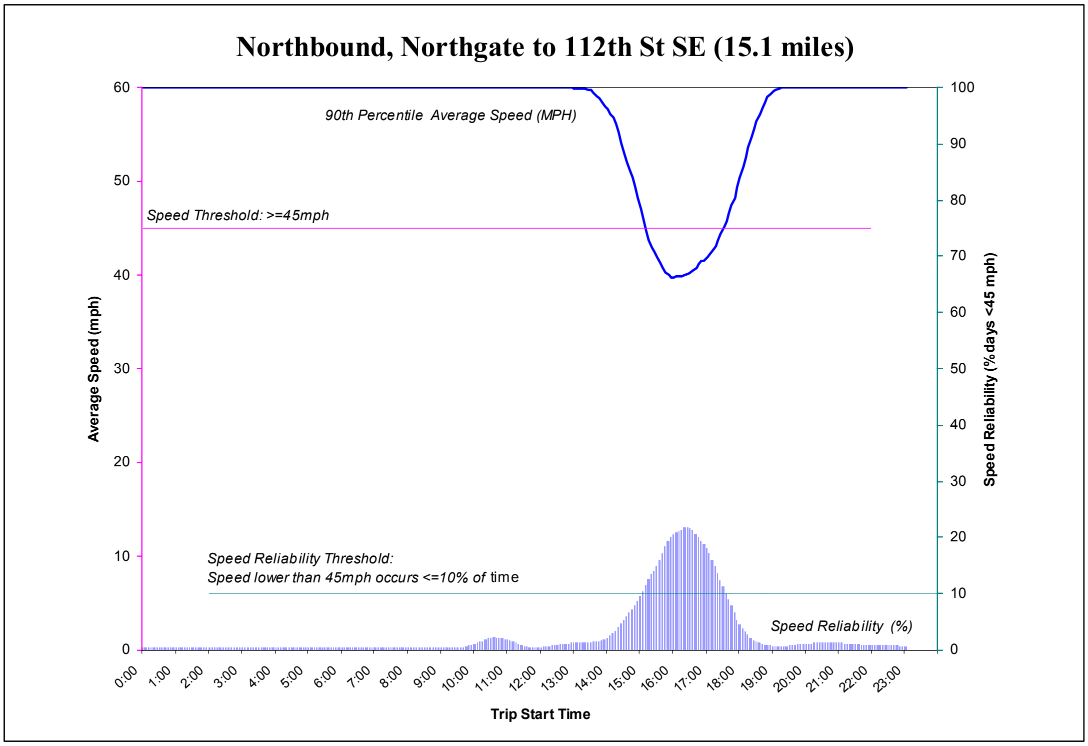
As the volume flow map indicated previously in Chapter 2, this HOV corridor has a strong directional pattern, with high southbound volumes traveling toward downtown

Seattle in the morning, and high northbound volumes traveling in the reverse direction during the afternoon commute. Near Northgate, HOV volumes can exceed 1,500 vplph during the PM commute.

Figure 3-3a shows that for the northbound trip from Northgate to 112th St SE, HOV lane vehicle travel can average less than 45 mph as often as 20 percent of the time during the evening commute. The contour map (see Figure3-3b) indicates that the northbound congestion is mostly limited to the corridor between Northgate and the Snohomish/King County line during the PM peak period. An examination of the operation of this stretch of roadway shows that the slowdown in the HOV lane is mostly caused by friction with slower moving GP volumes, as large numbers of vehicles move away from downtown Seattle in the afternoon commute period. HOV traffic also slows near the I-5/I-405 interchange between 4:00 PM to 6:00 PM.

**Southbound**

This is one of the most routinely congested freeway segments in the metropolitan area, and the HOV lanes are severely affected by this congestion. Southbound HOV lane vehicles experience slower travel speeds primarily during the AM peak period between 6:00 AM and 8:00 AM (see Figure 3-3a). HOV vehicle speeds fall below 45 mph in the corridor as often as 45 percent of the time. The contour map shows routine congestion near SR 104, and the HOV lane remains relatively congested from the I-5/I-405 interchange through the Northgate area as vehicles approach the entrance of the I-5 express lanes (see Figure 3-3b). HOV volumes are considerable during the morning commute (1,500 vplph near the Express Lanes entrance) as traffic moves toward downtown Seattle. While HOV volumes are high, they are not sufficient in size or duration to cause the HOV lane to congest. Instead, much of the slowdown may be



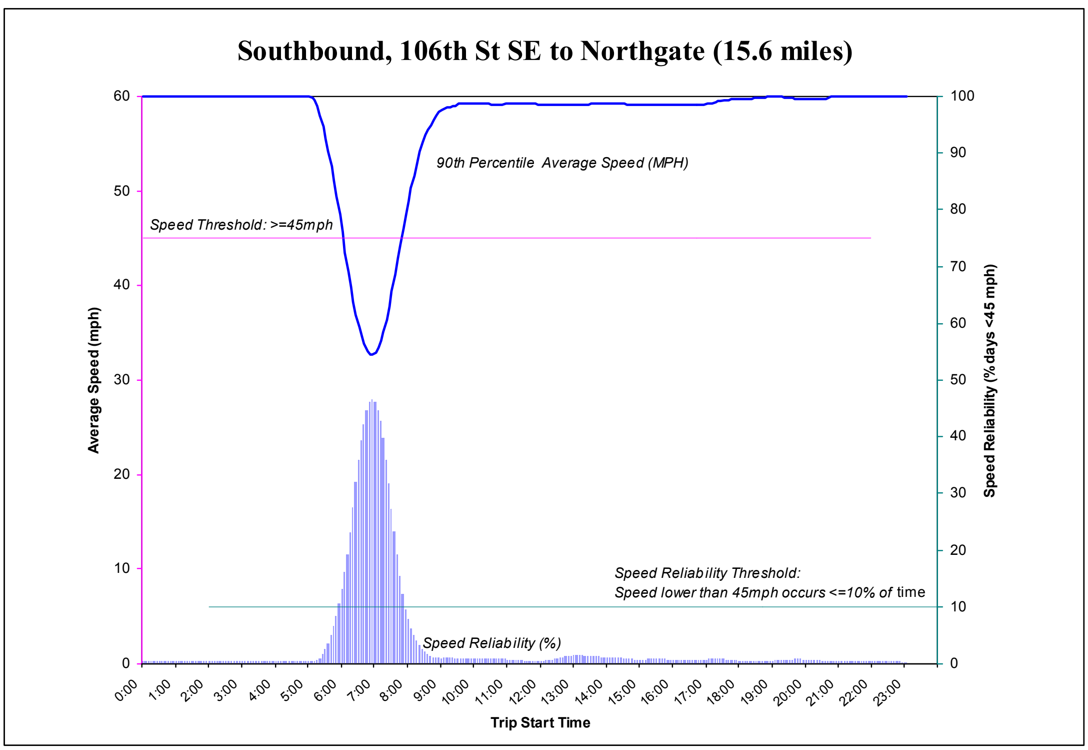




**Figure 3-3a. Average Weekday HOV Speed and Reliability (2000): I-5 North of the Seattle CBD**

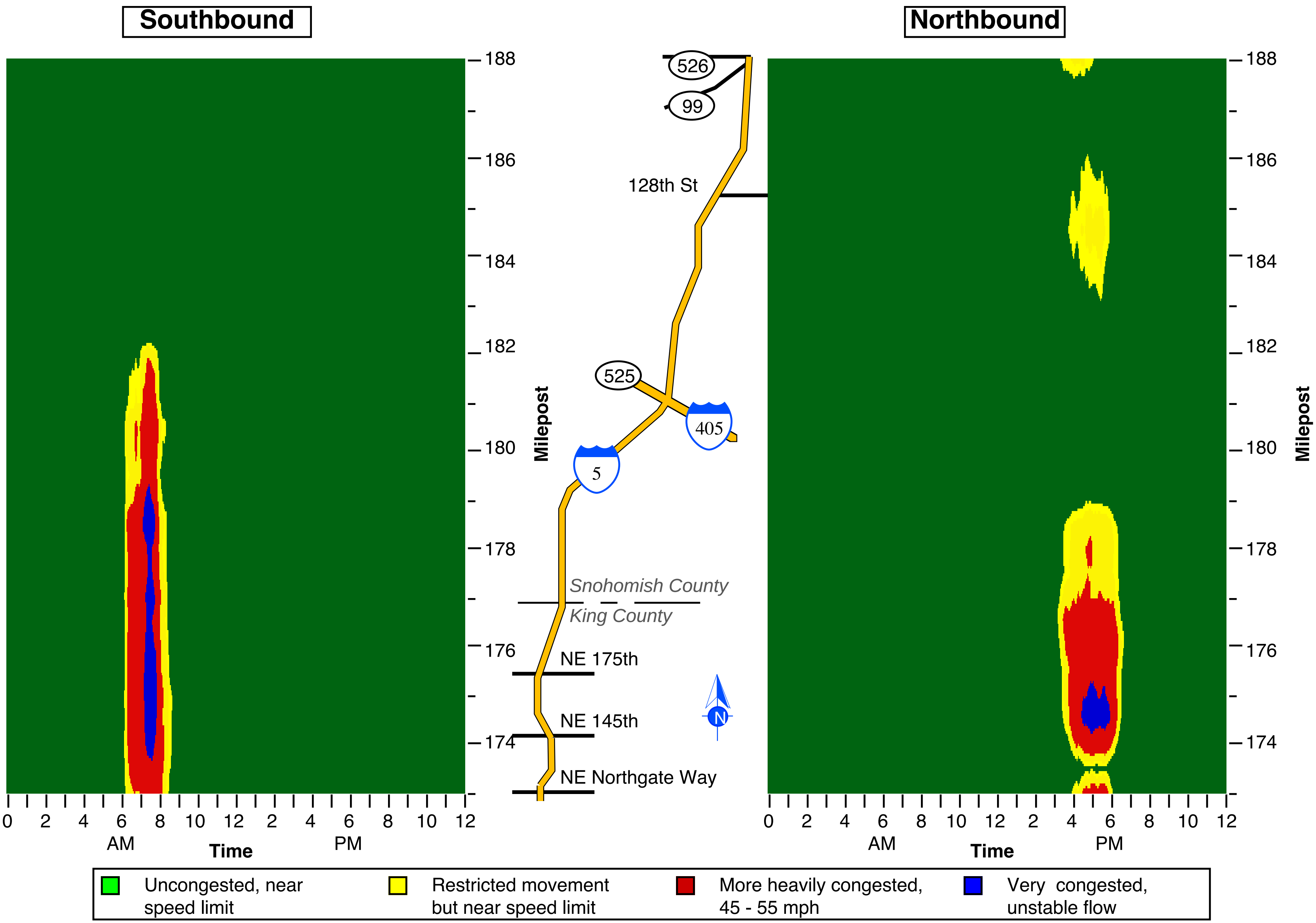



Figure 3-3b. 2000Weekday Average HOV Traffic Profile: I-5 North of the Seattle CBD.

attributed to an uphill grade at the southern terminus of this section and the lane friction resulting from the adjacent slow moving GP traffic.

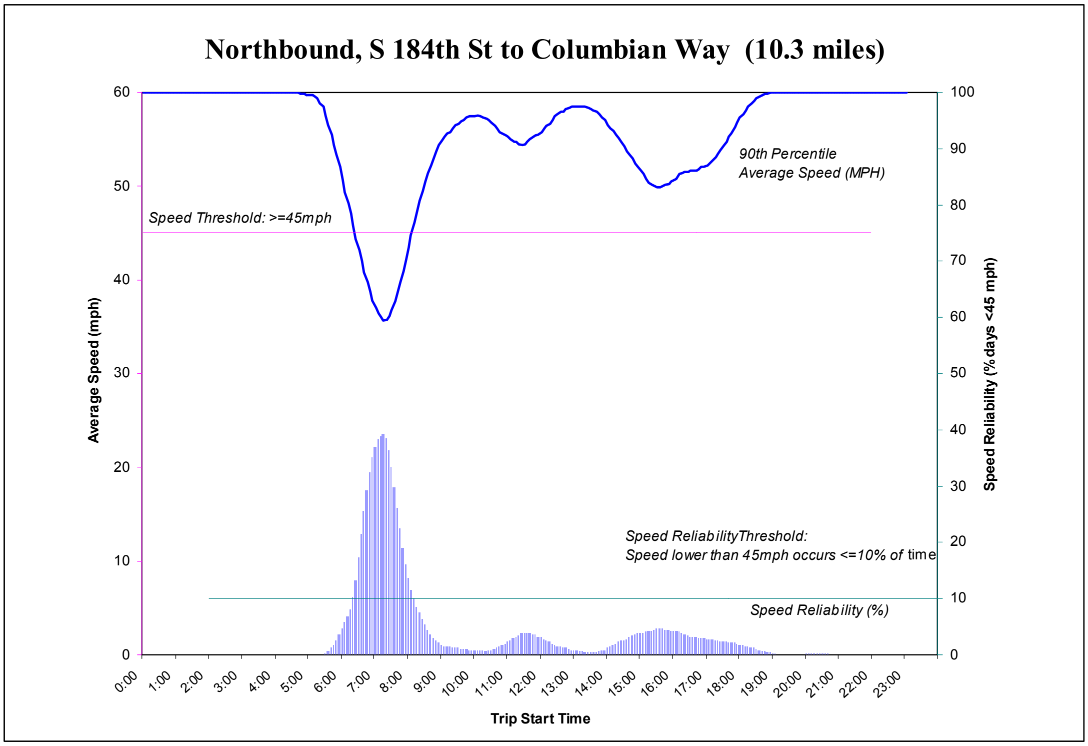
**I-5 South of the Seattle CBD**

**Northbound**

The 90th percentile speed for HOV vehicles drops to 35-45 mph during the AM peak period between 6:30 AM and 8:00 AM; this heavy congestion occurs as often as twice a week (see Figure 3-4a). The contour map shows that routine morning congestion northbound extends from Boeing Field to the end of the study section at the I-90 interchange (see Figure 3-4b). This graphic shows that HOV lane congestion on this ending segment is frequent, but because of the normally “good” performance of the lane farther south, it meets the 45 mph standard 60 percent of the time.

Unlike the merge congestion at the northern end of this segment, HOV slowdowns on the southern end are caused in part by friction between HOV and GP traffic. This is exacerbated by the loss of freeway capacity as the outside (right) GP lane becomes an exit-only lane through the West Seattle Freeway interchange.

HOV traffic normally flows freely much of the rest of the day, although some slow downs do occur from 3:00 PM to 6:00 PM. Northbound afternoon congestion is not as significant as the morning traffic situation. However, given that this is an “off peak” movement, it is still substantial. One source of afternoon congestion is the spill-back from the express lanes entrance. The HOV lane terminates near Yesler Way so that all traffic may enter the express lanes in the afternoon. The congestion level shown in the contour map makes evident the severe impact of this situation.



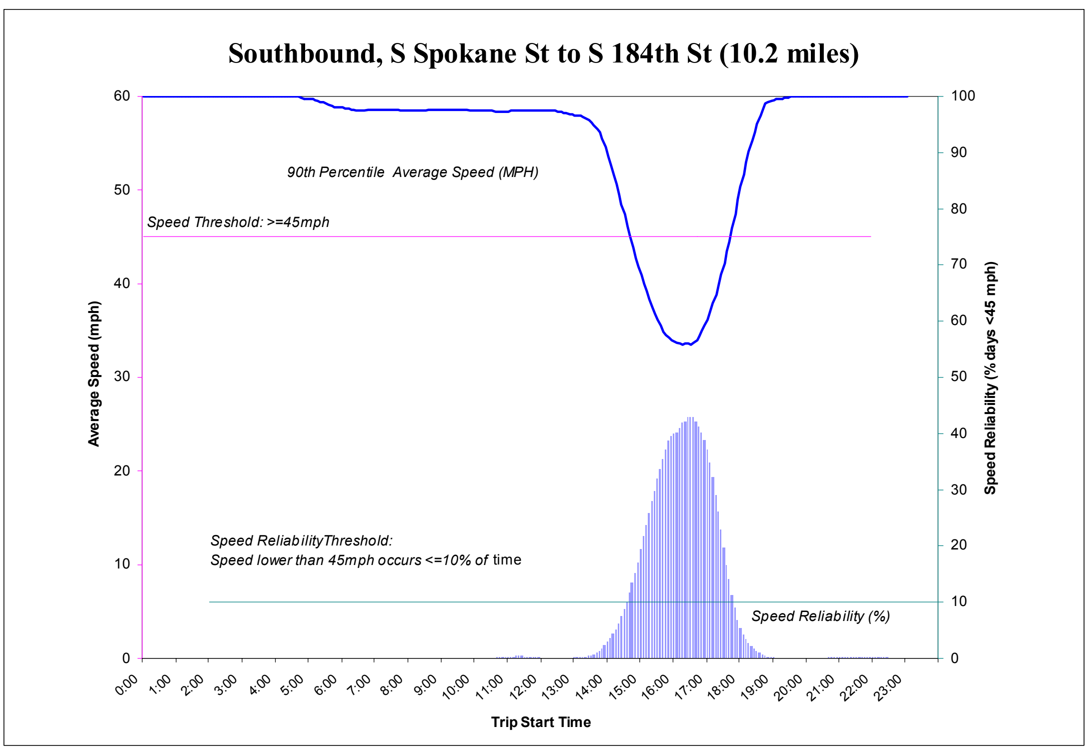




**Figure 3-4a. Average Weekday HOV Speed and Reliability (2000): I-5 South of the Seattle CBD**

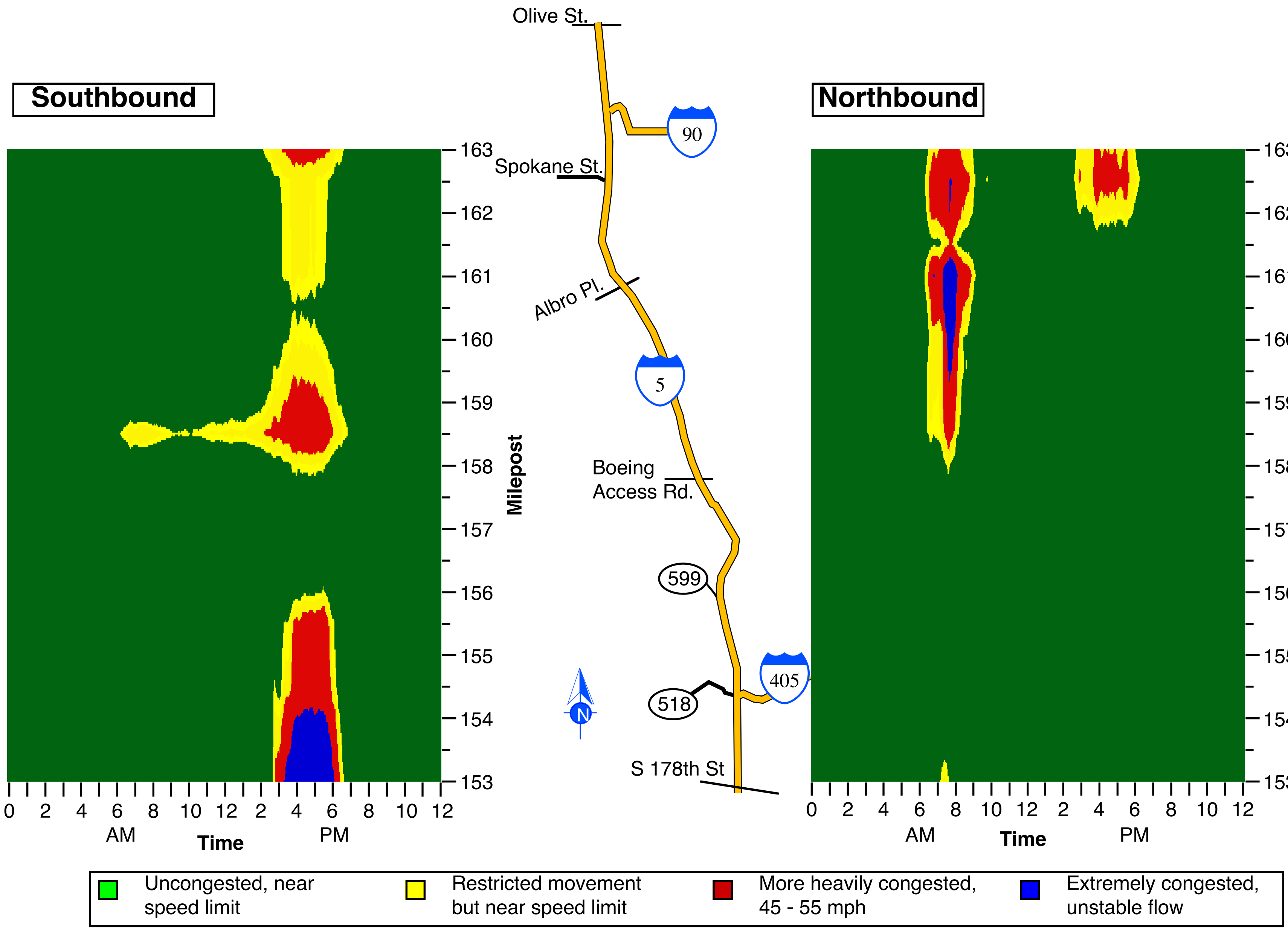



Figure 3-4b. 2000Weekday Average HOV Traffic Profile: I-5 South of the Seattle CBD.

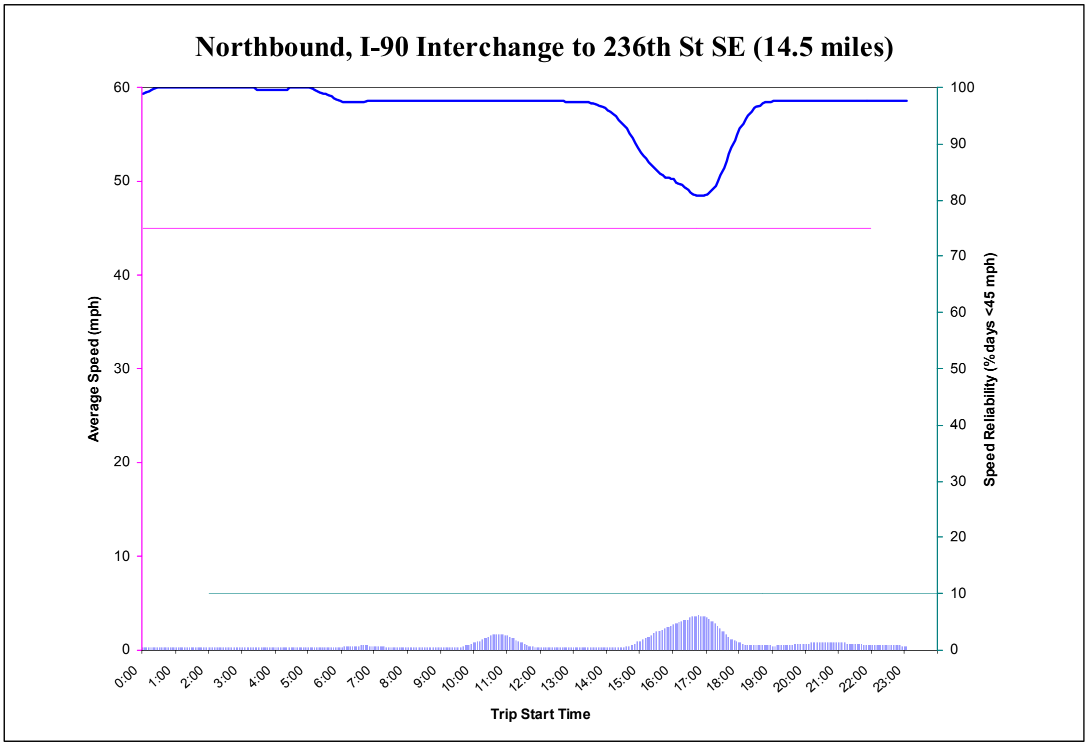
### Southbound

The HOV lane southbound out of the Seattle CBD is the poorest performing of the area's HOV facilities. Figure 3-4a shows that when HOVs travel southbound in the PM peak period, the average vehicle speed can slow to between 30 and 45 mph more than half of the time. Much of the significant slowdown is due to routine congestion near Boeing Field and near the Southcenter Hill on either side of the I-405 interchange (see Figure 3-4b). The Southcenter Hill is a particularly troublesome location because the steep grade and the effects of merging/diverging traffic caused by the I-405 interchange combine to frequently slow HOV travel. In addition, moderate congestion occurs just south of the Seattle CBD near Columbian Way as result of traffic merging from the I-5 mainline and the collector distributor from I-90.

## I-405 – North of I-90

### Northbound

Like most sections of the HOV lane system, this freeway corridor's HOV lane operates relatively well for most times during the day (see Figure 3-5a). Although the average vehicle speed can slow during the PM peak period, the average vehicle speed is always above 45 mph. Figure 3-5b shows that significant congestion is present in the north near the SR 522 Bothell/Woodinville interchange. A major construction project exists a few miles north of this interchange. Congestion often spills back, affecting the HOV lanes. Although significant congestion in the HOV lanes along this corridor is fairly rare, the high volume of merge/diverge movements within the corridor can affect average travel speeds. These include significant merge/diverge movements near the Redmond/Kirkland interchanges at NE 85$^{th}$ and Totem Lake.



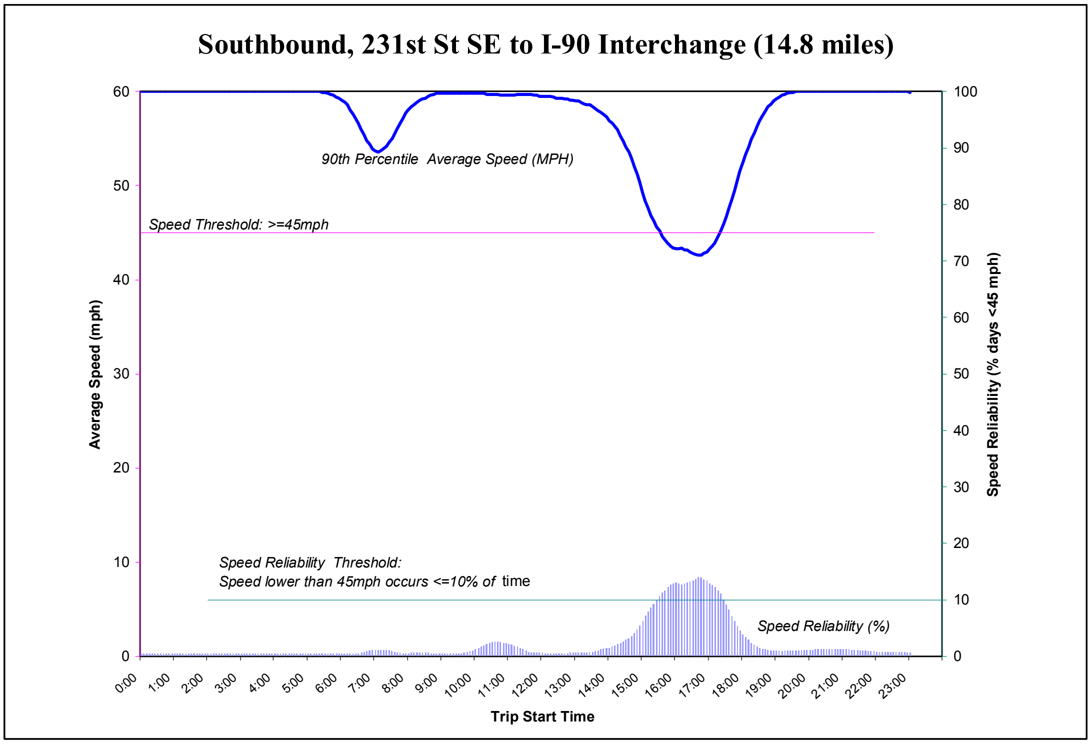




**Figure 3-5a. Average Weekday HOV Speed and Reliability (2000): I-405 North of I-90**

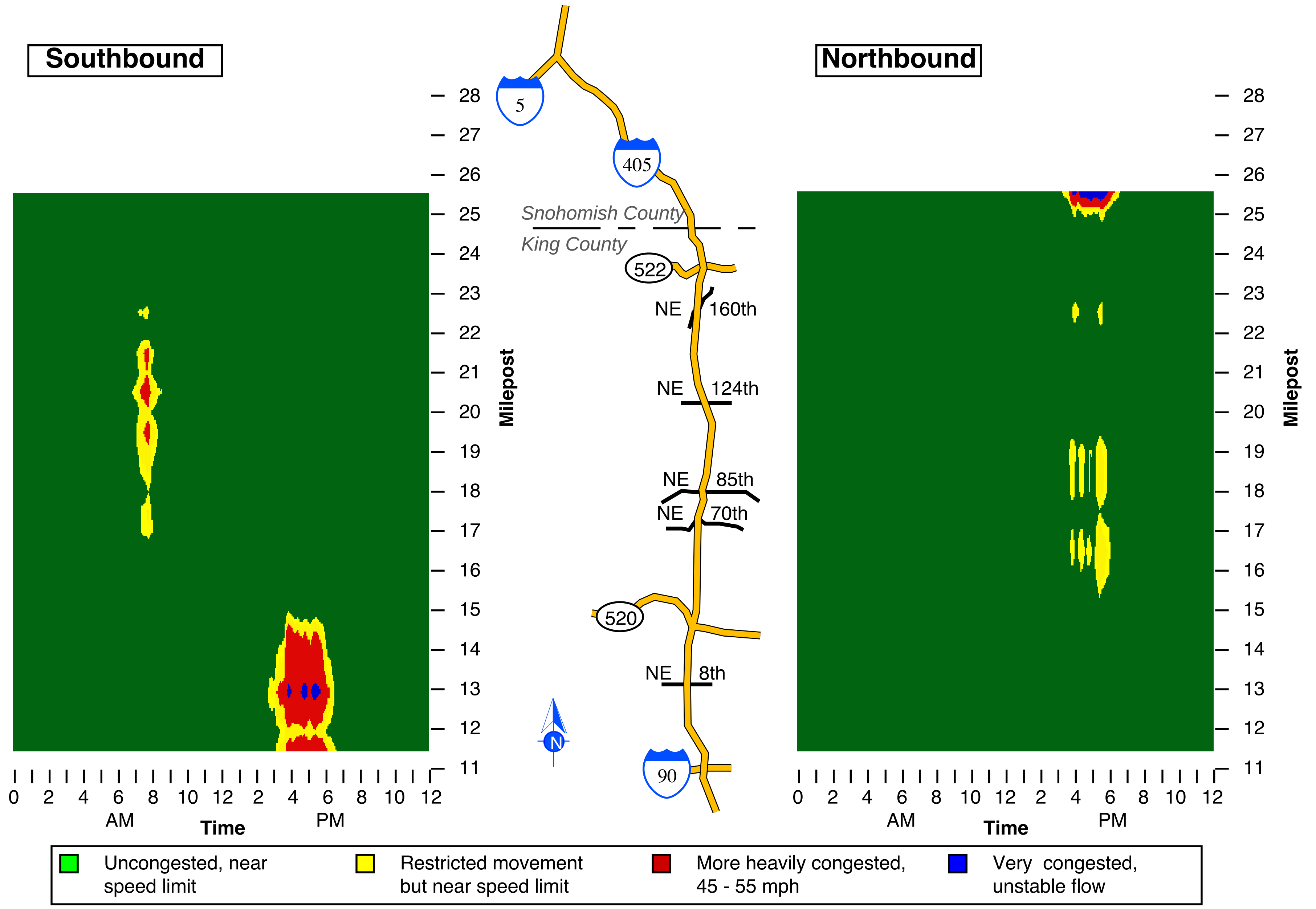



Figure 3-5b. 2000 Weekday Average HOV Traffic Profile: I-405 North of I-90

**Southbound**

Figure 3-5a reveals that the southbound HOV lane in this corridor also operates relatively well for most times during the day. The only significant routine HOV lane congestion in the southbound direction is through the downtown Bellevue CBD during the afternoon commute (see Figure 3-5b). Much of this congestion is related to friction from the vehicles entering the freeway at the Bellevue ramps, and from congestion backups from the I-90 interchange south of the city. Southbound HOV lane congestion near downtown Bellevue during the AM peak is rare.

**I-405 South of I-90**

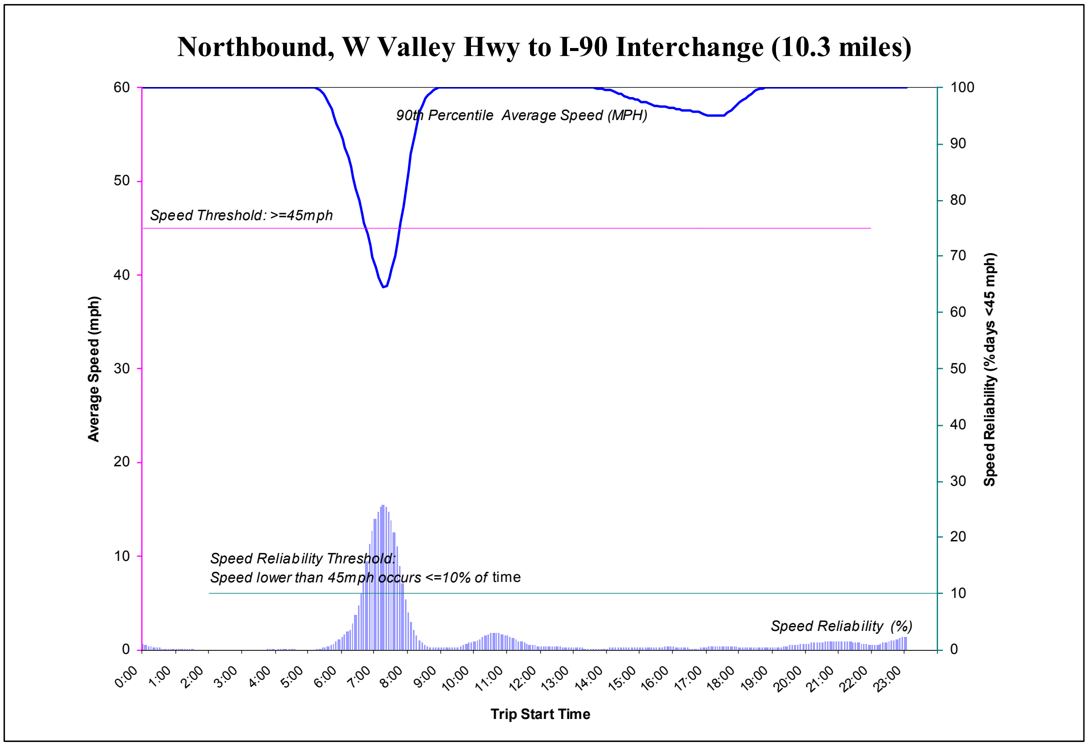
**Northbound**

The northbound stretch of I-405 from Renton to Factoria is one of the most congested General Purpose facilities in the Puget Sound. Heavy morning congestion occurs almost daily, and this heavy GP congestion has a significant impact on both HOV lane volumes and HOV lane performance.

As can be seen in Figure 3-6a, the 90$^{th}$ percentile HOV speed drops below 45 mph for one hour during the AM peak period. Figure 3-6b reveals that heavy congestion occurs from the Kennydale hill until just south of Coal Creek Parkway during the AM peak period. This minor but consistent slowing in the HOV lane is caused primarily by friction between HOVs and the slower moving GP traffic next to them. During the rest of the day, the HOV lanes perform as intended.

**Southbound**

The southbound HOV lanes on this section of freeway are more congested than the northbound HOV lanes. The 90$^{th}$ percentile speeds and the reliability of the facility show that the HOV vehicle speed can drop between 40 and 45 mph 20 percent of the time



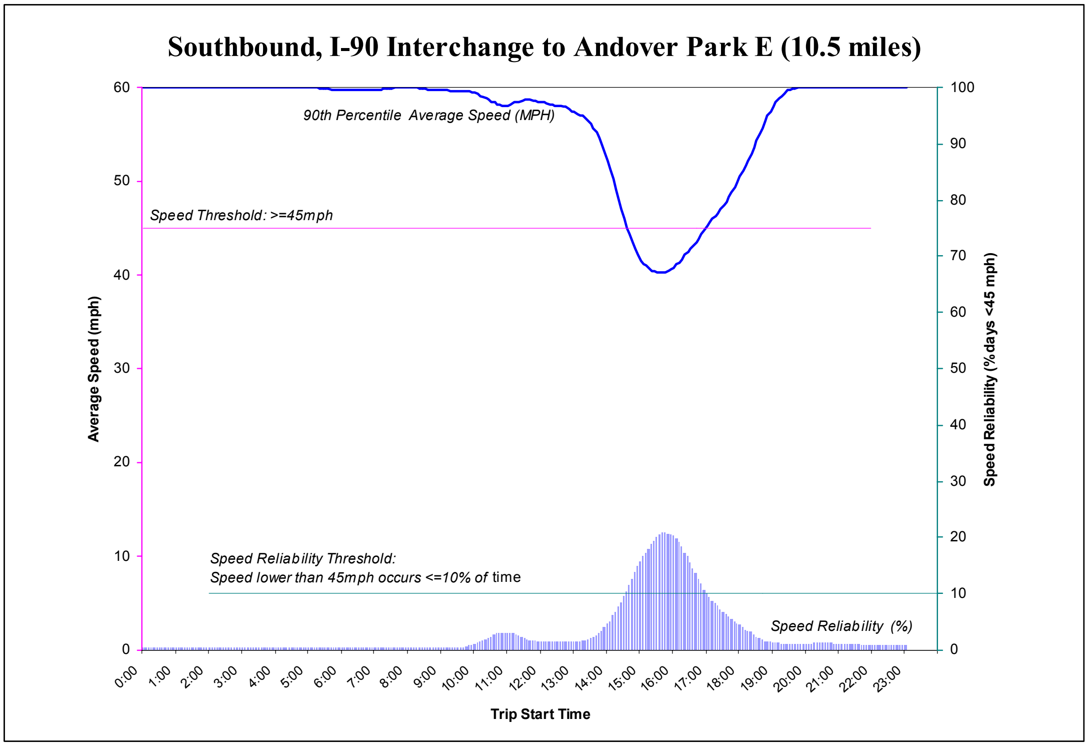




**Figure 3-6a. Average Weekday HOV Speed and Reliability (2000): I-405 South of I-90**

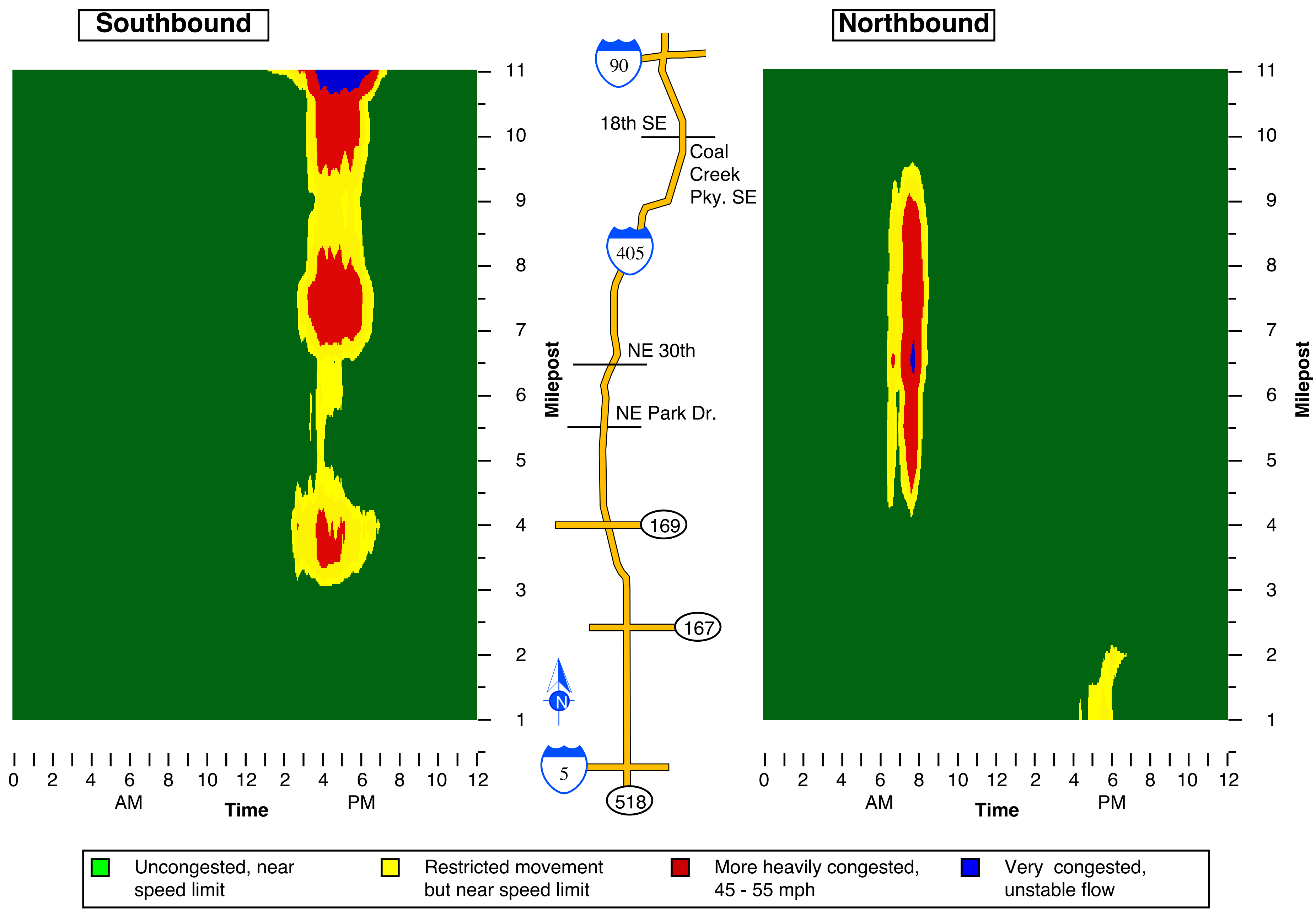



Figure 3-6b. 2000Weekday Average HOV Traffic Profile: I-405 South of I-90.

(see Figure 3-6a), and slow HOV lane speeds can last for well over two hours in the afternoon. Routine congestion occurs at sections of the southbound roadway from downtown Bellevue to the Kennydale hill and from Sunset Blvd to just north of the SR 167/I-405 Interchange (see Figure 3-6b).

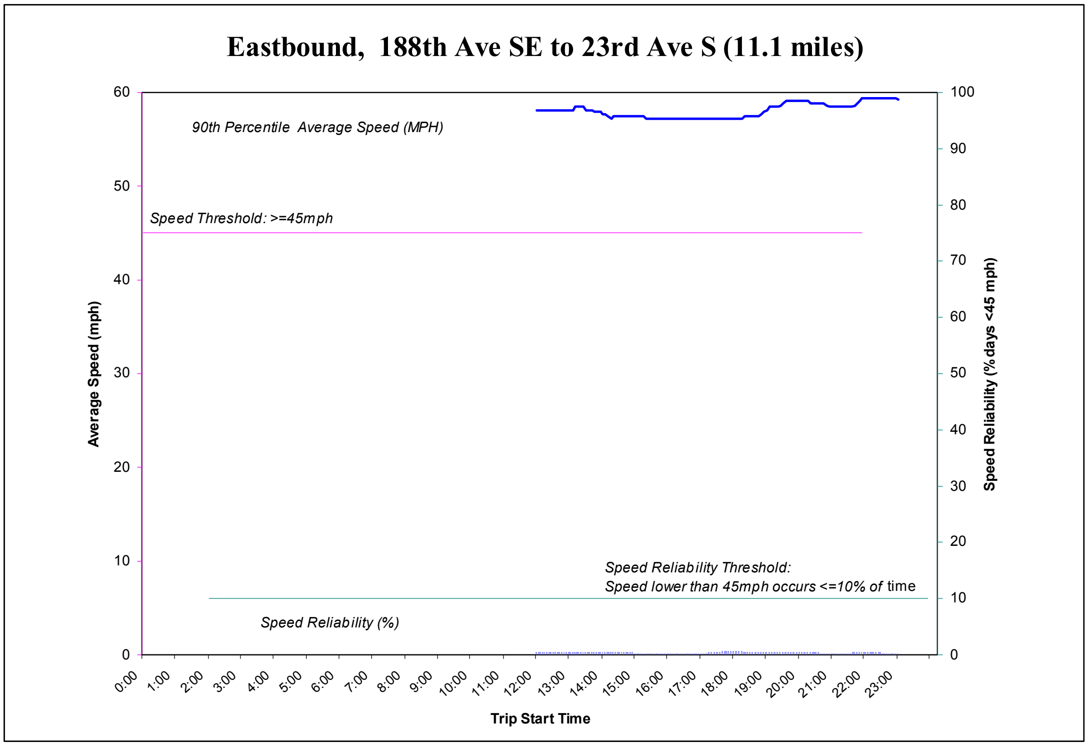
**I-90**

No significant congestion was observed in the HOV lanes (using the reversible lanes) on I-90. HOVs can expect to travel at or near the speed limit at nearly all times (see Figure 3-7).

**SR 520**

Westbound HOV lane vehicles travel at lower speeds between 4:00 PM and 6:30 PM (see Figure 3-8) as frequently as one third of the time during the evening commute. This is due to a series of factors, including extreme GP lane congestion, merge congestion caused by vehicles entering the freeway from Bellevue ramps and having to weave through the HOV lane into the stop and go GP lanes, and the effect that merge congestion has on the final merge just east of the Evergreen Point floating bridge. Significantly, these conditions have less of an impact in the morning peak period. This is partly because GP congestion is lower, and partly because HOV lane volumes are much lower in the morning than in the evening (although transit volumes are much higher in the morning).

Note that congestion east of the SR 520/I-405 interchange was not measured for this report because data collection in that area was disrupted by construction activities for much of the year.



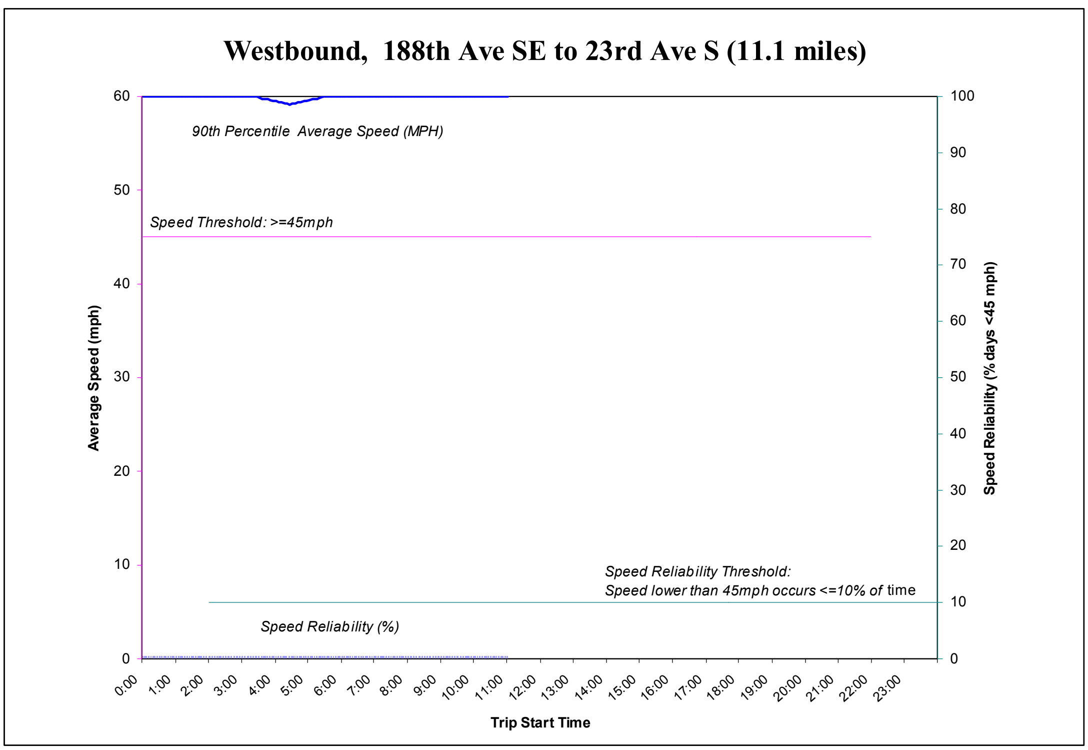




**Figure 3-7. Average Weekday HOV Speed and Reliability (2000): I-90**

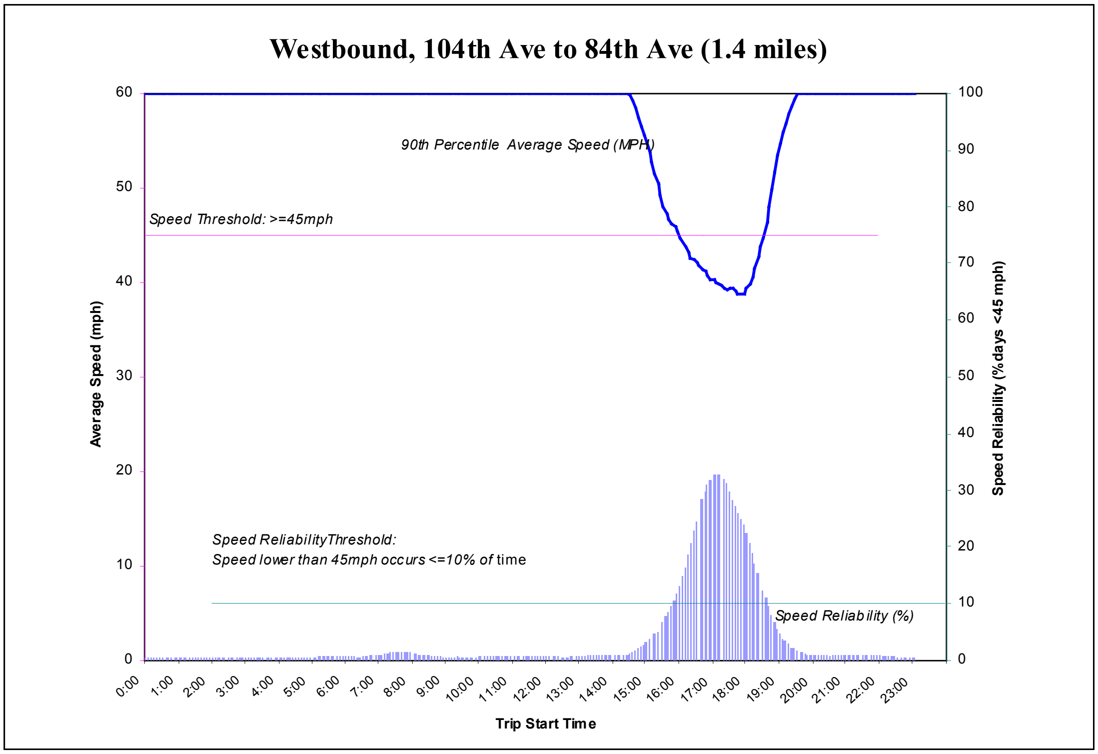
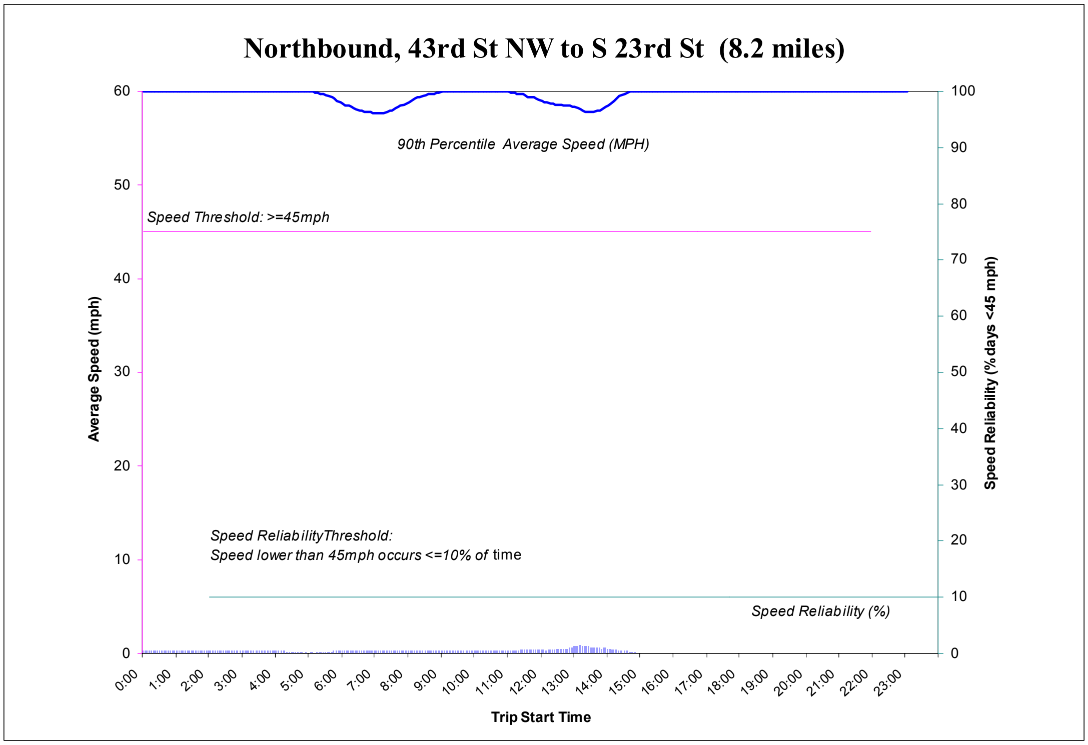



**Figure 3-8. Average Weekday HOV Speed and Reliability (2000): SR 520**

## SR 167

HOV lanes on SR 167 routinely travel at free flow speeds throughout the day in both directions. At no time during the day does the 90th percentile travel time fall below 45 mph for either northbound or southbound HOV traffic (see figures 3-9a and 3-9b). Slowdowns do occur near the northern terminus of this facility in the morning, and the southern terminus in the evening. Congestion in the north end is almost all related to spillback from the I-405 interchange, while congestion at the southern end relates mostly to congestion caused as the HOV lane ends and becomes a GP lane.



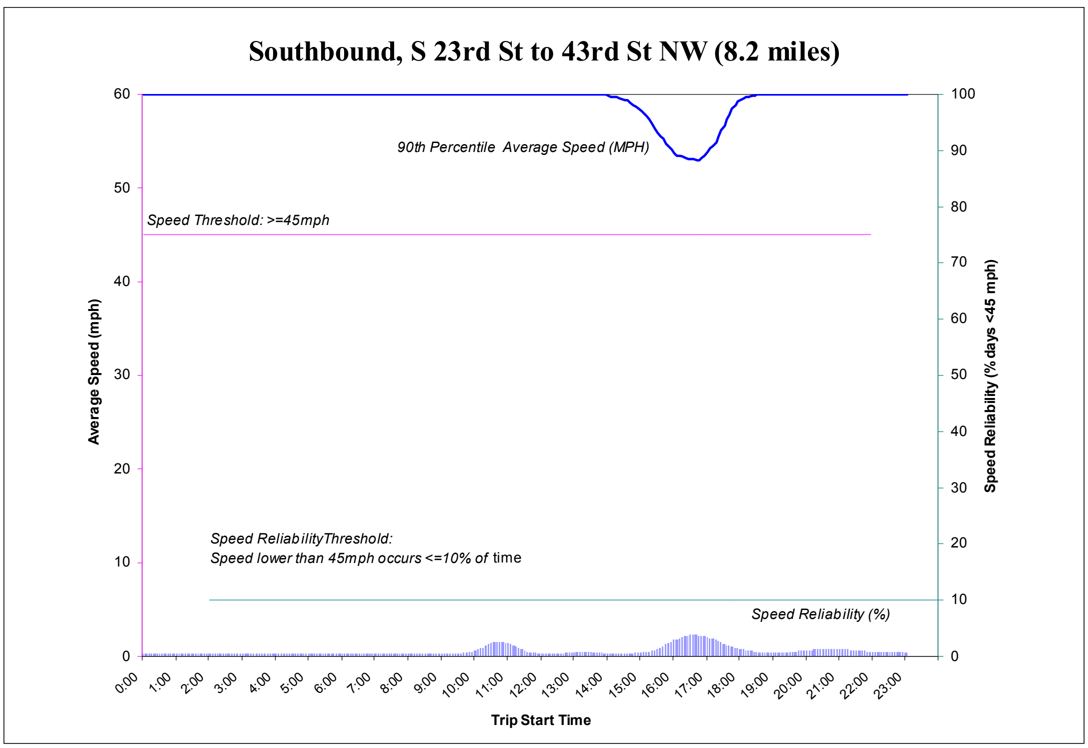




**Figure 3-9a. Average Weekday HOV Speed and Reliability (2000): SR 167**

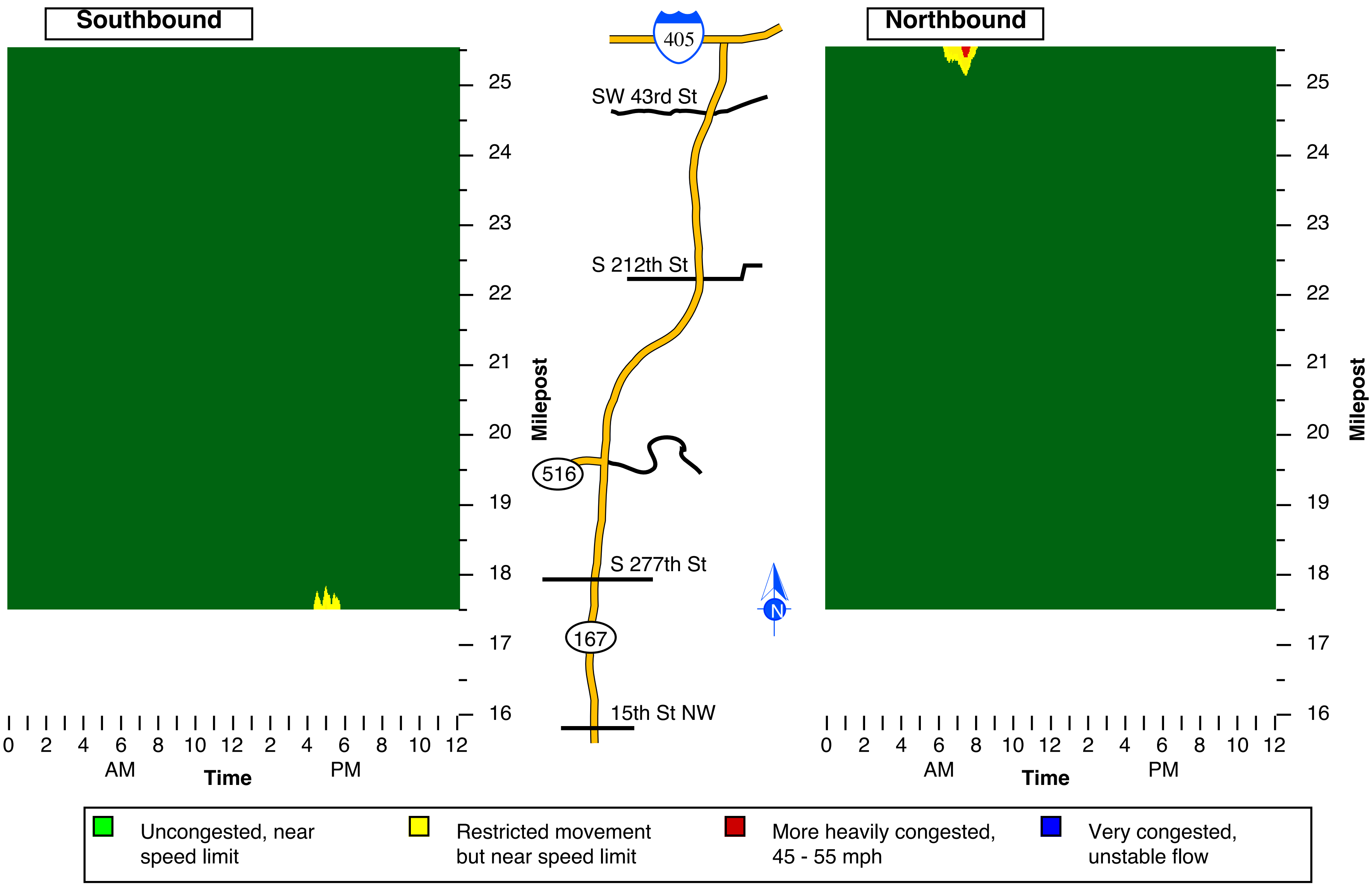



Figure 3-9b. 2000 Weekday Average HOV Traffic Profile: SR 167

## TRAVEL TIME SAVINGS

### Reading the Travel Time Graphs

To describe the time savings that travelers can expect to accrue when using the HOV lanes, a set of graphics that compare expected HOV and GP travel times were created. These graphs show estimated HOV travel time relative to GP travel time. Each graph describes the time it takes to complete a particular route by traveling in the HOV lane or the GP lanes. The average travel time for the trip can be read along the vertical axis. (Note that the vertical axis on these graphics does not start at zero.) The horizontal axis shows the time of day when the traveler enters the freeway. The average HOV travel time savings for the directional commute during the peak period is written in the figure.

Figure 3-10 shows an example of this type of graphic, an 8-hour slice of the travel time comparison graph for northbound I-5 from NE 137$^{th}$ St. to Alderwood. The results show that it takes longer to travel in the GP lane (roughly 13 minutes) than in the HOV lane (roughly 10 minutes) during the afternoon peak period. On average HOV lane users experience a travel time advantage of nearly 3 minutes during the afternoon peak period over the travelers in the adjacent GP lanes.

Figures 3-11 through 3-17 present GP and HOV travel time comparisons for the studied corridors. Travel times are computed for trips on each HOV corridor. Travel time on I-90 was computed only for trips using the reversible HOV lanes. Table 3-2 summarizes the travel time savings along the various corridors during 2000 in units of minutes and seconds per mile. These results show sizable benefits in travel time savings in most of the corridors. Some of the most significant savings are on I-5 during the

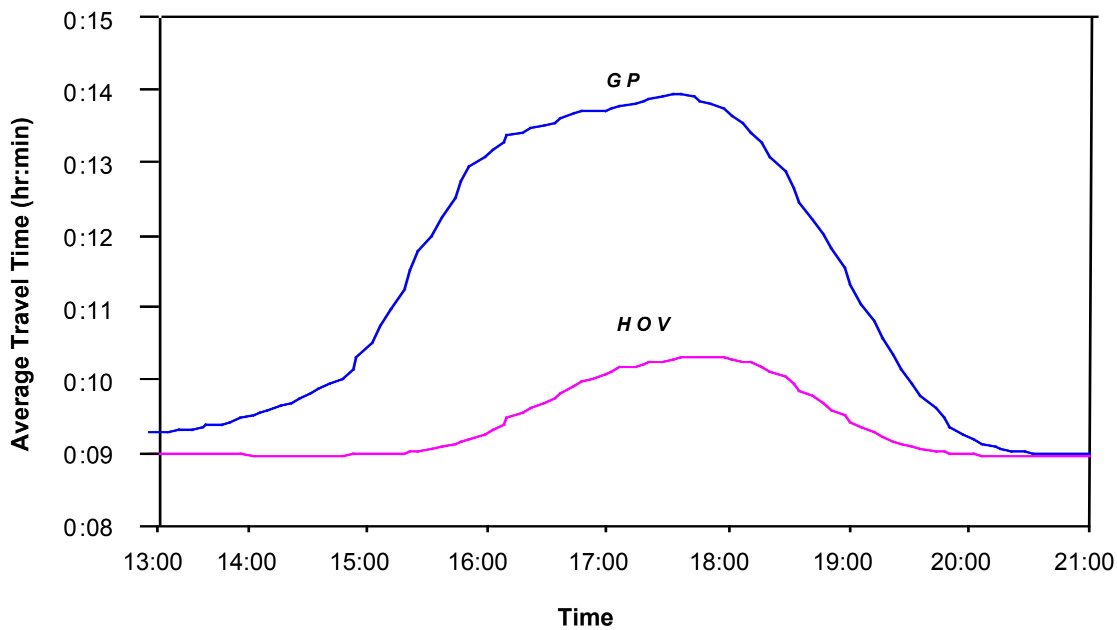
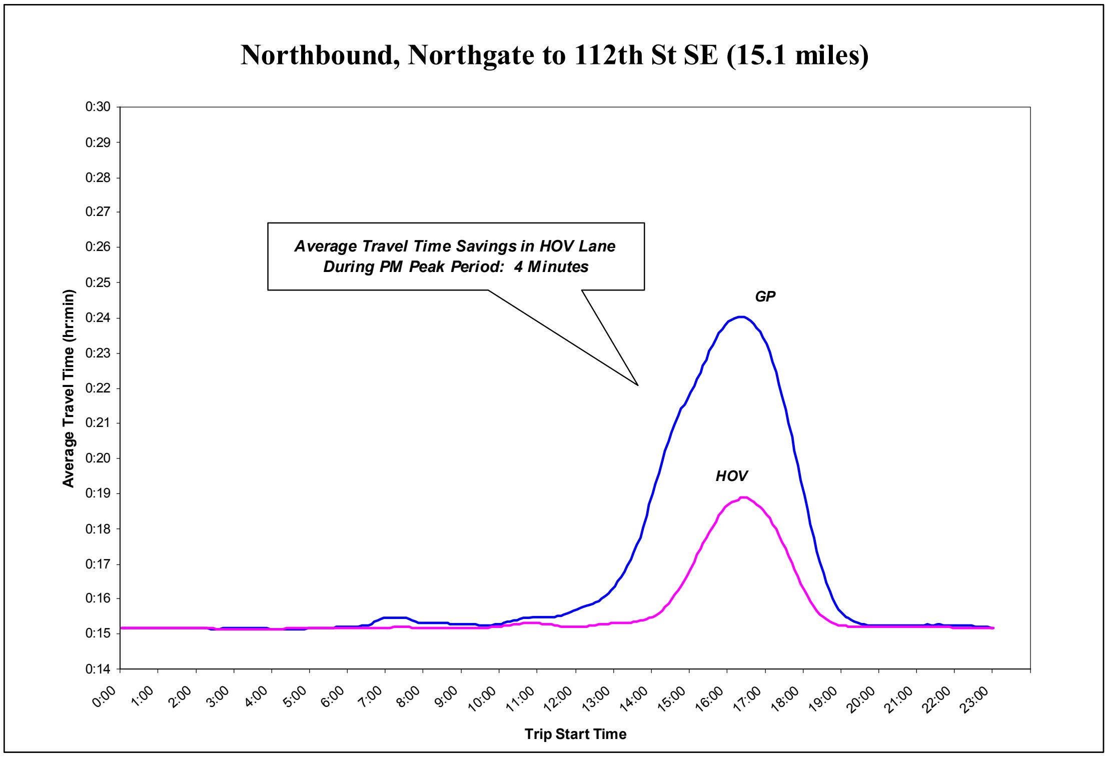



**Figure 3-10. Average Weekday Travel Time Graph: I-5 North of Seattle CBD, Northbound from NE 137th St. to Alderwood**

**Table 3-2. HOV Lane Travel Time *(Estimated from Average Speed)***

| | | | Travel Time Savings (Minutes) | | Travel Time Savings (Seconds per Mile) | |
|---|---|---|---|---|---|---|
| **Corridors** | **Dir.** | **Length (miles)** | **AM (6-9AM)** | **PM (3-7PM)** | **AM (6-9AM)** | **PM (3-7PM)** |
| **I-5 North of the Seattle CBD (Northgate – 112thSt SE)** | NB | 15.1 | | 4 | | 16 |
| | SB | 15.6 | 7 | | 27 | |
| **I-5 South of the Seattle CBD (Spokane – S. 184th St.)** | NB | 10.3 | 4 | | 23 | |
| | SB | 10.2 | | 2 | | 6 |
| **I-405 North of I-90 (231st St SE – I-90 Interchange)** | NB | 14.5 | | 8 | | 33 |
| | SB | 14.8 | 11 | | 45 | |
| **I-405 South of I-90 (I-90 Interchange – Andover Park E)** | NB | 10.3 | 12 | | 70 | |
| | SB | 10.5 | | 6 | | 34 |
| **I-90 (23rd Ave S – 188th Ave. SE)** | EB | 11.1 | | 2 | | 11 |
| | WB | 11.1 | 2 | | 11 | |
| **SR 520 (84th Ave. NE – 104th Ave. NE[1])** | WB | 1.4 | | 4 | | 171 |
| **SR 167 (S 23rd St – 43rd St. NW)** | NB | 8.2 | 4 | | 29 | |
| | SB | 8.2 | | 6 | | 44 |

[1] Data for this corridor east of 104th Ave NE were limited by construction activities



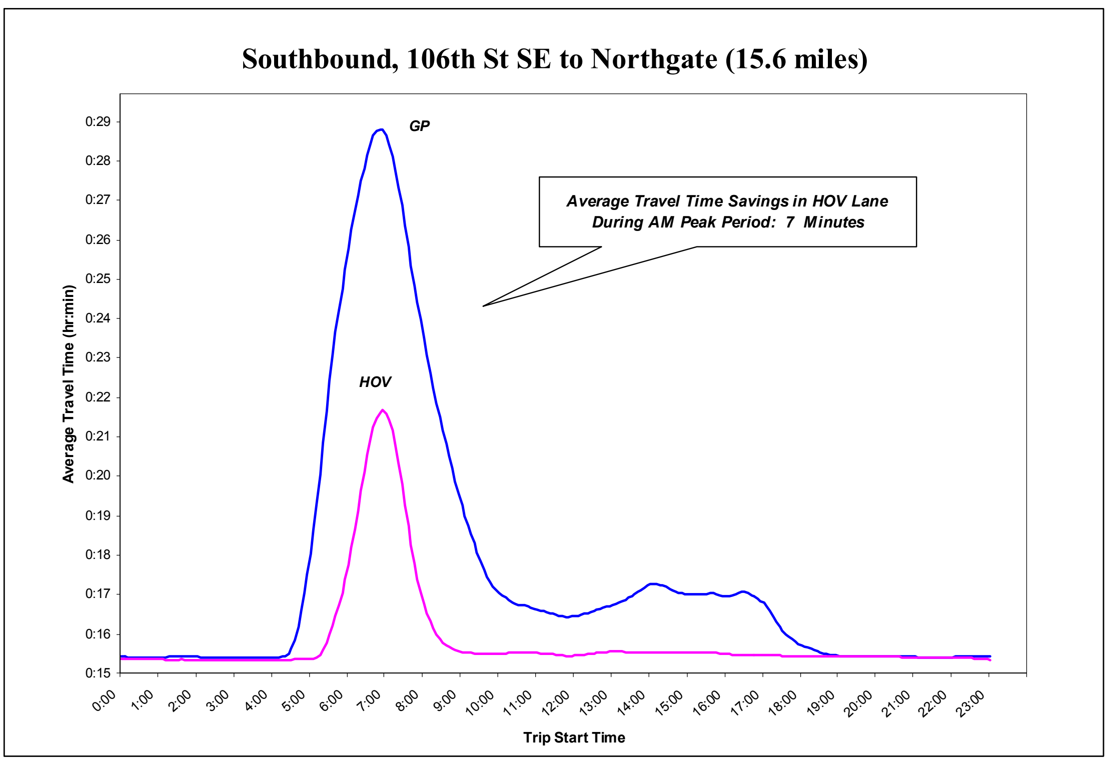
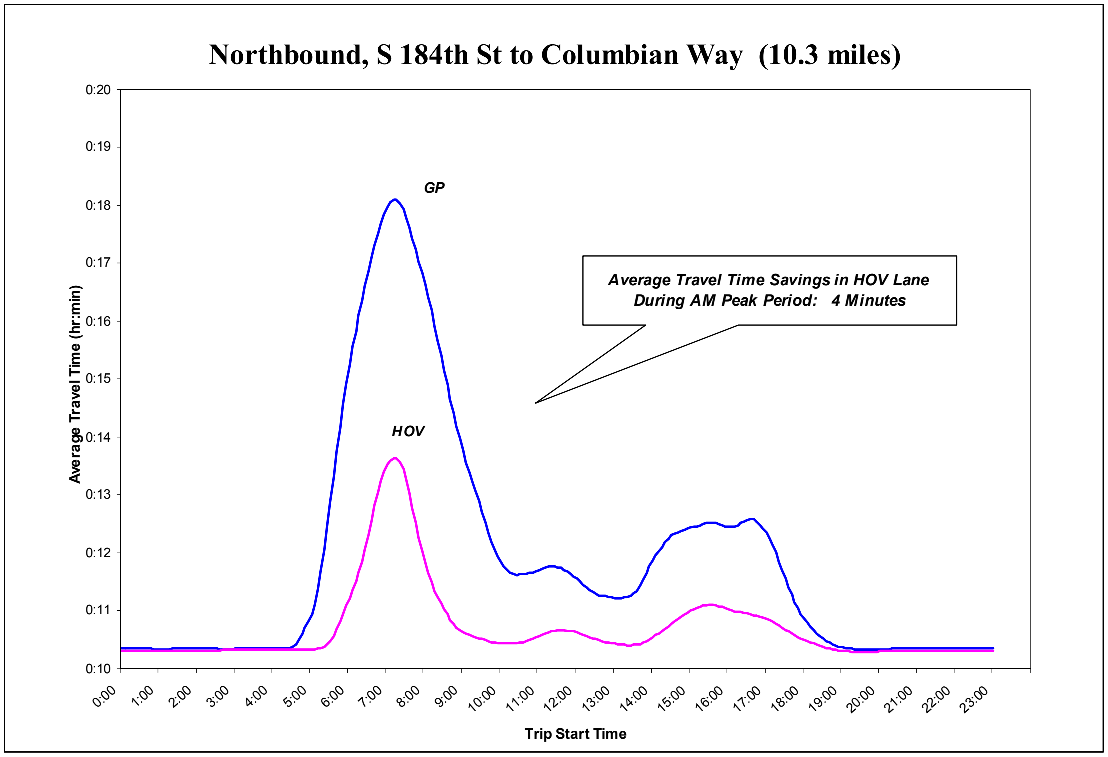




**Figure 3-11. Average Weekday GP and HOV Travel Time (2000): I-5 North of the Seattle CBD**



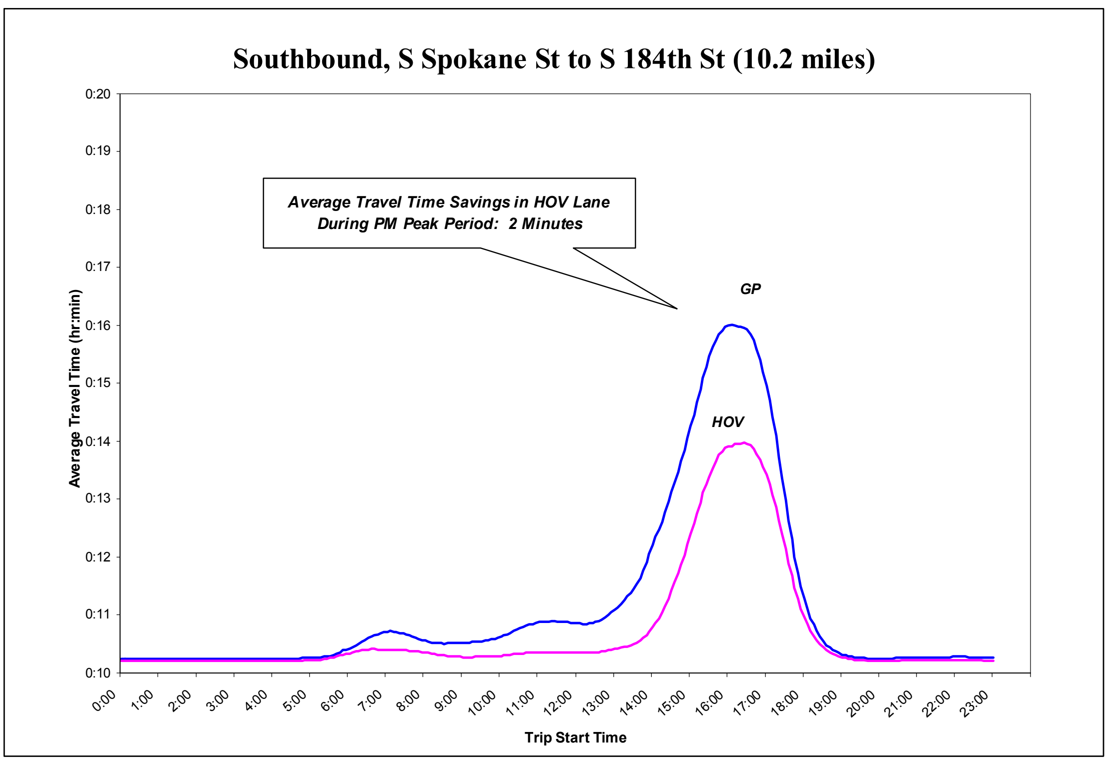
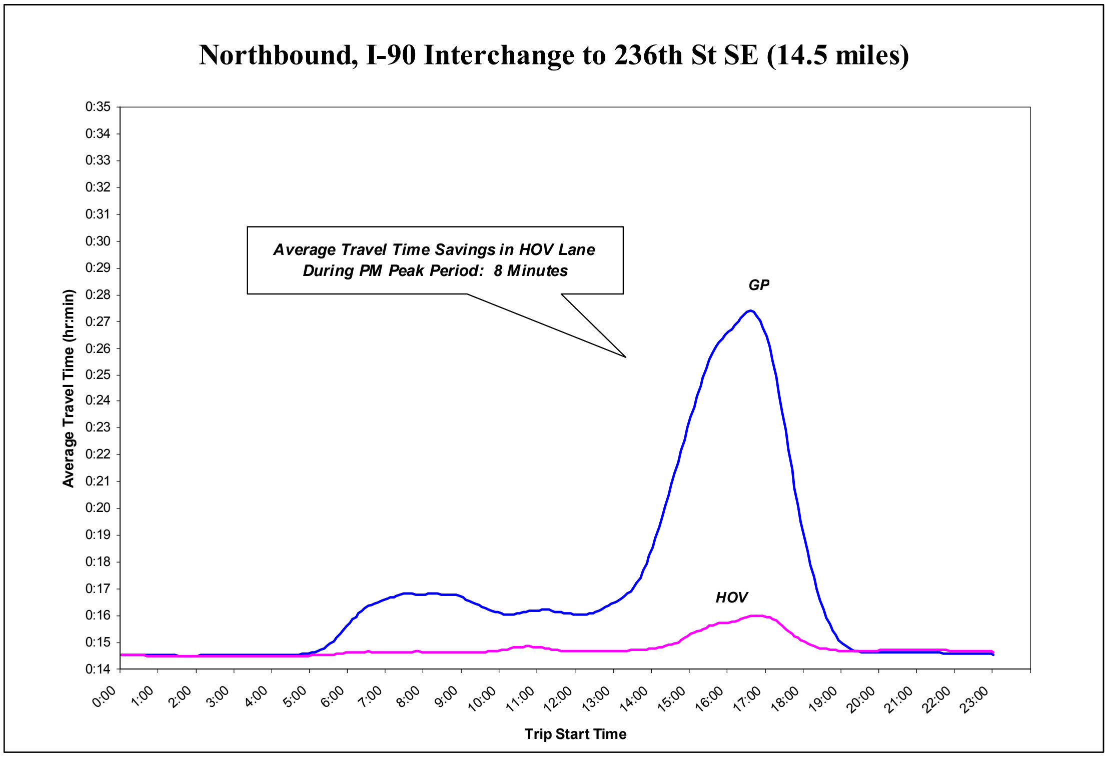




**Figure 3-12. Average Weekday GP and HOV Travel Time (2000): I-5 South of the Seattle CBD**



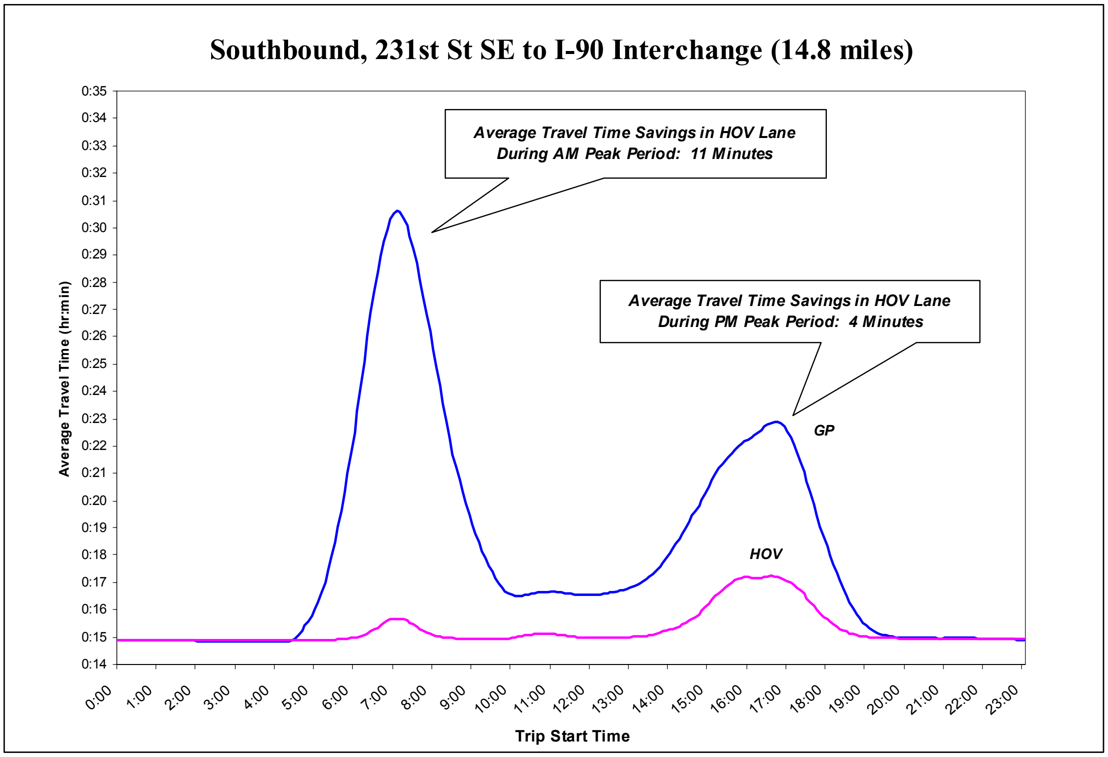
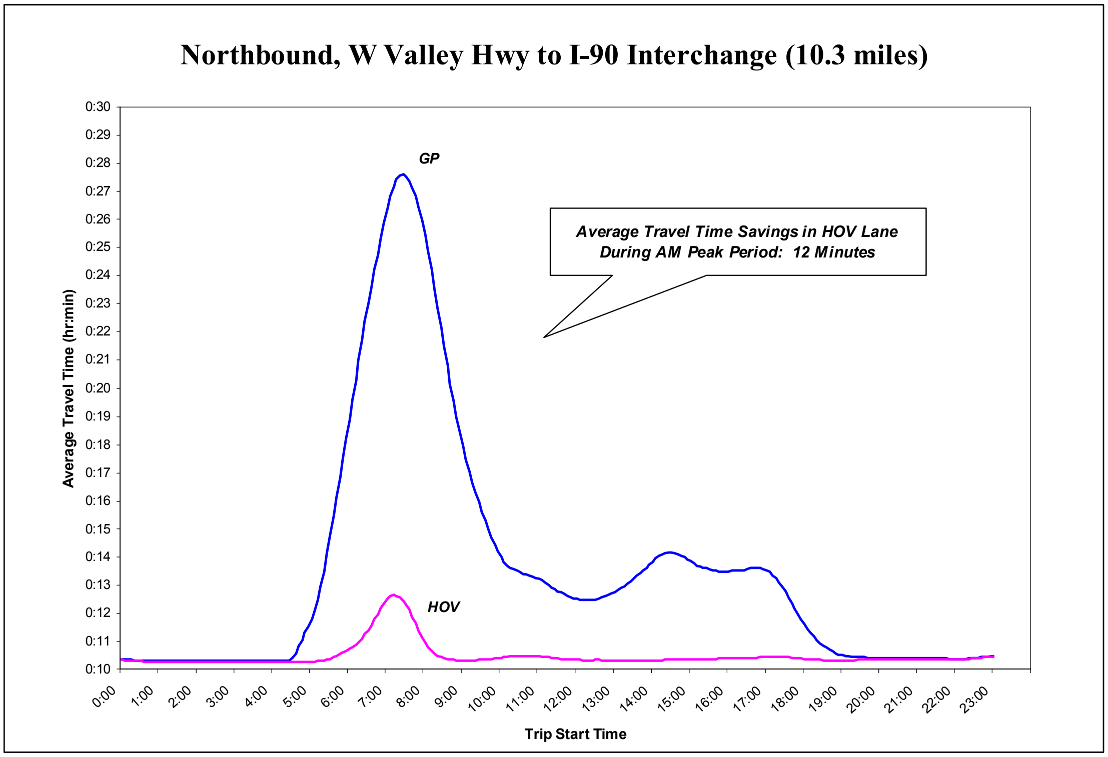




**Figure 3-13. Average Weekday GP and HOV Travel Time (2000): I-405 North of I-90**



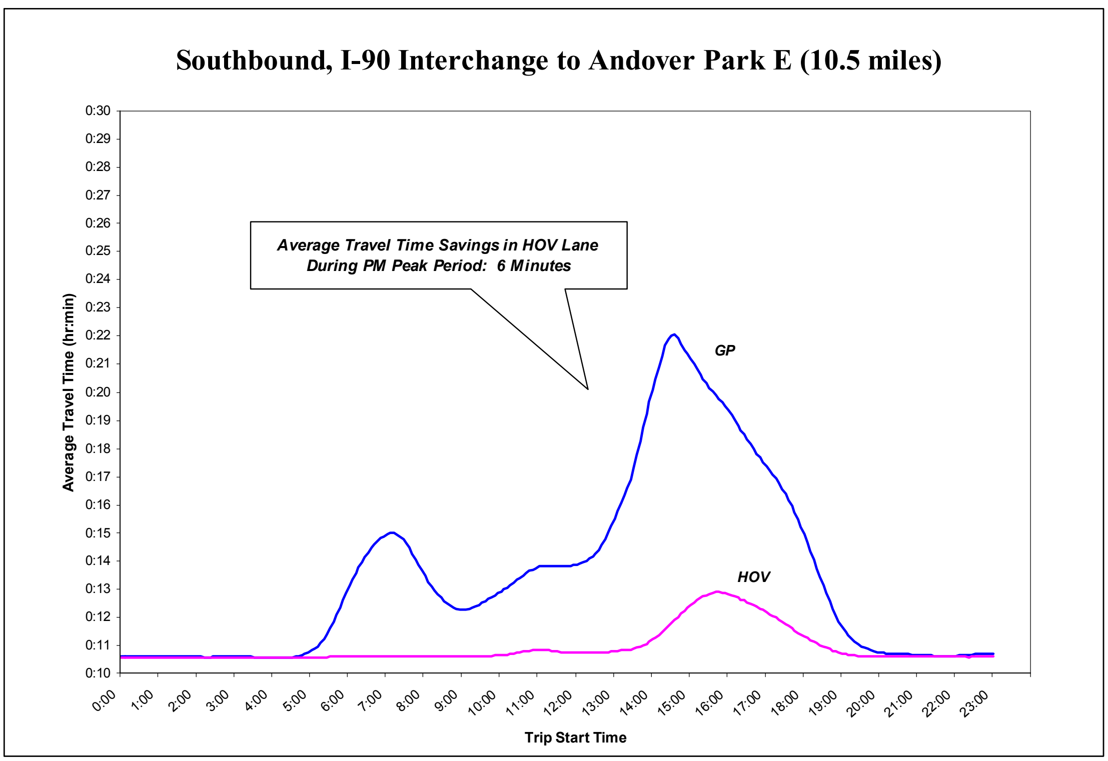
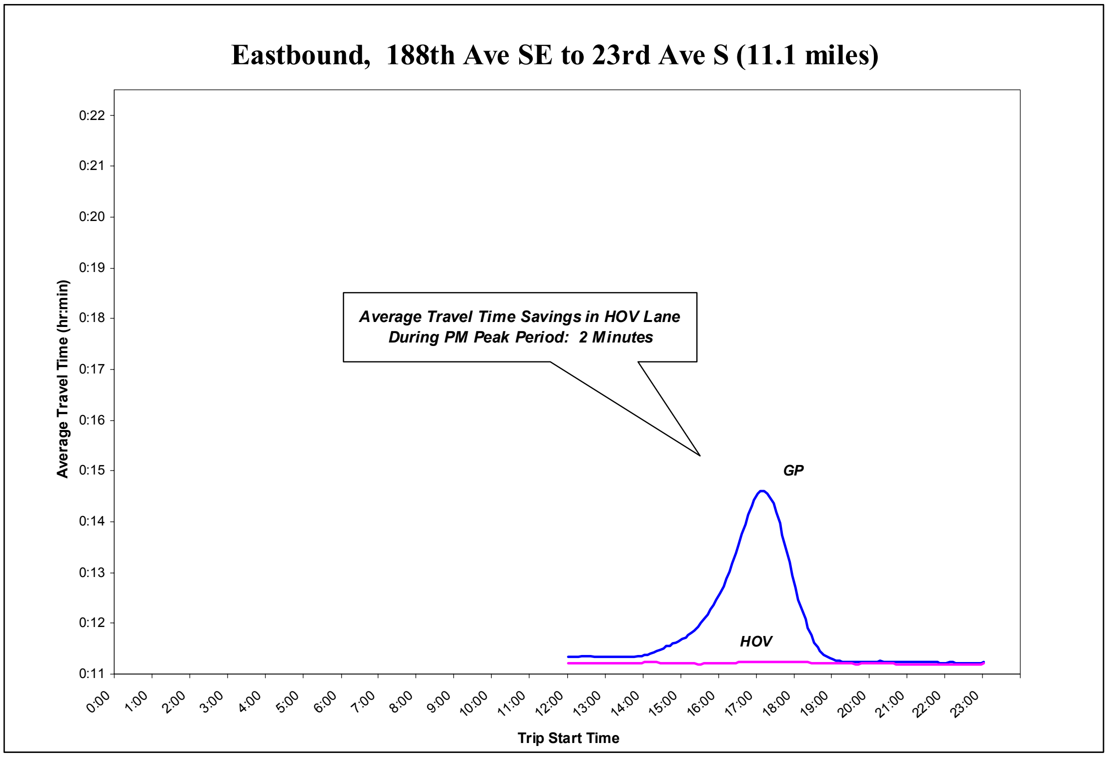




**Figure 3-14. Average Weekday GP and HOV Travel Time (2000): I-405 South of I-90**



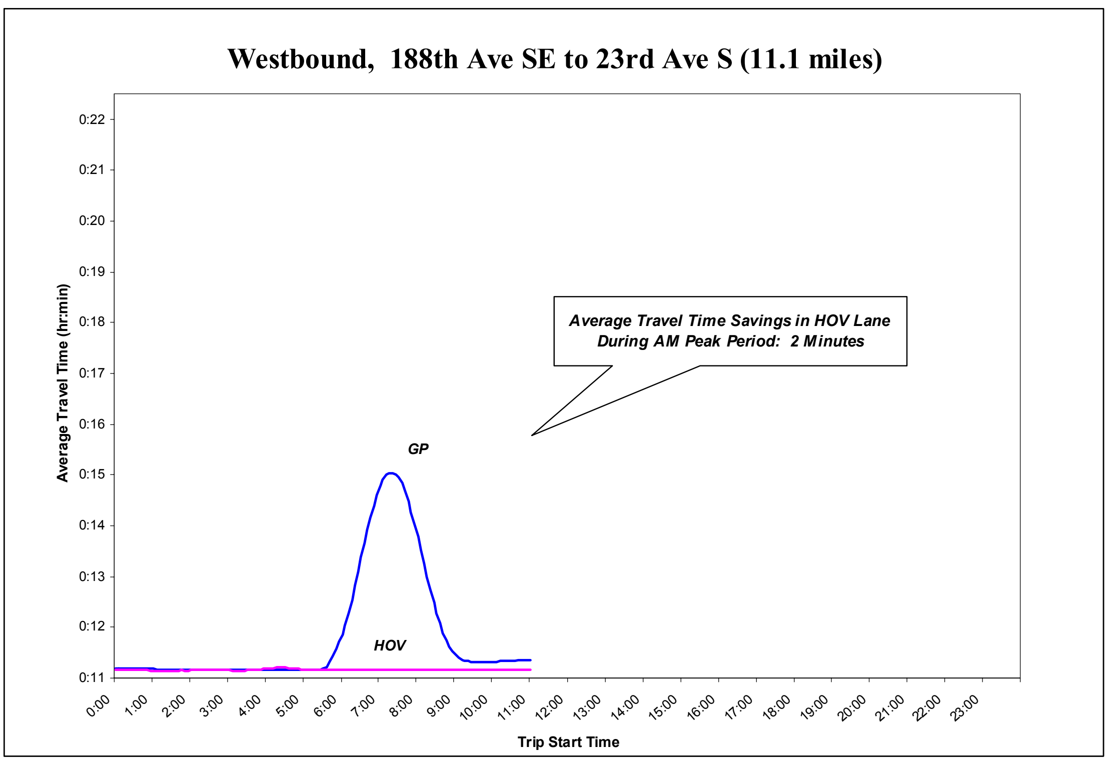




**Figure 3-15. Average Weekday GP and HOV Travel Time (2000): I-90**

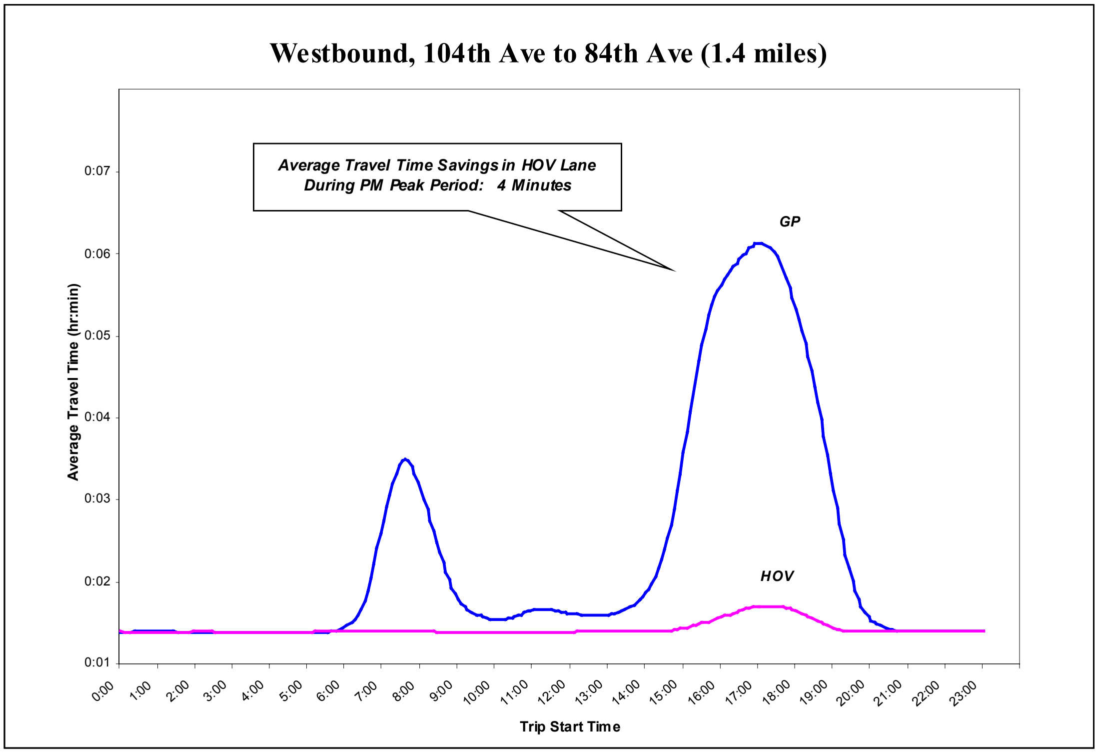
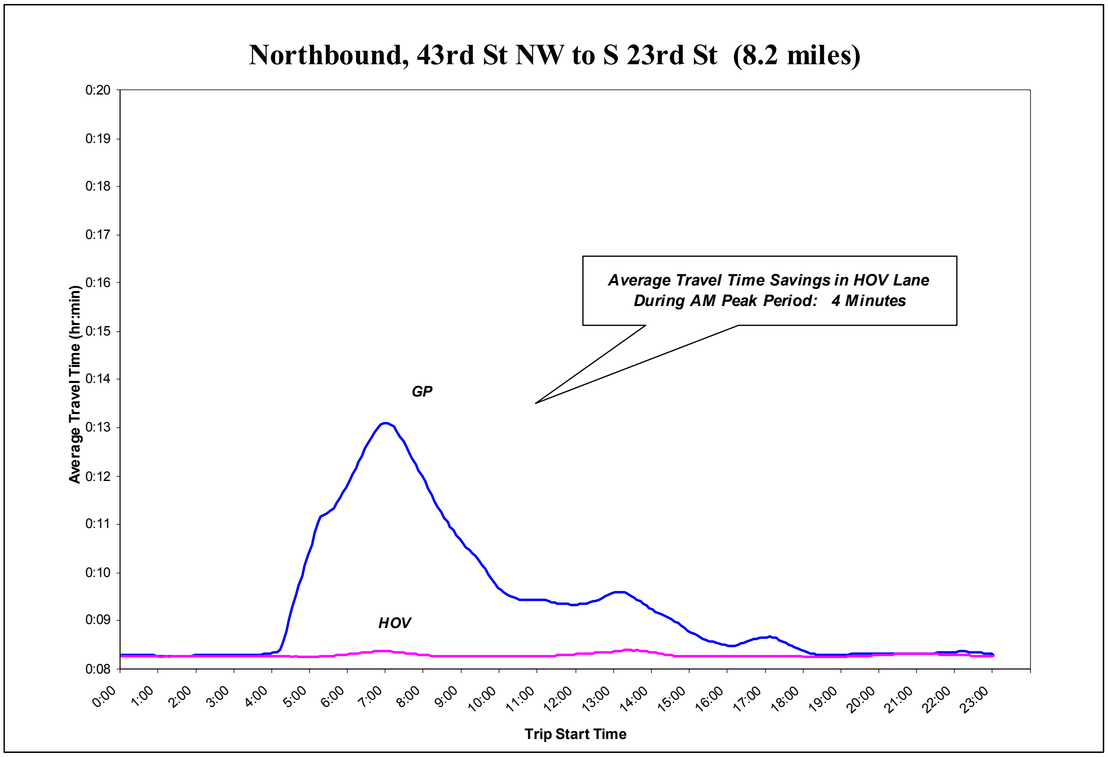



**Figure 3-16. Average Weekday GP and HOV Travel Time (2000): SR 520**

morning commute traveling southbound toward downtown Seattle, I-405 in the traditional commute directions, and westbound on SR 520 and southbound on SR 167 during the afternoon peak period.

In many cases, the more moderate level of travel time savings observed in the remaining HOV corridors is due to a variety of causes. These include low levels of traffic congestion (e.g., on I-90) and lane friction with congested adjacent GP lanes (e.g., southbound on I-5 south of the Seattle CBD during the afternoon commute).

It is interesting to note that although HOV facilities in two corridors may provide similar travel time savings (in seconds per mile), users may perceive the two facilities differently. For example, the HOV traffic on northbound I-405 traveling away from downtown Bellevue moves near the speed limit, whereas the southbound I-5 HOV traffic



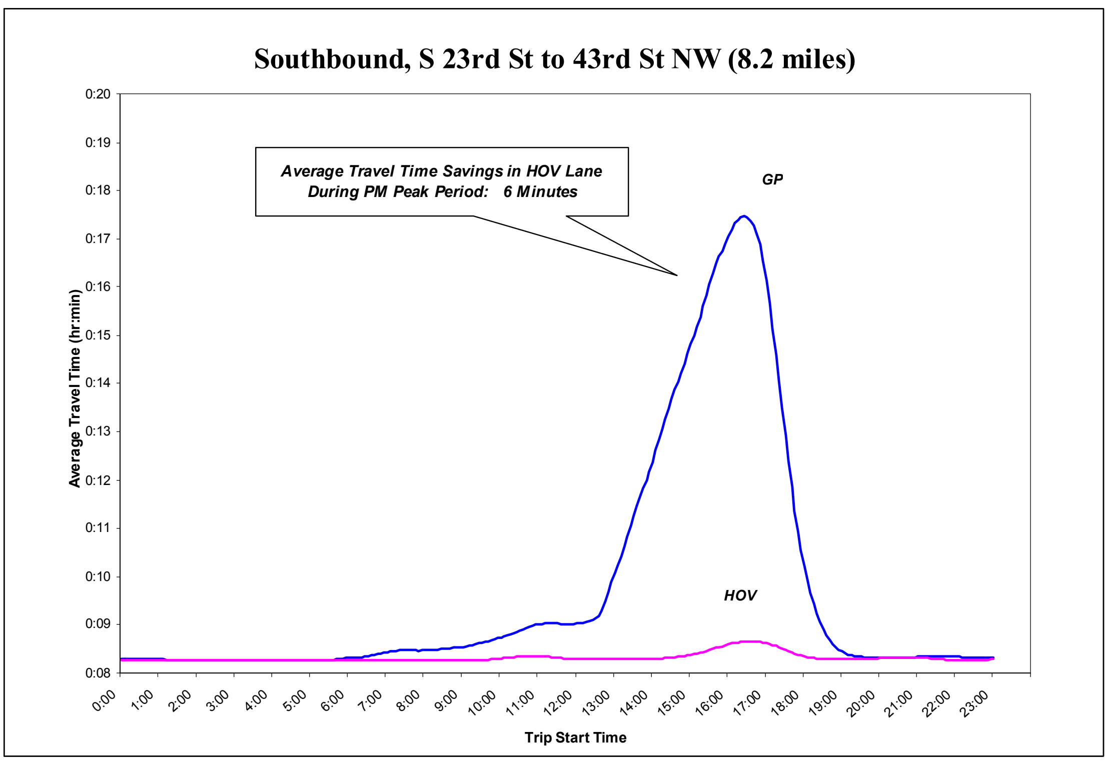




**Figure 3-17. Average Weekday GP and HOV Travel Time (2000): SR 167**

is forced to slow down because of lane friction with slower moving vehicles in the adjacent GP lane (see contour map). As a result, although HOV users in both corridors receive the same travel time savings benefit (27 to 33 seconds per mile) during the peak periods, the perceived benefits to the HOV users traveling at 60 mph may seem greater than those traveling at slower speeds.

## SITE-SPECIFIC OPERATIONAL PERFORMANCE

Although the measures presented above provide a top-level overview of system performance along a corridor as a whole, more detail about HOV traffic performance can be provided by examining the operation of HOV lanes at specific locations. The principal measures used to evaluate HOV performance at a particular site include the following:

- **Average Vehicle Volume at a Location, by Time of Day.** Vehicle volumes were calculated at 5-minute intervals over a 24-hour weekday and averaged over a full year at a given site. These volumes were then adjusted to a "per lane" hourly rate (vehicles per lane per hour, or VPLPH) to allow direct comparison between sites with varying numbers of lanes.

- **Average Speed at a Location, by Time of Day**. Weekday speed for a location was calculated at 5-minute intervals over a 24-hour weekday and averaged over a full year.

- **Percentage of Days During Which the Average Speed < 45 mph at a Location**. The percentage of weekdays during which vehicles in the HOV lane at this location and time travel less than 45 mph was computed. This measure helps show how "reliable" a given facility is.

Locations for which data are presented in this report include the sites in Table 3-3.

### Reading the Average Weekday Volume, Speed, and Reliability Conditions Graphs

Site specific HOV lane performance is illustrated with a graphic that combines HOV lane volume by time of day, and the frequency with which the HOV lane at that

**Table 3-3. Selected HOV Analysis Sites**

| Corridor | Location |
|---|---|
| I-5 North of the Seattle CBD | I-5 @ 112th SE – Everett (near Everett)<br>I-5 @ NE 145th St. (near Northgate) |
| I-5 South of the Seattle CBD | I-5 @ Albro Place (south of Seattle Downtown)<br>I-5 @ S 184th St. (south of Southcenter) |
| I-405 North of I-90 | I-405 @NE 85th St. (near Kirkland)<br>I-405 @ SE 59th St. (near Factoria) |
| I-405 South of I-90 | I-405 @ Tukwila Parkway (near Southcenter) |
| I-90 | I-90 @ Midspan (Floating Bridge)<br>I-90 @ Newport Way (near Issaquah) |
| SR 520 | SR 520 @ 84th Ave. NE (near Medina) |
| SR 167 | SR 167 @ S 208th Ave. S (near Kent) |

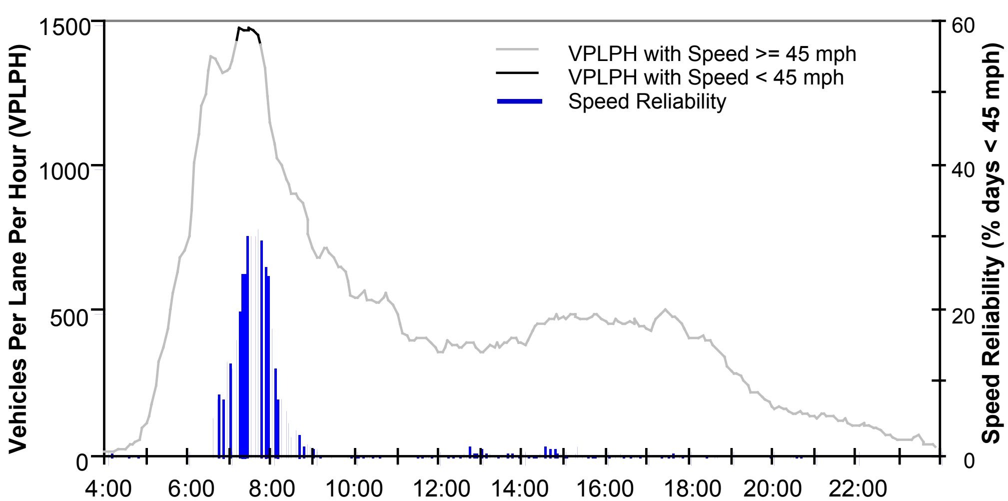



Figure 3-18. Average Volumes, Speed, and Speed Reliability Conditions Graph: Southbound on I-5 NE 137th St.

location fails to average 45 mph. An example of these graphs is provided in Figure 3-18. This figure illustrates performance for the southbound I-5 HOV lane at NE 137th St. near Northgate. It shows average volumes and travel speed conditions from 4:00 AM to 12:00 PM. The horizontal axis represents time of day, from midnight to midnight (for this example only 8 hours are actually shown). The line shows the expected traffic volume and is measured with the left vertical axis in units of vehicles per lane per hour. The volume line is further enhanced with color-coding. The color of the line reflects the expected speed of vehicles in the HOV lane on the average day:

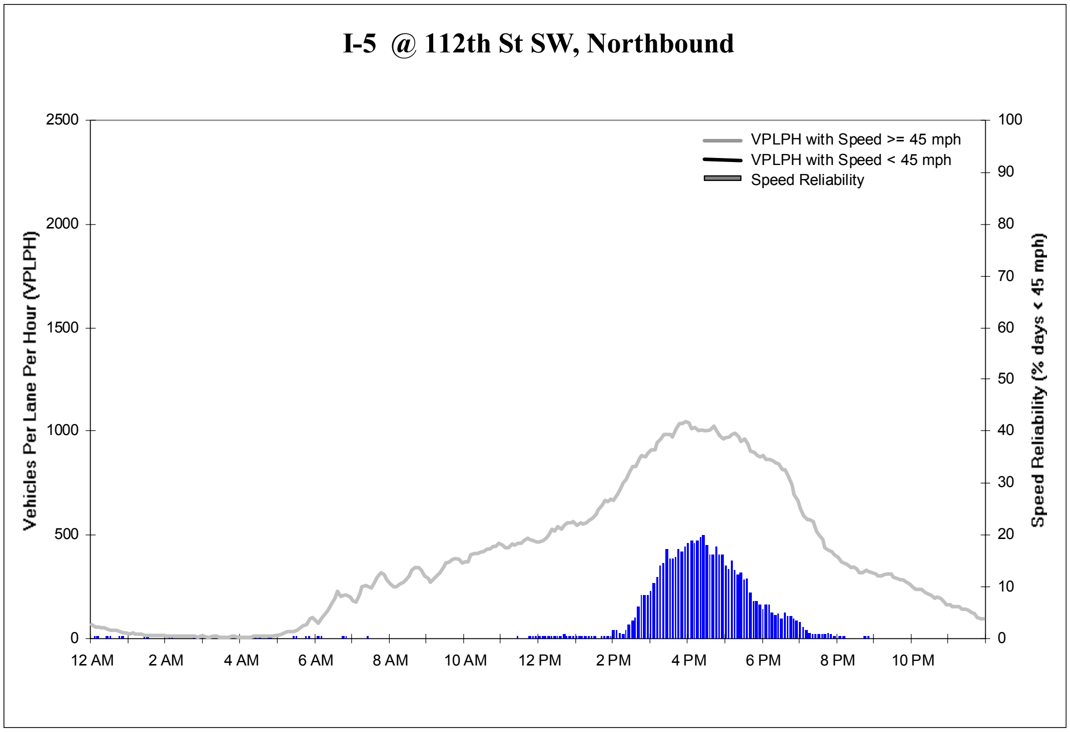
- gray indicates that traffic moves at or faster than 45 mph
- black represents traffic traveling slower than 45 mph.

The column graph is read using the right vertical axis. It illustrates the frequency with which congestion occurs at this location. In the example shown in Figure 3-18, HOV volumes can get as high as 1,400+ vplph during the AM peak period. Travelers can expect to travel faster than 45 mph throughout the day, except between 7:00 AM and 8:00 AM, when they they have approximately a 30 percent chance of encountering speeds of less than 45 mph.

**I-5 near South Everett (see Figure 3-19)**

**Northbound**

Average HOV volumes can approach 1,000 vplph during the PM peak period. Although moderate congestion occurs about once every week during the PM peak period, the average speed is still above 45 mph. In part, the high volume at this location and direction is caused by high Friday afternoon volumes. Peak hour Friday volumes are 250 vehicles higher than other weekday peak hour volumes, with Friday evening peak period volumes showing more than a 33 percent increase over other weekday peak periods.



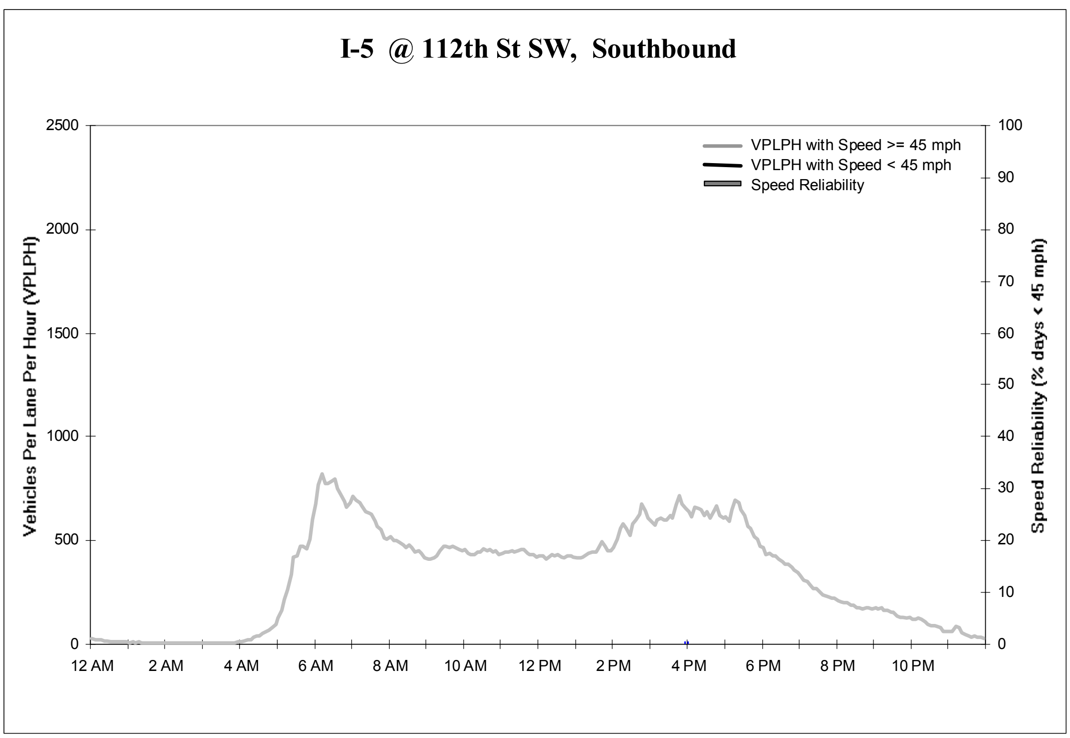




**Figure 3-19. Average Weekday Volume, Speed, and Reliability Conditions: I-5 @ 112th St SE**

These movements are not traditional commuter trips but a combination of commute trips and early weekend recreational travel. Because a large portion of long distance recreational travel includes vehicle occupancies of greater than two, the HOV lane essentially becomes a GP lane during these periods.

**Southbound**

HOV volumes are moderate throughout the day. Volumes approach 800 vplph during the AM peak period. No significant congestion was observed. (Note that the southbound direction is not subject to the same combination of peak period commute travel with peak recreational travel.)

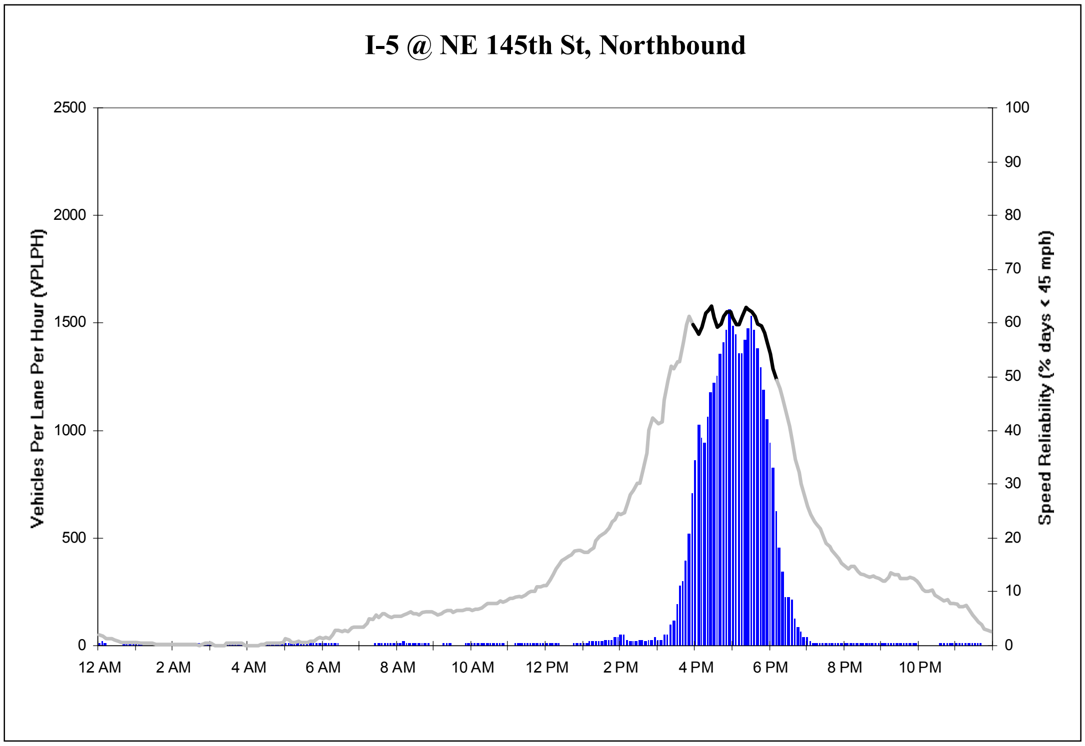
**I-5 near Northgate (see Figure 3-20)**

**Northbound**

HOV volumes are very high during the PM peak period and can reach 1,500 vplph during the evening commute. This location is just north of the end of the Express Lanes. Congestion occurs about half of the time during the evening peak period. This congestion frequently reduces the HOV lane speed to less than 45 mph during the evening peak period.

**Southbound**

As with the northbound PM peak period, HOV volumes at this site reach as high as 1,500 vplph during the AM peak period, but volumes remain below 700 vplph for the rest of the day. Between 7:00 AM and 8:00 AM, there is a significant chance of encountering enough congestion at this location for speeds below 45 mph to occur.



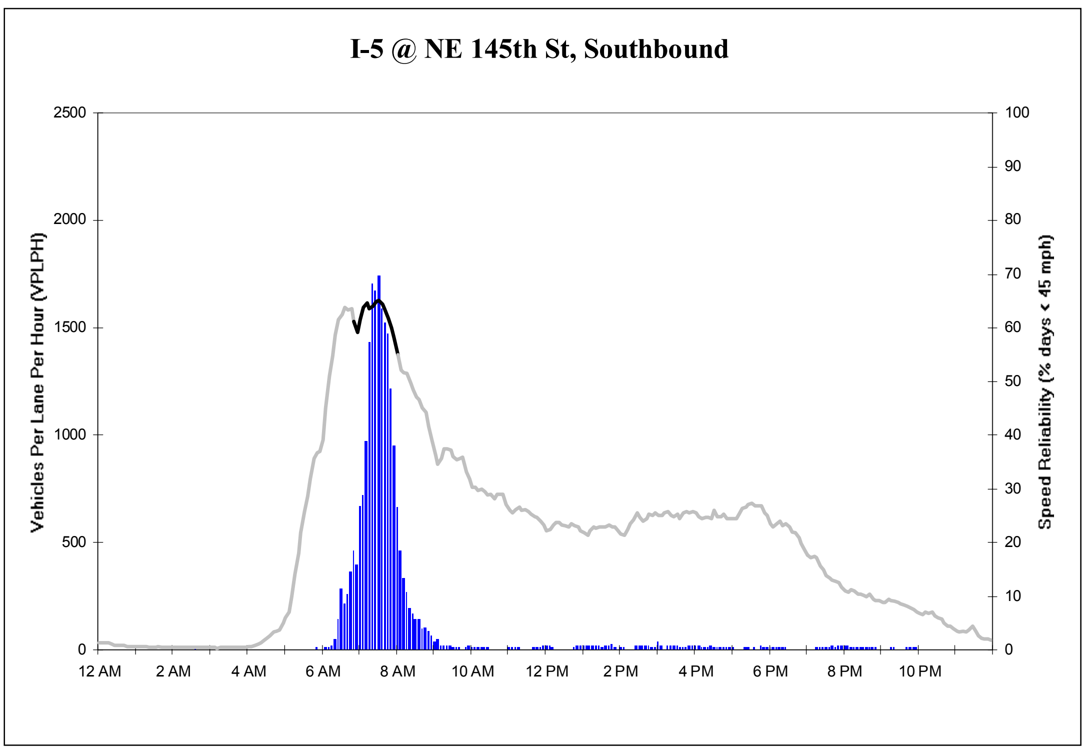




**Figure 3-20. Average Weekday Volume, Speed, and Reliability Conditions: I-5 @ NE 145th St**

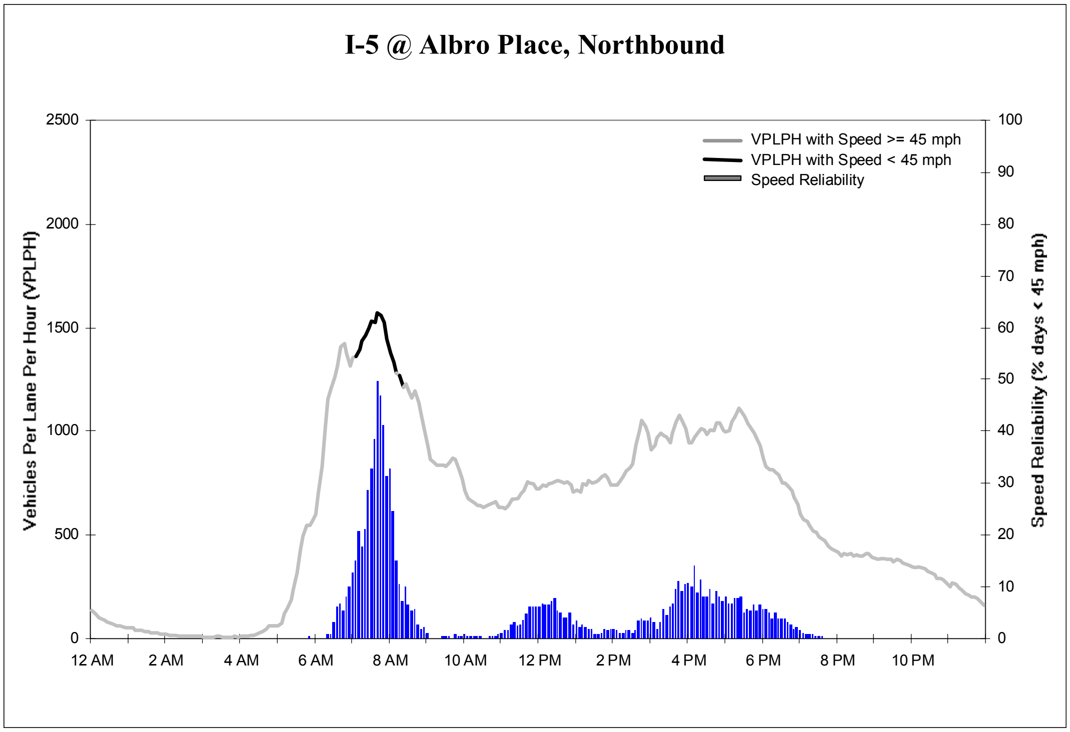
**I-5 South of the Seattle CBD (see Figure 3-21)**

**Northbound**

The highest volumes during the day at this location are in the AM peak, when close to 1,500 vplph use this HOV lane. This high volume, combined with recurring congestion in the adjacent GP lanes, frequently (twice a week) results in an average HOV speed of lower than 45 mph. Significant volumes (1,000+ vplph) also occur in the PM peak, although with less congestion. Still, this off-peak movement experiences congestion as frequently as once every two weeks. Much of the midday and afternoon congestion in the HOV lanes at this location is caused by spillback from congestion in downtown Seattle where the HOV lanes end before the Express Lanes entrance. This HOV lane becomes a GP lane just after the start of the I-90 interchange, and significant queuing in the lane occurs as vehicles wait to enter the Express Lanes. Volumes in the HOV lane remain significant (between 600 and 750 vplph) throughout the business hours of the day.

**Southbound**

Southbound HOV volumes are significantly higher in the PM peak than during the rest of the day, although these peak volumes of around 1,500 vplph generate little direct congestion. In part this is because merge and friction related congestion occurs upstream of this point, allowing traffic at this location to flow smoothly. Volumes during the middle of the day are in the range of 500 to 900 vplph, with speeds almost always greater than the 45 mph standard.



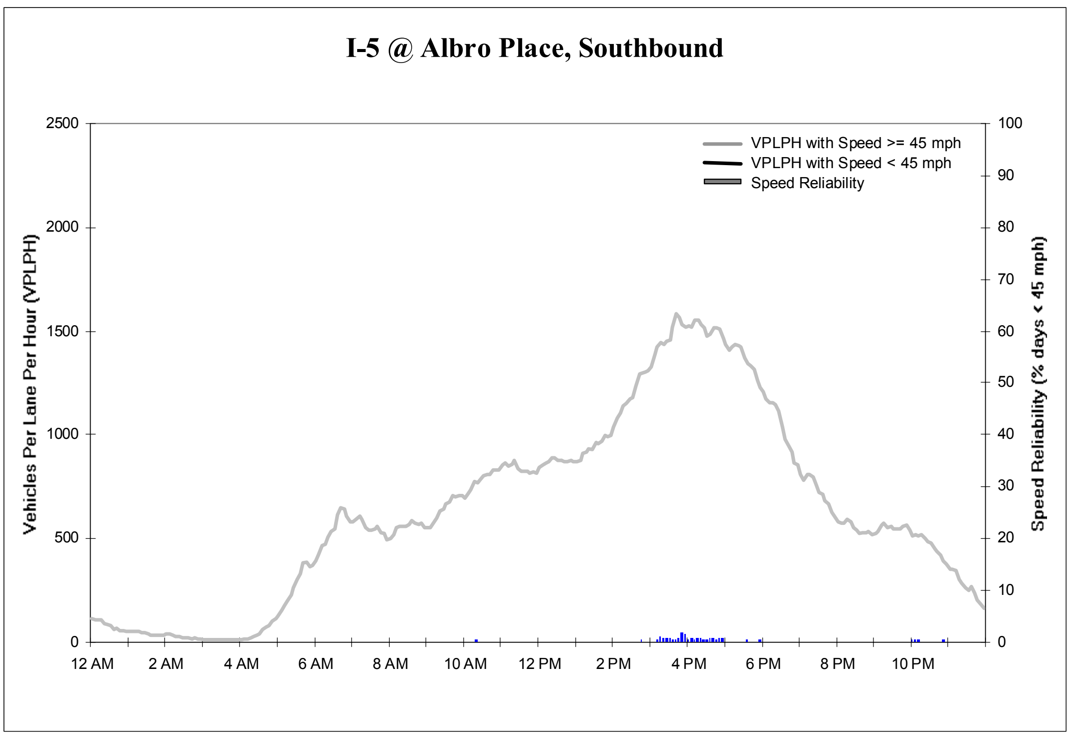




**Figure 3-21. Average Weekday Volume, Speed, and Reliability Conditions: I-5 @ Albro Place**

**I-5 near South of Southcenter (see Figure 3-22)**

**Northbound**

HOV volumes at this location are heavily peaked, although midday volumes are still substantial (around 500 vplph). Peak volumes approach 1,400 vplph during the AM peak period. This location is relatively free of congestion at all times during the day.

**Southbound**

The southbound HOV patterns are different than the northbound travel patterns. Most important is the considerable amount of congestion that occurs in the evening peak period. This site is at the top of the Southcenter Hill. The congestion observed is caused by a combination of the heavy HOV volumes and the grade of the roadway. Volumes in the evening peak period can reach more than 1,400 vehicles. Speeds lower than 45 mph can occur as frequently as 70 percent of the time between 3:00 PM and 6:00 PM. Southbound off-peak HOV volumes at this location are much lower than northbound off-peak HOV lane volumes. The northbound HOV lane has considerable off-peak use, while the southbound lane has relatively little use before 1:00 PM..

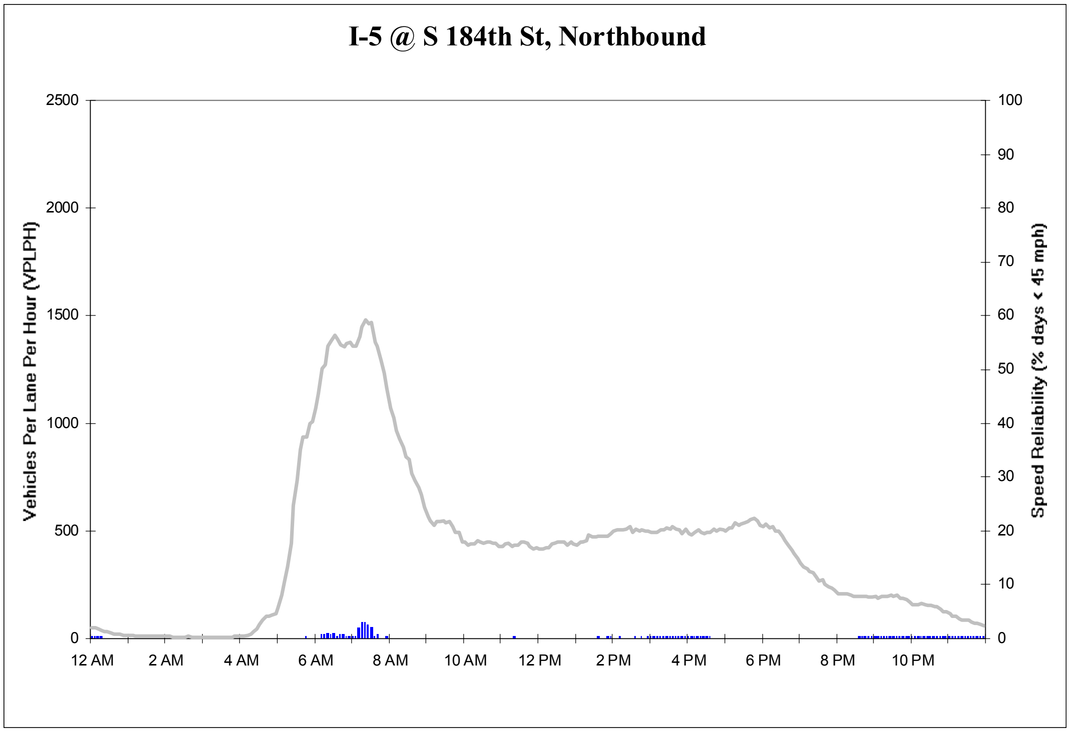
**I-405 near Kirkland (see Figure 3-23)**

**Northbound**

Relatively little congestion is present in the HOV lane at this location. (Congestion occurs farther north.) During the PM peak, HOV volumes exceed 1,400 vplph, and these volumes stay high for over three hours. During the remainder of the workday, HOV volumes remain fairly constant at a modest 300 vplph.

**Southbound**

The southbound HOV performance at this location is very similar to the northbound performance, although with a slightly lower peak period volume and a



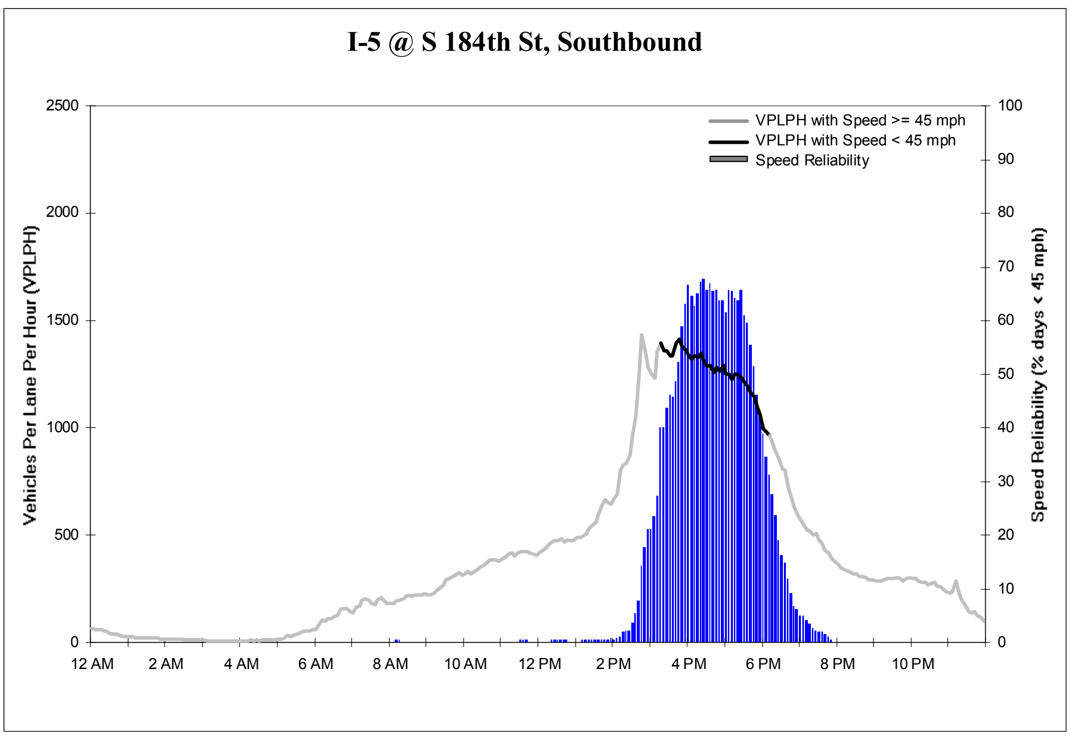
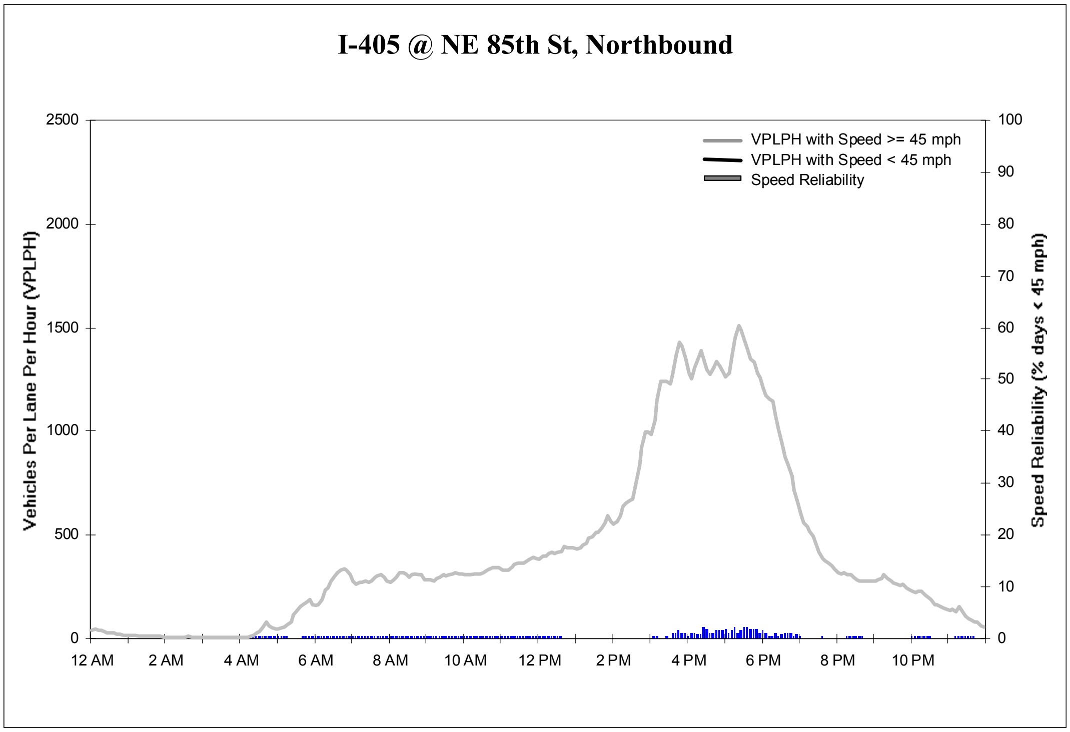




**Figure 3-22. Average Weekday Volume, Speed, and Reliability Conditions: I-5 @ S 184th St**



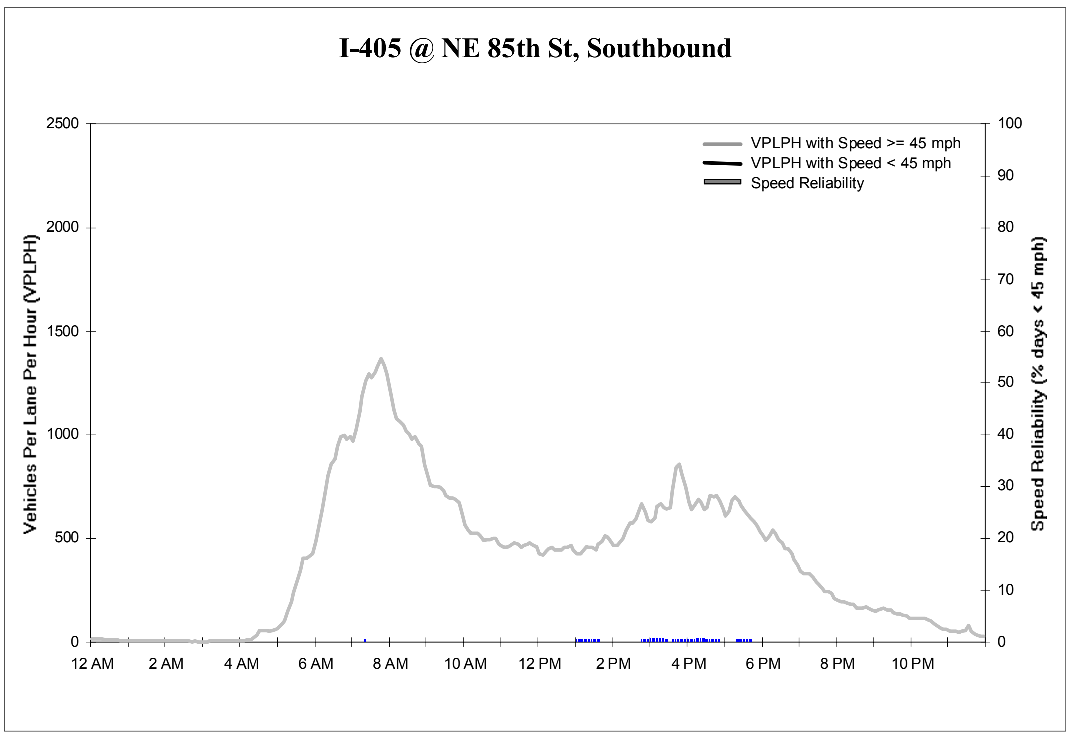




**Figure 3-23. Average Weekday Volume, Speed, and Reliability Conditions: I-405 @ NE 85th St**

slightly higher off-peak volume. HOV volumes peak at 1,300+ vplph during the morning commute, remain near 500 vehicles in the middle of the day, and climb back to over 600 vplph during the PM peak. Little significant congestion was observed at this location.

**<u>I-405 near Newcastle (see Figure 3-24)</u>**

**<u>Northbound</u>**

The HOV lanes on I-405 between Renton and Bellevue carry among the highest volumes in the region. Northbound vehicle volumes exceed 1,500 vlph during the AM peak. Midday volumes are near 700 vplph, but increase to over 900 in the PM peak. Congestion frequency is well over 20 percent during the AM peak period. Most of the congestion is caused by lane friction with the slow moving adjacent GP lanes.

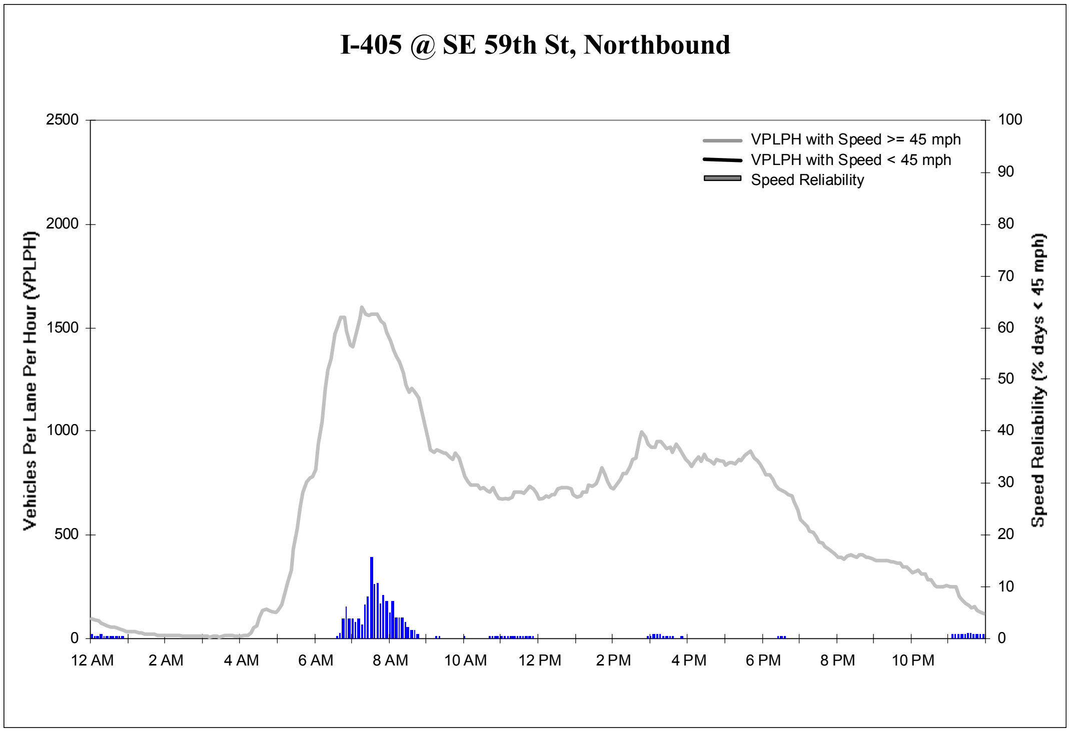
**<u>Southbound</u>**

Southbound HOV volumes exceed 1,600 vplph between 4:30 PM and 6:00 PM and remain substantial until after 7:00 PM. Congestion frequency is low, averaging less than once every two weeks throughout the late afternoon and evening. During the rest of the day, volumes average between 500 and 800 vplph with little congestion.

**<u>I-405 near Southcenter (see Figure 3-25)</u>**

**<u>Northbound</u>**

The far south end of I-405 has moderately low HOV use, especially in comparison to the section north of the SR 167 interchange. Also unlike the section north of SR 167, HOV volumes during the PM peak period are greater than those in the AM peak period. HOV volumes fluctuate around 500 vehicles per lane per hour throughout the morning and midday. The highest volumes of the day are just over 1,000 vplph in the evening peak. Congestion is well below 10 percent, with almost all of that caused by



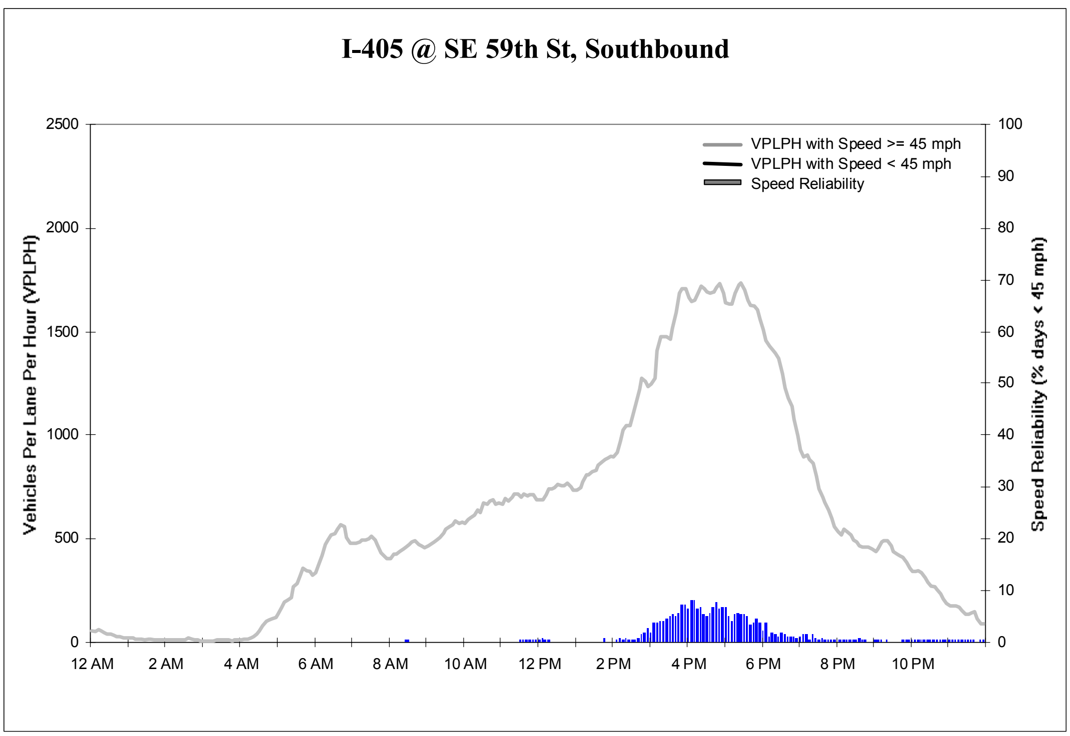
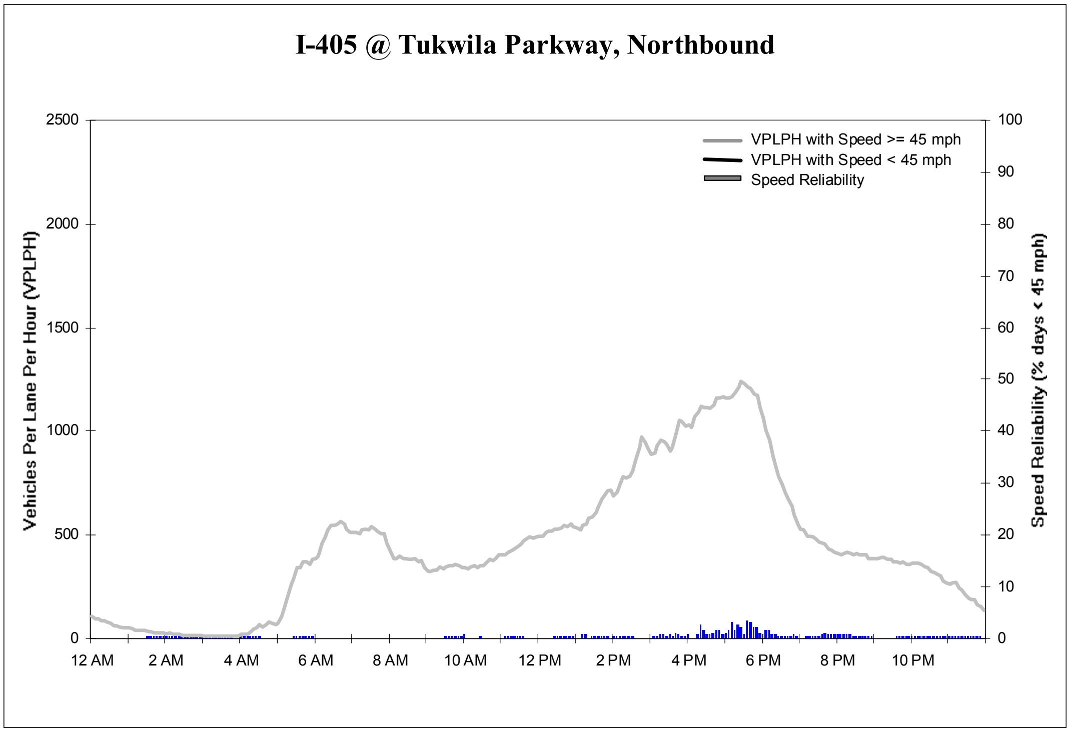




**Figure 3-24. Average Weekday Volume, Speed, and Reliability Conditions: I-405 @ SE 59th St**



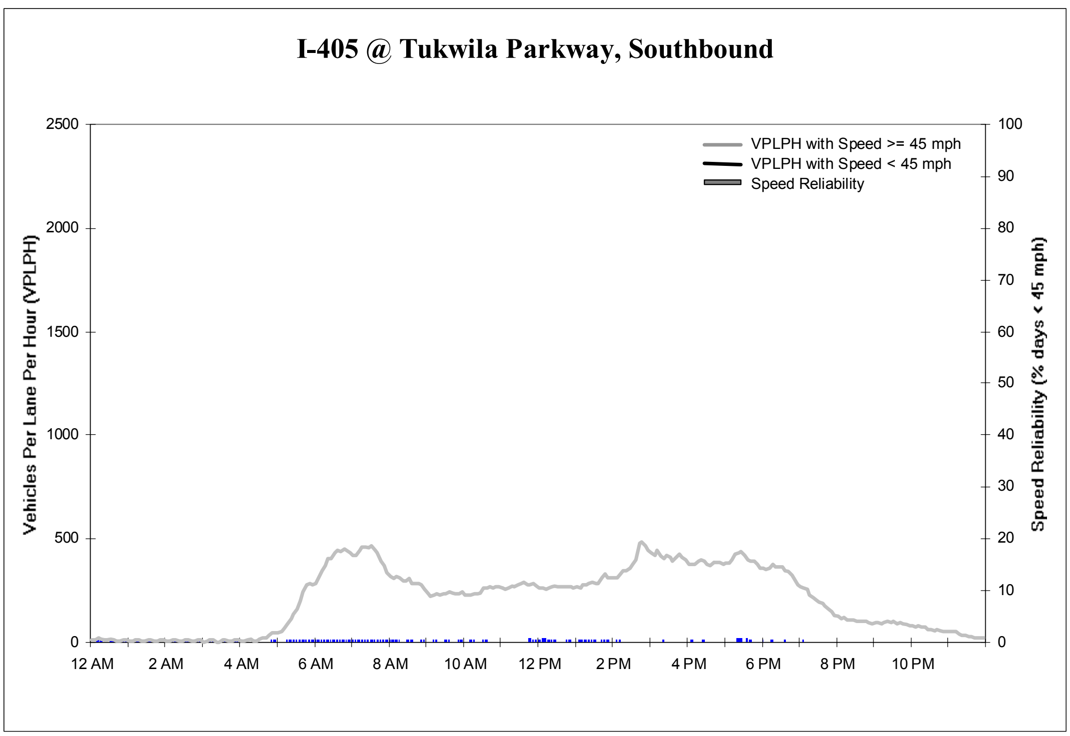




**Figure 3-25. Average Weekday Volume, Speed, and Reliability Conditions: I-405 @ Tukwila Parkway**

slow moving HOVs trying to merge through the slow moving GP lanes so that the HOVs can exit to southbound SR 167.

**Southbound**

Southbound HOV volumes are even lower than northbound volumes, and they are quite constant throughout most of the day. Both AM and PM peak periods experience roughly 500 vplph with no congestion. Midday volumes are slightly lower.

**I-90 Floating Bridge (see Figure 3-26)**

**Reversible Lanes**

The reversible roadway contains both HOVs and Mercer Island traffic in two lanes. There are two prominent volume peaks with 500 vplph (inbound to Seattle) in the AM peak hour and 800 vplph (outbound to Mercer Island) in the PM peak hour. Volumes during the rest of the day are relatively low. There is no congestion.

**I-90 near Issaquah (see Figure 3-27)**

**Eastbound**

The eastern end of I-90 has modest to low HOV volumes. While these HOV lanes are experiencing considerable volume growth as development continues in the eastern suburbs, like the I-90 general purpose lanes, these lanes do not experience either the volumes or congestion frequency observed on most Puget Sound area freeways.

Eastbound HOV volumes approach 600 vplph during the PM peak period. Volumes are relatively low throughout the rest of the day, as are GP lane volumes. HOV speeds are greater than 45 mph throughout the day.

**Westbound**

HOV volumes can approach 700 vplph during the AM peak period. Volumes are relatively low throughout the rest of the day. No congestion was observed.

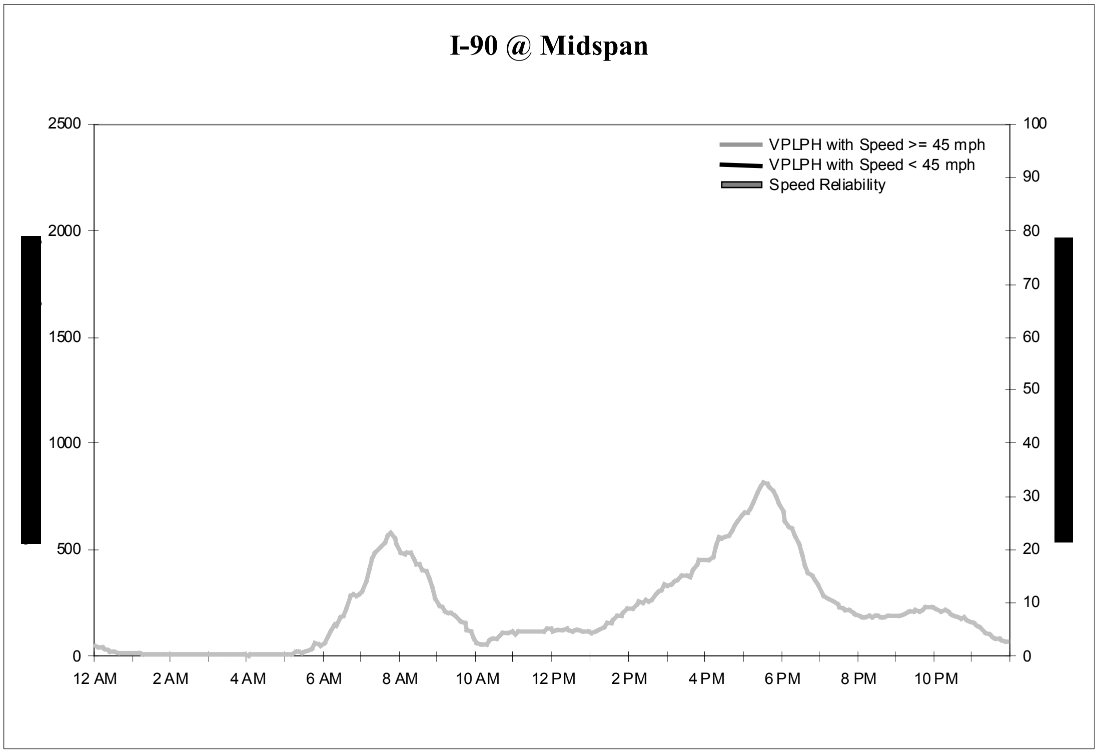
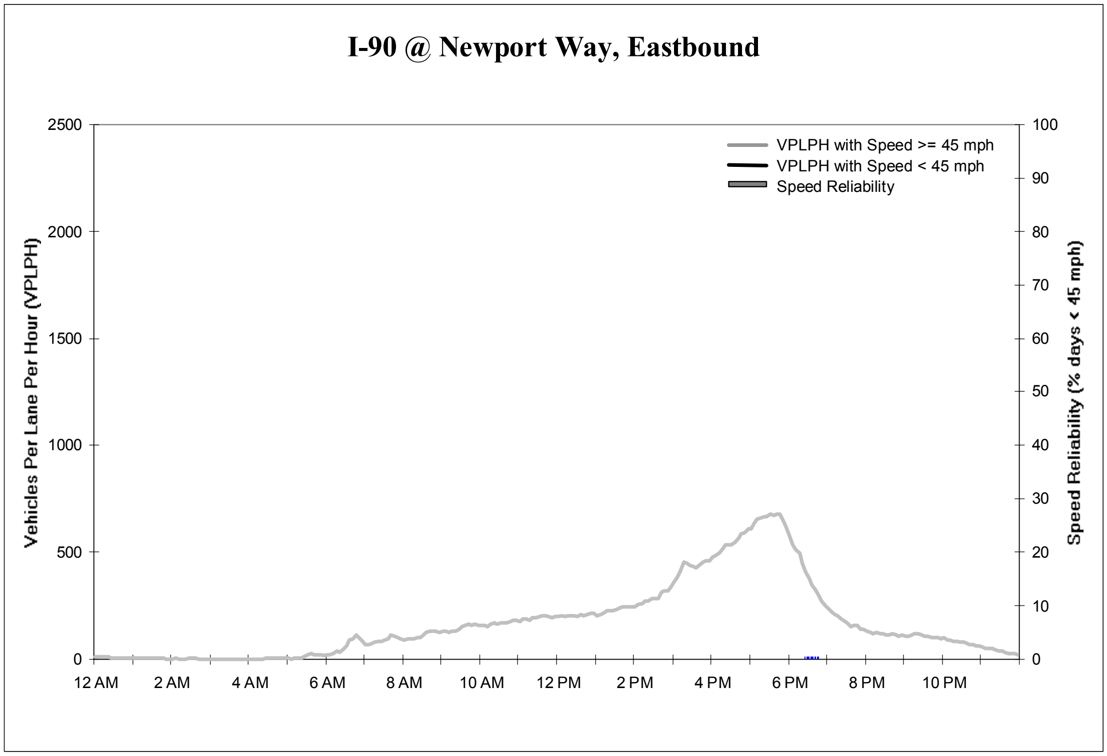



**Figure 3-26. Average Weekday Volume, Speed, and Reliability Conditions: I-90 @ Midspan**

## <u>SR 520 near Medina (see Figure 3-28)</u>

### <u>Westbound</u>

HOV volumes on SR 520 are constrained by the 3+ HOV designation on this portion of the facility. Vehicle volumes are highest during the PM peak period, averaging slightly more than 400 vplph. Volumes are low to moderate throughout the rest of the day. Congestion in the HOV lane occurs during the PM peak period less than 5 percent of the time. Most of this congestion is caused by lane friction in the restricted width shoulder HOV lane, although some congestion occurs as a result of spillback from congestion caused by the merge of the HOV vehicles at the bridge deck just west of this count location. (Note that there is no HOV lane eastbound on this section of SR 520, and data were not available for the new HOV facility east of the I-405 interchange.)



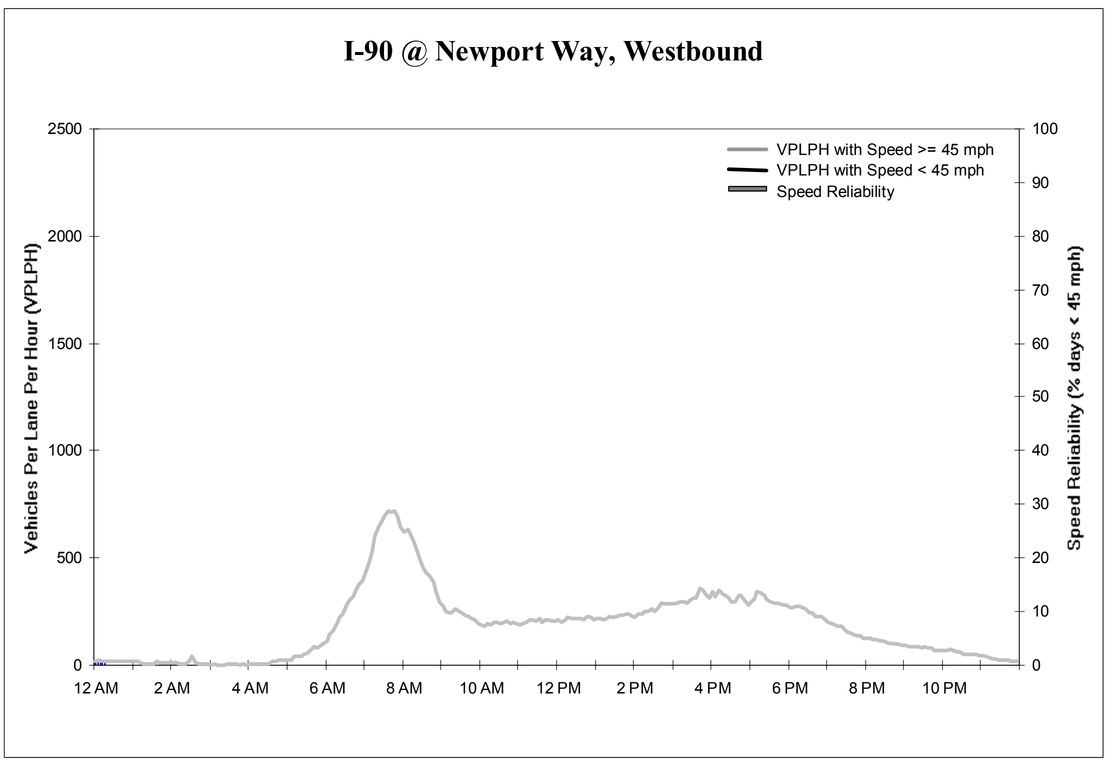




**Figure 3-27. Average Weekday Volume, Speed, and Reliability Conditions: I-90 @ Newport Way**

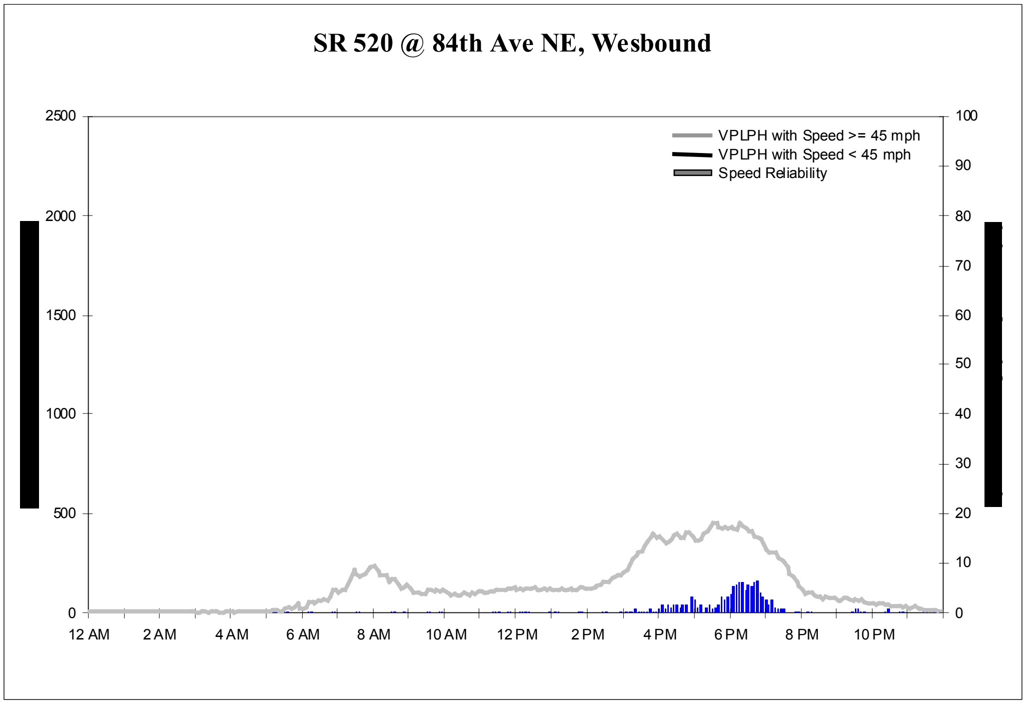



**Figure 3-28. Average Weekday Volume, Speed, and Reliability Conditions: SR 520 @ 84th Ave NE**

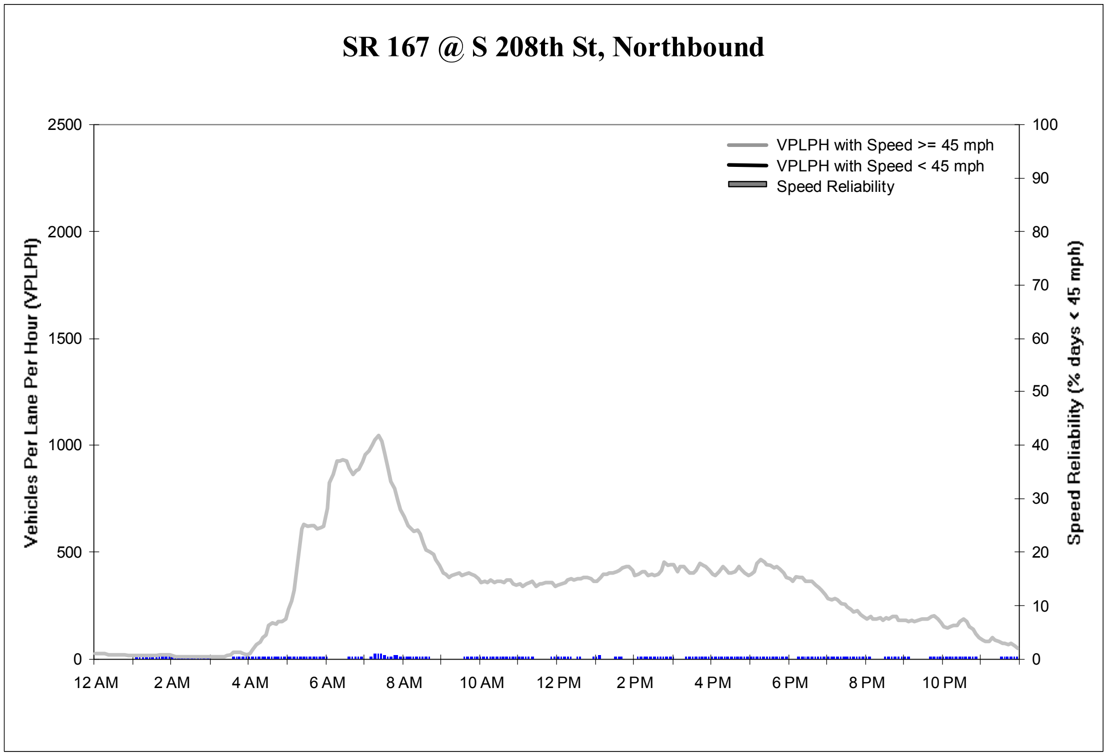
## SR 167 near Kent (see Figure 3-29)

### Northbound

Northbound HOV volumes are high during the AM peak period (~ 900+ vplph), but modest (400+ vplph) throughout the midday and evening. There is no congestion at this location.

### Southbound

Southbound PM peak period HOV volumes are more significant than northbound AM peak period volumes. Peak period volumes (1,000+ vplph) are higher, and the duration of the peak period is longer than the morning, northbound movement. However, the southbound movement has lower off-peak use than the northbound HOV lane, which has near constant volumes from 9:00 AM until 6:00 PM, while this southbound movement is almost nonexistent until 11:00 AM. There is still no congestion at this location.



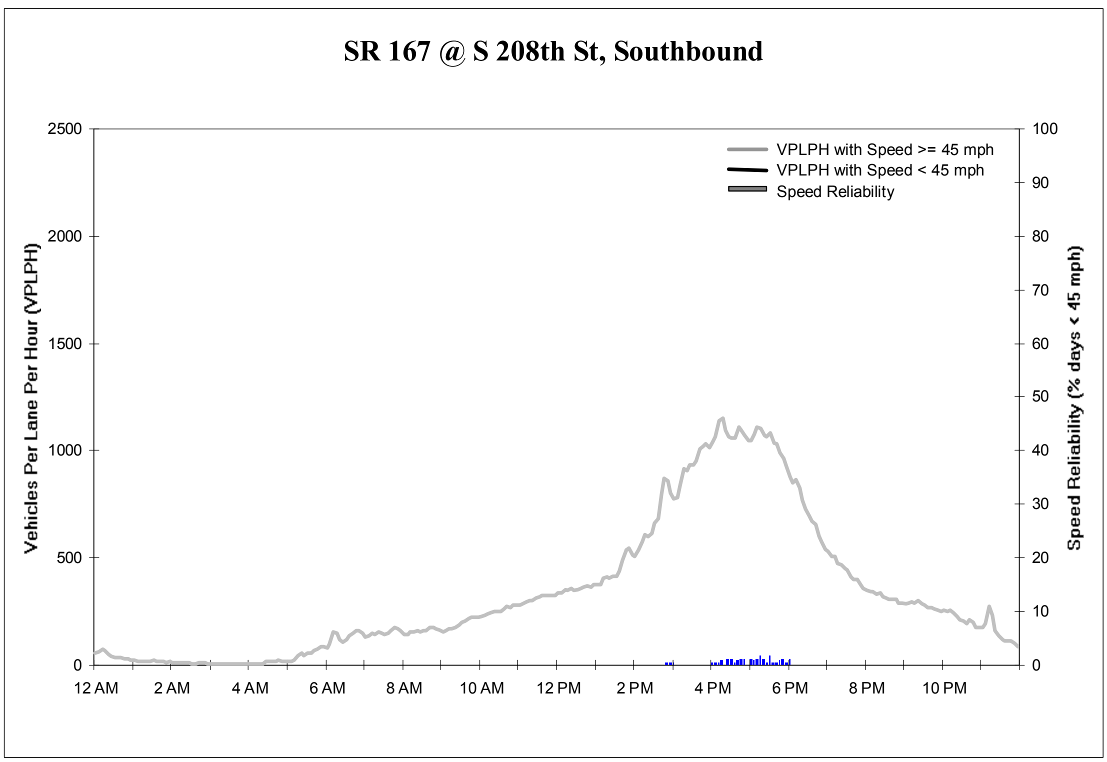




**Figure 3-29. Average Weekday Volume, Speed, and Reliability Conditions: SR 167 @ S 208th St**

# CHAPTER 4.
# HOV VIOLATIONS

HOV violation rates are not constant. They vary considerably from facility to facility, and from location to location along a facility. In general, the higher the HOV use, the lower the violation rate. In addition, the better the opportunity to "cheat and not get caught," the higher the violation rate. For example, violation rates tend to increase near points where HOV lanes merge with general purpose lanes, as some motorists seem to believe that getting into the HOV lane "just a little early" is not really a violation, and the short time spent in the HOV lane limits the chance that they will be observed by a State Patrol officer. Consequently, violations increase at the very end of HOV facilities and in the right hand HOV lanes approaching exits (e.g., SR 520 westbound approaching 92$^{nd}$ Ave NE).

For this report, violation rates were calculated by using vehicle occupancy data collected by traffic observers at a limited number of locations throughout the region. The rates reported are reasonable measures of system wide violation rates, but they may not be representative of the violation rates at specific locations.

Other sources that provided some insight into HOV violation rates and the outcomes of enforcement actions include the following:

- violation reports made to King County Metro's HERO program
- warnings and citations issued by the Washington State Patrol
- HOV cases processed in the district courts in counties that have HOV lanes

In addition to these measures of HOV violations, motorists' perceptions of compliance and enforcement of HOV restrictions were also solicited through a public opinion survey. Almost half of the respondents indicated that improving enforcement would be among their highest priorities for improving HOV lanes. HOV lane violation, considered a serious traffic violation, is perceived as common during peak commute hours. For more detailed information on the public's opinion regarding violations, please refer to Chapter 5, Public Opinion, of this report.

## VIOLATION RATES

Table 4-1 presents HOV violation rates measured as part of the routine system performance measurements. Figure 4-1 illustrates these violations in the context of the vehicle mode split measured at each data collection location. The violation rates in general are quite low, typically ranging from 1 percent to 7 percent, excluding some special cases. These low violation rates suggest that most people obey the HOV restrictions.

At a few locations, higher SOV volumes were observed in the HOV lanes. For example, at the HOV lane northbound on I-5 at Albro Place, the high percentage (23 percent) of observed SOVs is largely due to the fact that the HOV lane also serves as an inside exit lane at this location, and thus general purposes traffic mixes with the HOVs. This illustrates the point that violations increase toward the end of facilities and where HOV lanes are shared with exits.

The I-90 Midspan measurement also shows a high SOV volume (30 percent in AM, 50 percent in PM). This is caused by the legal access of SOVs traveling between Mercer Island and the Mt. Baker tunnel. Thus, while these vehicles decrease the average vehicle occupancy for this facility, they are not violators of the HOV regulations.

**Table 4-1. HOV Violation Rates**

| Location | AM Violation Rate and Roadway Direction | PM Violation Rate and Roadway Direction |
|---|---|---|
| I-5 @ 112th SE | 2% (SB) | 5% (SB) |
| I-5 @ NE 137th St. | 3% (SB) | 2% (SB) |
| I-5 @ Albro | 23% (NB)[1] | 4% (SB) |
| I-405 @ NE 85th St. | 3.5% (SB) | 7% (NB) |
| I-405 @ SE 59th St. | 4% (NB) | 6% (SB) |
| I-405 @ Tukwila Parkway | 5.5% (SB) | 5% (NB) |
| I-90 @ Midspan | 50% (WB)2 | 30% (EB)[2] |
| I-90 @ Newport Way | 5.5% (WB) | 7% (EB) |
| SR 520 @ 84th Ave NE | 8% (WB) | 9% (WB) |
| SR 167 @ S. 208th St. | 4% (NB) | 7.5% (SB) |

## THE HERO PROGRAM

The HERO program is a service provided by King County Metro that encourages motorists to report HOV violators by calling (206) 764-HERO or by sending in reports of violations electronically. The HERO program does not issue tickets because the State Patrol must actually observe the violation to enforce the infraction. However, HERO reports repeat violators to the WSP for possible enforcement action. Upon a first report, a brochure is sent to the alleged violator by HERO staff to provide information on HOV

[1] The HOV lane at this location includes SOVs legally using the lane to exit the freeway.
[2] SOVs may use the I-90 reversible roadway legally traveling between Mercer Island and downtown Seattle.

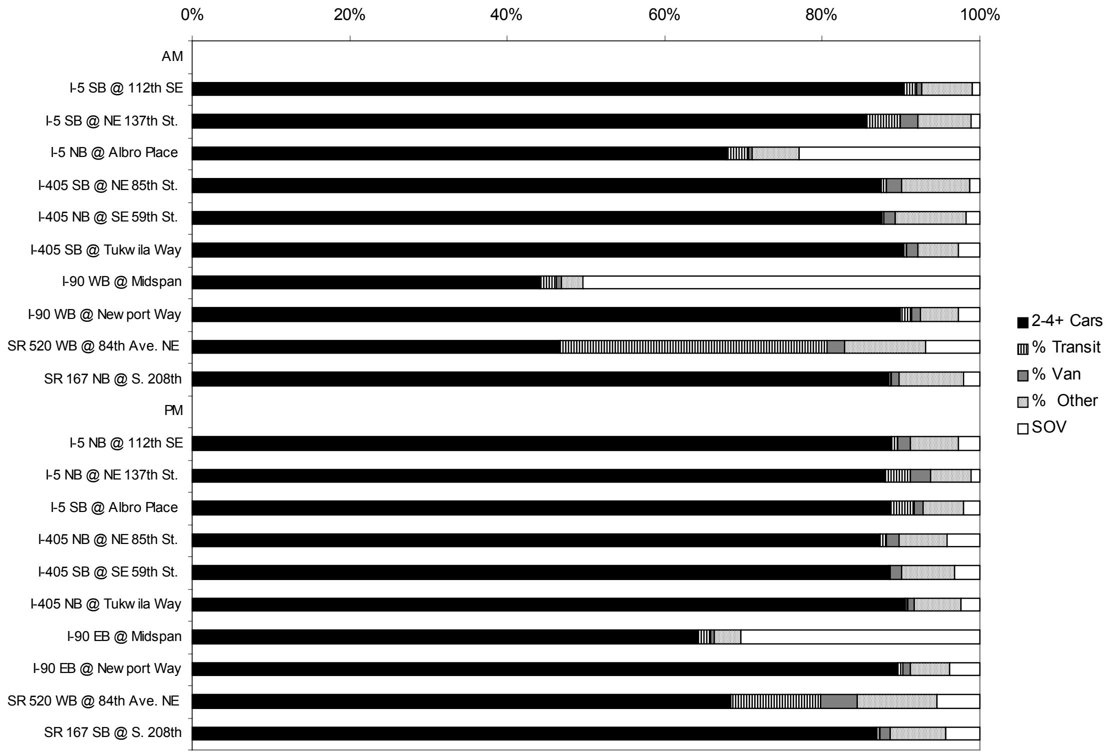



**Figure 4-1. Mode Split in HOV Lanes, from Observed Occupancy Rate (2000)**

lane policy and restrictions. Following a second report, the violator receives a letter from WSDOT, issued by the HERO office, that explains that the person's auto was observed violating HOV lane restrictions. If a third violation is observed, the vehicle owner receives a letter from the WSP, also issued by the HERO office.

Figure 4-2 shows a comparison of annual violation report rates for the HERO program by month from 1998 to 2000. The number of reported violations has increased steadily since 1993, with the total annual number of reported violators reaching 43,879 in 2000. This increase is in part fueled by the increase of the HOV lane system, and in part

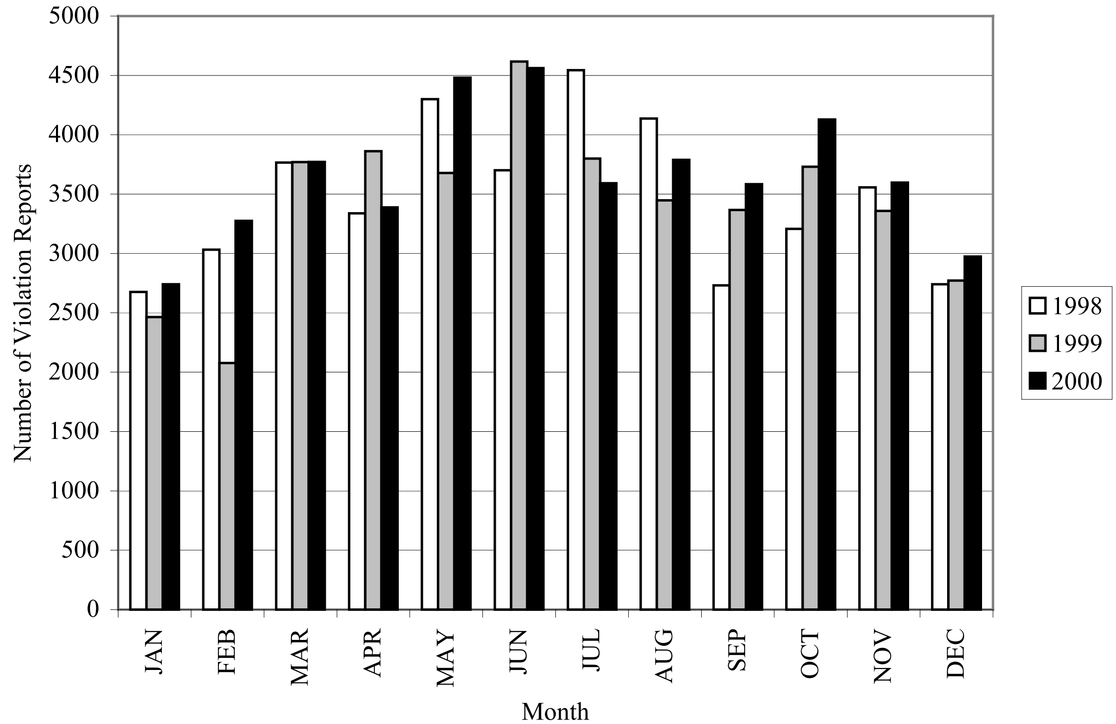



**Figure 4-2. HERO Program Actions 1998-2000**

by the availability of cellular phones, which make access to the HERO hotline easier. Reported violation rates decrease in the winter months because of diminished light levels, which make it difficult to see the number of occupants or the vehicle license plate of nearby cars.

## WASHINGTON STATE PATROL

The Washington State Patrol has primary responsibility for enforcing HOV lane restrictions on state highways. However, HOV enforcement is only one of many critical jobs performed by the WSP officers. Therefore, the number of HOV violation contacts and the number of citations issued is largely controlled not by the number of HOV violators, but by the officer time available for this function. The number of officer hours available for HOV enforcement is a function of the number of officer positions funded by the legislature and the priority of HOV enforcement relative to those other critical duties.

Although the WSP catches only a fraction of HOV violators on any single day, repeat violators have a significant chance of eventually getting caught. Troopers have the discretion to ticket offenders or to give verbal or written warnings as they see fit. (WSP officers have adopted a "zero tolerance" policy regarding HOV violations in an effort to curb persistent violation rates.) For 2000 the WSP reported 12,591 contacts with HOV violators and issued 9,045 tickets, for a ticketing rate of 72 percent (see Table 4-2). The number of tickets issued by officers in 2000 increased 44 percent after that of 1998. The 2000 ticketing rate was also the highest in the past nine years.

**Table 4-2. Washington State Patrol HOV Enforcement Actions, 1992-2000**

| Type of Action | Arrest Citations | Verbal Warnings | Written Warnings | Accident Citations | Other | Total |
|---|---|---|---|---|---|---|
| 1992 | 3,790 | 3,717 | 248 | 7 | 21 | 7,783 |
| 1993 | 3,655 | 3,389 | 259 | 5 | 33 | 7,341 |
| 1994 | 2,809 | 3,159 | 225 | N/A | 11 | 6,204 |
| 1995 | 3,893 | 2,734 | 415 | N/A | 11 | 7,053 |
| 1996 | 4,784 | 5,574 | 327 | N/A | 23 | 10,708 |
| 1997 | 7,014 | 4,786 | 503 | N/A | 24 | 12,327 |
| 1998 | 6,291 | 4,039 | 220 | N/A | 22 | 10,572 |
| 1999 | 7,915 | 3,534 | 190 | N/A | 20 | 11,659 |
| 2000 | 9,045 | 3,421 | 120 | N/A | 5 | 12,591 |

# CHAPTER 5.
# PUBLIC OPINION SURVEY FINDINGS

[Note: The following discussion of public opinion survey findings was originally published in August 1999 in *HOV Lane Performance Monitoring: 1998 Annual Report*. This discussion summarizes the most recently available WSDOT measurements of public opinion regarding HOV lanes. A new survey effort is planned when funding permits; results of that survey will be published as part of a future edition of the *HOV Lane Performance Monitoring Report*.]

Since July of 1993, 42,159 surveys have been mailed to owners of vehicles identified as HOVs and SOVs by traffic observers in the field. The overall response rate for the entire survey population was 23 percent, with a response rate of 24 percent from HOVs and 22 percent from SOVs. Many of the figures presented in this report are based on data collected from January 1998 until June 1999 to better illustrate the changes in demographics and opinion since the previous survey period. It should be understood that these opinions are compiled from the responses of returned surveys. Because of the random nature of the mailing and those returning the surveys, conclusions drawn from these data should not be considered completely representative of the driving population; rather they should be considered and further investigated in a more analytical fashion.

## DEMOGRAPHIC CHARACTERISTICS

The majority of survey respondents were male (57 percent), as depicted in Figure 5-1. The age group of the respondents ranged primarily from 31 to 64 (see Figure 5-2). As shown in Figure 5-3, 70 percent of survey respondents possessed a college degree or post-graduate education, 21 percent had attended only a community college, and 8 percent had finished only high school.

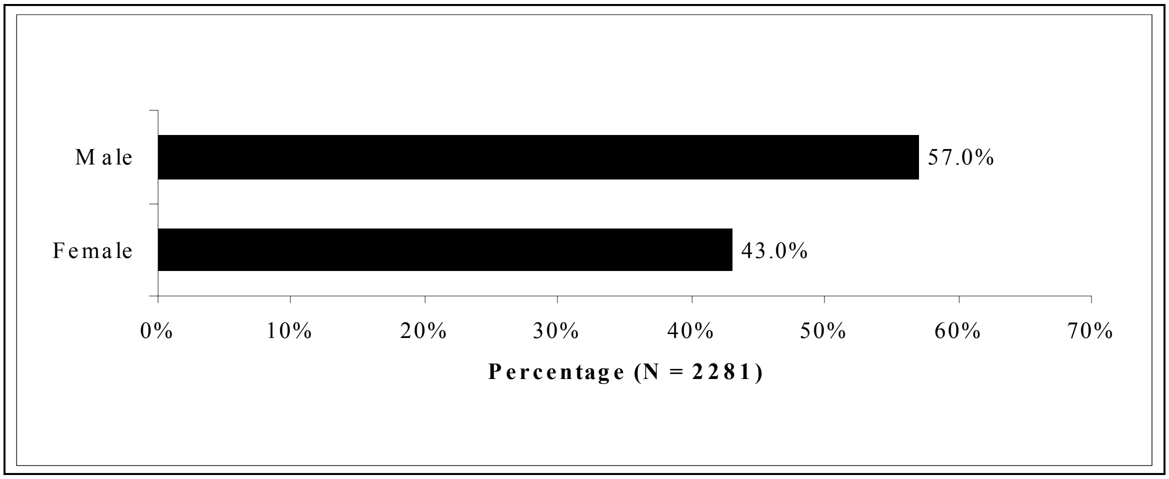



**Figure 5-1. Gender of Respondents**

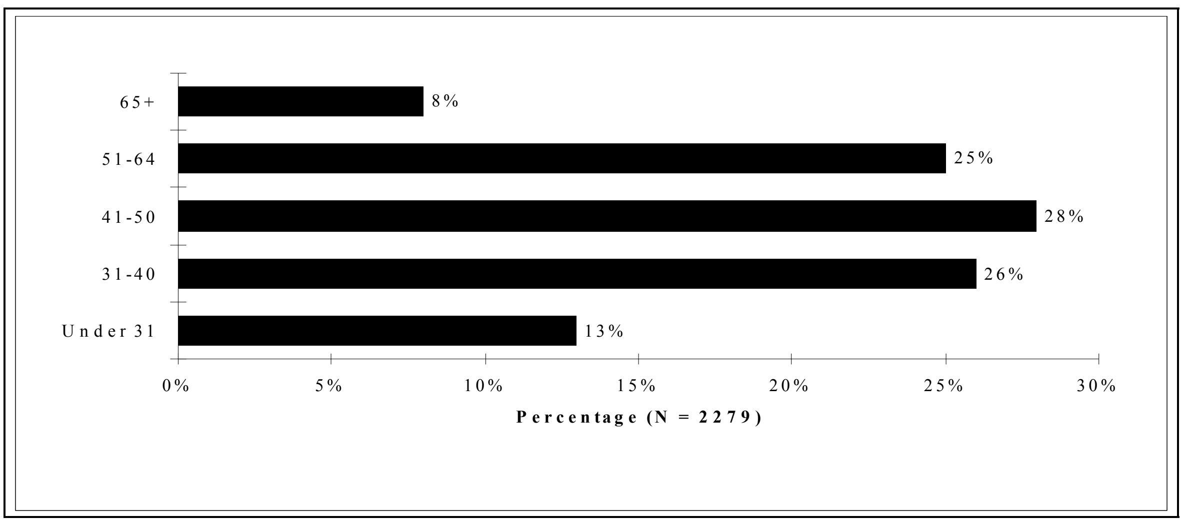



**Figure 5-2. Age of Respondents**

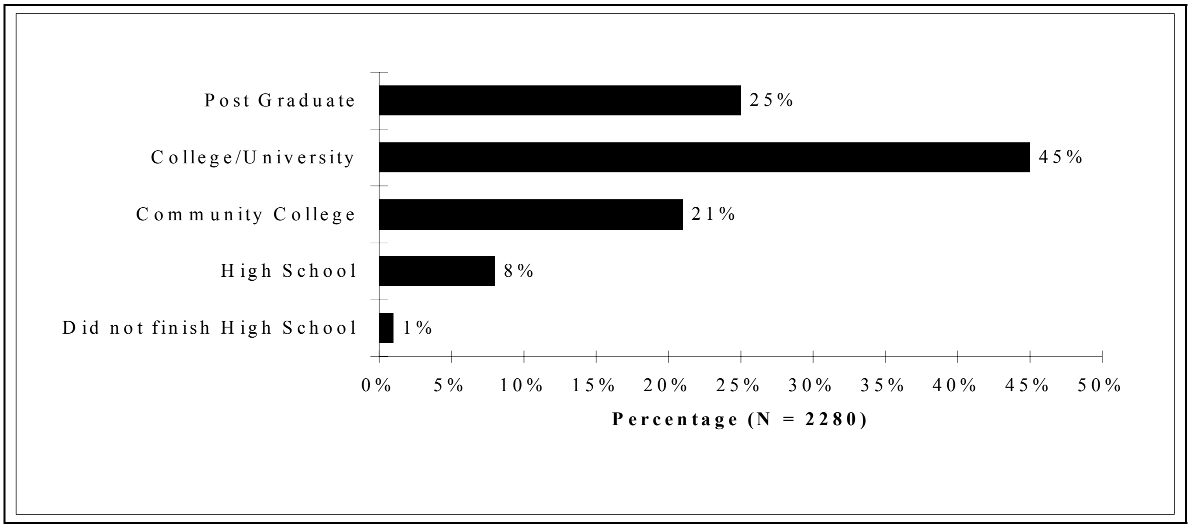



**Figure 5-3. Education Level of Respondents**

The public opinion survey also asked respondents to provide information on their domestic conditions. Of the returned responses, the most common cluster of domestic conditions was two people living in the household with no people under age 15 in the home, both working outside the home, and two vehicles (see Table 5-1).

## COMMUTE CHARACTERISTICS

The survey respondents were asked to describe their commute characteristics, including:

- their normal commute and trip routes
- their typical commute mode
- whether they had ever used HOV lanes to commute, and in which corridor
- whether they had ever opted not to use the HOV lanes when they were qualified to use the lanes, and the reasons for not using HOV lanes.

## Table 5-1. Domestic Conditions of Respondents

| Domestic Conditions | Number | Percentage |
|---|---|---|
| 2 people living in house<br>No people under 15 years of age<br>2 people working outside house<br>2 vehicles | **446** | **20%** |
| 1 person living in house<br>No people under 15 years of age<br>1 person working outside house<br>1 vehicle | **139** | **6%** |
| 3 people living in house<br>1 person under 15 years of age<br>2 people working outside house<br>2 vehicles | **118** | **5%** |
| 3-4 people living in house<br>2 or less people under 15 years of age<br>2 person working outside house<br>3 vehicle | **106** | **5%** |
| 2 people living in house<br>No people under 15 years of age<br>2 people working outside house<br>3 vehicles | **100** | **4%** |
| 2 people living in house<br>No people under 15 years of age<br>1 person working outside house<br>2 vehicles | **114** | **5%** |
| 4 people living in house<br>2 people under 15 years of age<br>2 people working outside house<br>2 vehicles | **100** | **4%** |
| 3-4 people living in house<br>2 or less people under 15 years of age<br>1 person working outside house<br>2 vehicles | **119** | **5%** |
| Other/No Response | **1038** | **46%** |
| **Total** | **2280** | **100%** |

**Commute and Trip Routes**

Figures 5-4 and 5-5 show the normal commute and trip routes for survey respondents. The percentage given represents the use of a given corridor by the survey population and not the percentage of total use for freeway corridors within the Puget Sound region. Originally, the commute route was determined by the highway corridor in which motorists were observed. This designation could then be used to measure sub-regional differences in opinion about HOV lanes. However, many respondents were observed in locations outside their normal commute routes or had commute routes that included more than one traffic observation corridor. To best analyze sub-regional differences in opinion, the commute route information was broken down into categories containing complete information on the commute route and other travel during peak hours. The major freeways located within the Puget Sound region were divided into ten corridors.

1. I-5 North
2. I-5 Central
3. I-5 South
4. I-90
5. SR 520
6. I-405
7. SR 16
8. SR 167
9. SR 410
10. SR 512

**Commute Mode**

One of the controls for classifying survey responses is commute mode. Figure 5-6 shows the actual commute modes of survey respondents. SOVs far outweigh those who rideshare, despite attempts to generate comparable samples of HOV and SOV drivers.

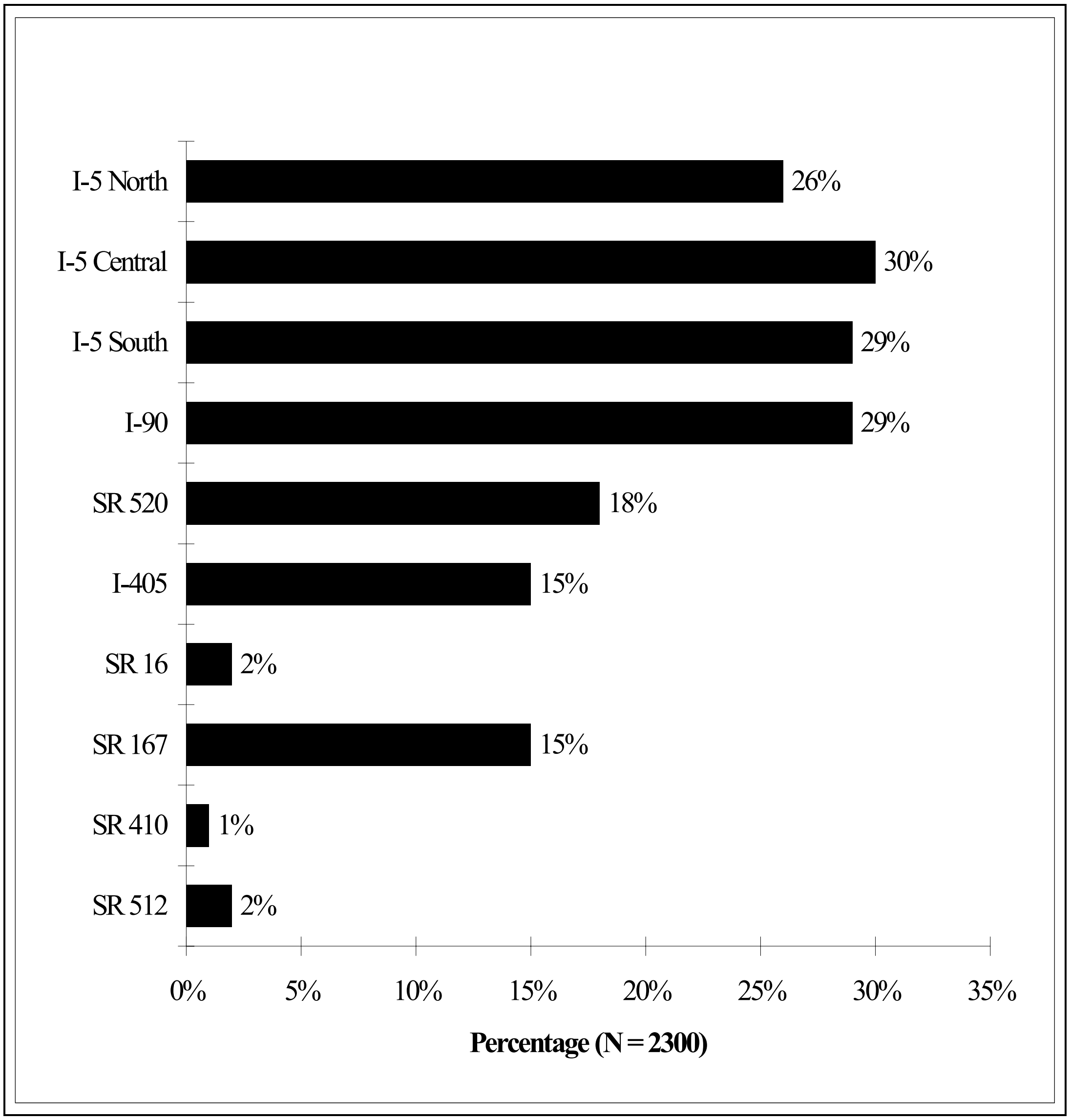



**Figure 5-4. Normal Commute Route**

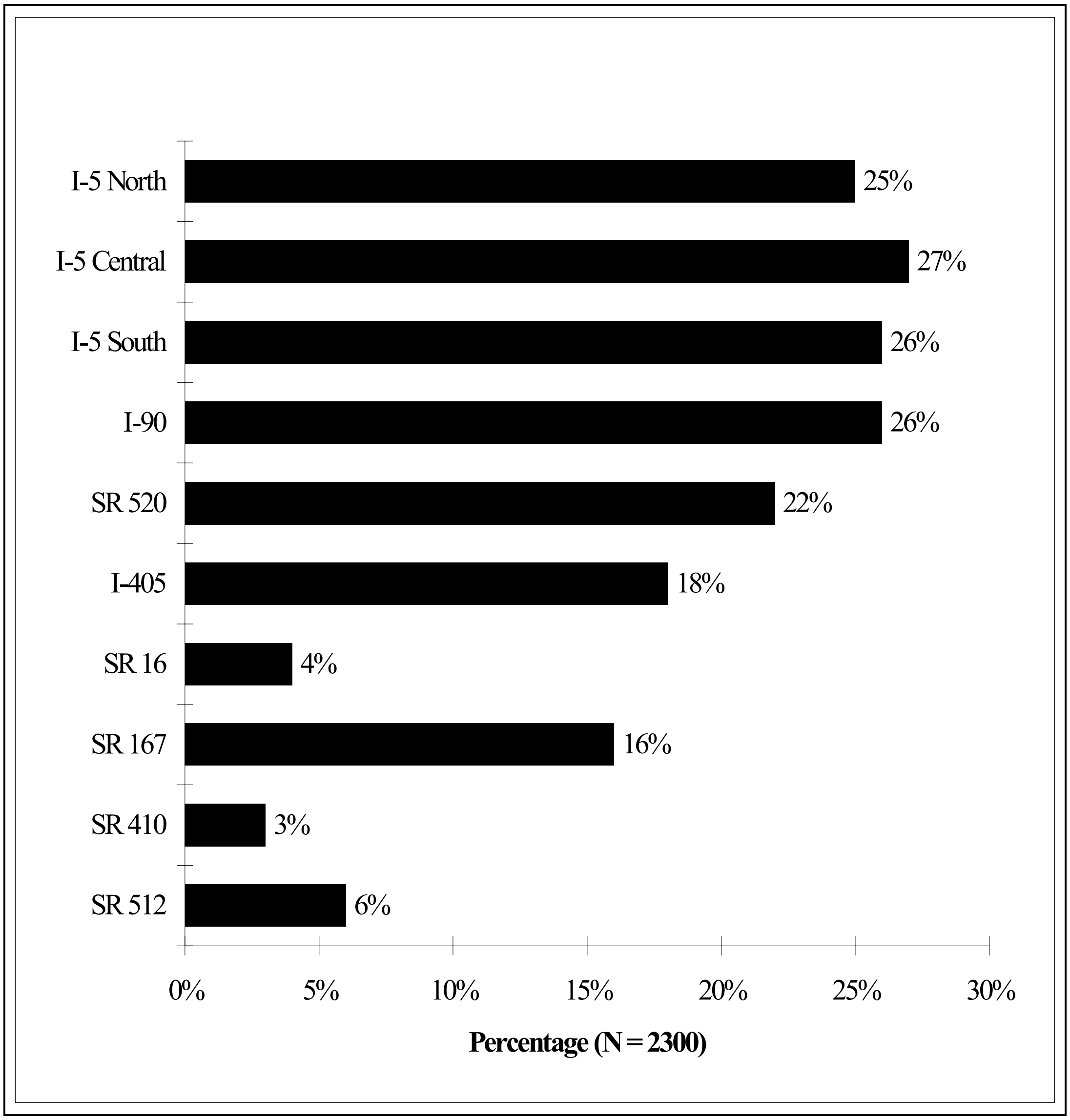



**Figure 5-5. Normal Trip Route**

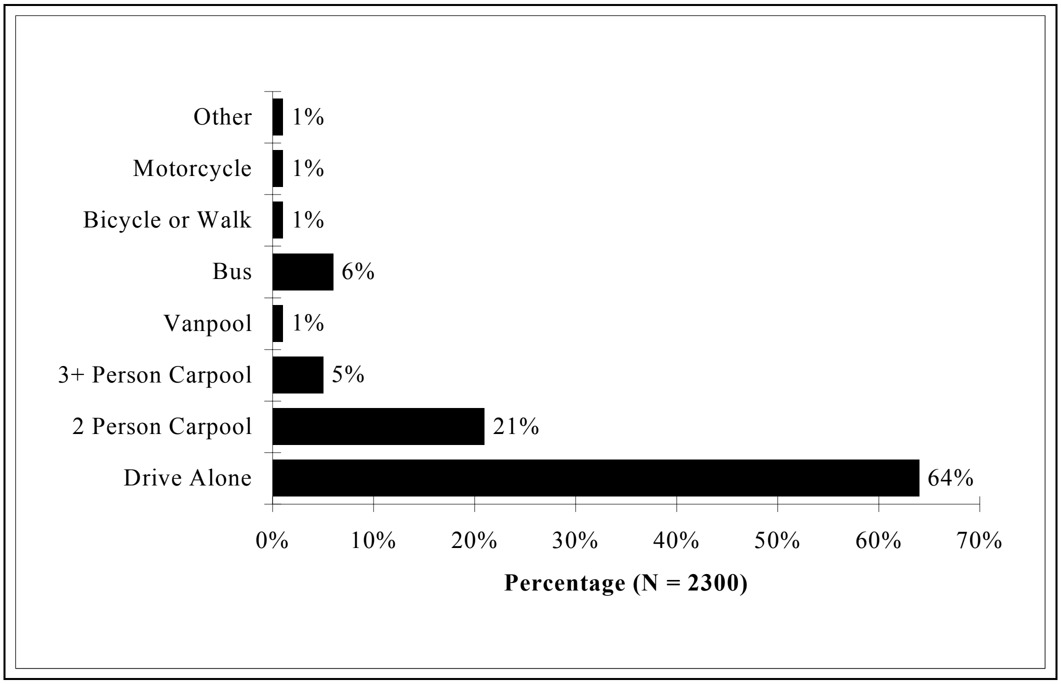



**Figure 5-6. Commute Mode**

**Past Use of HOV Lane**

Several major HOV system projects within the Seattle area had been completed since the last survey period. As a result, respondents expressed a greater frequency of HOV use throughout the Puget Sound region. Percentages in most corridors maintained or rose slightly over previous results. These results are definitely linked to these recent expansions to the HOV system (see Figure 5-7).

When asked about their usual driving mode while utilizing the HOV lanes about 64 percent of the respondents reported to be in a 2-person carpool (see Figure 5-8). Trends in HOV commute mode have continued to be dominated by 2- and 3+ person carpools. These mode choices are influenced by a variety of factors, one being the pressure of congestion levels. It is possible that commuters are responding to congestion pressures and subsequently have altered their commute mode for a more favorable option, namely HOV lanes. The high response percentage in 2- and 3+ person carpools could suggest that HOV lanes are popular during the work week when employees commute together.

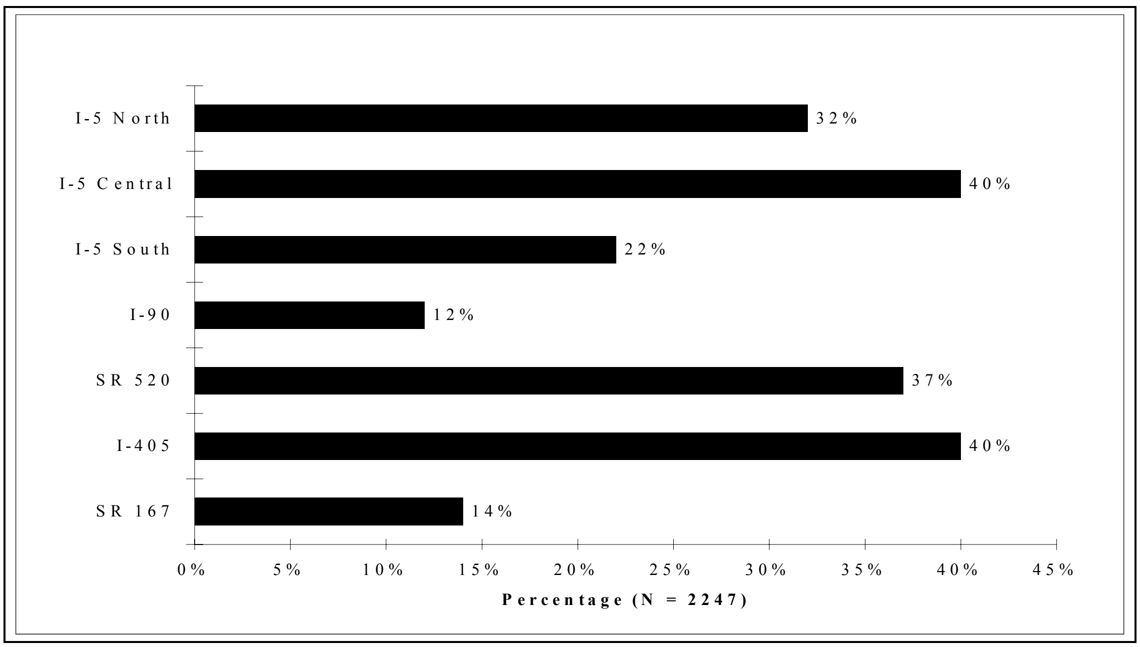



**Figure 5-7. Past Use of HOV Lane Corridors**

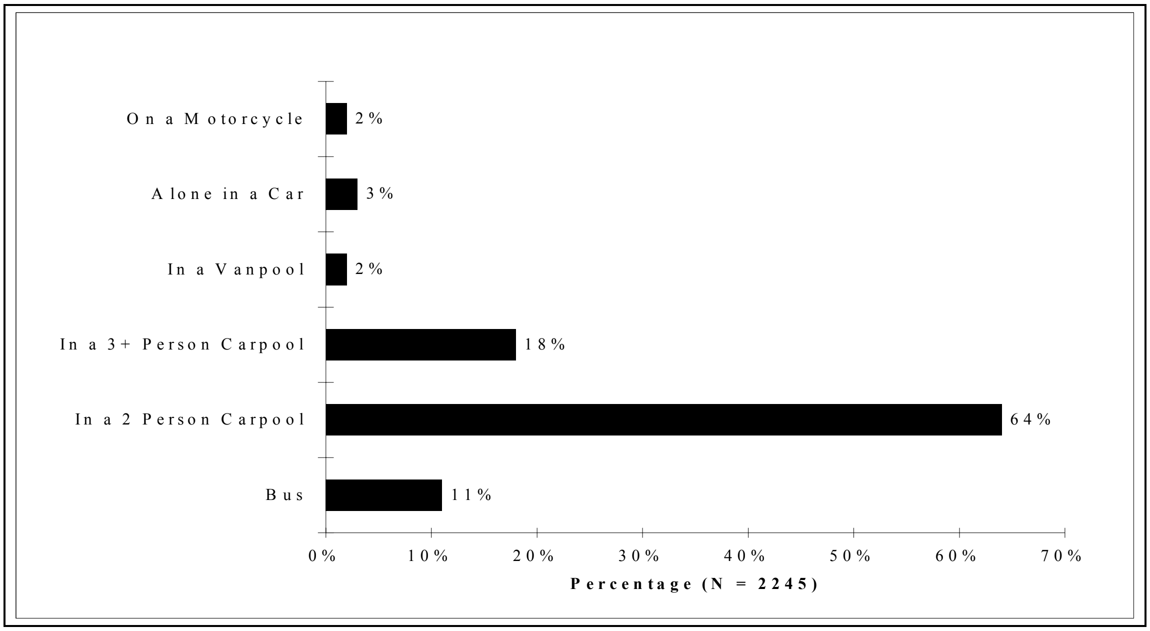



**Figure 5-8. Past Use of HOV Lanes**

## <u>Not Using HOV Lane</u>

The survey results show a significant number of respondents who, in the past, had chosen to not use HOV lanes when they were qualified to use the HOV lanes (see Figure 5-9). As shown in Figure 5-10, the most popular reason that kept them from using HOV lanes when they were eligible to use them was that the traffic was fast enough. Other reasons included the traffic in the HOV lanes being slower than that in the GP lanes and trouble in changing lanes.

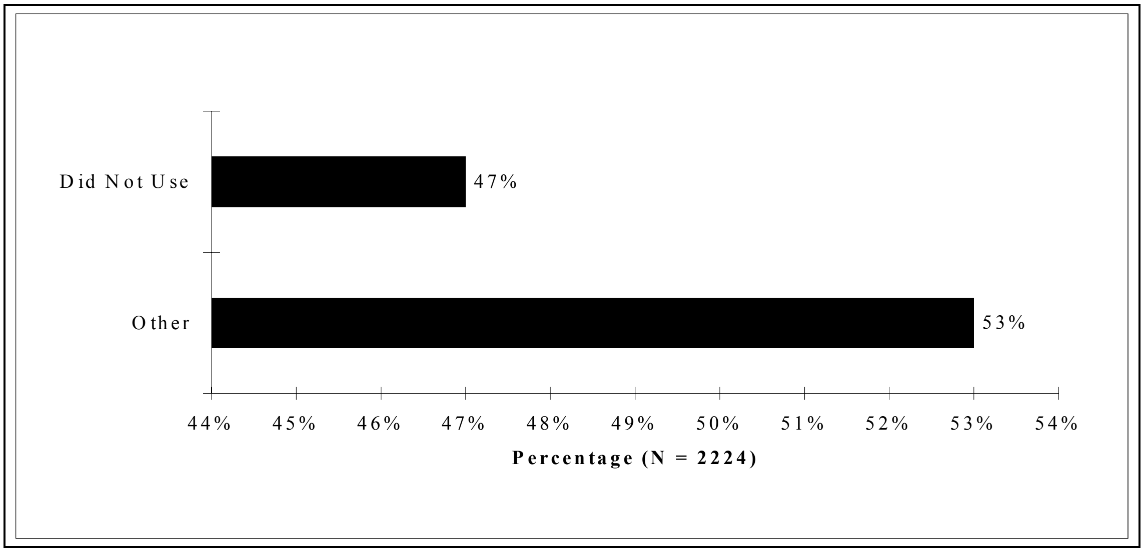



**Figure 5-9. Qualified for HOV Lane Use**

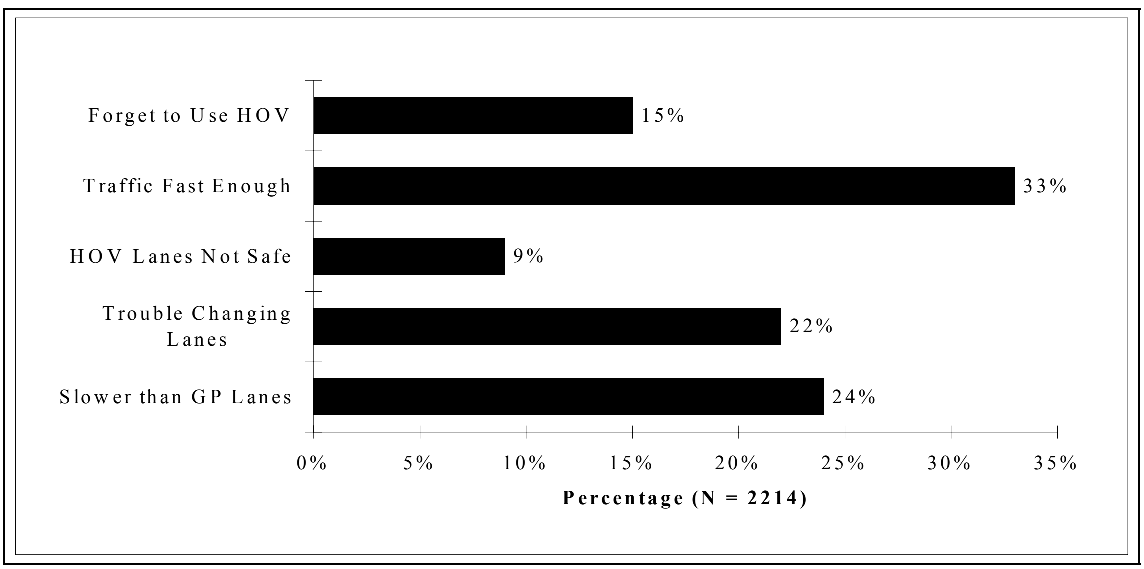



**Figure 5-10. Reasons HOV Lanes were Not Used**

## PUBLIC OPINIONS ON VARIOUS HOV ISSUES

The survey responses are broken down by normal commute mode and by the degree to which respondents agreed with individual assertions. Sample sizes for both HOV and SOV groups are provided for each question. A p-value, representing statistical significance, is also provided for each question. A p-value of .05 or less represents statistically significant differences of opinion between HOV and SOV groups.

It is important to note that in most cases, HOV and SOV drivers tend to share the same basic opinions on issues related to HOV lane effectiveness. The differences in opinion among HOV and SOV drivers are frequently based on the degree of support for or opposition to a particular issue. The survey results are grouped as follows: General Perception, HOV Lane Operation, HOV Lane Violations, and HOV Lane Improvements.

### General Perception

Overall, the support for HOV lanes continues to remain high among all commuters. Figure 5-11 shows that support for HOV lanes continues to be high among both SOV and HOV drivers, but support among SOV commuters has been showing signs of meager decline. Both groups agree that HOV lanes are convenient to use (see Figure 5-12). As expected, HOV drivers are stronger supporters because of the fact that they are more familiar with the benefits and hazards of the HOV system. However, many respondents felt that the HOV lanes are not fully utilized (see Figure 5-13). 46 percent of respondents disagreed that the HOV lanes are adequately used, 37 percent thought otherwise, and 17 percent remained neutral on this point.

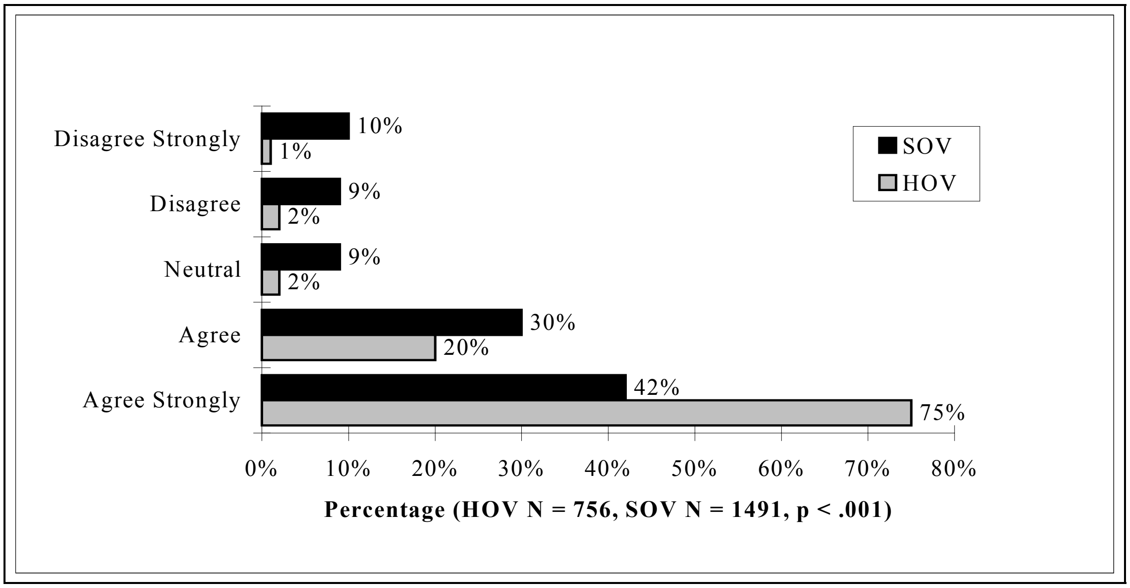



**Figure 5-11. HOV Lanes are a Good Idea**

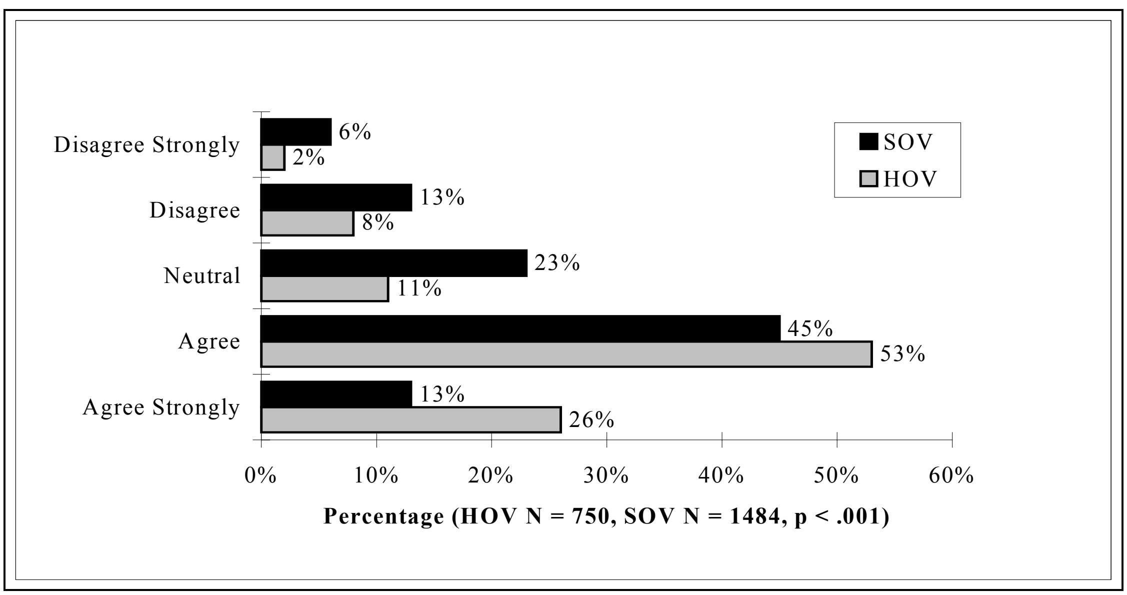



**Figure 5-12. HOV Lanes are Convenient to Use**

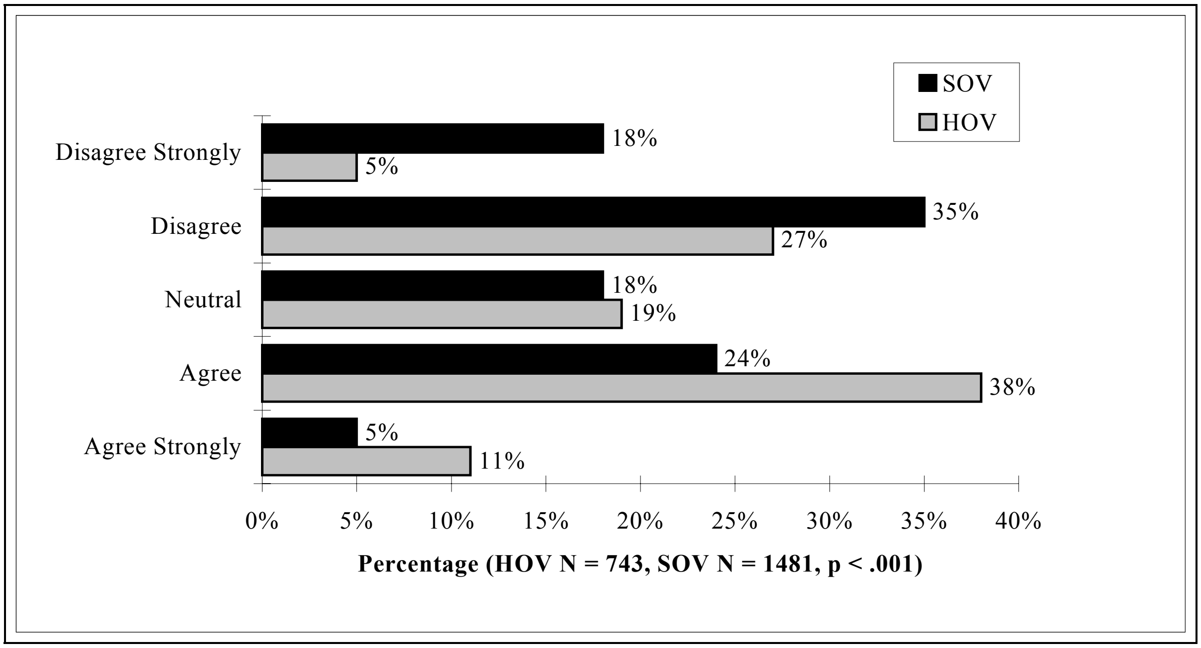



**Figure 5-13. Existing HOV Lanes are Being Adequately Used**

Figure 5-14 shows that a majority of commuters believe that HOV lanes are a fair use of taxpayers' money. HOV users have a united stance on this question. Although the opinions of HOV drivers and SOV drivers diverge on issues related to HOV lane usage, performance, and funding, the majority of both HOV and SOV drivers favor the idea of HOV lanes and additional HOV lane construction (see Figure 5-15). About 40 percent of HOV drivers as opposed to 23 percent of SOV drivers, felt that more HOV lanes will encourage carpooling (see Figure 5-16). However, when asked about whether HOV lanes help save all commuters a lot of time, a significant difference of opinion on the travel time issue was revealed (see Figure 5-17). As expected, SOV users tend to be more negative, as they are forced to wait in congestion bottlenecks during the peak commute period. Last, most respondents were basically neutral about whether vehicles darting in and out of the HOV lanes create a safety issue (see Figure 5-18).

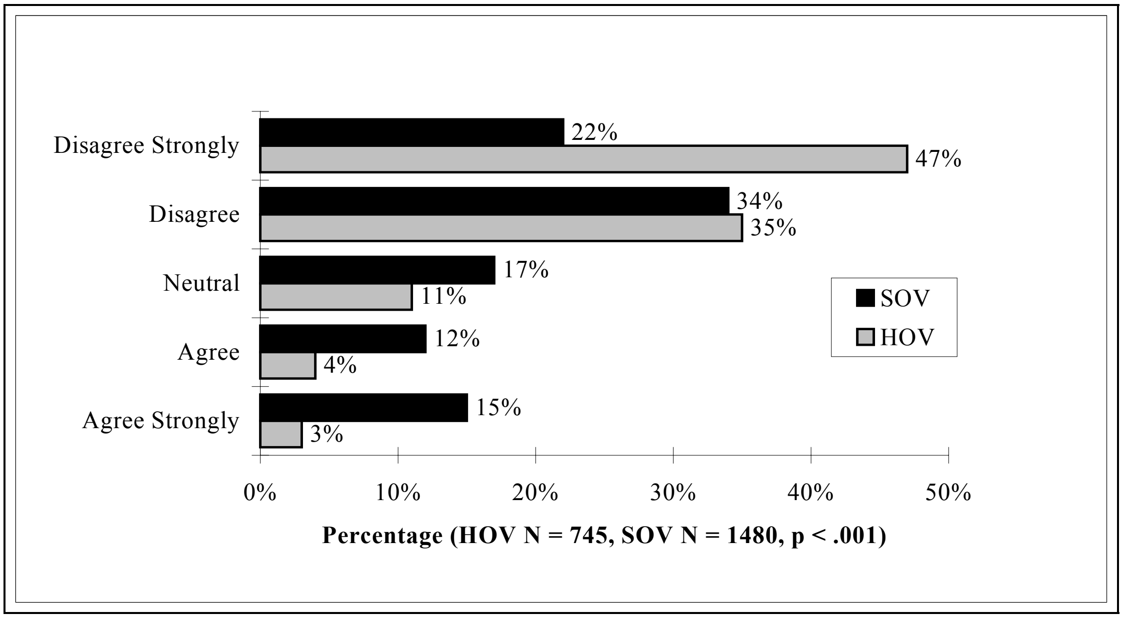



**Figure 5-14. Constructing HOV Lanes is Unfair to Taxpayers Who Choose to Drive Alone**

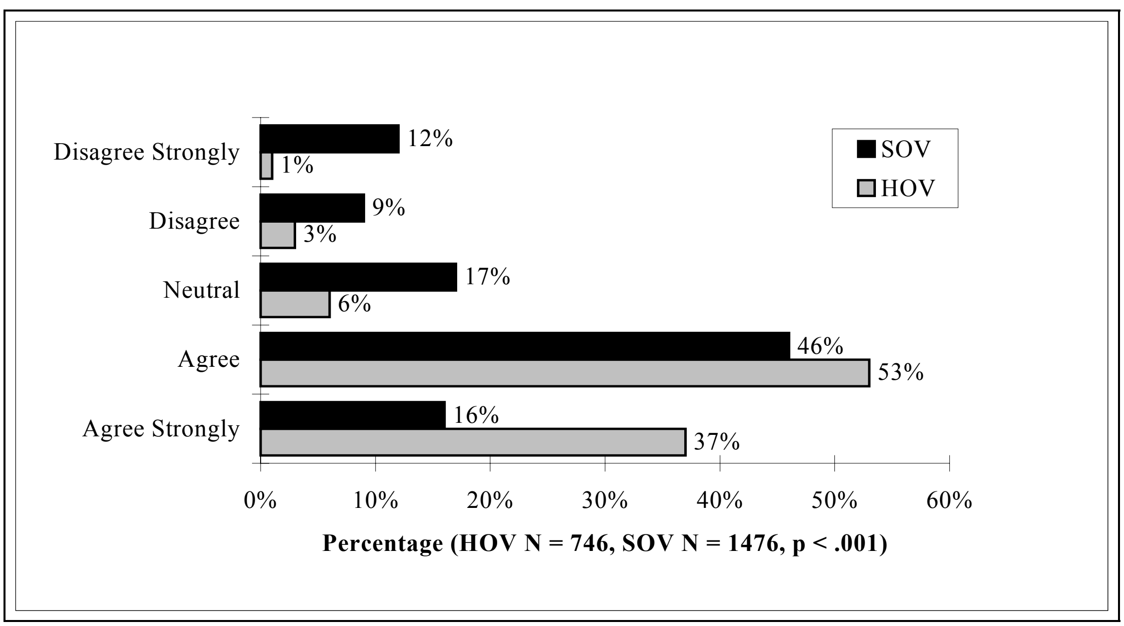



**Figure 5-15. HOV Lane Construction Should Continue, in General**

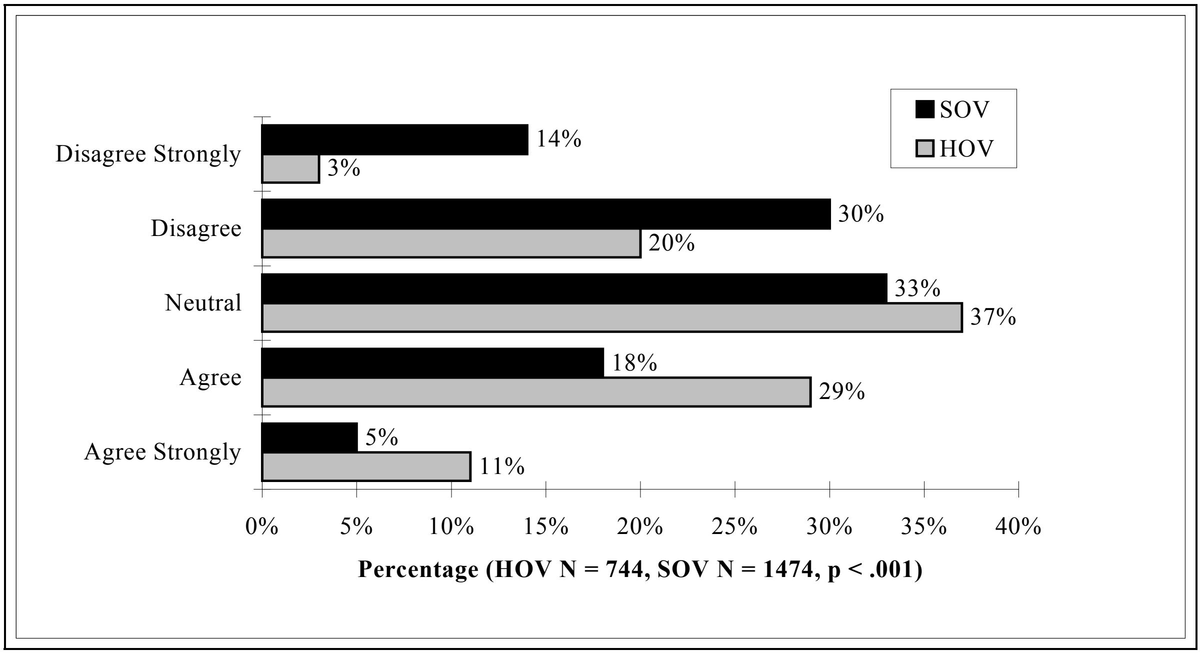



**Figure 5-16. More People Would Carpool if HOV Lanes Were More Widespread**

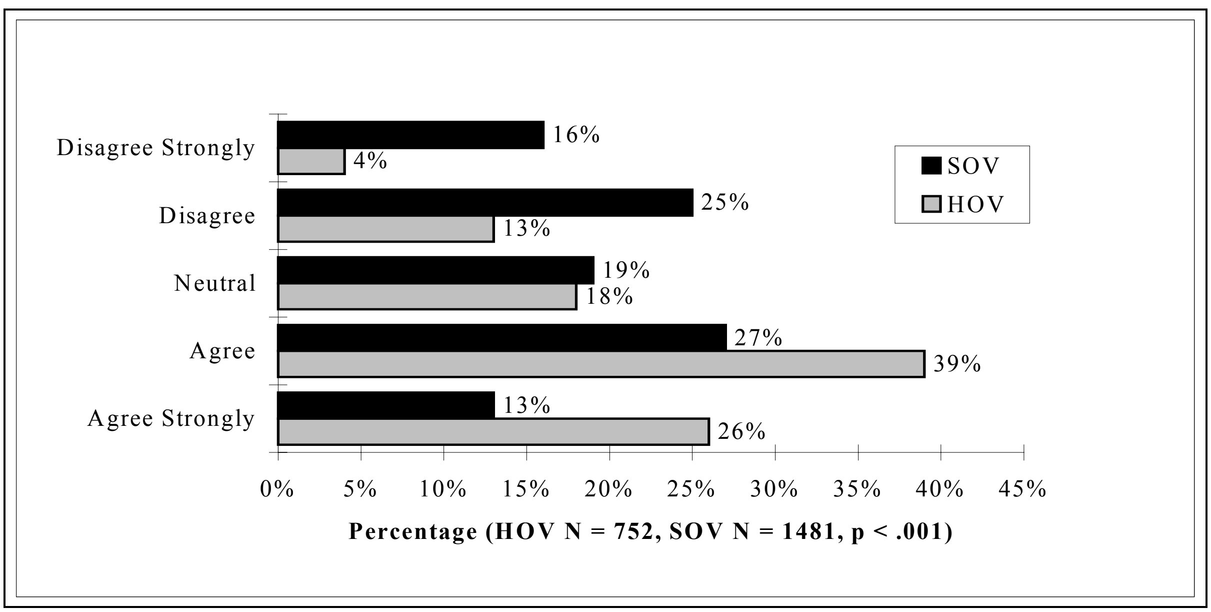



**Figure 5-17. HOV Lanes Help Save All Commuters a Lot of Time**

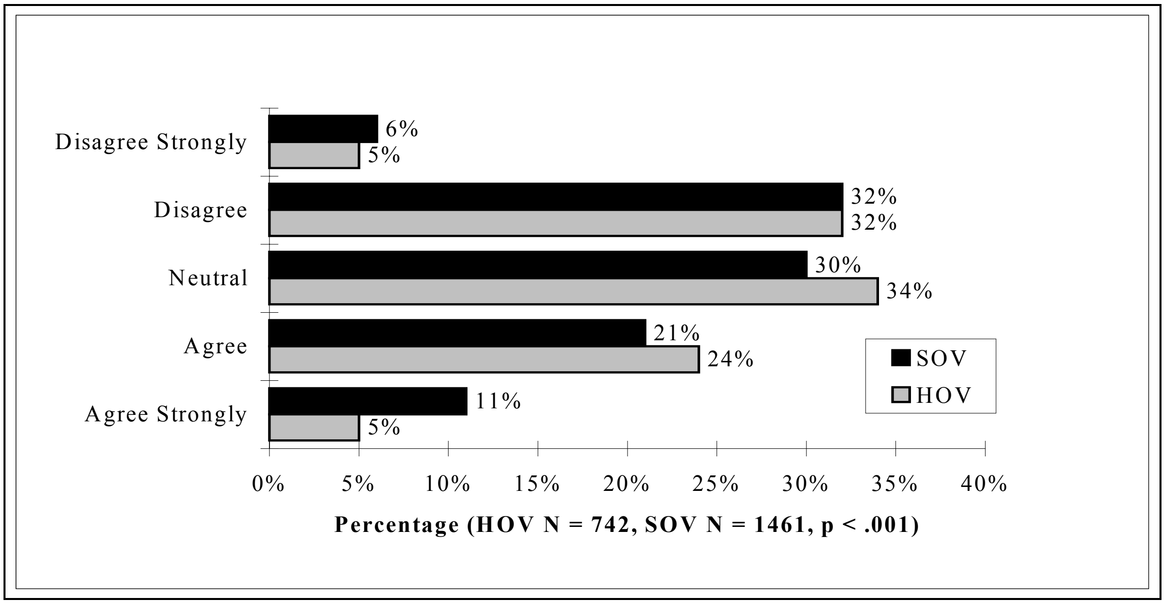



**Figure 5-18. Vehicles Dart In and Out of HOV Lanes Too Often for the Lanes to be Safe**

## HOV Lane Operation

Most respondents felt that HOV lanes should not be opened to all traffic; this was the opinion of 86 percent of the HOV drivers and 56 percent of the SOV drivers (see Figure 5-19). The difference in opinion between groups on this issue remained the same as it was in previous surveys.

Figure 5-20 shows that SOV users favor opening HOV lanes during non-commute hours, with 65 percent agreeing; HOV drivers remain undecided, with 40 percent agreeing and 44 percent against. Overall, HOV opinion leans toward keeping restrictions on HOV lanes even during non-commute times. Opinions on this option continue to vary widely.

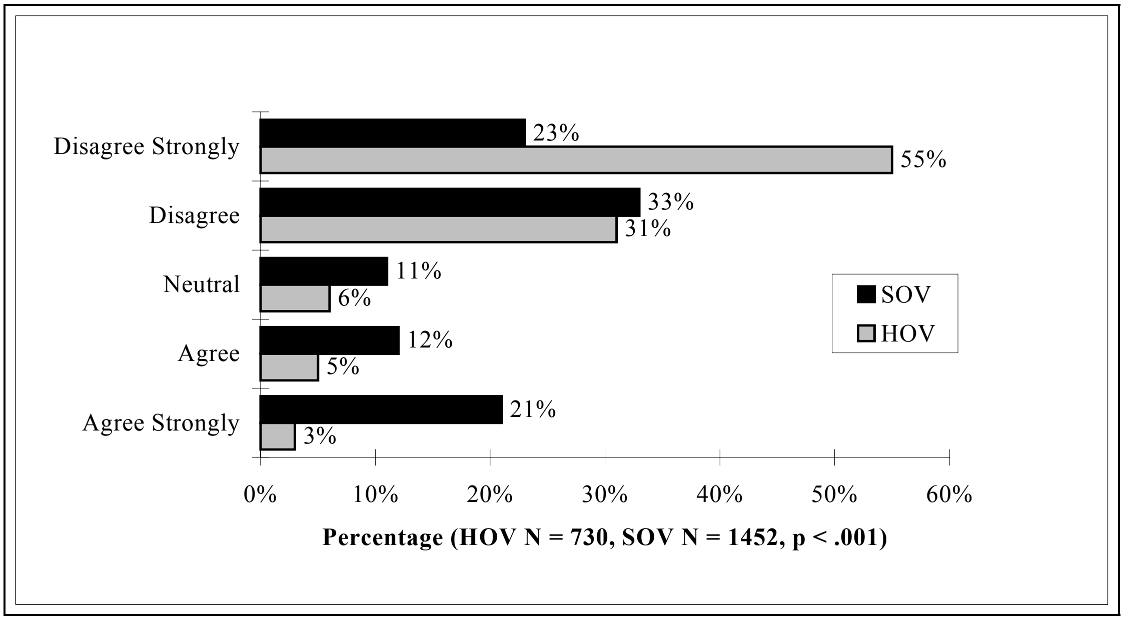



**Figure 5-19. HOV Lanes Should Be Opened to All Traffic**

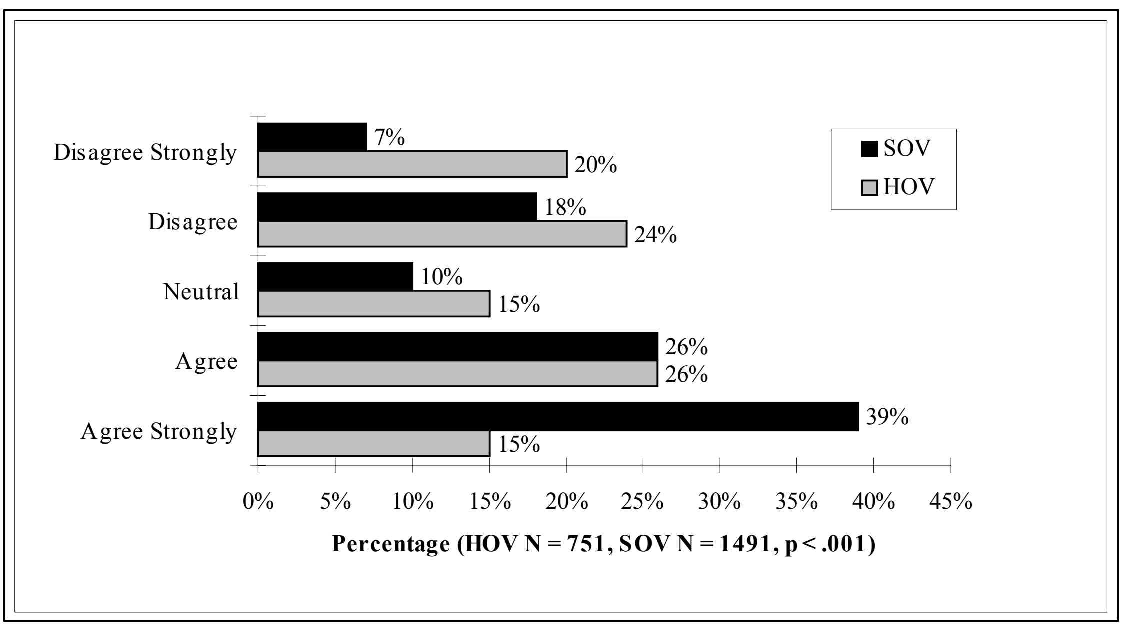



**Figure 5-20. HOV Lanes Should Be Opened to All Traffic During Non-Commute Hours**

## HOV Lane Violations

Overall, over half of the respondents agreed that violations are common during the commute hours (see Figure 5-21). Both groups appear to resent the fact that HOV lane violators are unwilling to sit in traffic like everyone else (see Figure 5-22). The majority of the survey respondents were neutral in their opinion of the HERO program (see Figure 5-23). This suggests that further public education may be needed to provide commuters with a greater understanding of the important role 764-HERO plays in controlling HOV lane violations.

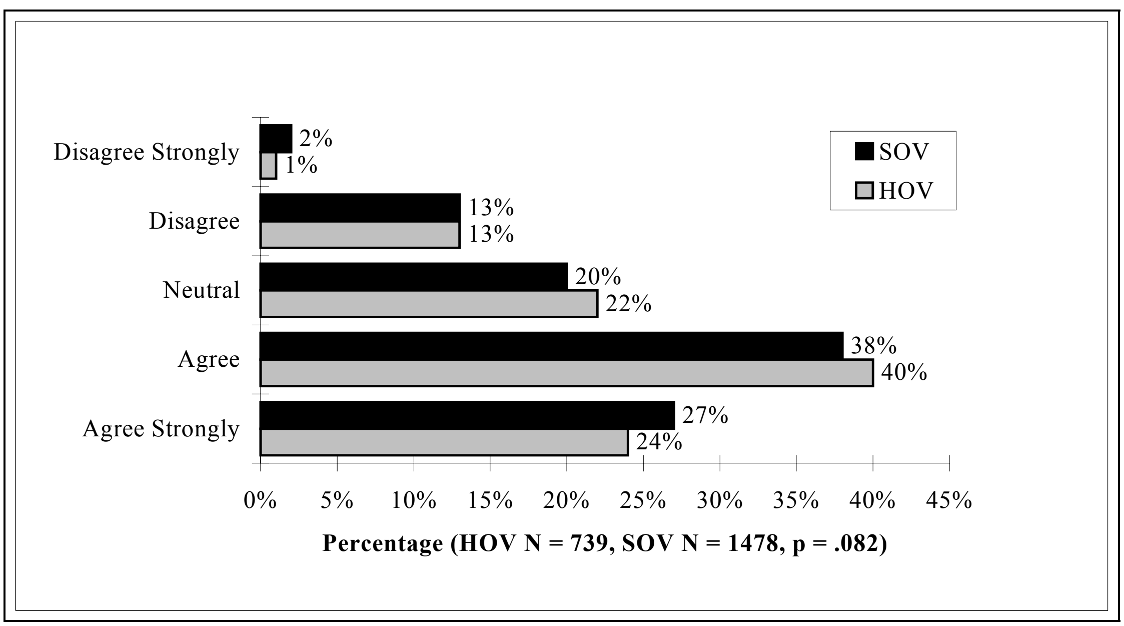



**Figure 5-21. HOV Violations are Common During the Commute Hours**

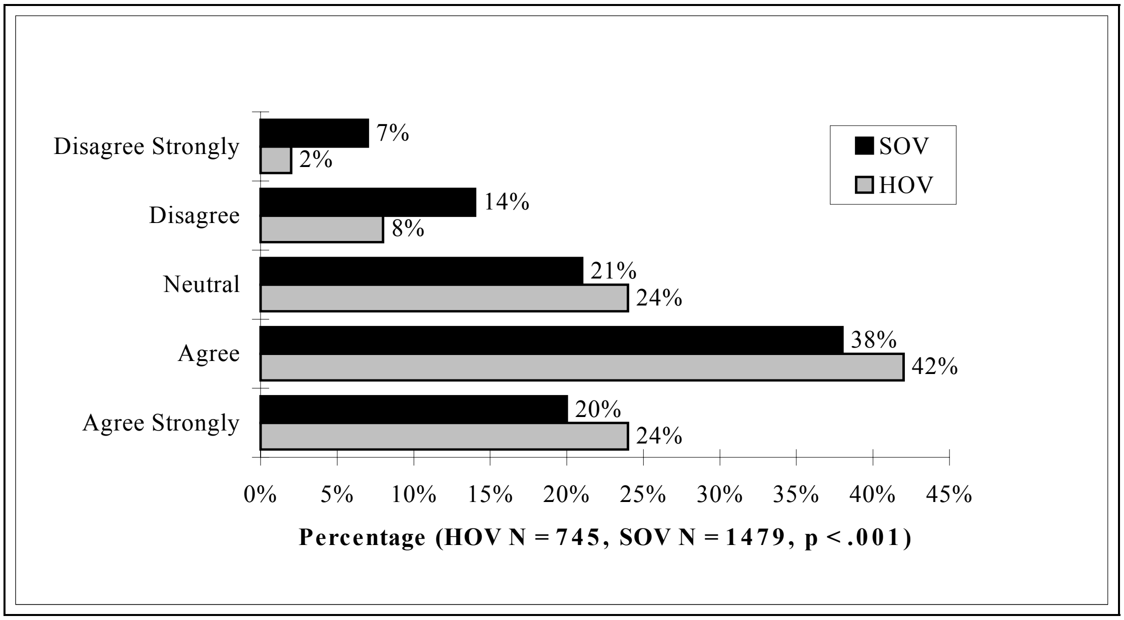



**Figure 5-22. HOV Violators Commit a Serious Traffic Violation**

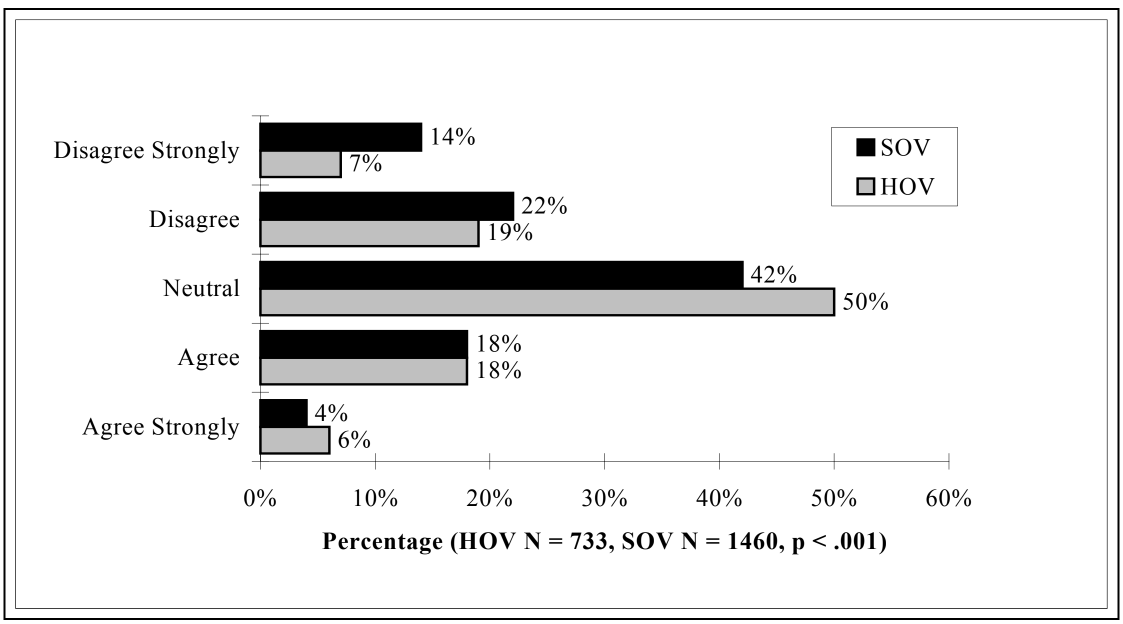



**Figure 5-23. HERO Program Helps Reduce HOV Lane Violations**

**HOV Lane Improvements**

Regarding options to improve HOV lane usage, enforcement concerns and access issues appear to outweigh transportation demand management measures such as employer subsidies for ridesharing and additional park & ride lots (see Figure 5-24). Figures 5-25 through 5-32 present how HOVs and SOVs view these options for improving HOV lane usage.

Better enforcement was selected the best option for increasing the attractiveness of HOV lanes (see Figure 5-24). As indicated earlier in Figure 5-21, HOV violations are perceived as common during the commute hours. Both HOV and SOV drivers appear sensitive to others abusing this special privilege (see Figure 5-25). Respondents also clearly favor constructing access ramps for inside HOV lanes (see Figure 5-26). Figures 5-27 and 5-28 reveal that respondents favor inside HOV lanes (38 percent) over outside HOV lanes (17 percent). This favorable response may be due to the public's strong desire to continue expansion of the freeways to improve efficiency and lane capacity. Making HOV lanes wider and safer continues to receive support from both groups of drivers (see Figure 5-29). The marginal difference between groups may be due to carpoolers having more experience with using HOV lanes.

Employer subsidies and increased frequency of bus service ranked equally as the most favored of the TDM measures (see figures 5-30, 5-31). However, their overall priority did not compare with issues related to HOV lane access, enforcement, and safety. Support for the option of building park & ride lots near freeway entrances and exits has remained relatively unchanged, with SOV drivers showing slightly more support than their ridesharing counterparts (see Figure 5-32). This may reflect the idea that park & ride lots are not as much assembly places for carpools as they are links to bus service.

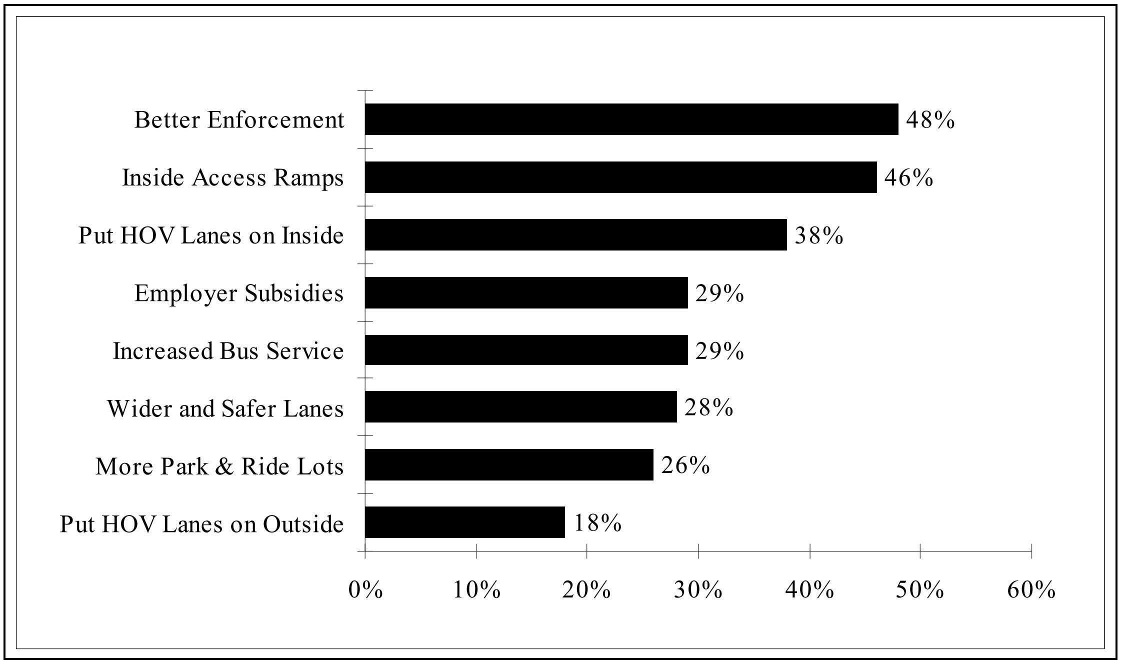



**Figure 5-24. Options to Improve HOV Lane Usage**

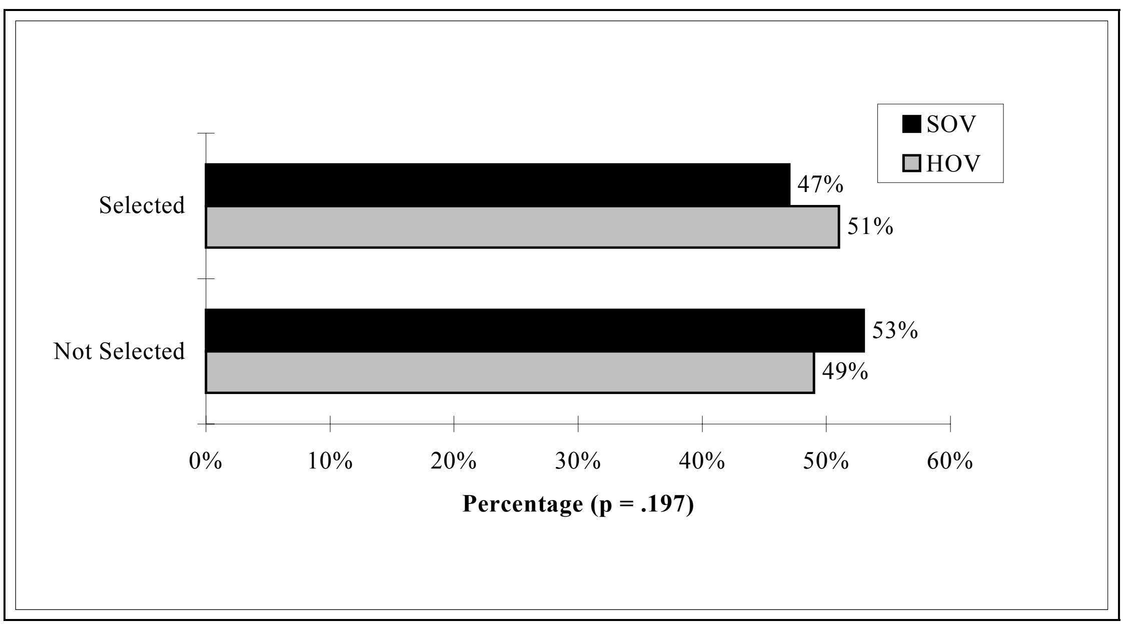



**Figure 5-25. Better Police Enforcement Against Violators**

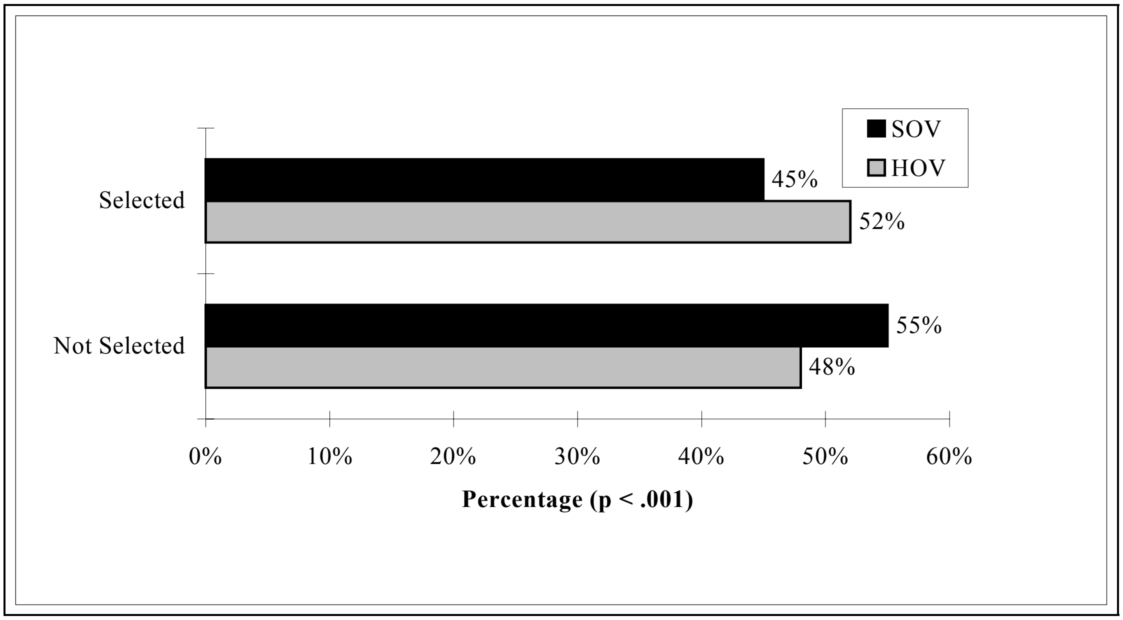



**Figure 5-26. Construct Access Ramps for Inside HOV Lanes.**

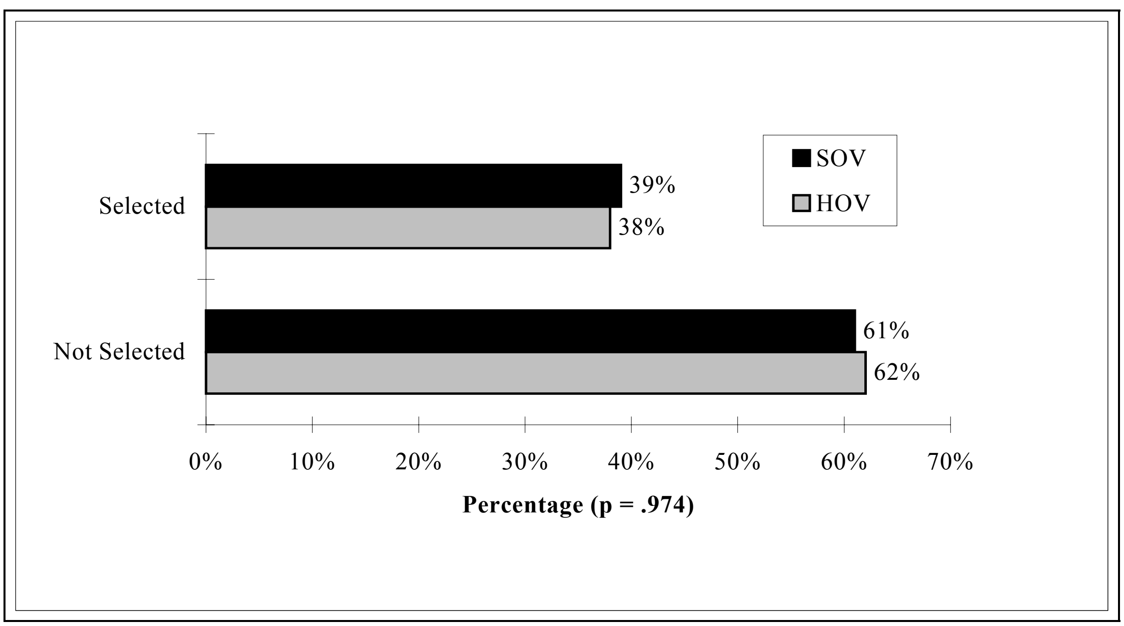



**Figure 5-27. HOV Lanes on Inside of Freeway.**

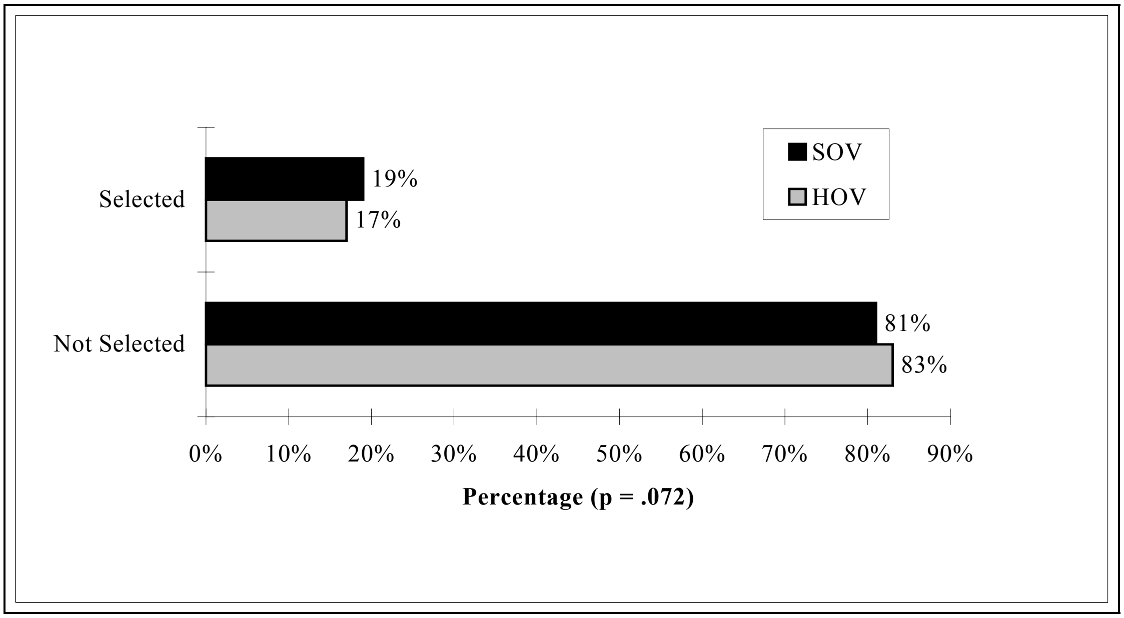



**Figure 5-28. HOV Lanes on Outside of Freeway**

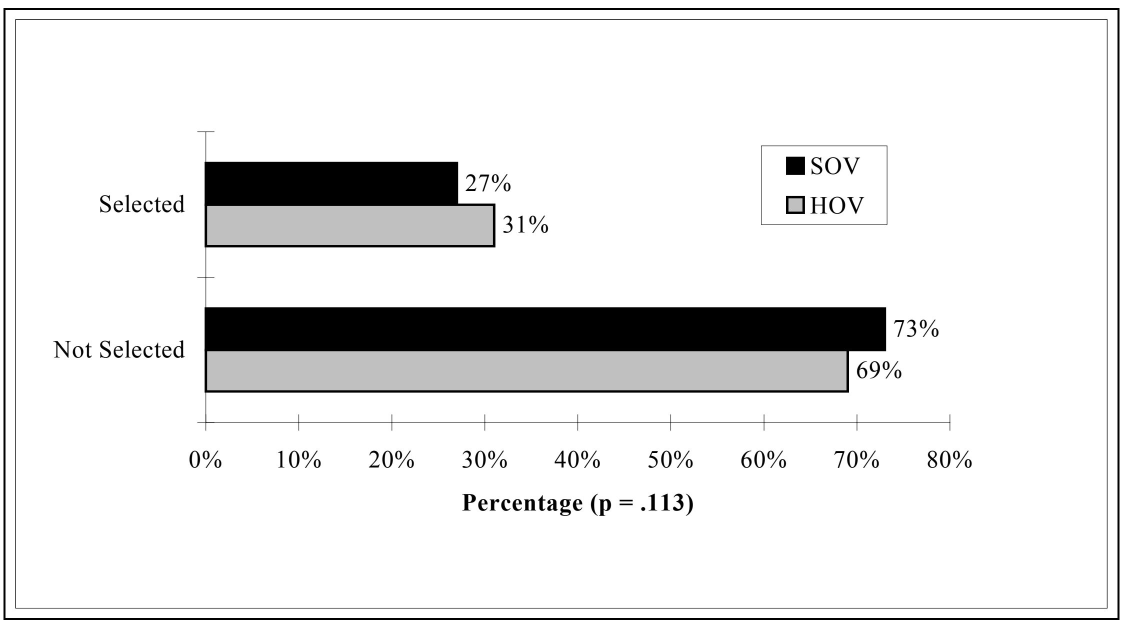



**Figure 5-29. Wider and Safer Lanes.**

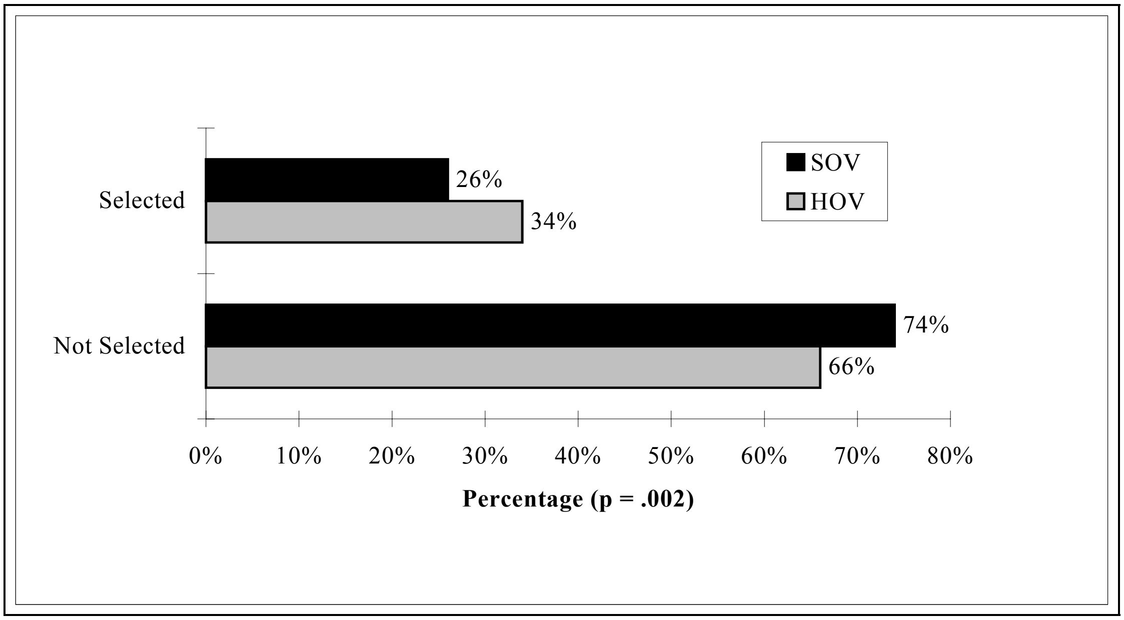



**Figure 5-30. Employer Subsidies for Ridesharing**

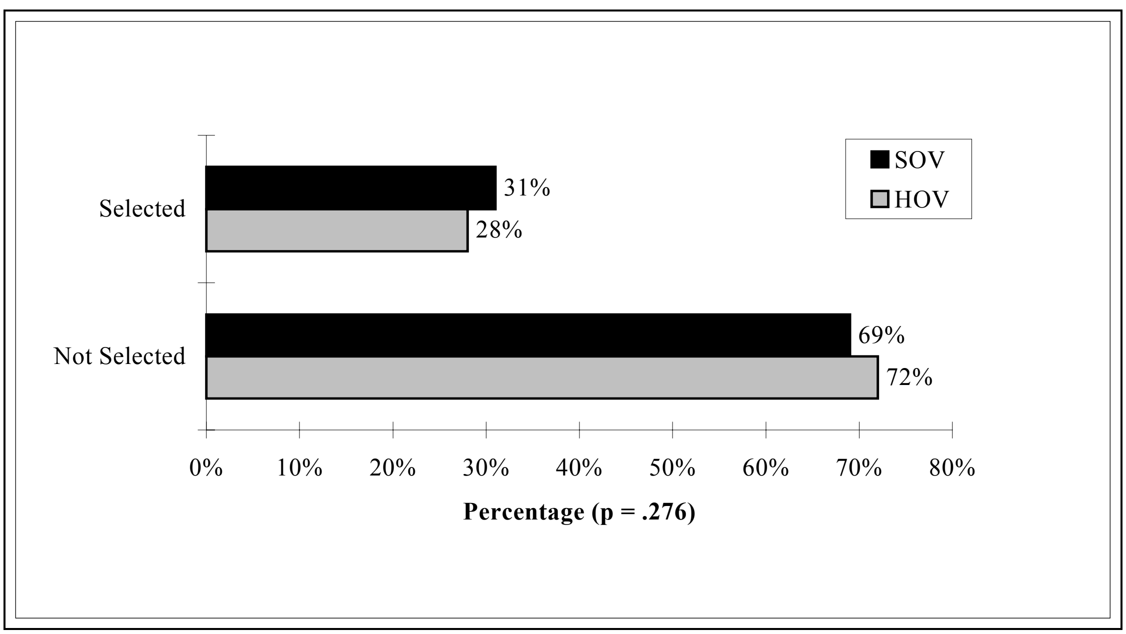



**Figure 5-31. Increased Frequency of Bus Service**

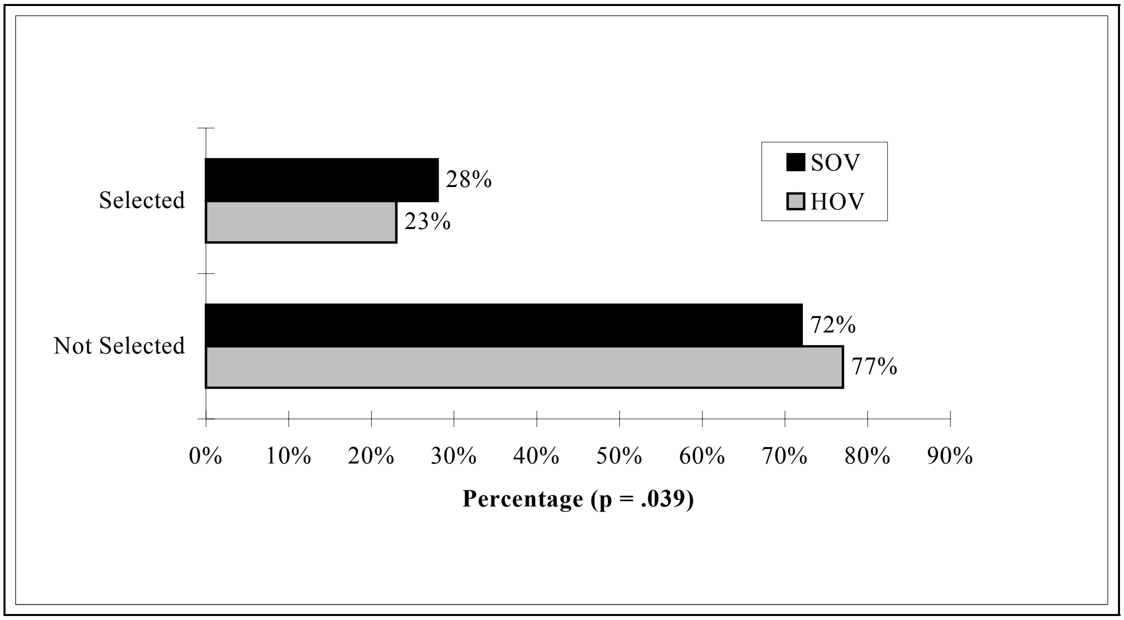



**Figure 5-32. Park & Ride Lots Near Freeway Entrances and Exits**