Operational Analysis of the I-405 HOV System

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This report documents an operational analysis of I-405 HOV facilities. The primary objectives of this analysis were (1) to provide information that could assist in the development of a coordinated plan for the I-405 high-occupancy vehicle (HOV) lane system to ensure that the existing and planned HOV facilities worked together and that transitions between facilities occurred smoothly, and (2) to survey the I-405 commuters as a means of understanding their perceptions of HOV lane operations and constraints on the ability of single-occupant vehicle (SOV) commuters to rideshare.

The analysis included an overview of HOV lane operations in the United States, a public opinion survey of commuters who primarily lived and worked east of Lake Washington, results of focus groups with workers who lived in east King County, transportation modeling centering on the I-5 corridor, traffic analysis of HOV lane options, a cost effectiveness analysis, and the results of a symposium that presented and discussed the results of the project.

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I-405 HOV System Operational Analysis

OPERATIONAL ANALYSIS OF THE I-405 HOV SYSTEM

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EXECUTIVE SUMMARY

This report documents an operational analysis of I-405 HOV facilities. The primary objectives of this analysis were two-fold:

1. to provide information that could assist in the development of a coordinated plan for the I-405 high-occupancy vehicle (HOV) lane system to ensure that the existing and planned HOV facilities worked together and that transitions between facilities occurred smoothly, and
2. to survey commuters who used the I-405 corridor as a means of understanding their perceptions of HOV lane operations and constraints on the ability of single-occupant vehicle (SOV) commuters to rideshare.

The analysis included an overview of HOV lane operations in the United States, a public opinion survey of commuters who primarily lived and worked east of Lake Washington, results of focus groups with workers who lived in east King County, transportation modeling centering on the I-405 corridor, traffic analysis of HOV lane options, a cost effectiveness analysis, and the results of a symposium on the project.

The symposium was held to present findings from the study and to gather responses from the symposium attendees regarding the project's six design issues. The symposium was attended by engineers and planners from the Washington State Department of Transportation (WSDOT), the Puget Sound Council of Governments, Metro, Snohomish Transit, transportation consulting firms, and local jurisdictions in eastern and southern King County. This chapter provides a summary of the results of the study.

SUPPORT FOR HOV LANE OPERATIONS

Overall, the survey respondents were very supportive of HOV lanes and programs to increase the use of HOVs and HOV lanes. However, despite the high level of support there was a pervasive view that existing HOV lanes were not being adequately used and that these facilities were frequently violated by SOV drivers who were rarely caught by the State Patrol. These perceptions of use and violation are important because they could eventually erode the high level of support for the HOV lanes.

The researchers recommend that the WSDOT undertake a public education program designed to inform the commuting public about current use of the HOV lanes. This public education program should build upon current support of HOV lane operations to increase the public's information about and awareness of the effectiveness of HOV lane operations.

HOV LANE PLACEMENT

From an operational point of view, the evidence concerning lane placement is mixed. In the I-405 corridor, trips are shorter than in corridors such as I-5 and I-90, where destinations tend to be in the Seattle CBD. Transit routes also tend to make frequent stops. In addition, outside HOV lanes function as extended ramps that general traffic uses to merge into congested conditions. Consideration of only these issues favors outside HOV lanes in the corridor.

However, the operation of outside HOV lanes is severely compromised at some highly congested ramps in the corridor. Some of that congestion can be mitigated through ramp metering, arterial treatments, and interchange redesign. However, congested ramps will always be a threat to the safe and efficient operation of outside HOV lanes.

One solution to this dilemma is to provide special access ramps to inside HOV lanes. However, this solution is very expensive, with questionable cost effectiveness. This issue is discussed in the next section.

Respondents in the public opinion survey had mixed perceptions concerning HOV lane placement. They tended to believe that outside placement of HOV lanes provided better access than inside HOV lanes. In addition, they thought inside placement of HOV lanes caused HOVs to weave across the general purpose lanes, leading to safety as well as operational problems. They also tended to believe that outside lanes were less likely to attract violators. However, outside lanes, while easy to access for HOVs, had the problem of mixing HOV and general purpose traffic when cars merged onto and exited off of the freeway. Survey respondents noted the safety implications of this weaving movement.

People tended to agree that right-side HOV lanes are easier to access than left-side HOV lanes; they only slightly favored the safety characteristics of left-side HOV lanes; and they did not consider right-side HOV lanes to be subject to as much potential violation as left-side HOV lanes. These findings suggest a general level of support for right-side HOV lanes. However, the survey responses regarding the left-side placement of HOV lanes might be biased by a lack of experience with these types of facilities among the predominantly Eastside sample. Strategies to decrease the merge and exit conflicts of HOV and general purpose traffic could improve the public's perception of the safety of accessing right-side HOV lanes.

The symposium attendees felt that HOV lane placement is a complex issue that the public does not fully understand or think about on a daily basis. The attendees felt that HOV lane placement should be consistent with land use patterns. The consensus was that right-side HOV lanes should be implemented in areas with less dense land-use patterns (e.g., east King County) and left-side HOV lanes should be implemented in areas with dense land-use patterns (e.g., the I-5 corridor terminating in downtown Seattle).

Given the mixed results of the operational analysis and the lack of clear public opinion regarding HOV lane placement, the researchers recommend that the WSDOT adopt the suggestion from the I-405 symposium attendees that HOV lanes be implemented in accordance with land use densities and resulting trip patterns. I-405 HOV lanes should be implemented initially on the right side of the freeway. This should be done in a way that allows for transition to left-side HOV lanes as land-use densities increase. The importance of reducing congestion on freeway ramps should be emphasized. HOV lanes should be viewed as evolutionary facilities that will eventually be located on the left-side of the freeway when commute trips to a common, centralized work destination predominate. Ultimately, separated facilities with special access ramps are the preferred solution.

SPECIAL ACCESS TO HOV LANES

Special access ramps provide access for HOV traffic to inside HOV lanes. This is an important operational improvement because it separates general purpose traffic and HOV traffic, thereby decreasing the potential for traffic conflicts at freeway merge and exit points. It also saves time for all traffic because HOVs do not have to weave across general purpose lanes to access an inside HOV lane. While special access ramps provide a time savings and optimal operational characteristics, there are significant barriers to their implementation. Right-of-way is scant in many parts of the corridor. Even where it is physically possible to build special access ramps, the expense is significant.

The public opinion survey results indicated a high level of public support for special access ramps as a means of providing incentives to people who rideshare. This high level of support was expressed even if the respondent did not rideshare and regardless of whether the respondent favored HOV lanes. The survey findings also showed that carpoolers supported special access ramps to a larger extent than both SOV drivers and bus riders. This is probably due to the fact that they operate a vehicle (or participate as a passenger in a vehicle) when using the HOV lane. The high level of approval from non-HOV users supports the observation that there is a generally high level of support for HOV lane treatments and operations among the public. Another important feature of special access ramps was noted by symposium attendees: special access lanes can be implemented over a period of years and thus are a flexible tool that can be implemented as HOV lane volumes and available resources warrant.

The symposium attendees were supportive of the concept of special access ramps to HOV lanes. An important point made by the symposium attendees was that special access ramps are facilities that can be implemented incrementally over time. Furthermore, special access ramps can be added to the freeway system after the construction of the HOV lanes has been completed. Therefore, ramps do not necessarily have to be implemented at the same time as construction of HOV lanes or support facilities such as park and ride lots. The ability to add special access ramps after the construction of the HOV facilities illustrates the flexibility of this approach.

The researchers recommend that the WSDOT consider the construction of special access ramps to accelerate the shift from outside to inside HOV lanes in the I-405 corridor.

RAMP METERING OF FREEWAY ENTRANCES WITH HOV BYPASS

Ramp metering is used extensively to the Puget Sound area and elsewhere to reduce traffic congestion on freeways and smooth the flow of traffic onto the freeway. Ramp metering is also important to the efficient operation of outside HOV lanes. Despite these benefits, when ramp metering is not properly implemented, it can result in excessive traffic back-ups on local arterials.

A related issue with ramp metering is the implementation of HOV bypass lanes. HOV bypass lanes enable HOVs to go around general purpose traffic that is waiting at the ramp meter and thus serve as an incentive to use an HOV.

The literature review for this project highlighted the effectiveness of ramp metering systems in decreasing freeway travel times, increasing freeway travel speeds, and decreasing accidents associated with merging onto a freeway. The public opinion survey results indicated a consistent neutrality regarding the ability of ramp meters to increase freeway travel speeds and decrease freeway travel times. However, the sample clearly supported the concept of HOV bypasses at metered freeway on-ramps as a means of providing an incentive and benefit to HOV users. Over 40 percent of the survey respondents agreed that HOV bypasses at metered ramps were a good method to reward and encourage HOV use. This agreement indicates a high level of support for HOV lane policies and operations. Furthermore, these results show support for HOV policies even when people do not clearly perceive potential benefits for them personally.

The symposium attendees observed that ramp meters are an effective strategy for managing freeway congestion and expressed the opinion that ramp meters and HOV bypasses should be implemented wherever possible. They concluded that successful ramp metering programs require agencies to monitor ramp meter operations continuously, adjust ramp meter operations as necessary, and work with local jurisdictions to prevent unacceptable ramp overflows.

The researchers recommend that the WSDOT implement ramp metering on I-405 with HOV bypasses wherever possible. They also recommend that the WSDOT undertake a public education program to increase the public's understanding of the effectiveness of ramp metering in potentially saving travel time and increasing consistent freeway travel speeds.

CARPOOL DEFINITION

Carpool definition has a direct effect on the number of HOVs that can use the HOV lanes. For example, if a carpool definition is too high for an area (e.g., three people), a facility may not achieve a satisfactory level of use. On the other hand, if the definition is too low for an area (e.g., two people), a facility may become congested and not be capable of providing the time savings that is necessary to attract new carpoolers.

Carpool definition is an important factor in the public's perception of the use of HOV facilities because it ultimately affects how many vehicles use the HOV lane, regardless of how many people are actually served by the facility.

The literature review showed that HOV definition varies across the United States. In general, as would be expected, higher HOV definitions are used where HOV facilities have high volumes. Both the focus group participants and the symposium attendees felt that carpool definition should be evolutionary rather than static. They felt that carpool definition should increase in relation to the use of the HOV lane. The analysis of the public opinion survey results revealed that an overwhelming level of support for the 2+-person carpool definition and a high level of support for changing the HOV definition from two-person to three-person on the basis of the congestion level of the HOV lane.

On the other hand, the survey respondents, generally did not consider the HOV lanes to be fully used and therefore were not concerned about them becoming congested. These perceptions of the HOV lanes are important because a continuation of this perception could erode the large base of public support for HOV lane operations.

The symposium attendees felt that carpool definition should be based on HOV lane volumes and prevailing land-use patterns. They considered carpool definition to be a natural progression in the operation of HOV lanes, so that a two-plus person carpool definition is employed with a less used HOV facility and three-plus person carpool definition is employed with a more used HOV facility. The attendees felt that this increase in HOV definition allows for the maintenance of a consistent level of service, which enables the HOV lanes to continue to attract HOV users by providing a consistent time savings over SOV commutes.

Because carpool definition ultimately affects the use and resulting level of service of the HOV lane facility, the researchers recommend that the WSDOT implement carpool definitions in accordance with existing land-use patterns and current levels of service observed in the HOV lane. This type of method for implementing carpool definitions would allow the WSDOT to tailor the definition to fit the needs of the HOV facility and the surrounding land-use patterns. They also recommend that the WSDOT undertake an active commuter education program to inform people about the current use of HOV lanes. This education program should increase the public's understanding of HOV lane operations and highlight the fact that HOV lanes appear "empty" because they are moving more people than vehicles. This education program could help build support for HOV lanes by increasing the public's understanding of the facilities.

HOURS OF HOV LANE OPERATION

HOV lanes may operate 24 hours a day, only during peak commute hours, or on some other schedule. A 24-hour operation policy provides consistent operation, which can decrease public confusion about HOV lane operations. Conversely, a peak hour HOV lane operation allows off-peak use of the HOV lane. This can address the public's concern that HOV lanes are not being adequately used.

The symposium attendees agreed overwhelmingly that HOV lanes should operate 24 hours a day to maintain consistency of operation and understandability. They felt that 24-hour operation of the HOV lanes encourages and promotes environmentally-conscious forms of travel. Furthermore, they stated that off-peak use of HOV lanes by general purpose traffic is not necessary because freeway traffic lanes are generally free-flowing during non-commute hours.

The literature review showed that hours of HOV lane operation vary widely across north America. However, even with the wide range of polices elsewhere and the advantages of peak hour operation, the analysis of the I-405 public opinion survey results, focus group comments, and symposium comments revealed a high level of support for 24-hour operation of HOV facilities. Therefore, the study team recommends that the WSDOT continue the current policy of 24-hour operation of HOV lanes.

ENFORCEMENT OF HOV LANES

Enforcement of HOV lanes is crucial to maintaining the integrity of HOV lane operations. Additionally, the public's perception of HOV lane violations can ultimately affect the public's support for HOV lane operations. If violation rates are perceived as low, the public is more likely to support HOV lane operations. However, if violation rates are perceived as high, public support may erode. Thus, public perception, as well as actual violation rates, are important in the analysis of the enforcement of HOV lanes.

The literature review revealed that HOV lane violation rates range widely, depending on several factors. An important issue is whether the HOV lane is physically separated from general purpose traffic. Generally, physically separated HOV lanes experience lower levels of violation than non-separated lanes. Current HOV lane violation rates along the I-405 and State Route 520 corridors range from 9 to 15 percent.

In the public opinion survey, respondents agreed that violations are serious and that fines should be severe. However, they also overwhelmingly agreed that violations are common and were neutral or disagreed that the State Patrol apprehends violators frequently. Additionally, the respondents in this study were neutral in their assessment of the effectiveness of HERO program.

In addition to the issues raised in the public opinion survey, the symposium attendees felt that it was important to include the Washington State Patrol in the design of HOV facilities to help create facilities that are enforceable and safe.

The symposium attendees overwhelmingly agreed that enforcement is necessary for the effective operation of HOV lane facilities. The attendees agreed that WSDOT must work with public agencies such as the Washington State Patrol and local jurisdictions to enhance the effective enforcement of HOV lanes. They also noted that it is important for the Washington State Patrol to be involved in the preliminary planning of HOV facilities to ensure that the facilities are designed for effective and safe enforcement.

The group agreed that they would like to see violation rates in the 10 to 15 percent range. While enforcement is important, the attendees also noted the trade-off between the cost of enforcement and the achievement of a zero violation rate. The attendees felt that a zero percent violation rate is not a practical goal, given the costs and limits in time, money, and personnel.

The researchers recommend that the WSDOT implement a public education program concerning current violation rates of the I-405 HOV lanes and the number of violators who are actually apprehended. Because a large factor influencing the perception of HOV lane violators is the presence of State Patrol troopers actually issuing citations, increased peak hour apprehension of violators would increase people's perceptions that HOV lane violators are being apprehended. Even if violation rates are relatively low, visible enforcement is important to maintain public support for HOV facilities.

To enhance effective enforcement, HOV facilities should be designed with adequate space for state patrol troopers to pull violators off the road. WSP should be involved from the early stages in the design and implementation of HOV facilities.

ANALYSIS OF MODE CHOICE

Statistically significant differences were observed between the SOV commuters, carpoolers, and bus riders with respect to their personal, home, workplace, and daily activity characteristics. Additionally, an analysis of the respondents' preference for commute mode indicated a potential market among SOV commuters for shifts to carpooling and riding the bus.

The strategies that have the potential to affect mode choice most strongly are listed below.

- **Employer Charge for Parking** — As long as parking is free and plentiful, commuters will likely choose to drive.
- **Decrease Zoning Requirements for Parking** — Oversupply of parking encourages inexpensive and abundant parking, minimizing the motivation to share rides.
- **Provision of Company Car** — The provision of a company vehicle would make employees less dependent on their own vehicle, and thus more able to carpool or take the bus.
- **Extensive and Pro-Active Carpool Matching Program** — Even though people express the opinion that they have no one to carpool with, this research showed that carpool partner availability may be higher than perceived.
- **Extension of Daycare Hours** — An early closing time at daycare facilities represents a significant limitation on the flexibility of commuters' schedule to accommodate carpooling or riding the bus.
- **Use of Daycare Facilities for Carpool Formation** — Carpool formation could be enhanced by allowing parents to park their cars on-site or near

the daycare facility, thus having the daycare facility operate as a small scale park-and-ride lot.

- **Increased Transit Service** — A significant percentage of SOV commuters indicated a preference for using transit, if it were available.
- **Implementation of a Complete System of HOV Lanes** — The current I-405 HOV lane system is incomplete and unconnected, and thus is not fully able to provide time savings advantages to people with long commutes.
- **Flexible Local Bus Service** — Flexible local transit service is one way to decrease commuters' need for personal vehicles for conducting errands during the workday.
- **Changed Land Use Patterns** — By changing land use codes to encourage a mix of uses in employment areas, the need to use a personal vehicle to run errands during the workday would decrease.

> The researchers recommend that the WSDOT continue to support and implement policies in the I-405 corridor designed to encourage the use of HOVs. Furthermore, the WSDOT should work closely with local jurisdictions and corridor employers to target SOV commuters who have an inclination to shift commute mode.

GENERAL CONCLUSIONS

The survey results showed that people are very supportive of HOV operations and policies to increase the use of HOV lanes, despite the fact that they currently drive alone to and from work. The survey showed that the public's opinions about the technical operational aspects of HOV lane placement, ramp metering, and special access were less well defined than their attitudes concerning carpool definition, hours of operation, and enforcement.

Given the lack of a clear public opinion regarding lane placement, ramp metering, and special access, it is important that the WSDOT provide public education concerning the effectiveness of chosen options for these elements of the HOV system. Education programs of this type will not only maintain the high level of support for HOV lane operations, but also build future support for these facilities.

INTRODUCTION AND OVERVIEW

This chapter provides an overview of the purpose of this study, the issues associated with the analysis, a description of the I-405 corridor, and an overview of the organization of the report.

OVERVIEW OF THE I-405 HOV LANE ANALYSIS

Seventeen lane-miles of HOV lanes have already been constructed in the I-405 corridor. HOV lanes are under consideration for the entire corridor. Preliminary engineering on additional segments has already been conducted. The HOV facilities in the system should function coherently, both from an operational perspective and from the highway users' perspective. However, the planning to this point has not regarded the corridor as a whole system. As further development of HOV facilities in the I-405 corridor continues, it is critical that the whole corridor be considered. A systems analysis is essential because all segments of the corridor must work together; provisions must be made for the coordination of transit, carpools, and vanpools; and jurisdictions that share responsibility for the corridor must have the capability to integrate their activities.

Transportation agencies commonly recognize that the emerging transportation problem is primarily in the suburbs. Projections for the Puget Sound region show growth in population and jobs occurring primarily outside the established CBDs. The implication of this growth pattern for transportation is that the primary load on the transportation system will be on circumferential routes. I-405 defines one of the major corridors for circumferential travel in the Puget Sound region. It is also a major thoroughfare for traffic going to and from King and Snohomish counties.

HOV lanes and ramp controls are relatively new types of transportation facilities. There are no standard ways of designing them. In fact, given the disparate environments in which they are implemented, such standards may not be advisable. Even though the benefits of HOV lanes, ramp controls, and other HOV facilities have been demonstrated in this region and in other parts of the country, they are still controversial. The advantages are not always obvious to the general public, and policy makers' opinions are affected by these impressions. The better the design and the more information available on the potential impacts of the HOV lanes, the more likely they will receive support.

The basic goal of this study was to develop a coordinated HOV plan for the I-405 corridor. The objectives of this analysis were to provide information that could assist in the development of a coordinated HOV plan for the I-405 corridor to ensure that the existing and planned HOV facilities worked together and that transitions between facilities occurred smoothly.

The analysis included an overview of HOV lane operations in the United States, a public opinion survey of commuters who primarily live and work east of Lake Washington, result of focus groups with workers who live in east King County, transportation modeling centering on the I-405 corridor, traffic analysis of HOV lane options, a cost effectiveness analysis, and the results of a symposium that presented the outcomes of the public opinion survey results.

The symposium was held to present findings from the I-405 HOV lane analysis and to gather data from the symposium attendees regarding six design issues. The symposium was attended by engineers and planners from the Washington State Department of Transportation (WSDOT), the Puget Sound Council of Governments, Metro, Community Transit, Snohomish Transit, SNO-TRAN, transportation consulting firms, and local jurisdictions in eastern and southern King County.

IDENTIFICATION OF ISSUES

Six design elements were identified as part of the effective implementation and operation of HOV lanes. These six design elements are listed below and guided the collection and analysis of data over the course of the analysis of the I-405 HOV lane system.

HOV Lane Placement

The primary issues of HOV lane placement concern the efficiency and safety of the HOV lane operations. HOV lanes are generally placed on the inside of the facility to minimize HOV's conflicts with merging and exiting general purpose freeway traffic. However, inside HOV lanes require HOVs to weave across the general purpose lanes, leading to safety as well as operational concerns. Outside lanes, while easy to access for HOVs, mix HOV and general purpose traffic when they merge onto and exit off of the freeway.

Ramp Metering and Ramp Metering with HOV Bypass

Ramp metering is used extensively in the Puget Sound area and elsewhere to reduce traffic congestion on freeways and smooth the flow of traffic onto the freeway. Ramp metering is also important to the efficient operation of outside HOV lanes. Despite these benefits, when ramp metering is not properly implemented, it can result in excessive traffic backups on local arterials.

A related issue with ramp metering is the implementation of HOV bypass lanes. HOV bypass lanes enable HOVs to go around general purpose traffic that is waiting at the ramp meter and thus serve as an incentive to use an HOV.

Special Access to HOV Lanes

Special access ramps provide access for HOV traffic to inside HOV lanes. This is an important operational improvement because it helps separate general purpose traffic and HOV traffic, thereby decreasing the potential for traffic conflicts at freeway merge and exit points. It also results in time savings for all traffic because HOVs do not have to weave across general purpose lanes to access an inside HOV lane. While special access ramps provide a time savings and optimal operational characteristics, there are significant barriers to their implementation. Right-of-way is scant in many parts of the corridor. Furthermore, even where it is physically possible to build special access ramps, the expense is significant.

Carpool Definition

Carpool definition has a direct effect on the number of HOVs that can use the HOV lanes. For example, if a carpool definition is too high for an area (e.g., three people), a facility may not achieve a satisfactory level of use. On the other hand, if the definition is too low for an area (e.g., two people), a facility may become congested and not be capable of providing the time savings that is necessary to attract new carpoolers. Carpool definition is an important factor in the public's perception of the use of HOV facilities because it ultimately affects how many vehicles use the HOV lane, regardless of how many people are actually served by the facility.

Hours of HOV Lane Operation

HOV lanes could be in operation 24 hours a day, only during peak commute hours, or on some other schedule. A 24-hour operation policy provides consistent operation, which can decrease public confusion about HOV lane operations. Conversely, a peak hour HOV lane operation allows off-peak use of the HOV lane. This can address the public's concern that HOV lanes are not being adequately used.

HOV Lane Enforcement

Enforcement of HOV lanes is crucial to maintaining the integrity of HOV lane operations. Additionally, the public's perception of HOV lane violations can ultimately affect the public's support for HOV lane operations. If violation rates are perceived as low, the public is more likely to be supportive of HOV lane operations. However, if violation rates are perceived as high, public support may erode. Thus, public perception, as well as actual violation rates, are important in the analysis of the enforcement of HOV lanes.

DESCRIPTION OF THE I-405 CORRIDOR

The I-405 corridor currently has seventeen lane-miles of operating HOV lanes, and a corridor-long system is proposed for future construction. In addition to the HOV lanes, 21 park-and-ride lots support the HOV lane operations in the I-405 corridor. Current HOV lane violation rates in the I-405 corridor range from 9 to 15 percent. A map of the HOV lanes and park-and-ride facilities located in the I-405 corridor is presented as Appendix A.

The I-405 HOV lanes have been implemented in response to the tremendous amount of growth that has taken place in east King County since the opening of the first floating bridge in the late 1940s. Residents and decision makers in eastern King County have been particularly concerned with traffic congestion and its impacts on quality of life and economic vitality. The Eastside Transportation Program (ETP) notes that east King County is

> one of the fastest growing areas in the State of Washington, in terms of population and economic activity. However, this economic vitality is being strangled by traffic congestion. Since 1970 the average daily traffic on I-405 has tripled and average daily traffic on SR 520 has doubled. Despite these dire traffic observations, east King County's employment is expected to increase by over 65 percent by the year 2005. (1)

The ETP was developed as a multi-jurisdictional means of addressing traffic congestion in east King County. The program proposes a mix of transportation system improvements, system expansions, and strategies to encourage commuters to use HOV rather than SOV modes. The recognition that demand on transportation systems must be managed is a concept that is gaining acceptability at all levels of government. (2, 3, 4)

ORGANIZATION OF THE REPORT

This report has been organized into four chapters. The first section contains the executive summary of the I-405 HOV lane analysis, as well as recommendations associated with the six design issues and the mode choice analyses. The second is this overview of analysis and associated issues. The third section describes the methodology used for the public opinion survey and the technical analyses. The last chapter presents the findings, which are organized according to the six HOV lane design issues and the mode choice analyses. For each of the six design issues, the following information is provided: HOV lane operations in North America, the public opinion survey results, the focus group process results, the I-405 HOV Lane Analysis symposium results, benefits and disbenefits associated with the design issues, and a summary of findings.

METHODOLOGY

The following chapter details the methodology used for the technical analysis and for the development and analysis of the I-405 HOV Lane Public Opinion Survey.

TECHNICAL ANALYSIS

The technical analysis for this project consisted of four parts: (1) network analysis, (2) weaving/merging analysis, (3) current volumes analysis, and (4) cost-benefit analysis. The objectives in the technical analysis include the following:

1. understanding temporal and spatial shifts of traffic,
2. forecasting traffic volumes and speeds,
3. gaining a more in-depth understanding of current traffic patterns,
4. assessing costs and benefits, and
5. forecasting modal shift.

Using the methods outlined above, the research team aspired to provide quantitative evaluations of alternative HOV lane locations, carpool definitions, special access construction, and ramp metering. The most optimistic aspiration envisioned an integrated model of the I-405 corridor that could be used to evaluate overall traffic movements, modal shifts, and local traffic movements in combination. Such a model has never been achieved. Instead of an integrated model, the project was able to shed light on individual aspects of the operational analysis that could be used in other parts of it. This section of the report describes that effort.

Network Analysis

The primary objective of the network analysis was to assess the shift of traffic within the I-405 corridor under various alternative HOV facility configurations. The research team wanted to produce volume and speed information for all links in the network. This information could be used to make decisions about the kinds of HOV facilities that would be most effective, to set priorities for building HOV treatments, and to predict where bottlenecks might occur.

Originally, project staff felt that using a full-blown transportation package such as UTPS or EMME2 was not justified for at least six reasons. First, traditional transportation models such as these are very difficult to calibrate and would require resources and time beyond the scope of this project. Second, such models may reproduce corridor-wide effects fairly well, but they do not do a very good job on individual links in the network. Third, such models are not capable of representing local effects of HOV lanes, ramp metering with HOV bypasses, or other HOV bypass facilities very well. Fourth, data concerning trip origins and destinations and characteristics of trip-makers are not available at a fine enough detail to model local effects on specific links very well. Fifth, mode splits are not integrated into the trip distribution estimation. Sixth, and perhaps most important, the model would have to be recalibrated for every alternative HOV package considered. That could require years of work.

NETPEM. Instead of using a full transportation model requiring data that were not readily available, the research team tried to find software that could represent corridor-wide effects of HOV treatments, but would be easy to use so that several alternative HOV treatments could be tested. The Network Performance Evaluation Model (NETPEM), developed at Oak Ridge Laboratories, appeared to satisfy the criteria for achieving the objectives of this project. The goal of the model was

> . . . to provide an assessment tool that is more accurate than quick-response or sketch planning techniques, and more sensitive to facility design and operation changes, without having its use become too burdensome in hardware, software, data preparation and report generation requirements. (5)

The model is designed to perform three functions simultaneously: (1) trip generation, (2) trip assignment, and (3) modal split.

The model develops solutions iteratively until convergence is achieved. Specifically, an initial set of origin and destination values is used to perform a simultaneous trip assignment and modal split solution. The program accomplishes this by first producing an equilibrium assignment of auto trips using the PARTAN technique. (6) Then it adjusts HOV and bus travel times, calculates out-of-pocket costs, and estimates modal split using a model calibrated through a multinomial logit formulation. The equilibrium assignment is performed again until convergence is achieved. Then, trip generation tables are adjusted to take into account new trip time and cost parameters. This whole process is repeated until sufficient convergence is achieved.

For this project, considerable effort was spent in trying to use the NETPEM model for the I-405 corridor. A network involving 352 nodes and 1,119 links was coded. The entire Puget Sound region was represented, with much finer distinctions for the I-405 corridor. Zonal data for 1988 and 2010 were obtained from the Puget Sound Council of Governments. To adequately represent the corridor, 57 zones were required, which exceeded the 30 zones allowed by NETPEM. Research staff obtained the object code for NETPEM (written in PASCAL) and revised it to accommodate the larger number of zones.

NETPEM is very easy to use, and calibration of the model can be accomplished by adjusting the distance from the end nodes (NETPEM represents the centroids of travel analysis zones as nodes in the network) to adjacent nodes in the network. By moving the end nodes around and making other adjustments in assumptions (such as free-flow travel times and capacities of links), flows estimated by NETPEM were compared with actual flows in the I-405 corridor.

Unfortunately, here is where a problem with the model resulted. Large variations from iteration to iteration were observed on some of the most important links in the network. Even though NETPEM does not use an all-or-nothing path assignment algorithm, convergence in overall parameters of the model does not necessarily imply convergence in specific parameters, such as the flow on one particular link. This meant that it would be very difficult to make definitive statements about the impact of specific HOV facilities on specific ramps or specific arterials leading into the freeway.

A Different Approach to the Model. The researchers recognized that the discontinuities in the output of NETPEM were probably the result of a very congested network. Just as in real life, when traffic flow breaks down, it is very difficult to predict the outcome. Apparently, NETPEM's algorithms were not able to deal with the levels of congestion in the corridor without producing discontinuities. After exploring this problem with the model extensively, the research team decided to try another approach. Note, however, that further investigation of NETPEM should be pursued to determine whether the discontinuity problem can be solved some other way.

Using the same network, an incremental, all-or-nothing trip distribution model was developed. In this type of model, a percentage of the traffic that doesn't lead to congestion anywhere is assigned to the network using a minimum path algorithm. Then a small (one or two percent) increment is added to the network on the basis of the speeds resulting from the initial assignment. Increments are continually added until all traffic is assigned to the network. This approach mimics what might happen if traffic in an unchanging network of roads and highways grew over time.

The initial runs of this model were very promising. Variations from observed link volumes were within 25 percent, with few exceptions. Further calibration efforts improved the fit. However, this model did not meet the criterion of ease of use that was originally sought. Only one or two calibrations could be run per day. Even if the model could have been calibrated acceptably for the baseline HOV configuration, the time and effort that would have been involved in testing numerous HOV facility configurations was deemed to be too extensive for use in this project. The network analysis was abandoned at this point.

Even though the network analysis did not produce results as originally conceived, some results of the analysis were useful. First, the analysis provided origin and destination estimates between ramps on I-405 that could be used to calculate the average trip distance on the facility.[1] That piece of information was useful in comparing the attractiveness of inside and outside HOV lanes. Alternative methods to obtain that information, such as license plate surveys or telephone surveys, would have been prohibitively expensive. A second useful result of the analysis was gaining experience with NETPEM. Even though the model apparently failed to accomplish the ideal outcome, it holds promise for the kind of analysis needed in this corridor. Further investigation of it should be pursued.

Weaving/Merging Analysis and HOV Lane Location

The second part of the technical analysis focused on the local effects of various HOV treatments in the I-405 corridor. The initial project plan envisioned that local effects of HOV lane location or ramp metering could be represented as variations in capacity in other models. As will be discussed in a later section, that objective was achieved, to some extent, for the cost-benefit analysis. However, because of the limited ability of the network models to estimate the impact of many HOV alternatives, this objective was not achieved in that environment.

One of the critical questions in comparing right-side versus left-side HOV lanes is the relative amount of delay caused by either forcing general traffic to weave through a right-side HOV lane before merging into the general traffic lanes or forcing HOV traffic to weave through general traffic lanes to access a left-side HOV lane.

The impact of delay can be considered in two ways:

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[1] Even though the accuracy of link volume estimates is doubtful, average corridor parameters such as trip distance on the freeway are probably fairly accurate, since the errors tend to even out in the averages.

1. the overall delay and its effect on total throughput of a highway; and

2. the relative delay to HOVs, which affects the ability of HOV lanes to generate mode shift.

The first kind of delay is measured by the average speed of all traffic on the facility. The second kind of impact is measured by the difference in travel speed between HOV traffic and general traffic.

A review of the literature revealed that no model or computer software has been developed to deal specifically with the differential weaving impacts of left- or right-sided HOV lanes. The 1985 Highway Capacity Manual (HCM85) contains procedures for analyzing weaving movements that are based on methods from the 1965 Highway Capacity Manual (HCM65). These methods are the most commonly used to design and analyze freeway configurations. However, the methods have been criticized for several reasons, including their insensitivity to volume and length parameters (7) and inadequate consideration of lane configuration. (8)

In this project, the researchers attempted to use the HCM85 methods to analyze the weaving impacts of access to right-side and left-side HOV lanes. Two problems were encountered.

1. None of the three types of weaving configurations in the manual exactly fit the weaving movements (better described as lane crossings) engendered by either type of HOV lane. The closest fit was the Type C weaving movement. However, the last part of the movement is a merge into a lane, rather than an exit to a left-side off-ramp.

2. Using a Type C weaving movement with the assumption that the movement into a relatively empty left-side HOV lane is equivalent to exiting a left-side off-ramp, it was possible to compute the speed for HOV traffic and general traffic separately. However, the discontinuity occurring between constrained and unconstrained conditions implied by the HCM85 methodology led to results that were very difficult to corroborate with actual freeway traffic operations.

For these reasons, the use of the HCM85 methodology was abandoned for this project.

Several macroscopic models for analyzing weaving movements were evaluated. A macroscopic model differs from a microscopic one in that it deals with aggregate factors, such as traffic volumes, flows, and capacities. Microscopic models simulate the behavior of individual drivers. The most promising macroscopic model is FREQ10PL. The FREQ family of models is designed to analyze freeway operations and deals with weaving movements to some degree. In particular, the FREQ10PL model is designed to analyze the impacts of priority lanes. For this project, the use of that model was investigated but rejected for the following reasons:

1. the model relies on the HCM65 methodology or simpler methods for analyzing weaving movements; and

2. the model does not deal with right-side HOV lanes.

No other existing macroscopic models could be considered candidates for analyzing the weaving impacts of right- versus left-side HOV lanes.

Microscopic models hold the most promise for providing precise analysis of the impacts of HOV lane placement on driver behavior. FRESIM is an example of such a model. However, that model has not been validated to the extent necessary to rely on it for this analysis.

For this project, the researchers attempted to build a simple microscopic model to deal specifically with the question of weaving impacts of right- versus left-side HOV lanes. However, they quickly discovered that the development of even a simple model would require a major investment of time. Additional resources would be required for data collection to validate findings.

As an alternative, a simple macroscopic model was developed for this project that can be used to gain an understanding of the relative merits of right- and left-side HOV lanes. The model was designed to test HOV lanes in both locations, in addition to testing the use of barrier or buffer separation of the HOV lane from general traffic and the construction of special access to the HOV lane. The results presented here are based on a configuration with one HOV lane and two general purpose lanes. The model was based on the following assumptions.

1. With a right-side HOV lane, entering general traffic adds to the HOV lane traffic for some specified distance, shifts to the first general traffic lane after another specified distance, and finally distributes itself between the two lanes. HOV traffic enters the HOV lane and remains there.

2. With a left-side HOV lane, entering HOV traffic moves across general traffic lanes within some specified distance until it reaches the HOV lane. Entering general traffic distributes itself between the two lanes.

3. Speed is based on the demand and capacity (assumed to be 2,000 vehicles per lane per hour in these examples) of each lane segment. If the demand is greater than the capacity, the actual volume throughput is reduced and the difference between demand and volume is added to the upstream segment of the lane. The speed calculation is discussed in detail elsewhere. (9)

4. There is "friction" between lanes such that an HOV lane operating at a high level of service cannot have speeds exceeding a certain level when the adjacent general traffic lane is moving slowly. The HOV speed is limited by a linear interpolation between a minimum speed (45 miles per hour in these examples) when the adjacent lane is moving at the minimum freeway speed (15 miles per hour in these examples) and a maximum speed equal for both lanes (60 miles per hour in these examples).

5. The volumes of general traffic and HOV vehicles entering the freeway are equal to the exiting volumes. This assumption was not necessary for the model formulation, but it simplified the calculations and reduced the number of parameters that had to be analyzed in this report.

6. All weaving segments are 800 feet long, and the distance between interchanges is 3 miles. A sensitivity test showed that the assumed length of weaving sections did not change results within a range of 500 to 1,200 feet. The effect of the distance between interchanges is discussed below.

Three assumptions about the distribution of demand in the lanes were tested. In the first, traffic demand was assumed to be evenly distributed among the lanes at all times. In the second, traffic demand was distributed according to the methods in HCM85, within the flow limits specified in the manual. When demand exceeded the flow limits, the congestion was assumed to be equally distributed among the lanes. In the third assumption, traffic was assumed to move across the lanes and add to the demand in a specified pattern. Figure 1 shows the demands used in this assumption for left-side HOV lanes. Right-side lane demands were done similarly. The variables were defined as follows:

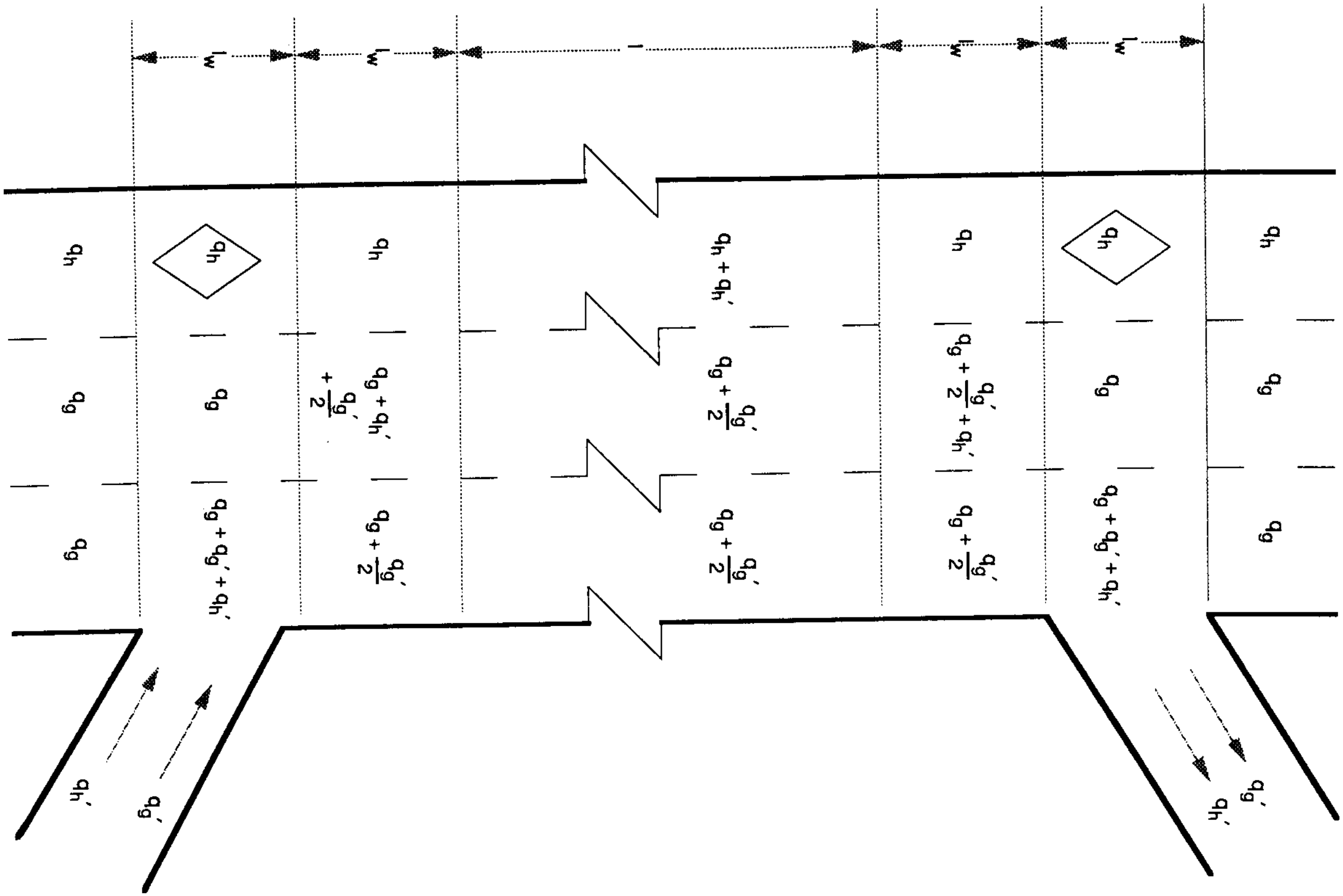

Figure 1. Demand Calculations for Weaving Analysis

q_h — base volume of HOV vehicles

$q_{h'}$ — entering (or exiting) volume of HOV vehicles

q_g — base volume of general traffic vehicles

$q_{g'}$ — entering (or exiting) volume of general traffic vehicles

l_x — segment lengths

A computer model was written in FORTRAN for operation on a personal computer. The purpose of the computer program was to test the sensitivity of the model to various assumptions and to compute the impact of various combinations of traffic volumes on the relative effectiveness of right- and left-side HOV lanes. The results are discussed in the chapters on lane placement and special access to HOV lanes.

Volume Analysis

Traffic volumes, especially by vehicle type, are important in the evaluation of the efficiency of various HOV alternatives. In addition, trip demand forecasts are essential for estimating the future efficacy and impacts of HOV facilities. For this study, three types of data were used:

Vehicular volumes	Current vehicular volumes are based on a combination of estimates provided by loop detectors and counts at ramps.
Auto occupancy and HOV violation rates	From late 1989 to fall of 1990, the WSDOT, with funding from the Puget Sound Council of Governments (PSCOG) and technical assistance from the Washington State Transportation Center (TRAC), conducted a regular program of auto occupancy counts in the Puget Sound region. Four of the count locations were in the I-405 corridor.
Trip demand forecasts	PSCOG provided trip origin destination tables for 2020 that were used to forecast trip demand levels in the I-405 corridor.

Cost Benefit Analysis

In one approach to evaluating the effectiveness of different investments (especially special access ramps to HOV lanes) in the I-405 corridor, a cost-benefit analysis was conducted. The analysis was based on previous work conducted by TRAC and described in detail elsewhere. (9) It is important to recognize, however, that this cost-benefit analysis software contained a simple corridor model that forecast the distribution of trips in time, space, and mode. The algorithm made use of capacity and volume information that were generated in the other parts of the technical analysis.

SURVEY DEVELOPMENT

The I-405 HOV Lane Public Opinion Survey was developed in three phases: a literature review of relevant survey instruments, use of focus groups to identify issues, and the pre-testing of survey questions through the use of focus groups. The following sections describe the survey development process.

Literature Review

A literature review was conducted to assist in the development of the survey instrument. The review explored the wording of different questions regarding HOV lane issues and mode choice attitudes. One source provided examples of several survey methodologies, such as personal distribution/mail-back surveys, telephone surveys, mail-out/mail back surveys, home interview surveys, workplace interview surveys, and on-board transit surveys. (10) Other examples of transportation survey formats and questions provided ideas for the phrasing of demographic, as well as technical, HOV questions. (11, 12, 13, 14) In the Puget Sound region, surveys were obtained from the Puget Sound Council of Governments (15), Gilmore Research (16), Elway Research (17), and Altair Research. (18) Once the literature review for development of the survey had been completed, a series of five focus groups was conducted to further identify issues unique to the I-405 corridor and east King County area.

Focus Groups

Focus groups were used in the survey development process because they provide insights into how the general public views HOV lane and mode choice issues.

Additionally, the researchers felt that the focus group process would allow the survey issues to be refined and suggest strategies for making these issues more understandable to the general public.

Focus groups have been used for many years by marketing agencies as a means of testing public attitudes towards products. However, focus groups are increasingly being used by public agencies as a means of obtaining qualitative information regarding public opinions of policies.[2] Focus groups typically range in size from seven to ten people, who have been drawn at random. The participants can be from the same organization or from different organizations. The key is that they generally do not have any technical knowledge of the subject to be discussed. Discussion is guided by a moderator to ensure that the group does not get off track or become dominated by one individual or point of view.

For the I-405 analysis, five focus groups were held before the development of the survey with employees of the following organizations: University of Washington, City of Bellevue, U.S. West Communications in Bellevue, Totem Lake Merchants in Kirkland, and Overlake Hospital in Bellevue. Selection of the employees for participation in a focus group was random. Random selection was considered important in obtaining a variety of people who drove alone, carpooled, or rode the bus. Initial contact with the employees was made by asking if they would like to attend an informal luncheon to discuss east King County traffic congestion and commuting options. Generally, these focus groups included people who were currently ridesharing or who had rideshared in the past.

Once the focus group meeting was under way, discussion usually turned to HOV lanes as a means of encouraging carpooling and bus ridership. The participants felt that ridesharing was going to be an important aspect in decreasing traffic congestion.

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[2] Stamm, p. 2, 1991.

However, the participants had problems thinking of strategies to motivate SOV drivers to rideshare. Generally, the participants viewed carpooling and riding the bus as necessary but extremely difficult, given people's needs to have daycare, make work related trips, and run personal errands.

On the basis of the findings of these five focus groups, the first draft of the survey was developed. This draft was kept in a long form that included all possible questions that could be asked regarding HOV lane operations, perceptions about mode choice, and constraints on HOV use. The first draft of the survey was submitted to the project's technical review committee for comment. Comments and suggestions were incorporated, and a second draft was produced.

Pre-Testing of the Survey Questions Through Focus Groups

The second draft of the I-405 HOV Lane Public Opinion Survey was pre-tested in a focus group format with employees from the University of Washington and the Microsoft Corporation in Redmond. Again, employees were selected randomly and contacted in a way that would not influence their perceptions of HOV lane issues and operations. As in the previously described focus groups, participants who were ridesharing or who had rideshared in the past were included. This second focus group process helped clarify the questions and weeded out overly complex or redundant questions and statements. In addition, the focus group at Microsoft was particularly helpful in suggesting formatting styles for the survey to enhance understandability.

Survey Design

On the basis of the findings of the first five focus groups, comments of the technical review committee, and pre-testing with the last two focus groups, the final survey instrument was produced. The I-405 HOV Lane Public Opinion Survey was designed to collect data in three basic categories:

1. demographics, mode choice, and constraints on mode choice;
2. attitudes about and perceptions of different modes of commute; and
3. attitudes about different HOV lane operations.

Demographics, Mode Choice, Constraints on Mode Choice. The demographic questions asked respondents about their current mode choice, age, family characteristics, number of household vehicles, income level, job, cost of parking at the work site, home and work locations, and constraints on mode choice (e.g., need for a car for daycare, work related trips, personal errands).

Attitudes About and Perceptions of Different Modes of Commute. The section on attitudes about different modes of commute was adopted from the Puget Sound Council of Government's Transportation Panel Survey. The Puget Sound Panel Survey was incorporated into this survey because the survey had been through an extensive pre-testing process and adequately addressed the mode choice issues associated with the I-405 analysis. These statements were used on the I-405 public opinion survey instrument to obtain data regarding the cognitive and affective perceptions people had about different modes of commute and about commuting in general. The statements about cognitive perceptions required respondents to rate the effectiveness of different commute modes with respect to travel time, cost, plan flexibility, and other factors. The statements concerning affective perceptions asked respondents to agree or disagree with statements about issues such as increases in taxes for more bus service, increases in parking costs for single-occupant vehicles, and others.

Attitudes About HOV Lane Issues and Operations. The section on attitudes about different HOV lane operations sought data regarding the way people perceived current use of HOV lanes; their support for HOV lanes; and their preference for HOV lane placement, hours of operation, and carpool definition. This analysis sought to determine whether differences existed among people who used different modes with their support and perceptions about HOV lane policies and issues.

Because a great deal of information was sought from the survey instrument, project staff decided to use three formats to decrease the length of the survey. The three formats were as follows:

1. Format that asked questions about
   a. demographics, mode choice, and constraints on mode choice;
   b. attitudes about and perceptions of different modes of commute; and
   c. attitudes about different HOV lane operations.
2. Format that asked questions about
   a. demographics, mode choice, and constraints on mode choice; and
   b. attitudes about and perceptions of different commute mode.
3. Format that asked questions about
   a. demographics, mode choice, and constraints on mode choice; and
   b. attitudes about different HOV lane issues and operations.

A copy of the survey instrument and a diagram illustrating the use of these survey formats is included as Appendix B. The following section provides information about the survey administration process.

SURVEY ADMINISTRATION

The literature review process not only yielded excellent examples of questions to ask on the I-405 Public Opinion Survey, it also illustrated the number of opportunities available for survey administration. Consideration of the method for administering the survey was seen as important because it would affect the length of the final survey instrument. The following section includes a brief examination of the methods that were considered but rejected, and a brief overview of the administration method that was used.

Survey Methods Not Employed for the I-405 HOV Lane Analysis

Four survey methodologies were considered but not used in the administration of the I-405 HOV Lane Public Opinion Survey. Those methods include the following.

License Plate Survey Using Video Cameras. This method would have involved use of video cameras to record the license plate numbers and number of vehicle occupants of morning commuters along the I-405 corridor. Once the license plate numbers had been recorded, names and addresses of commuters would have been obtained from the Washington State Department of Licensing. Postage paid mail-back surveys would have been sent to these commuters. This method was not used for two reasons: (1) the short days of early spring would have resulted in insufficient light for effectively surveying the license plates; and (2) mail-back surveys generally do not have a high level of response. A literature review revealed that a survey undertaken with this methodology resulted in only a 19 percent response rate. (14)

Survey Handed Out at Local On-Ramps. This method would have involved use of a postage paid, mail-back survey, which would have been handed out to commuters as they entered freeway on-ramps in the I-405 corridor. This method was not used because of the historically low response rates associated with mail-back surveys. (14)

Fixed Location Computers. This method involves survey respondents using a computer at a fixed location in order to answer the survey. The computer program automatically guides the respondent through the survey instrument while simultaneously coding the data for later analysis. Fixed location computers can be used at supermarkets, shopping centers, and shopping malls. This method was rejected for two reasons: (1) the researchers did not know how long it would take to collect data by this method, and the project time-line specified that data collection run from the middle of April through May 1990; (2) they also felt that this method would attract only people who were at ease with computers and people who frequented shopping centers or malls and would not produce a representative sample.

Telephone Survey. This method involves contracting the survey administration to a telemarketing firm. The primary advantage of this method over mail-out/mail-back surveys is that it allows for personal contact with the survey respondent. Despite this advantage, this method was not used because of its associated costs. Costs for this type of survey methodology were documented in a multi-year transportation study undertaken by the Metropolitan Council of the Twin Cities Area in St. Paul, Minnesota. The costs noted by this Council were in the $100,000 range for the telephone survey. This cost was greater than what was feasible within the budget for this study.

Survey Method Employed for the I-405 HOV Lane Public Opinion Analysis

After rejecting the methodologies covered in the previous section, the research team decided to administer the survey at driver's licensing offices in east King County, specifically the cities of Kirkland, Bellevue, and Renton. This method of administration was suggested as a result of a brainstorming session. The suggested administration process was to use a paper and pencil format with a postage paid, mail-back option if people were unable to complete the survey while waiting in line for their driver's license. This survey method was used for a number of reasons.

1. The researchers assumed that by gathering data at driver's license offices in east King County, the respondents would primarily be people who live and work in East King County, and thus be more likely to use I-405 for their commute to and from work.

2. They also assumed that this method would be an effective means of obtaining a random and representative sample of commuters since everyone has to renew their license in person at some time near their birthday.

3. The bias toward people with driver's licenses was not considered problematic, since over 95 percent of all east King County residents over the age of 16 have a driver's license. (16)

4. The researchers felt that the time people spent waiting in line could be used to complete the survey, thereby avoiding the low response rates typically associated with mail-back surveys.

5. This method of survey administration would allow the use of project staff and Washington State Department of Transportation staff, and thus data collection could be conducted relatively inexpensively.

The I-405 HOV Lane Public Opinion Survey was administered at the driver's licensing offices in Bellevue, Kirkland, and Renton during the months of April and

May 1990. The survey was administered during all office hours to ensure that the data collection effort was not biased by data collected only on certain days or only at certain times of the day. Additionally, data collection on Saturdays allowed contact with people who did not have the opportunity to renew their licenses during weekday office hours (8:00 a.m. to 4:30 p.m.).

The survey was administered by staff of the Washington State Transportation Center (TRAC) and the Washington State Department of Transportation (WSDOT). This was important because the survey staff had a clear understanding of HOV lane operations and transportation planning issues and thus could be of assistance in answering any questions.

Because the goal of the survey was to gather data about commuter attitudes, potential survey respondents were screened before being asked to complete a survey. This screening process included asking respondents whether they were willing to complete a survey about their trip to and from work and their perceptions about HOV lane issues and operations. If they did not commute during peak hours, they were not asked to fill out the survey. This method screened out retired people, people who did not commute on a regular basis, and people under 18 (generally students) who did not commute during peak hours. This bias was deemed acceptable because the goal of the survey was to concentrate on people who commuted to and from work along the I-405 corridor. For the most part, respondents completed the survey on the premises.

SURVEY RESPONSE RATE

A high response rate is desirable to avoid any bias resulting from important differences between respondents and non-respondents. This project was very successful in this respect. An 87 percent response rate was achieved by taking advantage of the fact that people had to wait in line at the driver's licensing offices. People were very receptive

Table 1. Response Rate I-405 HOV Lane Public Opinion Survey

Location	Number of Surveys Handed Out	Number of Surveys Received	Response Rate	% of Total
All Locations	1775	1545	87.00%	100.00%
Bellevue	581	518	89.00%	33.50%
Renton	483	436	90.00%	28.20%
Kirkland	566	516	91.00%	33.40%
Mailed Back	145	75	52.00%	4.90%

to completing the survey, and many actually said it was interesting. Table 1 displays the total number of surveys collected at each survey administration site.

As can be seen from Table 1, the number of surveys collected from each driver's licensing office was roughly the same. The number of surveys collected from the Renton driver's licensing office was lower than the Bellevue and Kirkland offices because this office generally has less business. Equality in the numbers collected from each office was seen as an important means of ensuring that overall survey results were not biased by the results of one office.

METHODOLOGY FOR STATISTICAL ANALYSIS

The evaluation of the I-405 HOV Lane Public Opinion Survey data involved a series of t-tests and chi-square tests as the primary methods of statistical analysis. T-tests were used to test the null hypothesis that a continuous variable's mean was the same in two groups. T-tests were used rather than analysis of variance because statistical significance tests were needed only between each of the three pairs of mode choice groups: SOV compared with Carpoolers, SOV compared with Bus Rider, and Carpooler compared with Bus Rider.

Analysis of variance would have yielded information about overall differences among the three groups but not about the specific differences between the three pairs.

Chi-square tests were used to test the strength of the relationships between non-continuous variables in the three mode choice pairs (SOV/Carpooler, SOV/Bus Rider, and Carpooler/Bus Rider). Non-continuous variables employ a categorical, non-ordinal scale.

The statistical analyses used a 95 percent confidence limit for determining whether observed differences or relationships were statistically significant. The 95 percent confidence limit means that one can be 95 percent confident that the observed differences are not due to random chance. It is important to note that the observance of a statistically significant result does not mean that causality can be inferred.

<u>Mode Choice Analysis</u>

The mode choice analysis used a series of t-tests and chi-square tests to determine the statistical differences between each of the three mode choice groups with respect to the following factors:

- personal characteristics (age, sex, education, occupation);
- home characteristics (household size, average number of workers, average number of children, household income, average number of household vehicles, and level of vehicle availability for commute purposes);
- daycare characteristics (use, responsibility for dropping off a child and/or picking up a child, average weekly daycare use, average closing time of daycare facilities, and the distance of the daycare facility from the respondent's home);
- workplace characteristics (work start and end times, morning and evening commute times, company size, parking problems, parking cost, and availability of a company car); and
- daily activity characteristics (use of personal vehicle for work related trips, use of personal vehicle for personal errands, and use of personal vehicle to drive to lunch off-site).

The examination of the differences among SOV commuters and carpoolers and bus riders was conducted to identify SOV commuters' constraints in using HOVs. Identifying these constraints to HOV use, will help officials develop policies that can encourage more SOV commuters to carpool or ride the bus. The information derived from these questions will be used to address the question "what are the differences among people who use different modes for commuting to and from work with respect to personal, home, daycare, workplace, and daily activity requirements?"

A second part of survey analysis attempted to determine whether there were differences in the perceptions of HOV lane issues and operations in relation to people's support for HOV lanes. This variable was referred to as the "favor HOV" variable. The purpose of creating this variable was to determine whether some global attitude was influencing attitudes about specific issues concerning HOV lanes. One hypothesis was that people who favor HOV lanes are supportive of HOV lane treatments, regardless of their current mode choice. The "favor HOV" variable was created on the basis of responses to the statement "HOV lanes are a good idea." Those who agreed or agreed strongly were placed in the "favor" group; those who disagreed or disagreed strongly were placed in the "not favor" group; and the neutral respondents were placed in the neutral group.

Table 2 displays the observed frequencies. From this table it is very clear that the respondents overwhelmingly thought HOV lanes were a good idea, despite the fact that nearly 80 percent of them were not able to use HOV lanes for their commute to and from work because they drove alone.

Table 2. Favor of HOV Lanes

"Favor" of HOV Lanes	Number of Responses	Percent of Total
Favor	599	89.0%
Neutral	32	4.7%
Not Favor	43	6.4%
Total	674	100.0%

Mode Preference Analysis

In addition to testing the differences among the three modes with respect to their demographic characteristics and constraints on HOV use, two types of preference analysis were conducted:

1. **cognitive preference analysis** — a set of statements requesting respondents to rate different commute modes (SOV, carpool, and bus) with respect to mode attributes such as travel time, cost, and plan flexibility and the importance the respondents placed on each of the mode attributes, and

2. **affective preference analysis** — a set of statements that had respondents agree or disagree with attitudinal statements about issues such as increases in taxes for more bus service, increases in parking costs for single-occupant vehicles, ease of using the bus, and ease of using a carpool.

The survey is attached as Appendix B, and these statements can be found in sections E and F of the survey. By analyzing commuter mode preferences, the researchers could identify SOV commuters who tended to think carpooling or riding the bus was more effective than driving alone. Once these commuters had been identified, an examination of the constraints on their ability to use HOV modes could be undertaken. This analysis could be used to address the second research question, "what are the differences between people who actually rideshare and people who prefer ridesharing yet continue to commute alone with respect to personal, home, daycare, worksite, and daily activity requirements?"

Cognitive Analysis. The cognitive analysis used data from the respondents' ratings of three different commute modes with respect to mode attributes such as travel time, cost, and plan flexibility and the importance they placed on those attributes to identify the mode they thought was most effective for commute purposes. The respondents' effectiveness ratings were then compared with their actual mode use to determine which commuters rated a different mode as more effective than their current mode. The goal of the cognitive preference analysis was to analyze the characteristics of respondents whose cognitive preference differed from their actual mode choice.

The researchers computed a cognitive preference score by multiplying the individual's **importance** ratings for each of ten variables by their rating of the **performance** of buses, carpools, and driving alone with respect to each of these ten variables. Performance scores were determined for each mode from these responses; these scores indicated a respondent's perception of the effectiveness of the three modes. The mode with the highest preference score was considered the cognitively preferred mode.

The cognitive preferences were then cross-tabulated with the mode the respondents actually used to determine correspondence between preference and actual choice. Respondents who cognitively preferred ridesharing yet drove alone were compared with the people who cognitively preferred ridesharing and actually rideshared. Those who cognitively preferred carpooling yet drove alone were referred to as the "Want to Pool" group; those who cognitively preferred carpooling and actually carpooled were referred to "Actual Pool" group; those who cognitively preferred using the bus yet drove alone were referred to as the "Want to Bus" group; and those who cognitively preferred using the bus and actually rode the bus were referred to as the "Actual Bus" group. T-Tests and chi-square tests were then used to determine the statistical differences between the "Actual Pool" and "Want to Pool" groups and the "Actual Bus" and "Want to Bus" groups on several variables indicating personal, home, daycare, workplace, and errand characteristics. This analysis was intended to shed light on why people who drive alone but prefer ridesharing modes do so. This should lead to the identification of constraints on HOV use and of strategies to encourage the use of carpools and buses.

People who prefer driving alone and do so are less likely to shift modes and require a different approach. It was assumed that these people viewed carpools and buses as less effective than driving alone, and thus policies to change their behavior have to address their basic views of carpool and bus commute modes.

Affective Analysis. The affective analysis used data from the respondents' agreement or disagreement with statements about the three commute modes (SOV, Carpool, Bus) that were designed to touch on subjective responses to the modes. Items included such issues as enjoyment of driving, lifestyle fits, and feelings about increases in taxes for more bus service or parking costs for single-occupant vehicles. The respondents' support for the three commute modes were then compared with their actual mode use to determine which commuters favored a mode that differed from their current mode use.

Affective preferences for a mode were identified through cluster analysis. This analysis method produces groups of respondents who react similarly to a set of variables. From the respondents' agreement and disagreement with the statements (Section E of the Survey Instrument), three affective preference clusters were identified: the drive alone cluster, the carpool cluster, and the bus rider cluster. Each cluster had response patterns that indicated agreement with statements supporting the use of one mode and disagreed with or were ambivalent about statements supporting the use of the other modes.

The three mode preference clusters were cross-tabulated with actual choice of commute mode. Those who affectively preferred carpooling yet drove alone were referred to as the "Want to Pool" group; those who affectively preferred carpooling and actually carpooled were referred to "Actual Pool" group; those who affectively preferred using the bus yet drove alone were referred to as the "Want to Bus" group; and those who affectively preferred using the bus and actually rode the bus were referred to as the "Actual Bus" group. T-tests and chi-square tests were then used to determine the statistical differences between the "Actual Pool" and "Want to Pool" groups and the "Actual Bus" and "Want to Bus" group on several variables indicating personal, home, daycare, workplace, and errand characteristics. This analysis mirrored the analysis of cognitive preference and mode choice, with the same objectives of identifying strategies for producing modal shift to HOV commute modes.

FINDINGS

This chapter provides details of the findings from this project. The findings came from several sources, including the literature review, the public opinion survey, the network analysis, the traffic analysis, and the symposium comments. The chapter is divided into four main sections: (1) general findings, (2) findings specific to the six issue areas, (3) the mode choice analysis, and (4) a summary of factors constraining HOV use.

GENERAL FINDINGS

This section provides general information about the survey sample. The sample is described in terms of normal commute mode, characteristics of carpools, reasons for driving alone, general comments, origin and destination patterns, and a comparison of the sample with the general population. This section also includes information about trip length on I-405 derived from the network analysis.

Mode Usage

The mode choice variable was created from the number of days respondents reported using a particular mode for travel to and from work. Four mode choice categories were created: SOV, POOL, BUS and OTHER. The SOV group was composed of respondents who used a personal vehicle three or more days per week for commuting to and from work. The POOL group included respondents who commuted three or more days per week in a carpool or vanpool with at least one other person. The BUS group constituted respondents who rode the bus two or more days per week. Since so few bus riders were in the sample, this method of coding allowed the examination of as many bus riders as possible. The OTHER group comprised respondents who walked, motorcycled, or rode a bike three or more days per week. Table 3 shows the sample's frequencies and percentages of use of the four mode choice groups.

Table 3. Mode Usage

Mode Choice Group	Number of Responses	Percent of Total
SOV	1137	79.00%
POOL	181	13.00%
BUS	91	6.00%
OTHER	30	2.00%
Total	1439	100.00%

As can be seen from this table, the majority of the survey respondents drove alone to and from work. The mode choice analysis examined and compared the characteristics of the SOV, POOL and BUS groups. The results of the analysis are presented in a later section.

Carpool Characteristics

Of the respondents, 13 percent carpooled to and from work at least three days per week. The average carpool size was 2.64 people. The majority of the carpools comprised co-workers, not spouses or children. This was an interesting finding because the literature reviewed suggested that, in general, the majority of carpools are made up of spouses and children. (19)

Only **four** respondents reported carpooling with a worker from a different company at a different site. The formation of carpools was largely done by the carpool members themselves. The percentage of carpoolers who reported forming their own carpools was 88; only 9.9 percent of the carpools were set up as the result of an employer program, and only 2.5 percent were set up by a transit agency. This finding shows that most carpoolers are setting up carpools on their own, even though a regional program could be assisting them.

Reasons for Driving Alone

Nearly 80 percent of the survey respondents drove alone. The primary reasons that people reported for driving alone were as follows:

- "No co-workers live near me." or "No neighbors work near my worksite." (14.7 percent)
- "It is convenient to drive alone."(11.1 percent)
- "I need my car for work."(11.1)
- "I have an odd schedule." or "No one has the same schedule as me." (7.5 percent)

Of all the reasons given for driving alone, only four people stated that they did so because they simply liked to drive alone. Responses to this question showed that commuters strongly believe that there is no one else to commute with, that they are "alone" when it comes to commute routes and schedules. The responses also showed a reliance on their personal vehicle for accommodation of odd work schedules and work related trips. Additionally, a fair number of respondents noted that they used their vehicles for commuting because it was convenient. These perceptions demonstrate both real and psychological barriers to the formation of carpools and use of the bus. Any policies to increase the use of HOVs should account for these real and perceived barriers to HOV use.

Comments

Only 17 percent of the survey respondents provided comments on the survey form. Caution should be exercised in generalizing too much from a few comments. However, they did provide another perspective on the attitudes of I-405 commuters. The most frequently made comments were as follows:

- support for light rail or recommendation for light rail — 2.6 percent of total comments, or 39 people
- observation that current Metro service is inadequate — 2.4 percent of total comments, or 36 people
- support for HOV lanes — 2.1 percent of total comments, or 32 people
- reasons for not using carpools or the bus — 2.0 percent of total comments, or 30 people

The most frequent comment made by bus riders was that Metro service was inadequate. The most frequent comment made by carpoolers was that HOV lanes were a good idea and that more should be constructed. The most frequent comment made by the SOV drivers was support or recommendations for light rail. Thus, respondents generally made comments that were consistent with their current mode choice. However, the fact that the SOV drivers desired light rail does not necessarily mean that they would use such a system. Using light rail is inconsistent with the reasons SOV commuters gave for not carpooling or taking the bus (e.g., it is inconvenient, they need a vehicle for work, they have an odd schedule, it takes too long, it is too difficult to use, and the like).

Origin and Destination of Commute Trips by Mode

Tables 4, 5, and 6 provide graphic representation of the origin and destination trip patterns for this sample's commute trips. A copy of the census tract map with the consolidated census tract groupings is presented in Appendix C.

Table 4. Home Location

Kirkland/Bothell/Redmond Area

Mode	Work Destinations					Total
	K/B/R	Bellevue	Renton	DT Seattle	Other	
SOV	30%	39%	6%	11%	14%	100%
POOL	31%	15%	0%	24%	30%	100%
BUS	7%	7%	7%	63%	10%	100%

See Appendix C for a graphic display of the consolidated census tract analysis areas. K/B/R refers to the Kirkland/Bothell/Redmond area; DT Seattle refers to Downtown Seattle; Other encompasses all other areas of King County, south Snohomish County, and North Pierce County.

Table 5. Home Location

Bellevue Area

Mode	Work Destinations					Total
	K/B/R	Bellevue	Renton	DT Seattle	Other	
SOV	11%	50%	9%	13%	17%	100%
POOL	12%	44%	9%	23%	12%	100%
BUS	4%	11%	4%	59%	22%	100%

See Appendix C for a graphic display of the consolidated census tract analysis areas. K/B/R refers to the Kirkland/Bothell/Redmond area; DT Seattle refers to Downtown Seattle; Other encompasses all other areas of King County, south Snohomish County, and North Pierce County.

Table 6. Home Location

Renton Area

Mode	Work Destinations					Total
	K/B/R	Bellevue	Renton	DT Seattle	Other	
SOV	3%	22%	34%	10%	31%	100%
POOL	4%	46%	19%	7%	24%	100%
BUS	0%	0%	2%	47%	51%	100%

See Appendix for a graphic display of the consolidated census tract analysis areas. K/B/R refers to the Kirkland/Bothell/Redmond area; DT Seattle refers to Downtown Seattle; Other encompasses all other areas of King County, south Snohomish County, and North Pierce County.

These tables show that the majority of respondents lived and worked in east King County and commuted between and within the cities of Kirkland, Bellevue, Renton and downtown Seattle. The bus riders exhibited the largest proportion of Seattle CBD work destinations. This predominant use of the bus to downtown Seattle was a result of Metro's service patterns, which were oriented to providing radial service to that location.

The carpoolers, unlike the bus riders, exhibited work destination patterns similar to those of the SOV commuters. A few more carpoolers worked in downtown Seattle; however, the vast majority carpooled to and from work in east King County. The similarities between the origin and destinations patterns of the Carpool and SOV groups indicates that SOV commuters have many opportunities for forming carpools. However, a psychological barrier to the formation of these carpools was confirmed by the fact that the primary reason SOV drivers reported for driving alone was that no one lived or worked near them. Policies to increase the use of carpools need to address this misperception to successfully shift people from SOV commutes to HOV usage.

Trip Lengths on I-405

Trip lengths were analyzed with output from the network model described in the methodology section. The model runs showed that HOV trips were a little shorter than SOV trips on the average. This was probably due to the fact that the model routed HOV through-trips to I-5. This may not have been realistic, since the model may have been overly responsive to the congestion on I-405 and the existence of HOV lanes on I-5. However, because there were relatively few HOV trips in the corridor, the trip length findings would not have been highly affected by including HOV trips with SOV trips for this analysis.

Table 7 shows the average trip length by section, followed by the percentage of trips within the indicated ranges. If any part of a trip occurred within a section, it was counted.

It was surprising to find that the average trip length within each section tended to be longer than the average trip length for the whole corridor. However, this is fairly easily explained. Short trips tended to be counted only once in each section. Long trips were counted in almost every section. As one can see, the percentages of all trips by section added up to 133.7 percent. This reflects the number of trips that were counted in

Table 7. Trip Lengths on I-405

Section	average length	< 3 miles	3-6 miles	> 6 miles	% of all trips
I-5 to I-90	5.54	45.0	18.9	36.1	47.5
I-90 to SR520	8.28	31.8	11.1	57.1	34.7
SR520 to SR522	8.76	17.9	22.8	59.2	35.7
SR522 to I-5	10.54	.8	31.9	67.3	15.8
All of I-405	5.68	38.8	24.4	36.8	100.0

more than one section. Double-, triple-, or quadruple-counting of long trips meant that average trip lengths by section were longer than overall average trip length.

The implications of these findings are important, however. In all sections except south of I-90, the majority of the trips that went through each section were longer than 6 miles. This is contrary to the usual characterization of I-405 as a corridor with predominantly short trips, which are implied when only the trip length distribution for the whole corridor is viewed.

<u>Comparison of the I-405 Survey Sample with Metro's 1989 Market Segmentation Sample</u>

Metro's 1989 Market Segmentation Survey was used as a means to test the representativeness of the I-405 sample's demographic characteristics in relation to all east King County commuters. Metro's 1987 Market Segmentation Study was designed to be a representative sample of the commuting population of east King County. The sample was contacted through random digit telephone dialing. Representativeness of a survey sample is important for making generalizations about the commuting population. Therefore, demographic data from this study's sample were compared with data from Metro's 1987 study.

Although some differences were observed between the two data sets, the comparison also showed that in both surveys the east King County commuters generally drove alone, were well educated, were employed in white collar occupations, had middle to upper-middle incomes, had an average of approximately three people per household, and owned an average of approximately 2.5 vehicles per household. Because the comparison of the two samples revealed these similarities, the researchers felt that the I-405 sample was representative of commuters in east King County. A table summarizing the comparison of key statistics from each study is provided in Appendix D.

Perceptions of and Support for HOV Lane Operations

The following section provides information regarding the study respondents' support for HOV lane policies and operations. Specifically, information is provided about (1) their view of HOV lanes as a good idea, (2) their belief that HOV lanes provide a good incentive for carpooling and riding the bus, (3) their perceptions that HOV lanes are being adequately used, and (4) their belief concerning the conversion of HOV lanes to general purpose lanes.

As can be seen in Table 8, the survey respondents agreed that HOV lanes were a good idea. The POOL and BUS groups agreed with this statement to a larger extent that the SOV commuters. This higher level of agreement is probably due to their ability to use the HOV lanes. As noted previously, this variable was used to create the "favor HOV" lane variable to aid in examining attitudes regarding HOV policies and operations. Of the sample, 89 percent favored HOV lanes, 4.7 percent were neutral, and 6.4 percent disagreed that HOV lanes are a good idea.

Overwhelmingly, the survey respondents agreed that HOV lanes provide a good incentive for carpooling and riding the bus. Table 9 shows that carpoolers and bus riders agreed with this assertion to a larger extent that SOV commuters. As one would expect, the majority of the "favor HOV" group agreed with this statement, while the majority of the "not favor HOV" group disagreed. Given that the "not favor" group did not favor HOV lanes, the researchers expected that they would not agree to statements about the

Table 8. ***"HOV lanes are a good idea."***

	Agree	Neutral	Disagree
Overall	87.7	6.9	5.3
SOV	86.2	7.5	6.3
POOL	91.8	4.1	4.1
BUS	94.1	5.9	0.0

Table 9. ***"HOV lanes provide a good incentive for riding the bus and carpooling."***

	Agree	Neutral	Disagree
OVERALL	71.7	17.5	10.8
SOV	68.1	19.8	12.1
POOL	77.8	13.9	8.3
BUS	91.2	5.9	2.9
FAVOR	78.8	14.1	7.1
NEUTRAL	37.2	46.5	16.3
NOT FAVOR	18.8	25.0	56.3

See *Methodology* for a definition of the "Favor HOV Lane" groups.

advantages of HOV lanes. However, the analysis showed that, among those who did not favor HOV lanes, barely half disagreed with the statement that they provide a good incentive for riding the bus and carpooling.

As shown in Table 10, less than 40 percent of the respondents agreed that current HOV lanes were being adequately used. The analysis of the survey respondents by mode choice did not reveal substantial differences among the three mode choice groups. An analysis of the survey respondents by their support for HOV lanes showed that, to an

Table 10. ***"Existing HOV lanes are being adequately used."***

	Agree	Neutral	Disagree
OVERALL	38.7	26.0	35.3
SOV	37.7	26.3	35.9
POOL	37.4	23.2	39.4
BUS	40.4	27.7	31.9
FAVOR HOV	43.1	28.6	28.3
NEUTRAL	11.7	46.4	41.9
NOT FAVOR HOV	1.6	6.3	92.1

See *Methodology* for a definition of the "Favor HOV Lane" groups.

Table 11. ***"HOV lanes should be converted to regular traffic lanes 24 hours a day."***

	Agree	Neutral	Disagree
OVERALL	18.5	19.7	61.8
SOV	18.1	22.1	59.8
POOL	27.6	15.3	57.1
BUS	17.5	12.5	70.0
FAVOR HOV	33.0	15.9	51.1
NEUTRAL	30.2	55.9	13.9
NOT FAVOR HOV	51.8	31.0	17.2

See *Methodology* for a definition of how the "favor HOV" lane groups were created.

overwhelming extent, people who did not favor HOV lanes did not agree that the HOV lanes were being adequately used. This perception of HOV lanes' underutilization appears to be a very strong factor in people's overall approval of HOV lanes. This perception is critical in affecting the level of public support for HOV lane operations.

According to Table 11, over 60 percent of the survey respondents disagreed that HOV lanes should be converted to general purpose traffic lanes 24 hours a day. Further analysis of the survey results showed little differentiation by mode choice, with the exception that bus riders disagreed with the statement to a slightly larger extent than the carpool and SOV groups. This higher level of disagreement may simply reveal a stronger support for HOV lanes.

The analysis of this question in relation to their support for HOV lanes showed that the "not favor" group agreed with this statement to a larger extent than the favor group. This level of agreement is reflective of their general lack of support for HOV lane operations. However, this group represented a minority of the sample. In general, the high level of disagreement that HOV lanes should be converted to general purpose lanes reflected a high level of support for continued HOV lane operations.

In conclusion, the responses to the statements identified above indicated a high level of support for HOV lane operations. Overwhelmingly, the sample members, despite their current mode choice (and thus their ability to use the HOV lanes) agreed that HOV lanes are a good idea, agreed that HOV lanes provide a good incentive for encouraging carpooling and riding the bus, and disagreed that HOV lanes should be converted to general purpose lanes. However, despite the high level of support for HOV lanes, there was a pervasive perception that the existing HOV lanes were not being adequately used. This perception, if allowed to continue, could undermine the high level of support for HOV lane operations that currently exists.

FINDINGS BY ISSUE AREA

HOV Lane Placement

HOV lane placement is a critical issue in the I-405 corridor. Current policy allows placement on both sides of the freeway, with the attendant problems of providing connections between sections with different placements and confusion experienced by highway users.

The wording to describe HOV lane placement can be confusing. Although it is standard engineering terminology to call HOV lanes located on the median side of the freeway "inside" lanes and HOV lanes next to the outside shoulder of the freeway "outside" lanes, the focus group process and informal conversations with commuters, revealed a general sense of confusion concerning the terminology "inside" and "outside." Therefore, to eliminate confusion in the public opinion survey, the terms "left-side" and "right-side" were used in place of "inside" and "outside" HOV lanes in questions about HOV lane placement.

Another important point concerning the survey is that two formats were used to obtain information about placement of HOV lanes. Because asking respondents about both left- and right-side placement would have been redundant, and asking respondents about only one option could have biased responses, one survey instrument asked respondents about the ease and safety of left-side HOV lanes and another survey instrument asked respondents about the ease and safety of right-side HOV lanes. To tie the two survey formats together, all respondents were asked about the violation potential of left-side HOV lanes. (As noted in the methodology chapter, three survey formats were used for collection of data, and the assignment of these HOV questions corresponded to the three formats.) All the survey instruments were randomly administered, and thus data collected from one type of survey were not over-represented.

The traffic analysis described in this section used the traffic model described in the methodology section.

Other HOV Operations in North America. A review of the 40 HOV facilities operating on freeways and expressways in North America showed that only 9.3 percent of these HOV lanes were located on the outside (right-side) of the freeway or expressway. Table 12 summarizes the locations that reported the use of outside HOV lanes. (20)

The Turnbull report confirmed that outside placement of HOV lanes on freeways and non-signalized expressways is a fairly uncommon practice. Furthermore, the report indicated that the Puget Sound area contains the only HOV lanes designed for automobiles operating on the outside lanes of a freeway.

The literature review concerning HOV lane placement examined efficiency and safety issues associated with HOV lane access. Highway engineers with the California Department of Transportation (CalTrans) and WSDOT were interviewed about the existence of standards for establishing weave and merge areas for access to HOV lanes. CalTrans engineers said that they are in the process of developing a standard for

Table 12. HOV Lane Placement in North America

LOCATION	NAME OF FREEWAY/EXPRESSWAY FACILITY
San Jose, California	• Montague Expressway — signalized arterial with HOV operations in peak hour only • San Tomas Expressway — signalized arterial with HOV operations in peak hour only • State Route 237 — portion of highway with HOV lanes is a signalized arterial with HOV operations in peak hour only
Seattle, Washington	• State Route 520 — westbound • Interstate 405 — from Sunset Boulevard to Coal Creek Parkway
Vancouver, BC	• Highway 99 — busway that restricts general purpose use

accessing inside HOV lanes that are not served by special access ramps. Their draft policy specifies a 1,000-foot weave or merge area from the freeway on-ramp to the inside HOV lane. (21) California's inside HOV lanes are either separated with a physical, concrete barrier or a buffer area ranging from 2 to 12 feet wide.

Conversations with WSDOT engineers revealed that informal standards exist for establishing freeway on-ramp merge areas with outside HOV lane operations. The minimum distance in which general purpose traffic is allowed to merge from an outside HOV lane into the general purpose lanes is 500 feet. (22) This distance is dependent on factors such as grade and space allowances. The minimum length in which general purpose traffic is allowed to use an outside HOV lane for exiting the freeway is 1,000 feet. General purpose drivers who use the HOV lane for exiting and use it longer than the 1,000-foot limit are in violation of HOV restrictions.

Many variables affect the operation of HOV lanes, and safety is a main concern. The literature review identified weaving, speed variance, and the length of gaps between automobiles as important in assessing the safety of HOV lanes.

Weaving is defined as the crossing of two or more traffic streams while travelling in the same direction along a significant length of roadway without the aid of traffic control devices. (23) A review of the literature about weaving associated with inside HOV lane placement showed that the current analytical tools for weaving analysis are not adequate to address the complexity of the phenomenon. Three publications specifically noted the limitations of the current methodologies, and all three recommended additional research into this subject.

In A Critique of Freeway Weaving and Ramp Operations Analysis Methodologies in the 1985 Highway Capacity Manual, (24) the authors critiqued the Highway Capacity Manual's (HCM's) ability to address what they defined as four common weave patterns. The HCM is the standard reference available to guide engineering design of highway facilities that have weave areas. While a complete critique of weave analyses methods was beyond the scope of this literature review, the fact that the authors found the HCM insufficient is important, since many transportation planning agencies use the Highway Capacity Manual during the facility design process. The authors recommended that additional research into the area of weave analysis be undertaken.

In Analysis of Weaving Areas, (23) the author noted the limitations of existing methodologies to effectively address complex weave patterns. Hausman analyzed seven weaving formulae using eight types of weaving sections and four ramp lengths. Through a technical analysis and comparison, the author noted the strengths and weaknesses of the seven formulae. He concluded by stating that the development of formulae that are sensitive to real world situations needs additional research. He also concluded that the current tools are not capable of addressing the full range of issues associated with weaving analysis.

Trivedi and Schonfeld, authors of Arterial Weaving Analysis, also noted a lack of adequate tools with which to analyze arterial weaving. (25) Arterial weaving differs from freeway weaving because freeway traffic flows are uninterrupted by traffic signals. Furthermore, freeway facilities differ from arterials in aspects such as level of service requirements, configuration, and merge area requirements. In reality, however, the differences between freeway and arterial circumstances may not be so different, since a great deal of peak hour operation of freeway facilities involves heavy volumes and a low level of service. From the authors' analysis, it was clear that additional research into weaving, both on freeways and urban arterials, is required to develop adequate tools.

The following reviews were less directly related to freeway weaving, but they supplement current knowledge about drivers' behavior in situations similar to weaving.

Garber and Gadirau began their article, Speed Variance and Its Influence on Accidents, by stating that an important traffic characteristic influencing safety is speed variance, yet currently little is known about what causes speed variance in the traffic stream. (26) In their analysis, the authors found that accidents increase with speed variance. The authors did not quantify the increase, but confirmed only that the correlation was present. This is an important factor for analysis of traffic weaving associated with an HOV facility.

In Influence of Stopped Gap Delay on Driver Gap Acceptance Behavior, Adebisi and Sama investigated the influence of stopped delay on gap acceptance behavior by drivers executing left-turns. (27) Although the investigation was primarily on minor streets, the findings may be applicable to ramp metering and freeway weaving analysis. The study supported the hypothesis that the duration of stopped delay drivers experience while assessing gaps in the main traffic stream influences their gap acceptance behavior. When there are minimal delays, drivers are relaxed and less sensitive to gaps. However, when the delay exceeds 30 seconds, drivers are more willing to accept shorter gaps. (27) The researchers intended to expand their statistical analysis to behavior in a queuing situation.

The Washington State Freeway HOV System Policy document specifically addressed the issue of inside versus outside HOV lanes and made the following recommendations:

- HOV lanes should be located on the inside when the following conditions exist:
    - trips are predominantly radial from outlying areas to a central business district,
    - freeway trips are long (e.g., greater than 6 miles), and
    - HOV lane volumes are approximately 1,500 vehicles per hour.
- HOV lanes should be located on the outside when the following conditions exist:
    - home to work trip patterns are not serving a single CBD,
    - freeway trips are less than 6 miles,
    - transit trips use almost all freeway on and off ramps for loading and unloading passengers, and

- when HOV lane volumes are approximately 1,100 vehicles per hour.

Weaving Analysis. One way to test the effectiveness of left- versus right-side HOV lanes is to estimate the impact on traffic speeds for both general traffic and HOVs. In the methodology chapter, the approach to conducting this analysis was described.

Three alternatives were tested: (1) HOV lanes on the right side, (2) HOV lanes on the left side with no special access, and (3) HOV lanes on the left side with separation from general traffic and special access ramps to avoid requiring HOVs to weave across the general traffic lanes. Several scenarios were tested. The parameters that varied included

- general traffic demand,
- HOV demand,
- on- and off-ramp volumes for general traffic and HOVs,
- number of general traffic lanes,
- different levels of "friction" between HOV lanes and general traffic lanes, and
- different maximum and minimum speeds.

In all scenarios within reasonable limits, the same general findings emerged.

Figures 2 and 3 show typical results. The x-coordinate is the level of demand per lane in the general traffic lanes. The y-coordinate is the average speed for the type of vehicle indicated. As demand increases, average speed goes down, as would be expected. However, congestion affects general traffic more severely for left-side HOV lanes than for either of the other two alternatives. Surprisingly, for maintaining general traffic speeds, right-side lanes outperform left-side lanes with special access. The reason for this is that right-side HOV lanes act as extended on-ramps that allow general traffic to merge efficiently into congested traffic, at least when HOV lanes are not heavily used.

Until congested conditions are reached, left-side lanes are slightly better than right-side lanes for HOVs, primarily because no general traffic crosses HOV traffic in

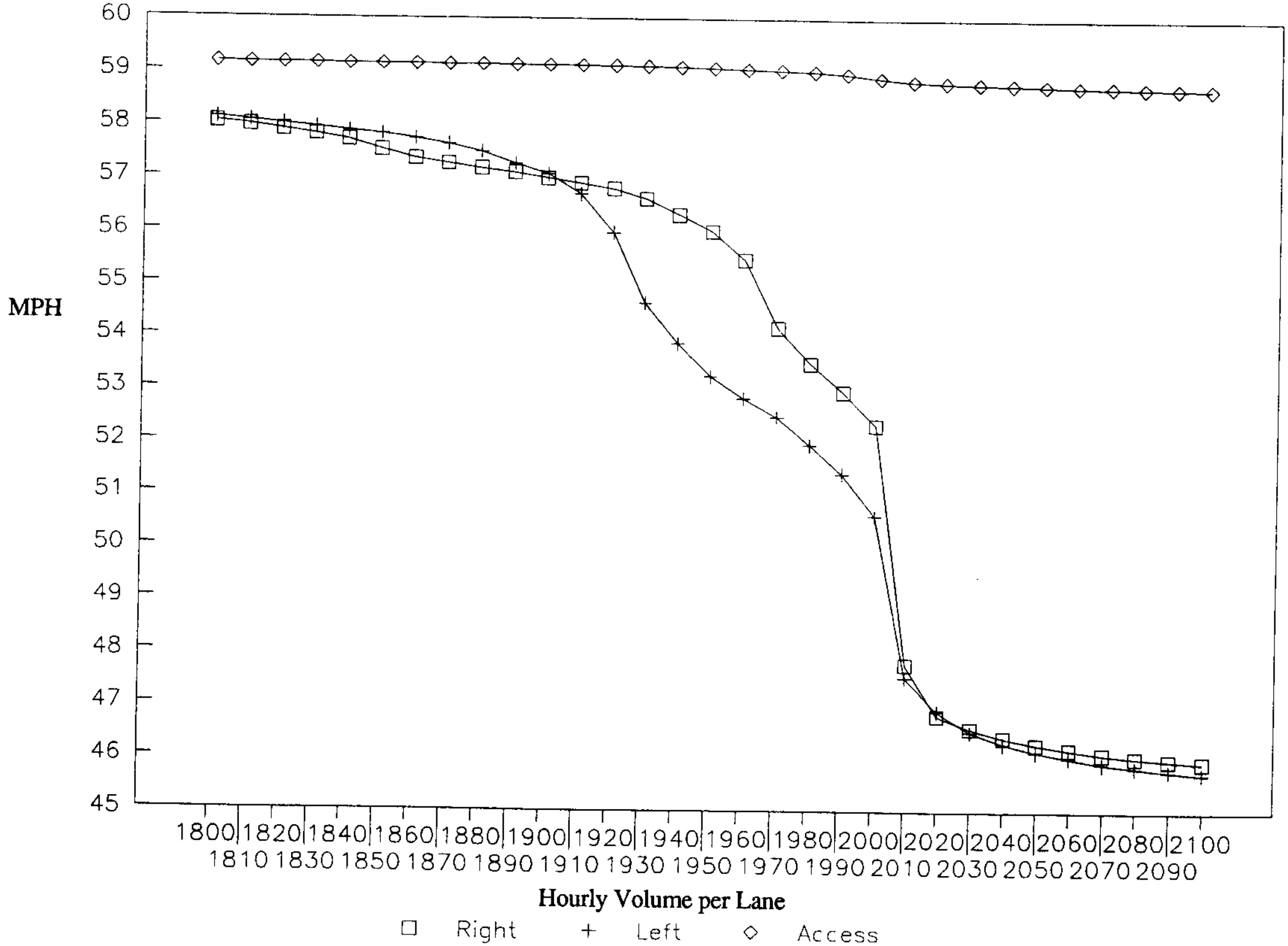

Figure 2. HOV Speeds

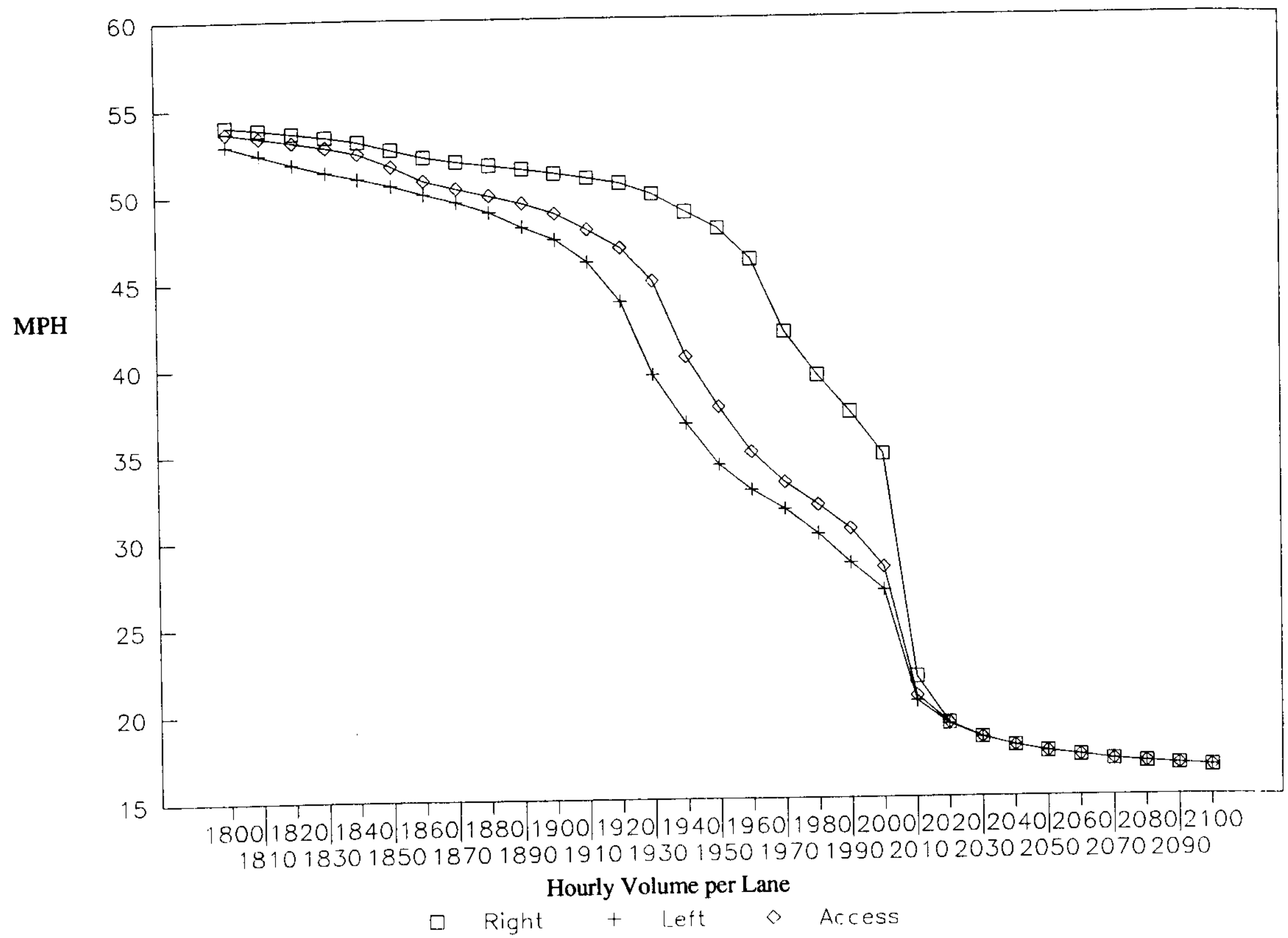

Figure 3. General Traffic Speeds

left-side lanes. HOVs are slowed only slightly when they weave across freely-flowing general traffic lanes. However, under congested conditions, right-side lanes outperform left-side lanes because of the assumed "friction" between the HOV lanes and general traffic lanes. When congestion slows down general traffic, it follows that HOV traffic is slowed down to some extent. The other reason that right-side lanes outperform left-side lanes is that HOVs experience a significant delay when they have to merge across congested general traffic lanes. Obviously, right-side HOV lanes, separated from general traffic, and with special access, are affected only slightly by overall congested conditions.

The current versions of the traffic model assumed that there was no significant congestion on freeway off-ramps. Obviously, if traffic on an off-ramp backs up to the freeway itself, right-side HOV lanes are severely affected. If there are frequent and severe back-ups of off-ramp traffic that cannot be mitigated by reconstructing ramps or retiming signals at intersections on the arterials accessed by the ramps, this problem should be considered a fatal flaw in providing good travel speeds for HOV traffic.

Public Opinion Concerning Lane Placement. The survey used three statements to obtain information about the respondents' perceptions of left-side or right-side HOV lane placement. The statements focused on the ease of accessing the HOV lane, the safety of the HOV lane operation, and the potential for violation. Tables 13 through 17 summarize the findings related to these statements.

As can be seen in Table 13, almost half of the respondents were neutral in their opinions about accessibility of left-side versus right-side HOV lanes. However, according to Table 14, respondents very clearly agreed that right-side HOV lanes are easier to access than left-side.[3] These basic patterns of responses were also observed independent of mode choice. The neutrality of the responses in the first question may

[3] It should be noted here that these two questions were asked of two different sub-samples of the population.

Table 13. ***"Left-side HOV lanes are easier to access than right-side."***

	Agree	Neutral	Disagree
OVERALL	22.5	42.6	31.9
SOV	26.7	44.1	29.2
POOL	27.3	36.4	36.3
BUS	7.1	57.2	35.7
FAVOR HOV	22.7	37.5	39.8
NEUTRAL	17.7	64.6	17.7
NOT FAVOR HOV	77.6	6.1	16.3

See *Methodology* for a definition of the "Favor HOV Lane" groups.

Table 14. ***"Right-side HOV lanes are easier to access than left-side HOV lanes."***

	Agree	Neutral	Disagree
OVERALL	67.1	21.9	11.0
SOV	67.0	22.3	10.7
POOL	63.1	20.0	16.9
BUS	76.4	20.6	2.9
FAVOR HOV	70.2	20.0	9.7
NEUTRAL	44.4	36.1	19.4
NOT FAVOR HOV	48.4	29.0	22.6

See *Methodology* for a definition of the "Favor HOV Lane" groups.

Table 15. ***"Left-side HOV lanes are safer than right-side HOV lanes."***

	Agree	Neutral	Disagree
OVERALL	38.2	30.5	31.3
SOV	37.4	31.5	31.1
POOL	50.0	21.9	28.1
BUS	25.0	34.4	40.6
FAVOR HOV	39.6	29.8	30.6
NEUTRAL	42.9	31.4	25.7
NOT FAVOR HOV	25.0	25.0	50.0

See *Methodology* for a definition of the "Favor HOV Lane" groups.

Table 16. ***"Right-side HOV lanes are safer than left-side HOV lanes."***

	Agree	Neutral	Disagree
OVERALL	28.7	41.9	29.4
SOV	26.5	40.2	33.3
POOL	36.3	45.5	18.2
BUS	28.6	57.1	14.3
FAVOR HOV	30.2	42.2	27.6
NEUTRAL	23.5	52.9	23.6
NOT FAVOR HOV	12.5	25.0	62.5

See *Methodology* for a definition of the "Favor HOV Lane" groups.

Table 17. ***"Violators are more likely to use left-side HOV lanes than right-side HOV lanes."***

	Agree	Neutral	Disagree
OVERALL	41.0	40.9	18.1
SOV	40.4	42.2	18.4
POOL	47.9	35.7	16.4
BUS	31.9	42.6	25.5
FAVOR HOV	43.3	39.5	17.1
NEUTRAL	30.2	52.8	17.0
NOT FAVOR HOV	17.0	48.9	34.0

See *Methodology* for a definition of how the "Favor HOV" were created.

reflect the lack of experience with this type of placement. The responses to the second question undoubtedly reflect a recognition of the fact that left-side HOV lanes involve a weave across general traffic lanes for HOVs. The lack of complementarity of the two questions is somewhat puzzling. However, it is clear that the respondents believe that right-side HOV lanes are easier to access.

A difference in the response pattern was evident between the groups that "favored" and did "not favor" HOV lanes. The "not favor" group believed, to a greater extent than the "favor" group, that left-side HOV lanes are easier to access than right-side HOV lanes. Since these people did not favor HOV lanes, they may have been rating left-side HOV lanes more favorably because they did not want HOV traffic interfering with their merge on and exit off of the freeway.

While respondents generally felt that right-side HOV lanes are easier to access than left-side HOV lanes, they were neutral in their assessment of the relative safety of right-side HOV lanes (see tables 15 and 16). They showed a slight tendency to rate left-side HOV lanes as safer than right-side lanes, especially the poolers. The mixed attitudes about relative safety may have been the result of differential experience with both types of HOV lanes.

The "not favor" group differed from the others' evaluation of the safety of HOV lane placement. In **both** questions, they disagreed with the statement. This probably indicated a general negative view of HOV lanes, especially their safety characteristics. The bus rider group also differed from the general evaluation of the safety of HOV lane placement and tended to rate right-side HOV lanes as the safest placement.

Table 17 shows that respondents tended to believe that violations are more likely to occur with left-side HOV lanes. This was observed most strongly among carpoolers. The "not favor" group differed from the general evaluation with a higher tendency to say that right-side HOV lanes would be more likely to be violated.

Information Obtained from the Focus Groups. The five focus groups had widely different opinions about HOV lane placement. In all instances, the moderator had to initiate the discussion of HOV lane placement, since participants did not bring the issue up on their own. Once the groups began discussing this issue, it was apparent that they could understand the pros and cons associated with both options of HOV lane placement.

The participants from Overlake Hospital thought inside lanes were better than outside lanes because they are easier to use. They thought that traffic that is slowing down to exit or merge interferes too much with outside HOV lane operation.

The Totem Lake Mall Merchants developed very strong views about this issue during the discussion. They thought that outside HOV lanes create bottlenecks where the lanes end and cited SR-520 as an example. Furthermore, they felt that merging and exiting traffic conflicts with outside HOV lane operation. When discussing inside HOV lanes, they did not emphasize these problems. Only a few participants from the Totem Lake Mall Merchants focus group had used the I-5 inside HOV lanes.

The focus group participants from U.S. West Communications were split on the issue of HOV lane placement. They were split on their views of safety for either placement option. They mentioned weaving as a problem with inside lanes and merging and exiting traffic as a problem with outside HOV lanes. Regardless of the problems associated with either placement of HOV lanes, they strongly felt that the placement of HOV lanes should be consistent throughout the Puget Sound region.

The City of Bellevue employees emphasized that right-side HOV lanes conflict with merging and exiting general purpose traffic. Like the Totem Lake Mall Merchants, they noted that a traffic bottleneck is created at the end of an HOV. This group, as at U.S. West, also desired to see HOV lane placement consistent throughout the Puget Sound region.

<u>Information Obtained from the I-405 HOV Lane Symposium</u>. The symposium attendees felt that HOV lane placement is a complex issue that the public does not fully understand or think about on a daily basis. The attendees felt that HOV lane placement should be consistent with land use patterns. The consensus was that right-side HOV lanes should be implemented in areas with less dense land-use patterns (e.g., east King County) and left-side HOV lanes should be implemented in areas with dense land-use patterns (e.g., the I-5 corridor terminating in downtown Seattle).

Even though the attendees felt that HOV lane placement should be consistent within a corridor, they recognized that this may not be possible given variations in roadway configuration and potential for HOV use resulting from land-use patterns. In conclusion, the symposium attendees felt that HOV lane placement should be an evolutionary policy that reflects the relative density of land-use patterns, rather than a static policy.

<u>Summary of Literature Review on HOV Lane Placement</u>. The following section summarizes the benefits and disbenefits associated with HOV lane placement. This information was derived from Turnbull, 1990 (<u>20</u>); Danaher and Markovetz, 1988

(24); Hausman, 1988 (23); Trivedi and Schonfeld, 1988 (25); Garber and Gadirau, 1989 (26); and Adebisi and Sama, 1989. (27)

1. Benefits associated with left-side placement of HOV lanes include

   - limited interference with merging and exiting general purpose freeway traffic,

   - potentially less violation of the HOV lane because SOV drivers would not use the lane for extended merges on and exits off the freeway, and

   - consistency with trip patterns to a large, centralized business district.

2. Disbenefits associated with left-side placement of HOV lanes include

   - the requirement that HOV users weave across general purpose lanes to access HOV lanes, and

   - inconsistency with short freeway trips that use most or all of the freeway exits.

3. Benefits associated with right-side placement of HOV lanes include

   - avoidance of the weave across general purpose freeway lanes that is necessary with the inside placement of HOV lanes,

   - consistency with short freeway trip lengths and freeway transit trips that use on- and off-ramps for loading and unloading passengers, and

   - consistency with dispersed trip patterns going to many work destinations.

4. Disbenefits associated with right-side placement of HOV lanes include

   - a mixture of general purpose traffic and HOV traffic at freeway merge and exit points.

Summary of Findings. The following section summarizes the findings that have been presented in the previous sections.

RIGHT-SIDE HOV LANES

- may offer some advantages to traffic flow by providing the equivalent of an extended on-ramp for merging into congested traffic,

- may run up against a fatal flaw if congestion at off-ramps cannot be kept at a low level,

RIGHT-SIDE HOV LANES (Continued)	•	tend to be seen as more accessible by respondents to the survey, and
	•	are seen by the public as being less subject to violation compared to left-side HOV lanes.
LEFT-SIDE HOV LANES	•	**clearly** offer better traffic operations only when there is special access to avoid the weaving movement across general traffic,
	•	are favored when trips are longer, and
	•	are seen as being slightly safer than right-side HOV lanes.

These findings suggest a general level of support for right-side HOV lanes under current conditions in the I-405 corridor. However, the survey responses about placement of HOV lanes may have been biased by a lack of experience with left-side HOV lanes among the predominantly Eastside sample of commuters. Strategies to decrease the merge and exit conflicts of HOV and general purpose traffic could improve the operation of right-side HOV lanes. Ramp metering with an HOV bypass (discussed in a later section) is one possible strategy to decrease merging conflicts between HOV and general purpose traffic. Strategies to reduce conflicts at off-ramps include redesigning interchanges and arterial signalization improvements.

Special Access to HOV Lanes

This section provides a cost analysis of special access to HOV lanes, information from the public opinion survey, focus group results, I-405 HOV lane symposium comments, and a summary of benefits and disbenefits associated with special access to HOV lanes.

Cost Analysis. It takes little imagination to understand the benefits of special access ramps for HOV lanes. If the requirement that HOVs weave across general traffic to access an HOV lane is removed, conditions are improved for both general traffic and for HOVs. Efficient transit connections allow buses to use the left-side HOV lanes **and** to make frequent stops to pick up passengers. However, the costs to provide special access to HOV lanes are substantial, and the benefits are very difficult to quantify. In this section, both costs and benefits are discussed and compared.

It was beyond the scope of this project to conduct preliminary engineering on special access ramps. However, WSDOT personnel from District One conducted a sketch level analysis of the feasibility and costs of special access ramps at each interchange in the I-405 corridor. Table 18 summarizes the findings. Access for all HOV movements would be possible unless otherwise noted. The major contribution to cost in the I-405 corridor would be the lack of right-of-way in the median of the freeway. At most interchanges, freeway widening would be required. Sometimes this would mean the acquisition of considerable right-of-way on the **outside** of the freeway. Terrain would also be a contributor to the cost side of the equation.

The analysis of costs and benefits described in the methodology section of this paper was used to examine the potential effectiveness of investments in special access ramps for inside HOV lanes. The process was carried out in two steps. In the first step, the computer program was used to estimate the benefit-to-cost ratio, assuming HOV lanes without special separation from general traffic and without special access ramps. The effects of inside versus outside lanes were tested by varying the capacities of HOV lanes and general traffic lanes. Other parameters were also varied to test the robustness of the findings. For the corridor as a whole, the benefit-to-cost ratios were between 10 and 20 when the construction of HOV lanes was compared with doing nothing at all. In the comparison between constructing HOV lanes and adding a general purpose lane, the ratio was between 5 and 10. From a purely cost effectiveness point of view, HOV lanes are justified in the I-405 corridor. The differences in capacities tested for inside and outside HOV lanes did not significantly affect the findings.

In the second step of the cost effectiveness analysis, special access to HOV lanes and barrier separation was studied. The computer software did not lend itself readily to testing this alternative. An attempt was made to modify the software to add this

Table 18. Feasibility and Cost Estimates for Special Access Ramps in the I-405 Corridor

Location	Construction and Feasibility Issues	Estimated Cost
SR5 Tukwila	• Not considered • Complex interactions • Extremely costly to provide directional ramps • Terrain problems • HOV ramp construction should be considered with other work • Widening existing ramps is only feasible solution	Not Applicable
SR181/Interurban Ave.	• Feasibility questionable • Considered access from SR181 on two ramp lanes EB on and off and WB on and off • Must widen interchange and freeway roughly 40 feet per ramp • Probable rebuilding of existing structures	Over $60 M
SR 167	• Widen south and west of interchange • Expensive flyover ramps • Terrain problems in SE quadrant	$60-80 M
SR169/Maple Valley Road	• Feasibility highly questionable • Must widen freeway to accommodate ramps • Encroachment on Renton aquifer and park	Not Applicable
SR900/Sunset Blvd.	• Inside ramps from Sunset to NB and SB I-405 north of Sunset only • Terrain difficulties • Widen I-405 top accommodate ramps • Replace structures	$40 M
SR900/NE Park Dr.	• Difficult terrain problems • Steep Hill north and west • Considerable wall work required • Inside HOV ramps from SR900 to freeway requires interchange widening • Replace existing structures over Park	$60-80 M
NE 30th	• Access for all movements • Widen NE 30th bridge • Increase structure to accommodate existing flyer stop	$30-40 M
NE 44th	• Access for all movements • Bridge to be replaced • Interchange to be widened	$40-50 M

Table 18. Feasibility and Cost Estimates for Special Access Ramps in the I-405 Corridor (Continued)

Location	Construction and Feasibility Issues	Estimated Cost
112th SE	• Access for all movements • Terrain problems with steep side hill • Replace 112th Ave. bridge	$35-45 M
Coal Creek Pkwy.	• Terrain problems with side hill and hill to north • Access for all movements • Replace bridges over Coal Creek Pkwy. • Widen interchanges • Extensive use of walls	$40-50 M
Factoria	• Part of future study • Alternatives for freeway to freeway HOV access difficult to identify	More than $100 M
SE 8th	• Access for all movements • Some terrain problems • Widen freeway at interchange and north • Replace bridges over SE 8th	$40-50 M
NE 4th	• Existing HOV ramp for outside HOV lane • Widen and completely rebuild interchange	More than $50 M
NE 8th	• Feasible only with separation of EB and WB traffic to new bridge crossing • Limited HOV access to center lanes possible • Interchange widening • Structure replacement	$40-50 M
SR520	• Part of freeway to freeway HOV study • Directional ramps very expensive	$80-100 M
NE 70th	• Terrain problems — side hill • Access to all movements • Replace NE 70th bridge	$40-50 M
NE 85th/SR908	• Access to all movements • Widen interchange • Replace two mainline bridges	$35-45 M
NE 116th	• Access to all movements • Replace bridges • Widen interchange • Modifications at NE 124th interchange	$40-50 M

Table 18. Feasibility and Cost Estimates for Special Access Ramps in the I-405 Corridor (Continued)

Location	Construction and Feasibility Issues	Estimated Cost
NE 124th	• Not feasible because of skew and interchange configuration	Not applicable
NE 132nd	• Access to all movements • Replace bridge • Relocate flyer stop	$35-45 M
NE 160th	• Terrain problems • Skew problems • Access to all movements • Replace bridge • Widen interchange	$45-55 M
SR522	• Part of freeway to freeway HOV study • Directional ramps very expensive	Not applicable
NE 195th	• Access to all movements • Replace bridge	$35-45 M
SR527	• Access to all movements • Widen interchange • Replace bridge and widen	$40-50 M
Swamp Creek	• Part of freeway to freeway HOV study • Directional ramps very expensive	Not applicable

alternative; however, it was clear that a very different modeling approach was required for this analysis.

A critical issue in analyzing the addition of special access ramps is travel time savings for the vehicles that actually use the ramps. For those vehicles, the savings can be significant. Estimates of this part of the overall travel time savings depends heavily on local conditions, and each location needs to be analyzed separately. The impacts on other traffic can be estimated and accounted for by adjusting the capacity of the general purpose and HOV lanes. The influence of special access ramps and barrier separation on mode choice is also heavily influenced by local conditions and depends to a great extent on the completeness of an HOV system. On the cost side of the equation, preliminary engineering is required to provide reliable estimates of construction costs.

For all these reasons, it was beyond the scope of this project to provide quantitative estimates of benefit-to-cost ratios for specific special access ramps or barrier separation of HOV lanes. However, some general guidelines for conducting such studies can be provided. In the analysis of HOV facility cost effectiveness, the **major** benefit is travel time savings. Other benefits include more efficient vehicle operation and shared costs resulting from modal shifts. However, an approach to prioritizing special access ramps and barrier separation that employed only travel time savings would produce useful information.

Travel time savings over the life of a structure should be considered. However, the value of the time savings should be discounted in making a decision for a current investment. Two types of travel times savings should be considered: (1) direct savings for people in vehicles using the ramps, and (2) savings accruing to people in vehicles that travel faster because weaving, merging, and exiting movements have been avoided.

An example will illustrate the approach. Suppose that a special access ramp for HOVs is to be constructed at an existing interchange near a park and ride lot. The analysis would employ the following steps:

- Twenty-five buses, carrying an average of 50 people will use the ramp on weekdays. The ramp will save 4 minutes in access time to the freeway and an additional 3 minutes on the freeway because the HOV lane can be used to go to the next bus stop. Total daily travel time reduction will be 8,750 minutes.

- 2,200 carpools and vanpools using the crossing arterial, carrying an average of 2.8 people, will use the ramp daily, saving 5 minutes access time to the freeway for each person and an additional minute on the freeway by avoiding weaving across general traffic. Total daily travel time reduction will be 36,960 minutes.

- 40,000 vehicles going by the intersection during the two peak periods each day, carrying an average of 1.15 people, will save an average of 1.5 minutes as a result of avoiding weaving movements by HOVs. Total daily travel time reduction will be 69,000 minutes.

- The total travel time saved each weekday will be 114,710 minutes.

- If travel time is valued at $7 per hour, the total savings will be about $13,400 per day.

- Considering only work days, this will constitute a savings of about $3.35 million per year.

- If this savings is extended over a 40-year life cycle of the ramp with a 4 percent discount rate, the total savings will be about $69 million.

The figure resulting from such a calculation can be compared with the current marginal costs of adding special access ramps at this intersection. Note that this analysis **does not** include the general benefits from additional modal shift generated by the travel time savings.

Literature Review. The literature review revealed that many jurisdictions have chosen to construct HOV facilities using special access ramps for accessing left side HOV lanes. In Houston, Texas, special access ramps are used on the Katy and North HOV transitways. These HOV facilities are separated from general purpose traffic by a physical barrier and flow concurrently with peak hour traffic.

Diagrams and cost estimates for constructing special access ramps to HOV lanes were obtained from the Texas Transportation Institute. A copy of a diagram depicting the configuration of these special access ramps is presented in Appendix E. The cost for constructing a "Texas T Ramp" is on the order of $2.5 to $3.5 million. (28) Actual time savings data were not available from the Texas Transportation Institute; however, it was estimated to be three to five minutes. (28)

Because safety is a major concern of HOV facilities, Safety of HOV Facilities Without Physical Separation, by Thomas Golob, was reviewed to assess the safety improvement potential of special access ramps with barrier separated HOV facilities. (29) This study examined the safety issues associated with the operation of freeway high-occupancy vehicle lanes that are not separated by physical barriers from the adjacent general purpose freeway traffic. Data were collected during 14 months of HOV lane operation in the Los Angeles area and compared with data that had been collected over the preceding six-year period. The author found that there were no adverse safety impacts associated with non-separated HOV lane operation. (30) The author noted that while the total number of accidents did not differ at a statistically significant level, accident location patterns migrated in association with the combination of congestion relief and more severe traffic bottlenecks downstream of the HOV project. While the HOV lane operations did not decrease safety, the migration of accidents illustrated the need to consider the corridor-long impacts of HOV operations.

Public Opinion Survey. In this study's survey, special access to HOV lanes was defined as the use of special ramps from local arterials or park-and-ride lots to left-side HOV lanes. Only one statement assessed opinions about special access ramps to HOV lanes. The decision to limit the questions was based on pre-testing of the survey in two focus groups. Focus group participants had difficulty understanding the concept of special access ramps to HOV lanes. The statements that were pre-tested required lengthy explanations by the group moderator. Since this explanation would not have been possible during the administration of the survey, these questions were not used on the final survey instrument. In addition, comments from the technical review committee suggested the elimination of the statements because of the confusing nature of the issue. The statement that was used on the final survey instrument focused on special access

Table 19. *"Special access ramps for HOV users from park and ride lots and arterials to freeway HOV lanes could attract a lot more HOV users."*

	Agree	Neutral	Disagree
OVERALL	54.0	34.4	11.6
SOV	51.7	34.5	13.0
POOL	66.7	32.3	1.0
BUS	58.4	33.3	8.3
FAVOR HOV	60.6	31.4	8.0
NEUTRAL	23.3	55.8	20.9
NOT FAVOR HOV	60.0	16.9	23.1

See *Methodology* for a definition of "favor" or HOV lanes.

ramps as a means of attracting more HOV lanes users by providing these HOV users with a time savings advantage over SOV travel.

As can be seen in Table 19, over half of the survey respondents agreed that special access ramps could attract more HOV users and that special access ramps could be an effective means of providing additional benefits and incentives to people who carpool and ride the bus. The analysis of the survey respondents by mode choice showed that the carpoolers agreed with this statement to a somewhat larger extent than both the SOV drivers and the bus riders. This attitude may have resulted from their direct experience with conflicts on on-ramps that mixed HOV and general purpose traffic.

The analysis of the survey respondents according to their attitudes toward HOV lanes shows a high level of support for special access ramps, even among those who did not favor HOV lanes in general. The results of these analyses, showed that the public is supportive of the development of special access ramps to HOV lanes.

Focus Groups. Focus group participants did not initiate discussion about special access ramps to HOV lanes. However, once the discussion started, the participants indicated that they were supportive of the concept of special access ramps to HOV lanes and felt that special access ramps would provide a substantial time savings advantage capable of attracting new HOV users.

I-405 HOV Lane Symposium. The symposium attendees were supportive of the concept of special access ramps to HOV lanes. An important point made by the symposium attendees was that special access ramps are facilities that can be implemented incrementally over time. Furthermore, special access ramps can be added to the freeway system after the construction of the HOV lanes has been completed. Therefore, ramps do not necessarily have to be implemented at the same time as HOV lanes or support facilities such as park and ride lots as constructed. The ability to add special access ramps after the construction of the HOV facilities illustrates the flexibility of this approach.

Benefits and Disbenefits Associated with Special Access Ramps. The following section summarizes the benefits and disbenefits associated with HOV lane placement. This information resulted from a review of the following literature: Fuhs, 1990 (31); Texas Transportation Institute, 1990 (28); CalTrans, 1990 (21); WSDOT, 1990. (32)

1. Benefits Associated with Special Access Ramps include
    - allowance for increased time savings for HOV lane users,
    - elimination of the problem of weaving across general purpose traffic to access the inside HOV lane, and
    - near elimination of violations by non-HOV traffic, if used with a physically separated HOV lane.
2. Disbenefits Associated with Special Access Ramps include
    - cost of construction, and
    - difficulty in construction of ramps because of site limitations.

Summary of Findings. The analysis of the cost effectiveness of special access ramps and barrier separation requires detailed knowledge of the feasibility and cost of construction at each potential site. However, the potential time saving appears to be substantial and could justify even a major capital investment at most sites.

The public opinion survey results indicated a high level of public support for special access ramps as a means of providing incentives to people who rideshare. This high level of support was observed even if the respondents did not rideshare, and regardless of whether the respondents favored HOV lanes. The survey findings also showed that carpoolers support special access ramps to a larger extent than SOV drivers and bus riders, likely owing to the fact that they operate a vehicle (or participate as a passenger in a vehicle) when using the HOV lane. The high level of support from non-HOV users indicated a high level of support for HOV lane treatments and operations.

Furthermore, as noted by the symposium attendees, special access ramps can be implemented over a period of years, and thus constitute a flexible tool that can be implemented as HOV lane volumes and available resources warrant.

Ramp Metering and Ramp Metering with HOV Bypass

This section provides information obtained from the summary of HOV operations in north America, the public opinion survey, the focus group process, and the I-405 HOV lane symposium. It concludes with a summary of benefits and disbenefits and an overall summary of findings.

In this discussion, ramp metering is defined as the use of traffic lights at freeway on-ramps to "meter" traffic onto the freeway. The purpose of the ramp metering system is to break up large blocks of traffic into a steady flow of traffic that is fed at a regular rate onto the freeway. (33) In many cases, ramp meters incorporate HOV bypasses into the operation, entitling people using HOVs to bypass the wait at the ramp meter and directly access the freeway. The HOV bypass is implemented as a means of providing a time savings advantage to HOV users. While ramp meters are very effective in smoothing out freeway bottlenecks, negative effects can result, including excessive queuing of traffic onto local surface streets and the diversion of freeway traffic onto local streets and arterials.

Summary of HOV Operations in North America. The literature review focused on collecting data about the effectiveness of ramp metering systems and the potential negative effects of queuing and the diversion of freeway traffic to local streets and arterials. Five publications were reviewed and are summarized below.

Currently, 26 ramp metering systems are operating or being implemented in the United States. These range in size from a single ramp meter to systems with more than 50 metered ramps. The larger ramp metering systems are primarily being implemented in large urban areas with deteriorating traffic conditions. The map of the ramp metering systems in North America is shown in Appendix F.

For the most part, ramp metering has been successful at decreasing freeway travel times, increasing freeway travel speeds, decreasing accidents, and decreasing fuel consumption and related emissions and pollutants. Table 20 summarizes the effects of ramp metering in different cities in the United States. (33)

Table 20. Summary of Ramp Metering Benefits in the United States

LOCATION	DECREASE TRAVEL TIMES	INCREASE TRAVEL SPEEDS	DECREASE ACCIDENTS	DECREASE FUEL USE
Denver, CO	37%	57%	5%	*
Detroit, MI	*	8%	50%	*
Long Island, NY	20%	16%	*	6.70%
Portland, OR	*	*	43%	540 gallons/day
Seattle, WA	48%	*	*	*

An asterisk (*) indicates that no information was reported for that variable.

In Ramp Metering: Does it Really Work?, Portland, Minneapolis, Seattle, and Austin were used as examples. The author concluded that ramp metering has proven to be a cost effective technique for increasing the available capacity of urban freeways and allowing active management of the freeway situation. (34) While ramp metering is considered effective, it is not a cure-all. The authors noted that ramp metering is usually implemented as part of a transportation system management strategy or plan. Additionally, for ramp metering to be successful, the implementing agencies must work with the local jurisdictions and residents to establish goals and limits of queueing and diversion, which should also include policies that pre-empt metering when queues overflow onto local streets.

In Metering Freeway Access, the author noted six benefits associated with ramp metering. (33)

1. Minimizes aggregate objective function such as total travel time to all freeway users.
2. Produces efficient use of the total capacity in a freeway corridor.
3. Discourages paths with high societal costs, e.g., short freeway trips.
4. Introduces order into the path-selection and jockeying of commuters.
5. Reduces the variance in trip times within a freeway corridor.
6. Generally, is publicly and politically acceptable.

In this article, the author also noted four disbenefits associated with ramp metering.

1. Encourages longer trips — actually favors longer trips and outlying commuters because they never have to wait at a ramp meter.
2. Transfers land values because ramp meters make accessing the freeway more difficult for people who live close-in and, alternatively, it makes accessing and using the freeway easier for people who live in outlying areas.
3. Favors through traffic because local users are metered off the freeway and encounter greater delays than non-local freeway users.
4. There are monetary costs associated with the implementation of a ramp metering system.

In another article, the same author stated that a major factor in determining whether to implement ramp metering is the effect of the facility on traffic flows, queueing, and delays. In Predicting the Impacts of Freeway Ramp Metering on Local Street Flows and Queues, the author suggested that CORQ and CORQ2 are effective means of modelling these traffic concerns. (35) The author concluded by noting that each freeway ramp meter control proposal needs to be evaluated on its own merits. There are no simple guidelines about whether to meter an on-ramp. While drivers favor rational controls, the benefits of ramp metering should not be overstated.

Freeway Metering Effects in Denver (36) detailed the success of a ramp metering demonstration project in Denver, Colorado. Ramp metering was implemented in the Denver urban area to decrease recurrent stop-and-go congestion on the freeway mainline, improve the average travel speed of the freeway mainline traffic, decrease side-swipe and rear-end vehicular accidents, and decrease auto emissions. These goals were to be accomplished while only 420 to 480 vehicles per hour were diverted off the freeway mainline and onto surface streets and arterials.

This demonstration project yielded five significant results:

1. travel speeds increased by 58 percent in the demonstration area;
2. travel speeds in the entire corridor increased by 23 percent;
3. ramp volumes decreased 200 to 300 vehicles per hour, while corridor volume increased from 6,200 to 6,490 vehicles per hour;
4. arterial traffic increased from 100 to 400 vehicles per hour without degrading the pre-project level of service; and
5. peaks of arriving motorists at freeway on-ramps spread out to avoid waiting at the meter.

The spread of peak hour use of the metered ramps resulted in a more efficient use of the freeway ramp. Before the metering project 54 percent of the 6:30 a.m. to 8:30 a.m. peak traffic arrived at a freeway on-ramp between 7 a.m. and 8 a.m.; after metering, only 49 percent of the morning peak traffic arrived between 7 a.m. and 8 a.m. This change represented a 5 percent decrease in peak hour use of the freeway ramp, and thus a more efficient use of the ramp. With ramp metering, Denver officials found that one lane of freeway could handle 22.5 percent more traffic than originally planned for. Furthermore, the system coordination plan worked well and was not difficult to implement.

While the benefits of ramp metering are not disputed, two publications were reviewed that cited the limitations of ramp metering. In The Choice Between Ramp Metering and HOV Lanes, the author concluded that ramp metering and HOV lanes are generally mutually exclusive of one another as transportation management strategies. If ramp metering is successful in keeping traffic flowing freely, there is no travel time advantage for the HOV lanes. (37) The author noted that ramp metering and HOV lanes have different requirements for success. For example, ramp metering is preferable in situations where excess traffic demand can be accommodated in queue storage on the on-ramps and/or diverted to adjacent arterials, whereas HOV lanes are preferable if traffic demand exceeds capacity and if land use conditions are favorable to carpool formation and express bus service. The author concluded by stating that both transportation management strategies need to be understood so that logical decisions concerning the choice between ramp metering and HOV lanes can be based on the unique conditions of the facility.

Limitations of the effectiveness of ramp metering were also noted in the Effects of Ramp Metering and Carpool Bypass Lanes on Vehicle Occupancy — Sacramento, California — US Highway 50. (38) In this publication, the authors examined the effectiveness of bypass lanes for HOVs at metered freeway on-ramps in attracting carpoolers and thus increasing average vehicle occupancy at these metered ramps. While the data did show that some changes resulted from the implementation of ramp meters with HOV bypasses, the authors concluded that, at the time of the study, the volumes and delays were so nominal that the time savings for carpools in the HOV bypass lane did not provide enough of an incentive for people to change modes. The authors noted that if congestion were to increase on SR 50, then time savings associated with the HOV bypass at the metered ramp might provide a greater incentive to carpool.

Speed Variance and Its Influence on Accidents and the Influence of Stopped Gap Delay on Driver Gap Acceptance Behavior were reviewed because of their indirect relationship with ramp metering operations. In Speed Variance and Its Influence on Accidents, (26) the goal of the research was not directly related to ramp metering. However, the research yielded a finding that may be applicable to ramp metering. The authors found the following:

- drivers tend to increase speed as the road geometrics improve, regardless of the posted speed limit;
- accident rates do not necessarily increase with an increase in average speed; and
- accidents increase with an increase in speed variance.

The authors did not state by how much accidents increase, only that the correlation was present. This could potentially be an important finding when planners accommodate for traffic entering or exiting an HOV facility.

In the Influence of Stopped Gap Delay on Driver Gap Acceptance Behavior, (27) the author investigated the behavior by drivers executing left-turns. Although the investigation was primarily on minor streets, the findings may be applicable to ramp metering. The author found that when there were minimal delays in making a left-hand turn, the drivers were relaxed and less sensitive to gaps. However, when the delay exceeded 30 seconds, the drivers were more willing to accept shorter gaps than normal. These findings indirectly support the use of ramp meters, since the purpose of ramp meters is to decrease the unpredictability of freeway access by metering and regulating the flow of traffic onto the freeway.

The Washington State Freeway HOV System Policy document incorporated a fairly extensive section on ramp metering with HOV bypasses. (32) This reflects a belief that ramp metering is an effective transportation system management tool. It also reflects the fact that ramp metering with HOV bypasses can be an effective tool for encouraging and rewarding those who travel in an HOV. The draft policies state the following:

- Ramp metering should be implemented where freeway speeds are regularly less than 50 mph for at least one-half hour during a peak commute period.
- HOV bypasses should be constructed when ramp meters are installed.

Public Opinion Survey. The survey used three statements to obtain information about public perceptions of ramp metering. The first statement was designed to obtain information about perceptions of the effectiveness of ramp metering in increasing freeway travel speeds for all freeway users. The second statement focused on perceptions of the time spent waiting at the ramp meter versus the potential for faster freeway travel times. The final statement concerned the effectiveness of HOV bypasses at ramp meters as a means of attracting more HOV users.

Table 21 shows that the largest proportion of the survey respondents were neutral in their assessment of whether ramp metering increases freeway travel speeds for all freeway users. However, among those who expressed an opinion, the tendency was to agree that ramp metering is effective at increasing travel speeds for all users. The analysis of the survey respondents by mode choice and degree of support for HOV lanes did not indicate significant differences among the groups. The neutrality of responses could have been a result of a lack of knowledge about the effectiveness of ramp metering, stemming from a lack of experience with ramp meters on I-405 and west-bound State Route 520. The high percentage of people who were neutral to **both** HOV lanes and this statement probably was the product of a response bias pattern.

According to Table 22, the response patterns to the second question were very similar to the previous one. There was a general tendency to be neutral, but those who expressed an opinion tended to agree that waiting at a ramp meter was justified because of improved freeway operations.

Table 21. *"Ramp metering increases freeway travel speeds for all users."*

	Agree	Neutral	Disagree
OVERALL	39.7	45.0	15.3
SOV	39.9	45.2	14.9
POOL	42.5	40.4	17.1
BUS	27.1	54.1	18.8
FAVOR HOV	43.3	43.6	13.1
NEUTRAL	16.3	65.0	18.7
NOT FAVOR HOV	43.7	31.3	25.0

See *Methodology* for a definition of how the favor group was developed.

Table 22. *"Faster travel times on the freeway make up for waiting at the ramp meter."*

	Agree	Neutral	Disagree
OVERALL	36.9	45.2	17.9
SOV	37.5	45.6	16.9
POOL	33.6	41.9	24.5
BUS	34.0	46.9	19.1
FAVOR HOV	45.1	25.8	29.1
NEUTRAL	23.3	55.7	21.0
NOT FAVOR HOV	45.1	25.8	29.1

See *Methodology* for a definition of how the favor HOV lane groups were developed.

In Table 23, a more revealing pattern of responses is observed than in the two previous statements. There was a stronger tendency for respondent to agree that HOV bypasses at ramp meters are a good incentive for increasing the use of HOVs. This agreement indicated support for freeway treatments that provide incentives and rewards to HOV users. In the analysis of the survey respondents by mode choice, no significant differences were observed among the three groups. However, there was a tendency for transit users to affirm the effectiveness of HOV bypass lanes as modal shift incentives.

Analysis of the survey respondents by degree of HOV lane support showed that the majority of the "favor" group agreed with this statement, while the majority of the "not favor" group disagreed. The "not favor" group's disagreement with this statement reflected this group's lack of support for HOV lanes, and therefore their lack of support for freeway treatments that benefit HOV users. It is important to remember that this group was in the minority.

Table 23. ***"Ramp metering with an HOV bypass is a good incentive to use the bus or car/vanpool."***

	Agree	Neutral	Disagree
OVERALL	45.2	39.5	15.3
SOV	44.3	39.8	15.9
POOL	47.0	34.7	18.3
BUS	55.3	34.0	10.7
FAVOR HOV	50.9	38.2	10.9
NEUTRAL	16.3	55.8	27.9
NOT FAVOR HOV	6.5	32.3	61.2

See *Methodology* for an explanation of the "favor" HOV lanes variable.

In conclusion, responses to these three statements indicated substantial support for ramp meters with HOV bypasses at freeway on-ramps. However, it was also clear that a substantial number of people on the Eastside have no strong opinions about the efficacy of such measures. This finding indicates the necessity of conducting public education when such measures are implemented.

Focus Group. For the most part, the focus groups had little to say about the ramp metering issue. The U.S. West Communications group was the only group to directly discuss the preferential treatment of HOVs. They noted that people using HOVs should be given as many incentives as possible. They noted the following incentives for HOV users: priority scheduling of traffic lights (they did not mention ramp metering per se), free turns at intersections, and preferential access to HOV lanes from park and ride lots.

I-405 HOV Lane Symposium. The symposium attendees observed that ramp meters are an effective strategy for managing freeway congestion and expressed the opinion that ramp meters and HOV bypasses should be implemented wherever possible. They concluded that successful ramp metering programs require agencies to monitor ramp meter operations continuously, adjust ramp meter operations as necessary, and work with local jurisdictions to prevent unacceptable ramp overflows.

Benefits and Disbenefits Associated with Ramp Metering and Ramp Metering with HOV Bypass. The results of the literature review and the analysis of public opinions about ramp metering suggests the following benefits and disbenefits associated with this issue.

1. Benefits Associated with Ramp Metering and Ramp Metering with HOV Bypass include

- decrease in traffic queuing at freeway on-ramp merge points,
- decrease in freeway travel times for all freeway users,
- more efficient use of the freeway,
- encouragement of shift to HOV modes,

- decrease in freeway trips with high societal costs (e.g., short freeway trips that could be better served by surface streets and arterials),

- reduction in variance of freeway trip times because of smoothed access onto the freeway and broken up traffic congestion bottlenecks, and

- smoothed peak hour use of freeway on-ramps because of encouragement for people to use the ramp earlier or later than prime peak times.

2. Disbenefits Associated with Ramp Metering and Ramp Metering with HOV Bypass include

- negative impacts on those who are metered off the freeway at the on-ramp,

- encouragement of longer freeway trips at the expense of shorter freeway trips, thus affecting urban land values,

- artificial alteration of natural behavior patterns and expectations, and

- possible high monetary costs.

Summary of Findings. The literature review highlighted the effectiveness of ramp metering systems in decreasing freeway travel times, increasing freeway travel speeds, and decreasing accidents associated with merging onto a freeway. The public opinion survey results indicated a high level of neutrality about, but substantial support for, the ability of ramp meters to increase freeway travel speeds and decrease freeway travel times. Respondents tended to support the concept of HOV bypasses at metered freeway on-ramps as a means of providing an incentive and benefit to HOV users. Almost half of the respondents agreed that HOV bypasses at metered ramps were a good method for rewarding and encouraging HOV use. This agreement was also indicative of a high level of support for HOV lane policies and operations.

Carpool Definition

This section contains a discussion of carpool definition based on an examination of HOV lane operations in North America, current traffic counts, information obtained from the public opinion survey, focus group comments, and discussion at the I-405 HOV

Lane symposium. The section concludes with a summary of the benefits and disbenefits of different carpool definitions and a general summary of the findings.

Carpool definition is an important consideration when HOV lanes are implemented because it controls the number of vehicles that qualify to use an HOV lane. While encouragement of HOV use is the primary goal of the HOV lane program, this must be balanced with the objective of maintaining a level of service that assures substantial time savings over the general purpose lanes.

Travel time savings is diminished when too many vehicles use the HOV lane. When this occurs, it may be necessary to increase the number of required occupants. However, if the carpool definition is too high, then fewer vehicles will be eligible to use the HOV lane and the facility will be appear to be under-used. Because public perceptions of HOV lane use have the potential to affect public support for HOV lane programs, the issue of carpool definition is an important one.

HOV Operations in North America. The literature review included the identification of trends in HOV definition in North America. A recent survey of HOV facilities showed that of the 40 different HOV facilities operating on freeways, (20)

- 43 percent have a two-plus person definition,
- 33 percent have a three-plus person definition,
- 23 percent are for buses only, and
- only one facility reported a dual definition of two-plus person in the off-peak hours and a three-plus person definition during peak commute hours.

The Washington State Freeway HOV System Policy document addressed the issue of carpool definition. The draft policies recommended that

- HOV lanes should provide at least one minute per mile travel time savings with a total of at least five minutes for HOV lanes users (AASHTO Standard),
- the "Empty Lane Syndrome" can be avoided by limiting the maximum gap between HOVs to 20 seconds,

- specific HOV facility definitions should be established through an operational analysis, and
- a 2+ carpool definition is more appropriate in areas with widely dispersed trip patterns and low employment and residential densities.

Current Occupancy Rates. Auto occupancy rates were monitored in both directions and in both peak periods on I-405 at 8th SE and at Kennydale from fall of 1989 through the summer of 1990. Table 24 shows the equivalent hourly volumes for different occupant vehicles during the highest half hour period. Even at the most highly used parts of I-405, the levels of demand indicated that a 2+ definition for carpools allows sufficient capacity in the HOV lane. However, volumes could increase dramatically over time with the successful implementation of TDM strategies in the corridor. A shift to a 3+ definition in the future might be warranted, but is not currently indicated.

Public Opinion Survey. The survey instrument included three statements to obtain information about carpool definition, potential for HOV lane congestion, and potential public support for increasing HOV definition in relation to HOV lane congestion.

Table 25 shows that nearly 80 percent of the respondents agreed that carpool definition should be two-plus. The analysis of the survey respondents by mode choice showed that the bus riders contained a lower proportion of respondents agreeing with this statement than the SOV and POOL groups. This finding showed that transit riders saw the advantage of keeping the HOV lane available for bus use. This response pattern could also have resulted from the fact that these people did not have to find and coordinate carpool members, and thus were unaware of the difficulties in establishing three-person carpools.

The analysis of the survey respondents by their attitude toward HOV lanes showed a slight tendency for people who favored HOV lanes to also favor a two-plus

Table 24. Traffic Volume by Occupancy

Location	Total	2+	3+
8th SE inbound	4402	483	56
8th SE outbound	5520	984	116
Kennydale	3887	602	165

Table 25. ***"Minimum vehicle occupancy for using all HOV lanes should be 2 people to allow more carpools to use the HOV lanes."***

	Agree	Neutral	Disagree
OVERALL	77.6	13.7	8.7
SOV	78.6	12.8	8.6
POOL	79.2	16.8	4.0
BUS	59.0	20.5	20.5
FAVOR HOV	76.7	11.5	11.8
NEUTRAL	64.2	28.6	7.2
NOT FAVOR HOV	66.6	10.0	23.4

See *Methodology* for a definition of the favor of HOV lane groups.

definition. However, the lower level of agreement by the "neutral" and "not favor HOV" groups can be explained by response biases. People who felt neutral about HOV lanes had a high tendency to respond "neutrally" to all questions. People who were not in favor of HOV lanes had a tendency to disagree with anything having to do with HOV lanes.

In sum, the high level of agreement with this statement was probably either related to a general feeling that HOV lanes were not being fully used, or that the definition currently used on I-405 was adequate.

As shown in Table 26, nearly half of the respondents disagreed that HOV lanes could become congested with a two-plus person carpool definition. The analysis of the respondents by mode choice did not reveal any differences between the response patterns of these groups. The analysis according to attitudes toward HOV lanes showed that the "not favor" group disagreed to a larger extent than the "favor" group that HOV lanes could be congested with a two-person carpool definition. The latter finding may simply illustrate the negative response pattern of those who did not favor HOV lanes. However, the fact that so many people could not imagine the possibility of congestion being created with a two-plus definition challenged transportation officials to provide good information on HOV lane use and to pay attention to public education concerning these matters.

According to Table 27, about half of the survey respondents agreed that the public would accept raising the carpool definition if the HOV lanes were to become congested. The analysis of the survey respondents by mode choice did not reveal any differences in these groups' response patterns. The slight differences observed in analysis by attitudes toward HOV lanes were probably a result of response biases.

In general, these responses to this question indicated public support for flexible policies in dealing with HOV lane carpool designation policies. The respondents agreed that if the lanes were to become congested, then an increase in the carpool definition would be acceptable. However, in light of previous finding that respondents did not perceive the HOV lanes to be fully used, it is likely that many people felt that this event was in far in the future.

Focus Groups. For the most part, the focus group participants favored a two-plus person carpool definition rather than a three-person definition. The U.S. West group was the only one that felt that the carpool definition should reflect the volume of use. The participants from Overlake Hospital thought that a two-plus person carpool designation was probably going to be more effective in attracting carpoolers than a three-plus

Table 26. ***"HOV lanes could become congested with a 2-person HOV designation."***

	Agree	Neutral	Disagree
OVERALL	23.4	31.4	45.2
SOV	22.4	31.7	45.9
POOL	28.3	25.3	46.5
BUS	26.8	34.1	39.1
FAVOR HOV	21.3	27.3	51.4
NEUTRAL	11.9	40.5	47.6
NOT FAVOR HOV	13.3	23.3	63.4

See *Methodology* for a definition of how the favor groups were created.

Table 27. ***"If HOV lanes became congested, changing the HOV lane requirement from 2 to 3 people would not be difficult for people to accept."***

	Agree	Neutral	Disagree
OVERALL	50.9	24.0	25.1
SOV	50.5	24.9	24.6
POOL	53.5	20.8	25.7
BUS	54.6	22.7	22.7
FAVOR HOV	59.7	17.0	23.3
NEUTRAL	41.9	37.2	20.9
NOT FAVOR HOV	43.0	24.2	32.8

See *Methodology* for a definition on how the favor HOV lane groups were created.

person designation, given the difficulty of getting people together because of different schedules and work location. The University of Washington group also favored a two-plus person carpool definition because they believed that carpools were difficult to form because of varying schedules and the need to have a personal vehicle available during the workday for work related trips.

In contrast, the concerns of the other two groups centered on the equity of a three-plus person carpool definition in light of the increasing number of two-person vehicles. The Totem Lake Mall Merchants participants also felt that existing HOV lanes were underused and that a three-plus person definition would just result in further decreasing HOV lane use. The participants from the City of Bellevue also perceived the HOV lanes as not being fully used and felt that a three-plus person carpool definition would further decrease the use of the already under-used HOV lanes.

I-405 HOV Lane Symposium. The symposium attendees felt that carpool definition should be based on HOV lane volumes and prevailing land-use patterns. They considered carpool definition to be a natural progression in the operation of HOV lanes, where a two-plus person carpool definition is employed with less well-used HOV facilities and the three-plus person carpool definition is employed with more widely used HOV facilities. The attendees felt that this increase in HOV definition would allow for the maintenance of a consistent level of service in the operation of the HOV lanes and would help continue to attract HOV users by providing a consistent time savings over SOV commutes.

Benefits and Disbenefits of Different Carpool Definitions. The literature review and public opinion analysis suggested that the following benefits and disbenefits are associated with carpool definition.

1. Benefits Associated with Two-Plus Person Carpool Definition include

   - ability to attract more carpoolers,
   - increased use of the HOV lanes, offsetting the "empty lane syndrome,"
   - increased number of people being served by an HOV lane,
   - possibility of the increased formation of two-plus person HOVs, and
   - enhancement of safety, since increased vehicle volumes in an HOV lane reduce the speed differential between the HOV lane and the general purpose lanes.

2. Disbenefits of Two-Plus Person Carpool Definition include

   - possibility of increased demand for HOV lane use and subsequent reduction in the level of service of the facility, which erodes the time savings advantage of HOV lanes,
   - potential to break up or discourage the formation of three-plus person carpools, and
   - confusion in transition areas where HOV definition switches to three-plus person designation.

3. Benefits of a Three-Plus Person Carpool Definition include

   - alleviation of potential congestion of HOV lanes that may result from a two-plus person definition, and
   - reduction in the total number of freeway trips and vehicle miles.

4. Disbenefits of a Three-Plus Person Carpool Definition include

   - decrease in the number of HOVs that qualify to use the HOV lane, and
   - contribution to the general perception that the HOV lane is not being fully used.

Summary of Findings. The literature review showed that HOV definition varies across the United States. Higher HOV definitions are used where HOV facilities have high volumes of traffic. The analysis of the public opinion survey results revealed an overwhelming level of support for the two-plus person carpool definition and a high level of support for changing the HOV definition from two-person to three-person on the basis of the congestion level of the HOV lane. Both the focus group participants and the symposium attendees felt that carpool definition should be evolutionary rather than static. They agreed that carpool definition should increase in relation to the use of the HOV lane. However, the survey respondents did not see the HOV lanes as being fully used and therefore did not see the lanes as able to become congested.

The perception that HOV lanes are not fully used is very important because a continuation of this perception could erode the large base of public support for HOV lane operations. Therefore, it is highly advisable that an education program be developed that explains issues concerning HOV lane usage.

Hours of HOV Lane Operation

This section's discussion of hours of HOV lane operations is based on a review of HOV lane operations in North America, information from the public opinion survey, focus group comments, and discussion at the I-405 HOV lane symposium. The section concludes with a summary of the benefits and disbenefits of differing policies for HOV lane hours of operation and a general summary of the findings.

Whether HOV lanes operate 24 hours a day or only during the peak morning and evening commute hours has an effect on the operation of the facility. Some argue that HOV lane operations should be enforced 24 hours a day to minimize any public confusion concerning HOV lane operation. However, critics of the 24-hour a day policy claim that peak-hour HOV lane operation (with general purpose traffic use during off-peak hours) allows for use of the HOV lanes by more people and thus decreases the perception that HOV lanes are underused.

Review of HOV Operations in North America. The literature review revealed the following:

- 40 percent of the HOV lane systems operate 24 hours a day, and
- 60 percent of the HOV lane systems operate only during peak commute hours.

The Washington State Freeway HOV System Policy document made the following recommendation:

- HOV lanes should operate 24 hour per day, 7 days per week.

Full-time operation of HOV lanes is recommended to encourage efficient and environmentally responsible forms of transportation. Furthermore, full-time operation of HOV lanes is recommended to maintain consistency of HOV lane operations and enhance and maintain understandability.

Public Opinion Survey. The survey instrument used two statements to obtain opinions about the hours of HOV lane operation. These statements were complementary and asked (1) whether HOV lanes should be in effect 24 hours and (2) whether HOV lanes should only be in effect during peak commute hours.

As shown in Table 28, over 60 percent of the survey respondents agreed that HOV lanes should operate 24 hours a day to maintain consistency of operation and understandability of operation. The analysis of the respondents by mode choice showed that carpoolers and bus riders agreed with this statement to a greater extent than those who drove alone. The higher level of agreement of the ridesharing groups reflected their concern with maintaining the viability of HOV lanes. Note that even the SOV group indicated a high level of support for 24-hour HOV lane operations.

The analysis of the survey respondents according to their attitude toward HOV lanes showed that people who favored HOV lanes supported 24-hours a day operation of HOV lanes, while those who did not favor them disagreed that the HOV lanes should be in effect 24 hours a day. This strong disagreement with a 24-hour policy by this group may have been simply a response consistent with not favoring HOV lanes at all.

The fact that 62.9 percent of all survey respondents agreed that HOV lanes should operate 24 hours a day indicates a high level of support for consistent HOV lane operations. This high level of agreement also indicates an understanding that general purpose use of the HOV lanes is not necessary during off-peak times because traffic

Table 28. ***"HOV lane requirements should be in use 24 hours a day to maintain consistency and understandibility."***

	Agree	Neutral	Disagree
OVERALL	62.9	14.4	22.7
SOV	58.0	16.0	26.0
POOL	73.4	8.2	18.4
BUS	62.1	15.6	22.3
FAVOR HOV	69.1	12.8	18.1
NEUTRAL	36.2	32.6	37.2
NOT FAVOR HOV	12.9	12.9	74.2

See *Methodology* for a definition of how the "favor" HOV lane groups were created.

Table 29. ***"HOV lane requirements should only be in use during peak morning and evening commute hours (at other times the lanes would be for regular traffic)."***

	Agree	Neutral	Disagree
OVERALL	38.2	19.1	42.7
SOV	40.5	19.9	39.6
POOL	39.2	15.5	45.3
BUS	42.2	17.8	40.0
FAVOR HOV	33.0	15.9	51.1
NEUTRAL	55.8	32.6	11.6
NOT FAVOR HOV	51.8	31.0	17.2

See *Methodology* for a definition on how the "favor HOV groups were created.

congestion is low or nonexistent at these times. The high level of agreement with this statement also reflects the high level of support for HOV operations, even by people who did not use the HOV lanes for commuting to and from work.

Table 29 deals with the hours of operation issue in a different way. The largest proportion of survey respondents disagreed that HOV lane requirements should only be in effect during peak commute hours. Given the response pattern about their agreement that HOV lanes should operate 24 hours a day, the level of disagreement with this statement was expected. However, the response to this question did not show as high a level of support for 24-hour operation as the previous one. Otherwise, the response patterns were similar to, and consistent with, those for the previous question.

Focus Group. The majority of focus group participants agreed that HOV lanes should operate 24 hours a day. Groups emphasized two different issues to support their opinions. The Overlake Hospital and City of Bellevue participants stated that traffic congestion only exists during the peak commute times, and therefore opening the HOV lanes up to general traffic use during non-peak times probably is not necessary. On the other hand, merchants from the Totem Lake Mall and University of Washington staff felt that the policy of peak-hour HOV lane operation would not be consistent and would cause confusion to drivers. The comments made by the all focus groups participants reflected a high level of support for 24-hour HOV lane operation.

I-405 HOV Lane Symposium. The symposium attendees agreed overwhelmingly that HOV lanes should operate 24 hours to maintain consistency of operation and understandability. They felt that 24-hour operation of the HOV lanes encouraged and promoted environmentally-conscious forms of travel. Furthermore, they stated that off-peak use of HOV lanes by general purpose traffic was not necessary because freeway traffic lanes were generally free-flowing during non-commute hours.

Benefits and Disbenefits Associated with Different Policies on HOV Hours of Operation. This analysis resulted in identification of the following benefits and disbenefits associated with 24-hour or peak-hour policies of HOV lane operations.

1. Benefits Associated with 24-Hour Operation of HOV Lanes include

   - establishment of a consistent HOV lane operational policy, enhancing public understanding of HOV lane operations,
   - reduction in violation potential because there is less confusion about the hours of HOV lane operations, and
   - provision of an additional incentive to rideshare to special events during non-commute hours (e.g., Seahawk Games, UW Games, or whenever congestion occurs).

2. Disbenefits Associated with 24-Hour Operation of HOV Lanes include

   - preclusion of the use of the freeway HOV lanes by SOV traffic during non-congested times.

3. Benefits Associated with Peak Hour Operation of HOV Lanes include

   - use of HOV lanes by general purpose traffic in off-peak hours to address the "empty lane" perception of HOV facilities,
   - increase in perception of equity of use by allowing SOV drivers to use these lanes in off-peak hours, and
   - availability of HOV lanes for clearing accidents or other incidents.

4. Disbenefits Associated with Peak Hour Operations of HOV Lanes includes

   - confusion and increased violation of the HOV lanes.

Summary of Findings. The literature review showed that hours of HOV lane operations vary across north America. The analysis of the I-405 public opinion survey results, focus group comments, and symposium comments revealed a high level of support for the 24-hour operation of HOV facilities. This high level of support for 24-hour operation of HOV lanes can be interpreted as representing a high level of support for HOV lane operations in general.

HOV Lane Enforcement

The section discusses the enforcement of HOV lanes and includes information from a review of HOV lane operations in North America, current violation rates, information from the public opinion survey, focus group comments, discussion at the I-405 HOV lane symposium.

Determent of HOV lane violations is essential in maintaining optimum HOV lane operation and also in maintaining public support for HOV facilities. Facility design can have a major impact on the ability to enforce HOV lanes in an effective and safe manner.

Review of HOV Lane Enforcement in North America. The literature review focused on information about violation rates of HOV lane facilities across the United States and information about different enforcement programs.

Issues in Enforcement of Busway and Bus and Carpool Lane Restrictions (39) provided a general overview of the issues associated with HOV lane enforcement. The authors noted that the development of enforcement techniques and strategies involves three basic considerations: (1) determination of the goals and objectives of the HOV facility performance; (2) determination of target violation rates; and (3) determination of a standard enforcement strategy that identifies the responsibilities of the different agencies. The authors concluded that the violation rates of HOV lanes are directly related to the HOV lane design. Physically separated HOV lanes have the lowest violation rates, while non-separated HOV lanes that operate concurrently with traffic have medium to high violation rates.

Agency Practices for Monitoring Violations of HOV Lanes (40) provided specific information on HOV lane violation rates. Table 30 summarizes the findings from the literature review. As can be seen from the table, HOV lane violations were higher for non-separated facilities than for barrier separated facilities. In addition, the observed violation rates were higher for the New Jersey HOV lane facility, which had peak-hour operation of HOV lanes in conjunction with a non-separated HOV facility.

Table 30. Violation Rates of HOV Facilities in North America

State	Type of Facility	Violation Rate
Virginia	•Non-separated •Separated — Reversible	• 20 to 30% • 2%
Texas	•Barrier Separated	• 1%
New Jersey	•Non-separated	• 30% • 40% in first and last 15 minutes of each peak period
Colorado	•Non-separated	• 9-31%

In addition to enforcement by the Washington State Patrol (WSP), Metro, supported by WSP and WSDOT, operates HERO. This program encourages freeway users to call and report the license plate number of HOV lane violators. The first time HOV lane violators are reported they receive information about HOV lanes and their purposes from Metro. The second time they are reported, they are sent a letter from the WSDOT informing them that they were observed violating the HOV lanes and explaining the purpose of the HOV lanes. The third time they are reported they receive a reprimanding letter from the Washington State Patrol informing them that the WSP will be watching for further violations. Habitual violators may also receive a home visit from the troopers.

A study was recently completed about the effectiveness of the HERO program. (42) While the analysis was unable to determine a statistically significant relationship between the number of HOV lane violations and the number of calls to HERO, the analysis revealed a high level of support for the program. The following is a brief summary of the findings:

- 71 percent of respondents thought the HERO program was a good idea,
- 6 percent had used the HERO hotline to report an HOV lane violator,

- 50 percent felt the hotline helped reduce the number of HOV lane violations,
- 6 percent felt the hotline reduced the number of HOV lane violators a great deal, and
- there were more calls to HERO when mainline freeway traffic was congested than at other times.

An analysis of the effectiveness of different HOV lane enforcement strategies has been completed by the Washington State Transportation Center. The strategies included saturation, occasional, passive, and random enforcement. The purpose of the analysis was to determine the effectiveness of short-term enforcement programs on the violation rates of new HOV facilities. The analysis concluded that, in the long run, all strategies were equally effective. However, the report recommended intensive enforcement for the first three months that an HOV lane is open.

Other issues associated with the violation potential of an HOV lane facility are its hours of operation and its design. The Shirley Highway HOV system in the Washington, DC area operated only during peak commute hours from 6 a.m. to 9 a.m. and from 3:30 p.m. to 6 p.m. At other times, the facility was open to general purpose traffic. The following violation rates were reported: (40)

- the violation rate for the majority of the peak hour of the peak period was 4 percent,
- the violation rate during the "shoulders" of the each peak period was 21 percent.

These findings suggest that variable hours of HOV lane operation are related to different levels of violation. Violation rates appear to be lowest during the height of the peak period.

In the Seattle area, violation rates vary according to which part of the HOV lane is monitored. The I-5 north HOV lanes opened in August 1983. In the first three months of operation, violation rates were higher (30 percent southbound and 44 percent northbound) near the end of the HOV lane restriction, where the lanes opened up to general purpose traffic use, than where the HOV lanes began, where they were much lower (between 17 percent and 18 percent). (42)

Design of the area for HOV lane enforcement is important for several reasons, including (1) the safety of the HOV lane violator, (2) the safety of the patrol officer, and (3) the ability of the patrol officer to remain hidden. Attention to physical design has been given. For example, Appendix G provides diagrams that illustrate HOV lane enforcement areas that provide adequate space for acceleration and pulling the violator off the road. (31)

The Washington State Freeway HOV System Policy document recommended the following policies:

- the HERO program should exist wherever there are HOV lanes;
- enforcement of HOV lanes should be undertaken by the Washington State Patrol;
- emphasis enforcement programs should be used for the first six months of operation of a new HOV lane or a change in the operation of an existing HOV lane;
- design of HOV facilities should incorporate safe enforcement features;
- signage and regulations should be clear and consistent to avoid driver/user confusion; and
- fines for HOV violations should be high enough to deter violators.

Current Violation Rates. Occupancy and violation data were gathered from late 1989 through the end of 1990 in the I-405 corridor. HOV lanes were observed during the peak hours in the northbound and southbound directions for half-hour periods near the Kennydale exit. In all, 77 data points were collected. In the adjacent general traffic lanes, 49 data points were collected.

During this data collection, the average violation rate in the HOV lane was about 15 percent. The compliance rate is the percentage of people in the corridor who obey the HOV restrictions. The average compliance rate was about 98 percent. Both of these statistics compared well with records at other places in the region and in the country in general.

<u>Public Opinion Survey</u>. The survey instrument included five statements about the enforcement of HOV lanes. These statements focused on three areas: (1) the seriousness and fines of HOV lane violations, (2) perceptions of the level of HOV lane violations, and (3) the effectiveness of the HERO program in deterring violations.

Table 31 shows that the majority of the survey respondents agreed that HOV lane violations represent a serious traffic violation. The analysis of the survey respondents by mode choice showed that the carpoolers and the bus riders agreed with the statement to a larger extent than the SOV drivers. These are important findings because they indicate a high level of public support for HOV lanes and the determent of HOV lane violators, even among those who do not use the HOV lanes.

The analysis of the survey respondents according to their attitudes toward HOV lanes showed that the "not favor" group disagreed that HOV lane violations are serious. Given this group's lack of support for HOV lanes, this finding is not surprising. However, the fact remains that the majority of respondents favored HOV lanes, and the majority of the survey respondents agreed that HOV lane violations are a serious traffic violation.

As shown in Table 32, nearly one-half of the survey respondents agreed that fines for HOV lane violator should be severe. While severe is a relative term, one could assume that respondents probably thought in terms of comparison with the average speeding ticket. Bus riders and carpoolers agreed with this statement to a somewhat greater extent than people who drove alone. Again, as with the previous statement, this higher level of agreement is reflective of their use of HOV lanes and an enhanced sensitivity to violations of the HOV lanes.

Table 31. ***"HOV lane violators commit a serious traffic violation."***

	Agree	Neutral	Disagree
OVERALL	52.4	25.6	22.0
SOV	51.4	25.1	23.5
POOL	54.1	30.6	15.3
BUS	62.5	18.8	18.7
FAVOR HOV	56.1	21.8	22.1
NEUTRAL	27.9	32.6	39.5
NOT FAVOR HOV	20.0	26.7	53.3

See *Methodology* for a definition of how the "Favor HOV" groups were created.

Table 32. ***"Fines for people who violate HOV lanes should be severe."***

	Agree	Neutral	Disagree
OVERALL	49.4	26.5	24.1
SOV	48.5	26.6	24.9
POOL	55.5	23.2	21.3
BUS	56.8	25.0	18.2
FAVOR HOV	52.3	23.4	24.3
NEUTRAL	30.3	34.8	34.9
NOT FAVOR HOV	20.0	20.0	60.0

See *Methodology* for a definition of how the "Favor HOV Lanes" groups were created.

The comparison of the survey respondents according to their attitudes toward HOV lanes showed that the majority of the "not favor" group disagreed with this statement. The high level of disagreement was consistent with their view that violation of HOV lanes is not a serious offense. Again, since this group did not favor HOV lanes, it is reasonable to expect that they would not agree with policies that support HOV lanes.

In summary, the survey respondents indicated a high level of agreement that fines for HOV lane violation should be severe. Agreement with this statement also indicated a high level of support for HOV lane operations in general and showed response patterns similar to the statement about the seriousness of the HOV lane violations.

Table 33 shows that the majority of survey respondents agreed that HOV lane violators are common during commute hours. The analysis of the survey respondents by mode choice revealed that carpoolers produced a larger proportion of agree responses than either the SOV or bus groups. This may have been due to the fact that they were driving in the lane and observing behavior, while bus riders were less aware of their surroundings. The fact that the survey respondents agreed that violations are common is important because it represents a perception that the HOV lanes are not operating as effectively as possible, and this could decrease the public's support for HOV lanes in the long run.

Disagreement and neutrality were the predominant responses to statements about the capture of HOV lane violators by the State Patrol, as shown in Table 34. The analysis of the survey respondents by mode choice did not reveal strong differences in response patterns among the groups. However, the carpoolers agreed to a somewhat greater extent with the statement than the either the SOV or bus respondents. This higher level of agreement by the carpoolers may have been the result of their greater awareness of enforcement activities than those who were passengers in a bus or driving an SOV.

Table 33. ***"HOV lane violators are common during the commute hours."***

	Agree	Neutral	Disagree
OVERALL	57.3	29.8	12.9
SOV	56.9	29.8	13.3
POOL	68.7	22.2	9.1
BUS	48.8	25.6	25.6
FAVOR HOV	51.4	24.9	23.7
NEUTRAL	51.3	26.5	22.2
NOT FAVOR HOV	51.7	29.0	19.3

See *Methodology* for a definition of how the "Favor HOV Lanes" groups were created.

Table 34. ***"HOV lane violators are often caught by the State Patrol."***

	Agree	Neutral	Disagree
OVERALL	21.9	38.2	39.9
SOV	20.5	40.0	38.5
POOL	34.4	24.2	41.4
BUS	22.7	31.8	45.5
FAVOR HOV	18.8	33.6	47.6
NEUTRAL	21.4	35.7	42.9
NOT FAVOR HOV	19.3	38.7	42.0

See *Methodology* for a definition of how the "Favor HOV Lanes" groups were created.

These patterns of responses may indicate a lack of information about the effectiveness of the Washington State Patrol's HOV lane enforcement program. It probably also reflects the fact that many HOV lane violators are not caught. Regardless of the interpretation, the perception that HOV lane violators are not caught is important because it can ultimately affect the integrity of HOV lane operations and public support for HOV lane policies and operations.

Nearly one-half of the survey respondents were neutral in their response to the statement concerning the efficacy of the HERO program, as shown in Table 35. A fairly large proportion of the respondents also disagreed. These findings contradict the previously-described evaluation of the HERO program. (41) The fact that such a large proportion of survey respondents were neutral in their assessment of the effectiveness of the HERO program probably indicates a lack of information about it.

Mode choice did not seem to affect perceptions of the effectiveness of the HERO program. The analysis of the survey according to attitudes toward HOV lanes showed that the "not favor" group produced a lower proportion of agree responses than the other groups. This low level of agreement reflected their general lack of support for HOV lanes and programs designed to promote HOV lanes.

Focus Group. Participants from all of the focus groups knew about the HERO program and how it worked, and several had used it in the past. Both the Totem Lake Mall Merchants and the University of Washington focus groups felt that HOV lane violators were common but rarely caught. The Totem Lake Mall Merchants expressed a great deal of frustration with violators. The University of Washington staff was the only group that felt that enforcement appears to decrease the number of HOV lane violators.

I-405 HOV Lane Symposium. The symposium attendees overwhelmingly agreed that enforcement is necessary for the effective operation of HOV lane facilities.

Table 35. ***"HOV lane violations are minimized by the HERO program (this program encourages people to call in and report HOV lane violators)."***

	Agree	Neutral	Disagree
OVERALL	19.3	49.7	31.0
SOV	18.4	49.0	32.6
POOL	22.3	51.4	26.3
BUS	22.7	47.8	29.5
FAVOR HOV	18.2	41.3	40.5
NEUTRAL	14.3	50.0	35.7
NOT FAVOR HOV	6.5	51.6	41.9

See *Methodology* for a definition of how the "Favor HOV Lanes" groups were created.

The attendees agreed that WSDOT must work with public agencies such as the Washington State Patrol and local jurisdictions to enhance the effective enforcement of HOV lanes. The symposium attendees also noted that it is important for the Washington State Patrol to be involved in the preliminary planning of HOV facilities to ensure that HOV facilities are designed to facilitate effective and safe enforcement.

The group agreed that they would like to see violation rates in the 10 to 15 percent range. While enforcement is important, the attendees also noted that there is a trade-off between the cost of enforcement and the achievement of a zero violation rate. The symposium attendees felt that a zero percent violation rate is not a practical goal, given the costs and limits in time, money, and manpower.

Conclusions. The literature review revealed that HOV lane violation rates tend to range widely, depending on whether the HOV lane is physically separated from general purpose traffic. Generally, physically separated HOV lanes experience lower levels of violation than HOV lanes that are not physically separated from general purpose freeway traffic. Current HOV lane violation rates along I-405 are on the order of 15 percent. By most standards, this is an acceptable level of violation.

Physical design of HOV facilities is important in the safe and effective enforcement of HOV lanes. The evidence points to the importance that the Washington State Patrol be involved at an early stage in HOV facility design.

The analysis of the public opinion survey data showed that respondents agreed that violations are serious and that fines should be severe. However, although the survey respondents overwhelmingly agreed that violations are common, they were neutral or disagreed that the State Patrol apprehended violators frequently. Additionally, the respondents were neutral in their assessment of the effectiveness of HERO program. These results indicate the need for an education program concerning the current violation levels of the I-405 and State Route 520 HOV lanes, the effectiveness of the State Patrol in apprehending violators, and the effectiveness of the HERO program in decreasing potential HOV lane violations. Furthermore, information should be made available showing the high level of public support for the HERO program.

MODE CHOICE ANALYSIS

The objective of this part of the analysis was to determine whether differences exist among people who use different modes. The mode choice analysis examined personal, home, work, and daily activity characteristics of the three mode choice groups to identify barriers to HOV use. Examination of this set of characteristics may suggest potential policies that could be implemented to encourage shifts to HOV. Following is a summary of variables used in the analysis and an indication of their relationship to mode choice.

Variables with NO Statistically Significant Differences

The analysis of the mode choice groups did not reveal statistically significant differences among the three groups for the following variables:

- Sex
- Age
- Household Size
- Average Number of Children
- Dropping Off a Child at Daycare
- Picking Up a Child From Daycare
- Average Number of Days per Week that Daycare is Used
- Average Daycare Closing Time
- Distance of Daycare Facility from Home
- Average Work Starting Time
- Average Work Ending Time
- Average Number of Days with a Parking Problem at Work
- Average Number of Days Personal Vehicle is Used for Work Related Trips
- Average Number of Days Personal Vehicle is Used for Personal Errands

The lack of statistically significant differences among the three mode groups for the average number of a days per week that a personal vehicle is used for work related trips and personal errands was contrary to other findings in this study. For instance, focus group participants indicated that they could not carpool or take the bus on a regular basis because of their need to make work related trips and to conduct personal errands. Other research has also shown this factor to be important in mode choice. Since no statistically significant differences were observed among the three groups for these variables, they are not discussed in this analysis. The responses to these questions are shown in Appendix H for reference purposes.

Variables with Statistically Significant Differences

Statistically significant differences for the following variables were observed:

- Education
- Occupation
- Average Number of Workers per Household
- Household Income
- Average Number of Household Vehicles
- Vehicle Availability for Commute Purposes
- Use of Daycare
- Morning and Evening Commute Times
- Company Size
- Parking Fee at Work Site
- Availability of Company Car for Work Related Trips
- Use of Personal Vehicle for Driving to Lunch

A table that summarizes the specific differences between the mode choice groups is presented in Appendix I. Since statistically significant differences for these variables existed among the mode choice groups, they may provide insight into mode choice. The relationships between these variables and mode choice are described in the following sections. They are divided into personal, home, and work characteristics.

Personal Characteristics. Table 36 summarizes the personal characteristics responses of the three mode choice groups and shows the statistical differences (based on chi-square tests) observed between mode choice pairs.

The SOV and POOL groups differed significantly by level of education. The POOL group reported the largest proportion of high school graduates and the smallest proportion of college graduates. The lower education level of the carpoolers was consistent with the fact that the POOL group reported the largest proportion of shop/craft

Table 36. Personal Characteristics of Mode Choice Groups

Variable	SOV	POOL	BUS	Stat Sig SOV/POOL	Stat Sig SOV/BUS	Stat Sig POOL/BUS
Education (% in cat)						
Hi School	15.9	31.0	13.3			
Comm Coll	24.2	23.0	14.5	0.002	n/a	n/a
College	42.2	31.9	55.4			
Post-Grad	17.7	14.1	16.9			
Occupation (% in cat)						
Mgr/Adm	25.0	21.8	18.1			
Pro/Tech	29.9	19.1	36.1			
Shop/Craft	13.1	27.8	7.2	0.0037	0.0008	0.0068
Secretary	7.5	7.8	16.9			
Sales/Serv	18.4	14.8	13.0			
Other	6.1	8.7	8.7			

*Mgr/Adm = Managerial/Administrative; Pro/Tech = Professional/Technical; Shop/Craft = Shop or Production Worker, Craftsman or Foreman; Sales/Serv = Retail Sales, General Sales (Real Estate, Broker, etc), Personal Services Worker; Other = Student, Truck Driver, Delivery, etc. Chi Square Tests were used on the Education and Occupation variables. n/a refers to no statistically significant difference observed between the two groups with respect to the variable.

workers. These people may have been carpooling because of opportunities to commute with co-workers and also because these types of companies are frequently located in suburban areas, rather than urban cores like downtown Seattle. The rate of carpooling was not related to owning fewer vehicles.

Differences were observed between all three pairings of the groups for the occupation variable. The predominate occupation categories for the SOV and BUS groups were managerial/administrative and professional/technical. The BUS group had a higher proportion of professional/technical workers and secretaries than either the SOV or POOL groups. These professional/technical workers probably used the bus because they were travelling to an urban core, such as Bellevue or downtown Seattle, where these professions are commonly located. Secretaries were less likely to have a car available.

Home Characteristics. Table 37 summarizes the responses by mode choice group for home characteristics and presents the statistical differences observed between the pairs of groups.

The average number of workers per household differed between the SOV and BUS groups and between the BUS and POOL groups. The BUS group had a lower average number of workers per household than either the SOV or POOL groups. The

Table 37. Home Characteristics of Mode Choice Groups

Variable	SOV	POOL	BUS	Stat Sig SOV/POOL	Stat Sig SOV/BUS	Stat Sig BUS/POOL
Avg#Workers	1.91	2.26	1.40	n/a	0.038	0.007
Use Daycare (% in cat.)						
Yes	11.90	19.00	6.80			
No	88.90	81.00	93.20	0.043	n/a	0.01
Hshold Income (% in cat)						
15 - 24999	11.20	24.00	35.70			
25 -34,999	13.30	20.00	7.20			
35 -54,999	35.20	24.00	28.60	0.004	0.00	n/a
55 -74,999	19.90	32.00	7.10			
75 -99,999	12.20	0.00	14.30			
100,000+	8.20	0.00	7.10			
Avg#Hshold Vehicles	2.42	2.47	1.99	n/a	0.001	0.004
Avg#Days/Wk Car Available for Commute	4.91	4.57	4.43	0.00	0.00	n/a

*Hshold=household; Avg= average; Vehicle availability of 4+ refers to always having a vehicle available for commuting purposes. T-Tests were used for Average Number of Workers per Household, Average Number of Vehicles per Household, and Average Number of Days per Week that a Vehicle is available for commute. Chi Square Tests were used for Use of Daycare and Household Income. n/a refers to no statistically significant differences between the two groups with respect to the variable.

POOL group, on the other hand, had the highest average number of workers. This probably indicates that people who have more opportunities for carpool formation within their household do so.

The carpoolers had the highest level of daycare use of the three mode choice groups. This suggests that the use of daycare does not rule out the ability to carpool. Generally, people who use daycare (a minority of this sample) are largely responsible for dropping off and picking up a child and use daycare a majority of the workweek. Carpoolers appeared to have reconciled their daycare responsibilities with their commute schedules. This reconciliation is contrary to the common perception by SOV drivers that they cannot carpool because of their daycare needs.

Household income differed according to mode choice. In general, the SOV group had the largest proportion of respondents in the middle to upper income categories. Both the POOL and BUS groups had a larger number of respondents in the $15,000 to $24,999 category than the SOV group. In general, lower household income probably motivates carpoolers and bus riders to seek alternative commute modes to save money, possibly either in the form of general transportation costs or parking fees. However, there were a couple of anomalies. A substantial number of higher income households contained people who carpooled to work. This relationship may have been related to a greater number of workers per household, and thus higher incomes and more opportunities to commute. There were also some very high income bus riders. Almost 30 percent of the bus riders had annual incomes of over $55,000. Good bus service can be attractive even when there are no financial barriers to driving a car.

The average number of household vehicles was lowest for bus riders. This was not unexpected. However, a surprising finding was that the number of vehicles per worker was **highest** in households with bus riders. On the average, the SOV group had a car available more of the time than the POOL and BUS groups. The fact that the SOV groups had a vehicle readily available for commute purposes means that this group did not have to consider other commute alternatives, and thus they chose the most convenient alternative, driving their personal vehicle. The fact that bus riders had more vehicles per worker, yet the lowest car availability, was puzzling. No data were collected on the type of vehicle in the household, but the result may have been explained by a large number of special purpose vehicles in bus rider households.

In general, the analysis showed that there were more differences between people who rode the bus and SOV commuters than between carpoolers and SOV commuters. This indicates that bus riders on the Eastside are a distinct group. They either are forced by economics to use a bus or are able to a conveniently commute to high paying jobs in downtown Seattle or Bellevue. The similarities between carpoolers and SOV commuters suggests that it may be easier to shift SOV commuters into a carpool than onto the bus.

Workplace Characteristics. Table 38 summarizes the responses of the three mode choice groups concerning their workplace characteristics.

The BUS group reported the longest morning and evening commute times, followed by POOL people and the SOV drivers. The disparity in commute times was explained partially by the fact that bus riders and carpoolers had longer distance commutes. People are more likely to take the time to form carpools when the distance is longer. Longer bus commutes were explained by the large number of people who commuted to downtown Seattle by bus.

The survey instrument had respondents report the number of employees who worked at their organization. However, the results did not reflect the number of employees at a given worksite. The results showed that bus riders tended to work at larger companies than SOV drivers. Typically, these large companies were located near bus lines. Thus, it is convenient, often a direct route, to use a bus for travel to a large company. On the other hand, bus service to small companies outside the urban core is inconvenient or non-existent or involves several transfers and a walk. The inconvenience

Table 38. Workplace Characteristics — Mode Choice Groups

Variable	SOV	POOL	BUS	Stat Sig SOV/POOL	Stat Sig SOV/BUS	Stat Sig BUS/POOL
Morning Commute Time — Min.	24	27	32	0.029	0.00	0.011
Evening Commute Time — Min.	28	33	39	0.001	0.00	0.018
Company Size (% in cat.)						
1 - 25	38.00	39.30	17.60			
25 - 100	20.50	17.90	5.90			
100 - 1000	24.00	10.70	23.50	n/a	0.0029	n/a
1000+	17.50	32.10	52.90			
Parking Fee (% in cat.)						
Yes	8.30	9.40	27.50	n/a	0.0001	0.0086
No	91.70	90.60	72.50			
Company Car (% in cat.)						
Yes	30.10	35.00	60.00			
No	55.80	50.00	40.00			
Sometimes	11.60	5.00	0.00	n/a	0.026	0.047
Don't Know	2.50	10.00	0.00			
Avg # Days/Wk Use Personal Car to Drive to Lunch	2.49	2.42	1.53	n/a	0.008	0.039

T-Tests were used for Morning and Evening Commute times and Average Number of Days per Week that a Personal Vehicle is used for Work Related Trips. Chi Square tests were used for Company Size, Parking Fee, Company Car. n/a refers to no statistically significant differences between the two groups with respect to that variable.

of bus service makes driving alone more attractive. Employees in small companies who cannot drive alone tend to choose carpooling for their commute.

Very clear differences in having to pay to park at work were observed among mode choice groups. Nearly 30 percent of the bus riders reported that their company charged to park at the worksite, whereas with less than 10 percent of the carpoolers and SOV drivers had to pay for parking. Paying to park was a significant reason for the differences between this sample's mode choices. The influence of the cost of parking on mode choice was consistent with all other studies that have included this factor.

Of the people who paid to park, 57 percent worked in the downtown core of Seattle, 24 percent worked in downtown Bellevue, and 12 percent worked in the University District area. Other work locations where businesses charged for parking included the Beacon Hill neighborhood in Seattle, the Overlake area in Bellevue, downtown Kirkland, Totem Lake Mall in Kirkland, downtown Bothell, downtown Kent, South Center Mall in Tukwila, SeaTac Airport, and downtown Tacoma. The findings confirmed the observation that employees who work for companies located in dense urban areas are more likely to pay to park than people who work for companies located in less dense suburban areas.

The BUS group reported the highest level of company car availability. The unavailability of a company car probably meant that some SOV commuters who might otherwise have shared rides used their personal vehicles for commuting because they needed them to make work related trips during the workday.

The high average number of days per week that a personal vehicle was used for work related trips (three or more days per week for all three groups — see Appendix J for specific averages), combined with the fact that the majority of SOV and POOL respondents did not have access to a company car for these trips, suggests these respondents were using their personal vehicles by necessity and not completely by personal choice or preference. In addition, the fact that the BUS people had to use their personal vehicles for work or for personal errands probably accounted for their not using the bus on a daily basis. The high average of personal vehicle use for personal errands (three or more days per week for the SOV and POOL groups) suggests these respondents did not have alternatives available, such as walking or using the bus. Furthermore, the use of a personal vehicle for running errands during the weekday is a habit many people have difficulty breaking to accommodate a carpool or bus schedule. People may rely on their personal vehicle out of necessity and habit to complete errands during the workday.

Unlike personal and home characteristics, factors relating to workplace characteristics present more opportunities for public and private policy actions to encourage the use of HOVs. For instance, a comprehensive system of HOV lanes can be implemented to provide a travel time savings advantage to commuters with long commutes. Public policy cannot mandate company size. However, policies can be developed to encourage small companies to locate in areas of high density, which provide the critical mass necessary to support transit service. Policy could also influence the location of companies so that they are coordinated with support services such as restaurants, retail uses, and professional offices. This coordination of land uses could make commuters less dependent on their personal vehicles for workday trips, and thus more able to rideshare to work. Additionally, policies to assist small companies in acquiring a company vehicle for employee use could be effective in increasing the ridesharing ability of their workers by making them less reliant on their own vehicles for getting their jobs done.

Summary

Note that the sample for this study did not represent the typical commuter population in the region. They tended to be young, professionals, with middle to upper-middle incomes, and access to a personal vehicle for commuting to and from work. These respondents also did not tend to pay to park at their worksites and were dependent on their personal vehicles for making work related trips three or more days per week. The origin and destination data showed that there are opportunities for matching carpool members. However, the comments showed that psychological barriers to carpool formation prevented respondents from recognizing that they lived or worked near anyone with whom they could carpool. Policies to stimulate mode shift from SOV will have to address both the real and the psychological barriers to HOV use.

CONSTRAINTS TO HOV USE

One of the goals of the I-405 HOV Lane Analysis was to determine the differences between people who actually rideshare and SOV commuters who would prefer to rideshare. The cognitive and affective preference analyses addressed this issue. A description of these analysis methods is provided in the methodology section. The analyses were undertaken to identify those SOV commuters who thought carpooling or riding the bus was more effective than driving alone. Once these commuters had been identified, then an examination of their constraints to HOV use could be undertaken.

Tables 39 and 40 summarize the findings of both the cognitive and affective preference analyses. The tables cross-tabulate actual mode use with the respondents' preference for SOVs, carpools, and buses as a means of commuting to and from work.

Table 39. Cognitive Preference Compared with Actual Mode Use

	SOV	POOL	BUS
Cognitively Prefer SOV	n=255 74%	n= 19 32%	n = 7 23%
Cognitively Prefer Carpool	n=52 15%	n = 31 53%	n = 7 23%
Cognitively Prefer Bus	n = 37 11%	n = 9 15%	n = 17 54%

Table 40. Affective Preference Compared with Actual Mode Choice

	SOV	POOL	BUS
Affectively Prefer SOV	n = 336 62%	n = 20 24%	n = 2 5%
Affectively Prefer Carpool	n=123 23%	n = 43 51%	n = 3 7%
Affectively Prefer Bus	n = 80 15%	n = 22 25%	n = 38 88%

These tables shows that, as might be expected, SOV commuters tended to prefer the SOV mode. However, a substantial number of SOV commuters indicated a preference for carpooling or bus riding. Of the SOV commuters, 26 percent expressed a **cognitive** preference for other modes, and 38 percent expressed an **affective** preference for other modes.

Other studies have shown that 40 percent of SOV commuters would shift out of their personal vehicle if the circumstances and incentives for HOV use were right. (43, 44) Therefore, further analysis was conducted on the SOV respondents who rated carpooling and riding the bus higher than driving alone to determine what barriers existed to these people's use of HOVs for commute purposes. The following is a list of factors for which there was a statistically significant difference between the actual ridesharers and the SOV respondents who rated ridesharing as effective but who drove alone.

- **"Want to Pool" and "Actual Pool" Groups**
  - Average Number of Children per Household
  - Morning Commute Trip Time
  - Evening Commute Trip Time
  - Average Number of Days per Week Drive to Lunch
- **"Want to Bus" and "Actual Bus" Groups**
  - Average Number of Workers per Household
  - Average Number of Vehicles per Household
  - Dropping a Child Off at Daycare
  - Picking a Child Up from Daycare
  - Work Start Time
  - Morning Commute Trip Time
  - Evening Commute Trip Time
  - Worksite Parking Fee

- Average Number of Days per Week Use Vehicle for Personal Errands
- Average Number of Days per Week Drive to Lunch

Tables showing the actual differences between these groups are presented in Appendix J.

An analysis of the origin and destination patterns by mode preference did not reveal many differences between the "Actual Pool" and "Want to Pool" groups. However, the "Want to Bus" group generally exhibited a dispersed suburban work pattern that was very unlike the downtown Seattle work destinations reported by the "Actual Bus" group. Thus, it would appear from the origin and destination data that the members of the "Actual Bus" group were using the bus for commute trips because it was convenient and served their work destination. Members of the "Want to Bus" group, however, did not work in areas that typically had convenient transit service. If it existed, they would have probably used it.

The fact that the origin and destination patterns of the "Actual Pool" and "Want to Pool" groups were similar suggests that many opportunities existed for matching carpool members. However, because of psychological barriers ("I don't live near any one to carpool with") and actual barriers, the "Want to Pool" group had not acted upon their preference for carpooling.

Constraints to Carpooling

A significant difference in the average number of children per household was observed between the "Actual Pool" and the "Want to Pool" groups. Members of the "Want to Pool" group had a higher average number of children than those of the "Actual Pool" group. The fact that the "Want to Pool" group had more children may mean that they were less able to participate in a carpool because of the need to drop off and pick up a child from daycare or to be available for extra-curricular activities for older children.

Analysis showed that members of the "Actual Pool" group also had a much longer commute than the "Want to Pool" group. Short commute distances may have been a factor that kept "Want to Pool" people from acting upon their preference for carpooling. As long as other incentives for carpooling are minimal, the formation time for short carpool commutes will be a barrier to would-be carpoolers.

Members of the "Actual Pool" group did not drive to lunch as frequently as the "Want to Pool" group. This finding may indicate that members of the "Want to Pool" group had fewer lunch alternatives within walking distance of their worksite, or that they did not have an alternative means of reaching restaurants, such as a bus or shuttle. "Want to Pool" respondents may have become dependent on their personal vehicles for going to lunch.

In conclusion, both the "Actual Pool" and "Want to Pool" respondents were young, well-educated, and employed in white collar occupations. The home-to-work travel patterns show that the majority of these respondents lived and worked in areas along the I-405 corridor, specifically between and within the cities of Kirkland, Bellevue and Renton. Because the travel patterns of both groups were similar, psychological barriers to carpool use may have been important for the "Want to Pool" respondents. Psychological barriers to carpool use were indicated by the comments the "Want to Pool" respondents gave for not carpooling. The most frequent reasons were as follows:

- "Nobody lives or works near where I do." (28 percent)
- "I need my car for work." (25 percent)
- "I do not know anyone to carpool with." (17.8 percent)
- "Driving alone is convenient." (16.7 percent)
- "I have odd hours or a changing schedule." (8.4 percent)

Constraints to Bus Use

The "Want to Bus" group contained a higher average number of household workers than the "Actual Bus" group. A possible reason that the "Want to Bus" group had not been able to act upon their affective preference for taking the bus could have been the difficulty or inability to coordinate family schedules. The "Actual Bus" group may have been able to more easily take the bus because of fewer people in the household and thus fewer schedules to coordinate.

The "Want to Bus" group reported nearly 2.5 vehicles per household, compared with 2.0 per "Actual Bus" household. This finding was consistent with the literature review, which showed that access to a personal vehicle for commute purposes encourages SOV use. While policies to directly limit vehicle ownership would be difficult to implement, these findings illustrate the importance of taking auto ownership into account.

Unlike the "Actual Bus" respondents, the majority of the "Want to Bus" group were responsible for both dropping off and picking up a child from daycare. These daycare responsibilities mean that the "Want to Bus" respondents had less flexibility in their daily schedules and would find it difficult to use infrequent bus service. Another major limitation was reported by the "Want to Bus" group. They reported an earlier daycare closing time than the "Actual Bus" group. While the majority of "Want to Bus" respondents did not use daycare, the people who did were faced with a tremendous constraint on their schedules by the need to pick up a child from daycare, typically by 6:00 p.m.

On average, the "Actual Bus" group started work earlier than the "Want to Bus" group. The "Want to Bus" group, on the average, started work at 9:10 a.m. This means that their ability to use a bus may have been constrained by lack of a bus service that could get them to work on time. In addition, many of these respondents could avoid the morning peak hour traffic and thus had less incentive to commute with others.

The "Actual Bus" group reported a much higher number of respondents whose employers charged for parking at the worksite. Only 10.8 percent of the "Want to Bus" group paid to park at their worksite, in comparison with 25 percent of the "Actual Bus" respondents. This finding was consistent with the literature review, which showed that when SOV drivers perceive parking to be free and do not personally pay for parking, they will likely drive alone.

Access to a company vehicle for work related trips was very different for the two groups. Seventy-five percent of the "Actual Bus" group reported having a company vehicle available for work related errands, whereas 57.2 percent of the "Want to Bus" did not have access to a company vehicle. The fact that companies do not have vehicles available for employee use means that many employees may be unable to ride the bus because they need their personal vehicle to make work related trips.

In conclusion, both the "Actual Bus" and the "Want to Bus" groups were young, well educated, and employed in white collar occupations. The home-to-work travel patterns indicated that the "Actual Bus" respondents took the bus because service was available and generally convenient. Furthermore, the majority of these respondents used the bus for travel to work in downtown Seattle (67 percent) and downtown Bellevue (25 percent). The "Want to Bus" group tended not to work in downtown Seattle. They worked within the I-405 corridor and commuted between and within the cities of Kirkland, Bellevue, and Renton. Current bus service for suburb-to-suburb commutes is not as rapid or as plentiful as bus service to downtown Seattle. Therefore, the "Want to Bus" respondents may not have been able to use a bus because there was no service between their suburban home and suburban work locations. While the "Want to Bus" group rated the bus as more effective, in general, than an SOV for commute purposes, current transit service is not effective enough to cause them to shift out of their SOV. To attract commuters who are not transit dependent, transit service will have to provide time savings and attractive scheduling that rivals SOV use.

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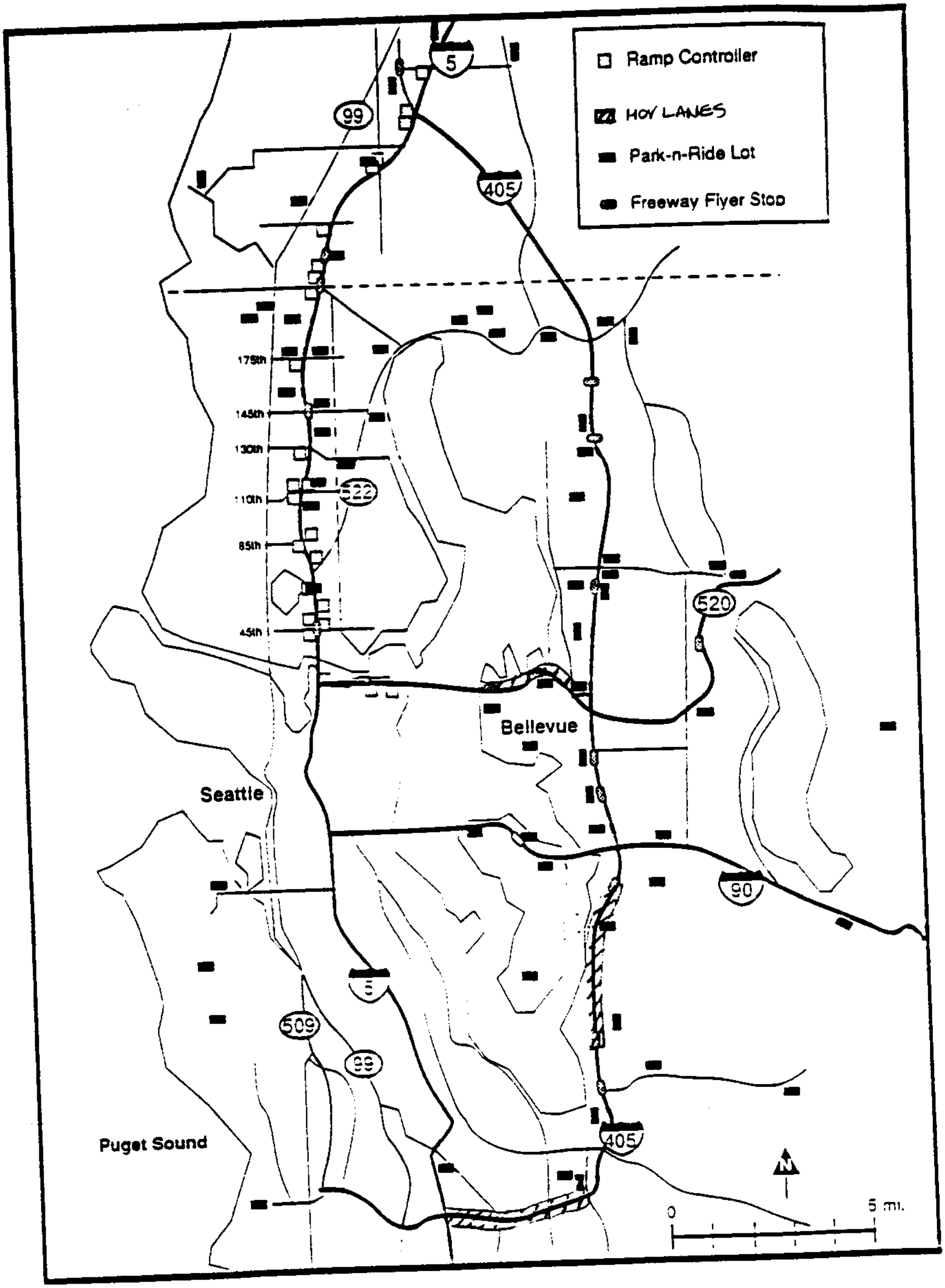
APPENDIX A

I-405 CORRIDOR


Ramp Controller
HOV LANES
Park-n-Ride Lot
Freeway Flyer Stop
5
99
405
175th
145th
130th
110th
522
85th
45th
520
Bellevue
Seattle
90
509
Puget Sound
N
0
5 mi.

APPENDIX B

SURVEY INSTRUMENT LONG FORMAT

AND

DIAGRAM OF SURVEY FORMAT INTERACTION

Washington State Department of Transportation   University of Washington   TRAC Washington State Transportation Center

I-405 HIGH OCCUPANCY VEHICLE LANE ANALYSIS
PUBLIC OPINION SURVEY

The Washington State Department of Transportation and the University of Washington are working together to systematically study the high-occupancy vehicle (HOV) lanes on Interstate 405. In order to design freeways which are more responsive to your needs, we need to understand your perceptions of HOV lanes and HOV use and we need to know why you choose to commute the way that you do. Feel free to add comments on the last page. All responses are confidential. Thank you!

SECTION A: YOUR TRIP TO AND FROM WORK

1. Please indicate your typical travel pattern to and from work on a daily basis by <u>writing</u> the <u>number</u> of workdays per week you use a particular method of commuting.

	THIS YEAR		LAST YEAR	
	To Work	From Work	To Work	From Work
Drive Alone	___	___	___	___
Bus	___	___	___	___
Carpool - you and 1 other person	___	___	___	___
Carpool - you and 2 or more other people	___	___	___	___
Vanpool	___	___	___	___
Bike, Motorcycle, Walk	___	___	___	___
Other: ______________	___	___	___	___

2. Have you changed jobs or moved in the last year? ___Yes ___No

3. For commuting to and from work, have you <u>ever</u>... (check yes or no for each item)

YES	NO	
___	___	Used the bus?
___	___	Participated in a carpool with 1 other person?
___	___	Participated in a carpool with 2 or more people?
___	___	Participated in a vanpool?

4. How long is your average commute trip?
________Minutes in the morning ________Minutes in the evening

5. Over the past year, have you changed your commuting start times (either to or from work) to avoid congestion?
___Yes ___No
I now leave home earlier/leave work earlier _____Minutes
I now leave home later/leave work later _____Minutes

6. When you drive alone: (if you've never driven alone, skip to question 7)
6a. Why do you drive alone? ________________________________
6b. How many days a week do you have a problem finding a parking space at or near your worksite when arriving at work? Circle the number that applies.
0 1 2 3 4 5

7. WHEN YOU TAKE THE BUS: (If you've never taken the bus, skip to question 8)
7a. What route number(s) do you normally take? ____ ____ ____
7b. Do you use a park and ride lot? ___Yes ___No

8. **WHEN YOU CARPOOL AND/OR VANPOOL:** (If you've never car/vanpooled, skip to Section B).

8a. How many people are in your car/vanpool? ____

8b. How was this car/vanpool set up? ____Transit Agency ____Employer Program ____Self

8c. Of the people in your car/vanpool, how many are:

____Spouse/roommate
____Children/siblings ages 0-6
____Children/siblings ages 7-16
____Children/siblings ages 17+

____Work for same employer
____Work for different employers, same location
____Work for different employers, different location

8d. Do you use a park and ride lot? ____Yes ____No

SECTION B: YOUR WORK PATTERN AND WORKSITE

1. **At what time do you usually:** (please fill in time and circle <u>am or pm</u>)
   a. Arrive at work ____:____ am pm
   b. Leave work ____:____ am pm

2. **How flexible are the hours you can arrive at and leave from work?**
   ____Very Flexible ____Somewhat Flexible ____Not at All Flexible

3. **How many people are employed with your company or organization?**
   ____1-25 ____26-100 ____100-1000 ____1000+

4. **Does your employer or building manager provide any of the following items?**
   Please check the appropriate blank if you know about these items, use the items or don't know.

	KNOW	USE	DON'T KNOW
Bus pass discount	___	___	___
Employer pays all or part of parking	___	___	___
Car/vanpool parking discount	___	___	___
Car/vanpool reserved parking	___	___	___
Vanpool fare discount	___	___	___
Guaranteed ride home in the case of emergencies	___	___	___
Flexible work schedule or days	___	___	___
Transportation fairs/information days	___	___	___
Commuter Information Bulletin Board	___	___	___
Employee/Building Transportation Coordinator	___	___	___
Bicycle Racks or storage	___	___	___
On-site showers and/or lockers	___	___	___
Other: ____________________	___	___	___

5. **When you get to work, where is the vehicle you ride in usually parked?**
   (Bus riders skip to Section C)

____Free parking where I work
____Free parking nearby
____Free space on street nearby
____Elsewhere, I am dropped off

____Pay parking where I work $__________per month
____Pay parking nearby work $__________per month
____Metered space on street $__________per month

SECTION C: EXTRA WORKDAY TRIPS

Extra workday trips refer to any trip you make on the way to and from work. It also includes trips you make on your lunch hour.

1. Work Related Trips:

1a. Do you use a car to make work related trips during the day? ____Yes ____No (if no, go to question 2)
1b. How many workdays per week (average)? ____WORKDAYS per Week
1c. Does your company have cars available to use for work related errands, meetings, travel, etc?
____Yes ____No ____Sometimes ____Don't Know

2. Daycare:

2a. Do you use day care? ____Yes ____No (if no, go to question 3)
2b. How many workdays per week (average)? ____WORKDAYS per Week
2c. Are you the one who typically drops off or picks up the child (children)?

	YES	NO
Drops Off	____	____
Picks Up	____	____

2d. How far is your daycare facility from home? ____Miles
2e. What time does your daycare facility close? ____:____pm
2f. Are there penalties for picking up children after closing hours? ____Yes ____No

3. Personal Errands:

3a. Do you use a car to run errands during the workday? ____Yes ____No (if no, go to question 4)
3b. How many workdays per week do you run errands (average)? ____WORKDAYS per Week
3c. How close to work is the nearest branch of your bank? ____Miles
3d. Is there an automatic teller machine within walking distance to work? ____Yes ____No
3e. Please check the errands you typically perform during the week:

	BEFORE WORK	DURING BREAKS	AFTER WORK
Grocery shopping	____	____	____
Pick up/drop off dry-cleaning	____	____	____
Gift/personal shopping	____	____	____
Other____________	____	____	____

4. Lunch:

4a. Does your worksite have facilities for lunch? ____Yes ____No
4b. Do you eat lunch at your worksite? ____Yes ____No
4c. Are there restaurants within walking distance of your worksite? ____Yes ____No
4d. How often do you drive your car to go to lunch off-site (average per week)? ____WORKDAYS per Week

SECTION D: IMPORTANCE RATING

Please rate how important each of these items is to you in deciding to travel to and from work. Circle the appropriate number.

	Very Important				Not At All Important
Ability to arrive on time.	1	2	3	4	5
Ability to travel without changing vehicle.	1	2	3	4	5
Not having to deal with traffic congestion.	1	2	3	4	5
Protection from weather.	1	2	3	4	5
Short travel time.	1	2	3	4	5
Daily cost of use.	1	2	3	4	5
Flexibility to change plans when desired.	1	2	3	4	5
Freedom from threats to personal safety.	1	2	3	4	5
Avoiding stress.	1	2	3	4	5
Minimizing pollution.	1	2	3	4	5

SECTION E: AGREEMENT/DISAGREEMENT STATEMENTS

Please indicate to what extent you agree or disagree with the following statements.
"1" means you agree strongly and "5" means you disagree strongly.

	Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
I would be willing to pay higher taxes to improve bus service.	1	2	3	4	5
I enjoy driving my car even in heavy traffic.	1	2	3	4	5
My schedule is too erratic to be in a carpool.	1	2	3	4	5
If parking prices get much higher, I will be less likely to drive my car to work.	1	2	3	4	5
Taking the bus does not fit my lifestyle.	1	2	3	4	5
I do not know anyone to carpool with.	1	2	3	4	5
People who drive alone should pay more for parking than people who car/vanpool.	1	2	3	4	5
Carpooling is an enjoyable way to travel.	1	2	3	4	5
Riding the bus helps reduce traffic congestion.	1	2	3	4	5
I do not want to rely on someone else to pick me up to get to work on time.	1	2	3	4	5
It's a hassle to take the bus.	1	2	3	4	5
I like the freedom of driving my own car.	1	2	3	4	5
Taking the bus is an enjoyable way to commute.	1	2	3	4	5
People only ride the bus to work if they have to.	1	2	3	4	5

SECTION F: PERFORMANCE RATING

Please rate the performance of ALL 3 ways of traveling to and from work. This means rating ones you do not use. Your perceptions are very important. Use the following scale.

Extremely Well	Well	Neutral	Poorly	Extremely Poorly
1	2	3	4	5

Item	Method of Travel: BUS	DRIVE ALONE	CAR/VANPOOL
Ability to arrive on time.	___	___	___
Ability to travel without changing vehicle.	___	___	___
Not having to deal with traffic congestion.	___	___	___
Protection from weather.	___	___	___
Short travel time.	___	___	___
Daily cost of use.	___	___	___
Flexibility to change plans when desired.	___	___	___
Freedom from threats to personal safety.	___	___	___
Avoiding stress.	___	___	___
Minimizing pollution.			

SECTION G: HIGH-OCCUPANCY VEHICLES (HOVs) AND HOV LANE OPERATIONS

This section asks questions relating to high-occupancy vehicles (HOVs) and HOV lane operations. Please answer these questions whether or not you have had experience with using an HOV or HOV lanes. Your perceptions regarding HOVs and HOV lanes are very important.

DEFINITIONS:

HIGH-OCCUPANCY VEHICLE (HOV) is a vehicle that carries 2 or more people.
HOV LANE is a lane reserved for exclusive use by people in HOVs.
COMPLETE SYSTEM OF HOV LANES means that HOV lanes would extend from Tukwila to Bothell on Interstate 405.
RAMP METERS are stop lights on freeway on-ramps that regulate traffic entering the freeway.
RAMP METERS WITH HOV BYPASS are ramps with stop lights that regulate traffic entering the freeway. The bypass for HOVs means that HOVs do not have to wait for the signal to turn green to enter the freeway.

1. Have you ever used a high-occupancy lane while traveling... (check yes or no for each one)

YES	NO		YES	NO	
___	___	On a bus	___	___	On a motorcycle
___	___	In a carpool	___	___	Alone
___	___	In a vanpool	___	___	Alone for turning

2. Do you ever have enough people in the vehicle to use the HOV lanes but don't?

___YES ___NO

If yes, why? ___they are slower than regular lanes ___traffic moves too fast
___too much trouble to change lanes ___forget
___they are not safe

3. Please indicate to what extent you agree or disagree with the following statements.
"1" means you agree strongly and "5" means you disagree strongly.

	Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
HOV lanes help decrease traffic congestion for all commuters.	1	2	3	4	5
HOV lanes are a good incentive to use the bus or car/vanpool.	1	2	3	4	5
More express bus service during peak commute times would encourage more people to use the bus.	1	2	3	4	5
More suburban bus service on the east side of Lake Washington would encourage people to use the bus.	1	2	3	4	5
Building more freeways and arterials would substantially decrease traffic congestion on the east side of Lake Washington.	1	2	3	4	5
Adding lanes to existing freeways and arterials for regular traffic would substantially decrease traffic congestion.		2	3	4	5
Building a light rail system connecting the east side of Lake Washington with Seattle would substantially decrease traffic congestion.	1	2	3	4	5
A combination of a complete HOV lane system and expanded bus service would substantially decrease traffic congestion.	1	2	3	4	5

3 continued. **LEFT-SIDE HOV LANE**
This diagram shows a left-side HOV lane.

RIGHT-SIDE HOV LANE
This diagram shows a right-side HOV lane.

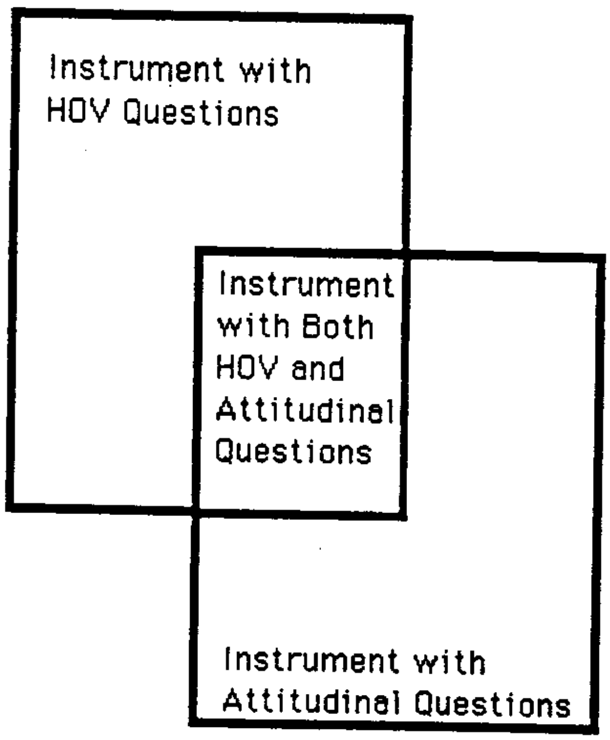
	Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
HOV lanes are a good idea.	1	2	3	4	5
Existing HOV lanes are being adequately used.	1	2	3	4	5
Left-side HOV lanes are easier to access than right-side.	1	2	3	4	5
Right-side HOV lanes are safer than left-side.	1	2	3	4	5
Violators are likely to use left-side HOV lanes than right-side.	1	2	3	4	5
Special ramps for HOV users from park and ride lots and arterials to freeway HOV lanes could attract a lot more HOV users.	1	2	3	4	5
Ramp metering increases freeway travel speeds for all users.	1	2	3	4	5
Faster travel times on the freeway make up for waiting at the ramp meter.	1	2	3	4	5
Ramp metering with an HOV bypass is a good incentive to use the bus or car/vanpool.	1	2	3	4	5
HOV lane requirements should be in use 24 hours a day to maintain consistency and understandability.	1	2	3	4	5
HOV lane requirements should only be in use during peak morning and evening commute hours (at other times the lanes would be for regular traffic).	1	2	3	4	5
HOV lanes should be converted to regular traffic 24 hours a day.	1	2	3	4	5
Minimum vehicle occupancy for using all HOV lanes should be 2 people to allow more carpools to use the HOV lane.	1	2	3	4	5
HOV lanes could become congested with a 2-person HOV designation.	1	2	3	4	5
If HOV lanes became congested, changing the HOV lane requirement from 2 to 3 people would not be difficult for people to accept.	1	2	3	4	5
HOV lane violators commit a serious traffic violation.	1	2	3	4	5
Fines for people who violate HOV lanes should be severe.	1	2	3	4	5
HOV lane violators are common during the commute hours.	1	2	3	4	5
HOV lane violators are often caught by the State Patrol.	1	2	3	4	5
HOV lane violators are minimized by the HERO program (this program encourages people to call in and report HOV lane violators).	1	2	3	4	5

SECTION H: ABOUT YOURSELF

1. Are you... ___Male ___Female
2. What is your age? ___Under 31 ___31-40 ___41-50 ___51-64 ___65+
3. What major intersection is closest to your home?
   ____________ and ____________ in the City of ____________
4. What major intersection is closest to your worksite?
   ____________ and ____________ in the City of ____________
5. Including yourself, how many people are in your household?
   ___Total ___Ages 0-6 ___Ages 7-16
6. How many people in your household regularly work outside the home? _____People
7. What was your approximate annual HOUSEHOLD income before taxes last year?
   - ___Less than $7,500
   - ___$7,500 to $14,999
   - ___$15,000 to $24,999
   - ___$25,000 to $34,999
   - ___$35,000 to $54,999
   - ___$55,000 to $74,999
   - ___$75,000 to $99,999
   - ___$100,000 or more
8. What is your highest level of schooling?
   - ___High School
   - ___Community College/Trade School
   - ___College
   - ___Post Graduate
9. What is your occupation?
   - ___Manager or Administrator
   - ___Shop or Production Worker
   - ___Craftsman or Foreman
   - ___Secretary or Clerical
   - ___Military
   - ___Professional or Technical: Lawyer, Engineer, etc.
   - ___Personal Services Worker: Waiter, Guard, etc.
   - ___Sales: Marketing, Stockbroker, etc.
   - ___Retail Sales
   - ___Other____________
10. How many vehicles, in working condition, are in your household?
    (include company vehicles) ___Vehicles
11. Whether you use it or not, do you have a car available to drive to work?
    - ___Always
    - ___Most of the time
    - ___Occasionally
    - ___Rarely
    - ___Never

PLEASE USE THIS SPACE FOR COMMENTS: ____________

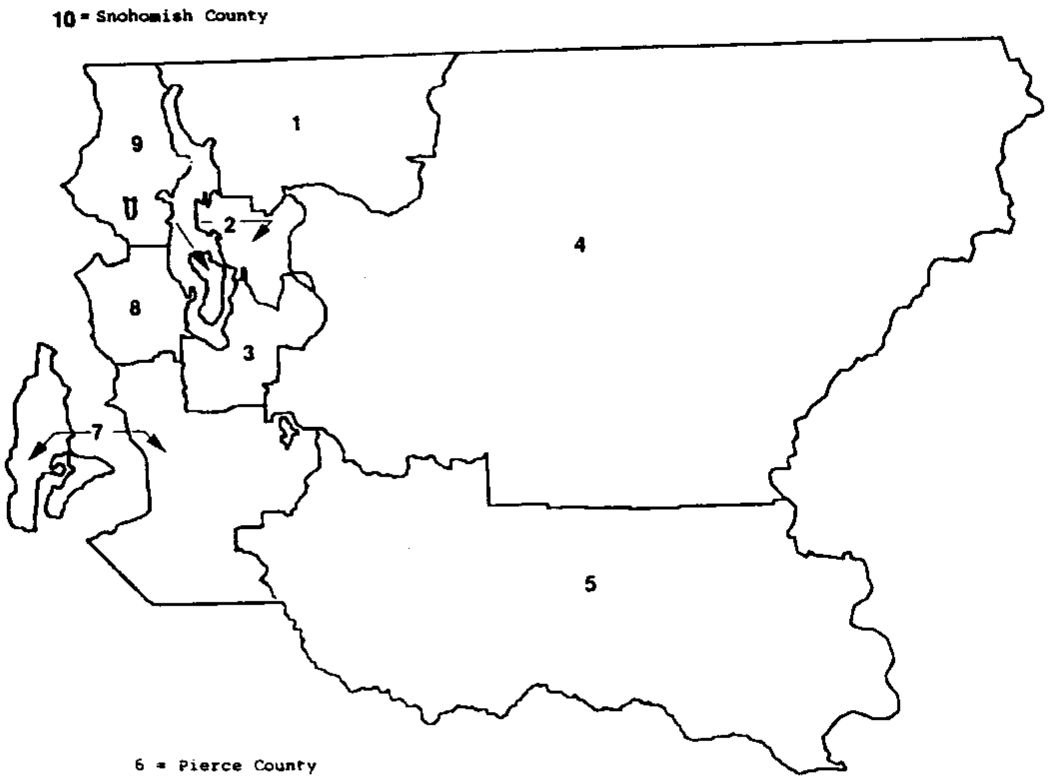
THANK YOU FOR COMPLETING THIS SURVEY!
PLEASE RETURN IT TO THE SURVEY ASSISTANT or USE THE BUSINESS REPLY OPTION


Instrument with
HOV Questions
Instrument
with Both
HOV and
Attitudinal
Questions
Instrument with
Attitudinal Questions

APPENDIX C

CENSUS TRACTS

APPENDIX C
Census Tract Groupings
King County, Washington



APPENDIX D

COMPARISON FOR REPRESENTATIVENESS OF SURVEY SAMPLE

APPENDIX D

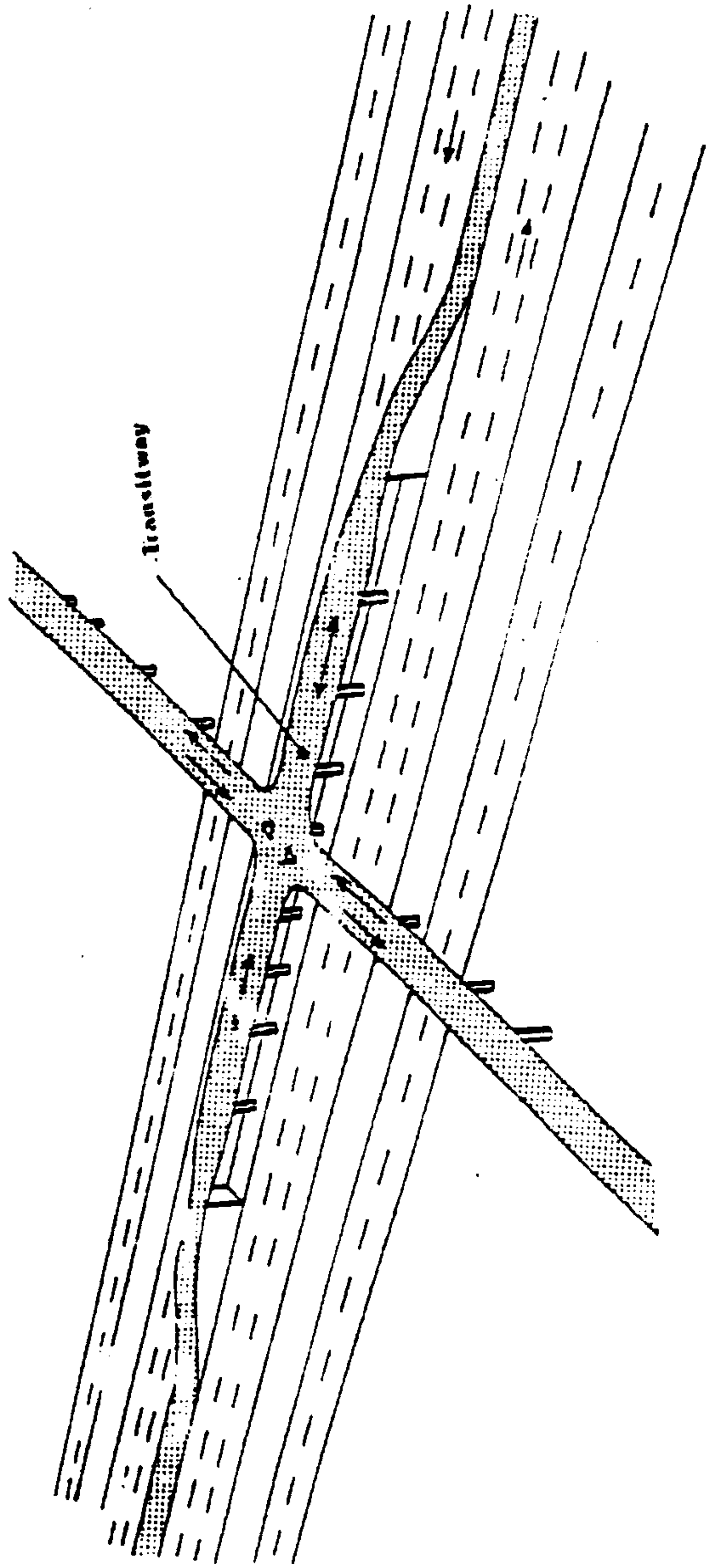
COMPARISON FOR REPRESENTATIVENESS OF SURVEY SAMPLE

Variable	Metro 1987 East King County Market Segmentation Study Findings	1990 I-405 HOV Lane Public Opinion Survey Findings
Mode Choice (% in cat)		
SOV	68.00%	79.00%
POOL	16.00%	13.00%
BUS	10.00%	6.00%
OTHER	6.00%	2.00%
Education (% in cat)		
High School	27.00%	17.80%
CC/Trade	30.00%	23.00%
College	27.00%	42.30%
Post Graduate	17.00%	16.90%
Occupation (% in cat)		
Mgr/Adm	11.00%	22.80%
Pro/Tech	19.00%	29.00%
Prod/Craft	7.00%	6.20%
Secretary	10.00%	8.40%
Sales/Service	6.00%	5.70%
Other	56.00%	27.90%
Income (% in cat)		
Under $25,000	17.00%	15.70%
$25 - 54,999	56.00%	45.40%
$55,000 +	27.00%	38.90%
Household Size - avg	2.9	2.96
Household Vehicles - avg	2.6	2.41

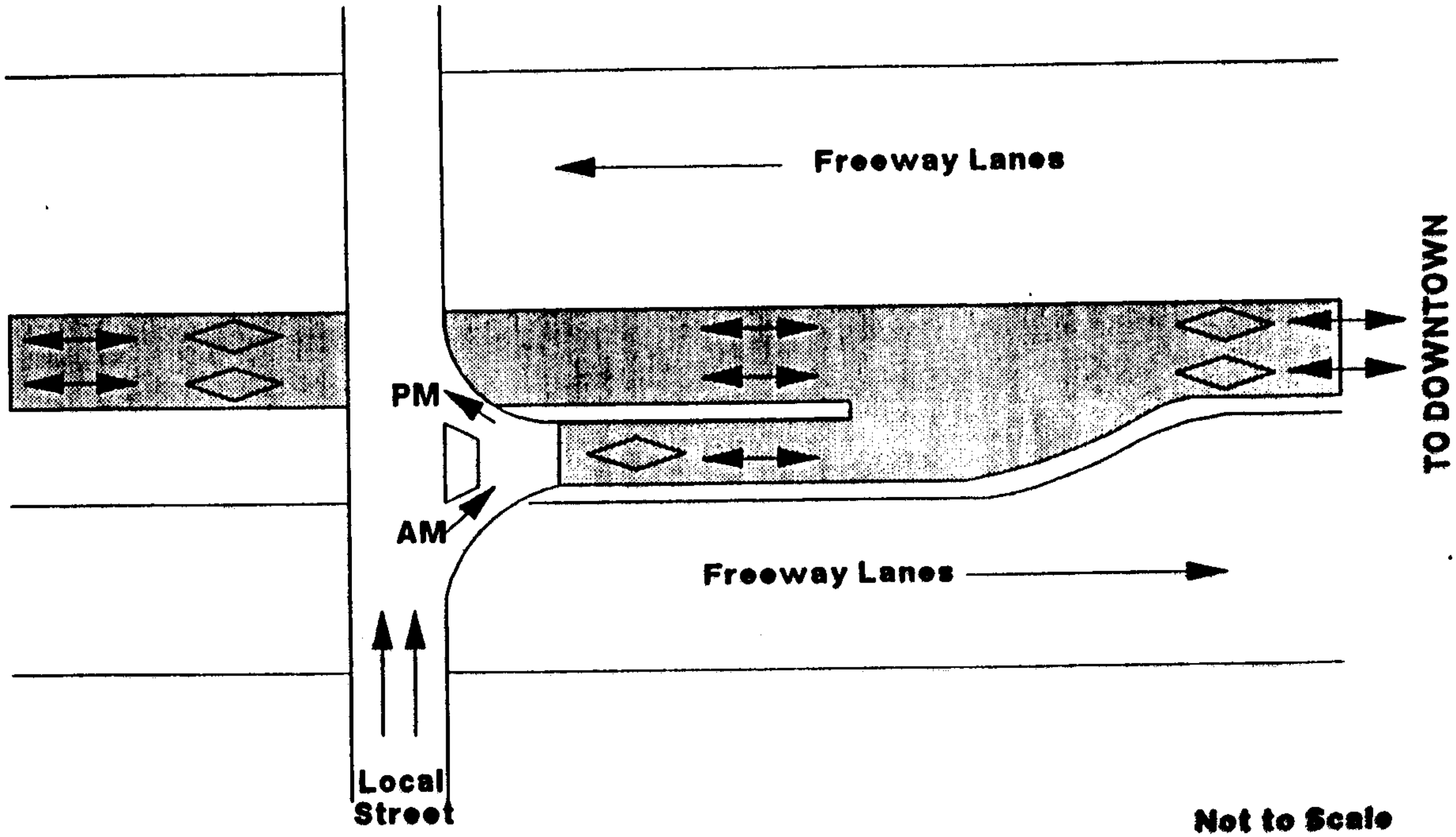
APPENDIX E

SPECIAL ACCESS RAMP

HARSTON "T-RAMP"


Transitway

Elevated Access Ramp At Intermediate Location On Freeway Transitway.

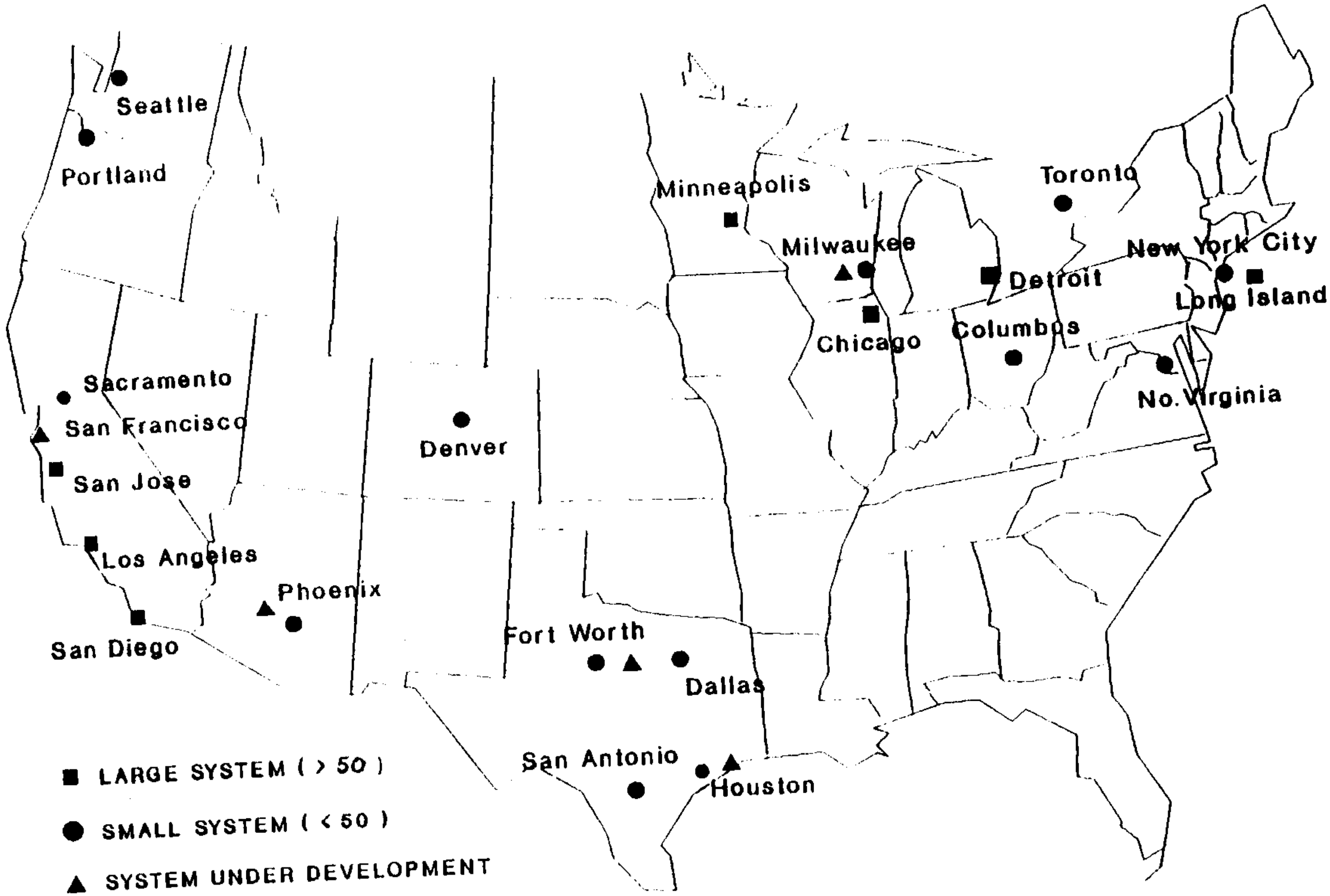


Not to Scale

APPENDIX F

MAP OF RAMP METERING SYSTEMS

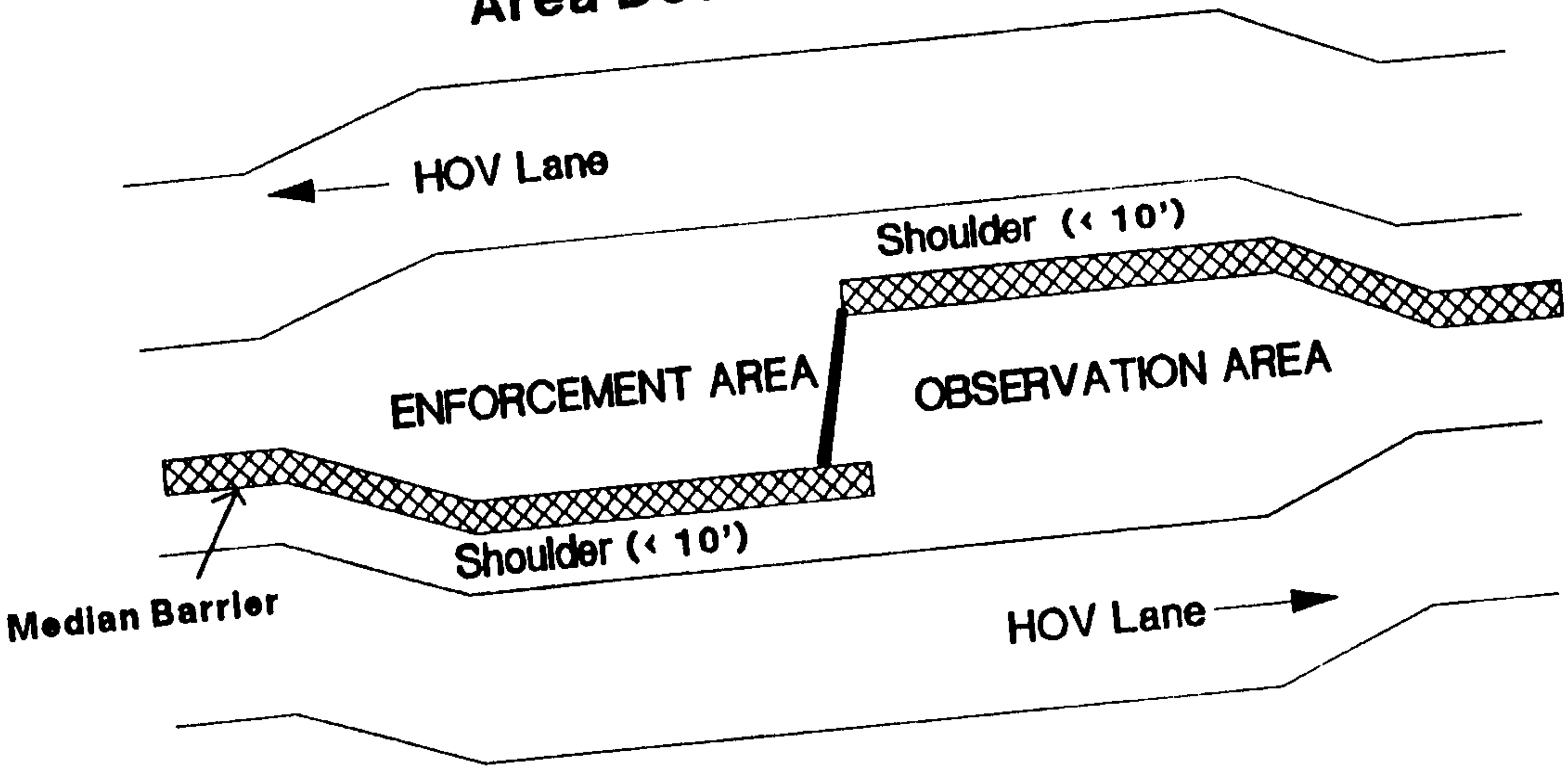
RAMP METERING SYSTEMS



APPENDIX G

DIAGRAM OF HOV LANE ENFORCEMENT CONFIGURATION

Proposed Bi-Direction Enforcement Area Detail.



APPENDIX H

SURVEY RESPONSES

APPENDIX H

I-405 HOV LANE PUBLIC OPINION SURVEY FINDINGS

PERSONAL CHARACTERISTICS

Variable	Overall	SOV	POOL	BUS
Sex (% in cat)				
Male	55.20	55.30	54.30	52.30
Female	45.80	44.70	47.70	47.70
Age (% in cat)				
<31	35.90	34.20	44.90	40.00
31 - 40	29.60	30.10	28.40	28.20
41 - 50	23.30	24.60	20.70	20.00
51 - 64	10.00	10.20	6.00	11.80
65 +	1.10	0.90	0.00	0.00
Education (% in cat)				
High School	17.80	15.90	31.00	13.30
Comm Coll	23.00	24.20	23.00	14.50
College	42.30	42.20	31.90	55.40
Post-Grad	16.90	17.70	14.10	16.90
Occupation (% in cat)				
Mgr/Adm	22.80	25.00	21.80	18.10
Pro/Tech	29.00	29.90	19.10	36.10
Shop/Craft	13.20	13.10	27.80	7.20
Secretary	8.40	7.50	7.80	16.90
Sales/Serv	17.90	18.40	14.80	13.00
Other	8.70	6.10	8.70	8.70

HOME CHARACTERISTICS

Variable	Overall	SOV	POOL	BUS
Hshold Size	2.96	2.95	3.04	2.79
Avg# Workers	1.86	1.91	2.26	1.40
Avg# Children	1.24	1.70	1.11	0.90
Life Stage (% in cat.)				
Single	23.60	24.50	14.10	25.70
Mul Ad/No Ch	9.50	9.30	18.30	14.30
Mul Ad/6<	21.90	20.70	25.30	20.00
Mul Ad/7>	45.50	45.50	42.30	40.00
Hshold Income (% in cat)				
15 - 24999	15.60	11.20	24.00	35.70
25 -34,999	12.60	13.30	20.00	7.20
35 -54,999	32.80	35.20	24.00	28.60
55 -74,999	20.20	19.90	32.00	7.10
75 -99,999	11.10	12.20	0.00	14.30
100,000+	7.60	8.20	0.00	7.10
Avg # Hshold Vehicles	2.41	2.42	2.47	1.99
Avg # of Days/Wk. Car Available for Commute	4.85	4.91	4.57	4.43

DAYCARE CHARACTERISTICS

Variable	Overall	SOV	POOL	BUS
Avg # of Days/Wk. Use Personal Car for Work Related Trips	3.57	3.56	4.02	3.32
Avg # of Days/Wk. Use Personal Car for Own Errands	3.14	3.10	3.32	2.80
Avg # of Days/Wk. Use Personal Car to Drive to Lunch	2.42	2.49	2.42	1.53

WORK CHARACTERISTICS

Variable	Overall	SOV	POOL	BUS
Work Start Time Avg.	8:24 AM	8:24 AM	7:54 AM	8:00 AM
Work End Time Avg.	4:35 PM	4:43 PM	4:05 PM	4:02 PM
Morning Commute Time - Min.	25	24	27	32
Evening Commute Time - Min.	27	28	33	39
Company Size (% in cat.)				
1 - 25	37.90	38.00	39.30	17.60
25 - 100	19.50	20.50	17.90	5.90
100 - 1000	22.00	24.00	10.70	23.50
1000+	20.00	17.50	32.10	52.90
Avg # Days/Wk Parking Prob	0.47	0.45	0.63	0.33
Parking Fee (% in cat.)				
Yes	9.00	8.30	9.40	27.50
No	91.00	91.70	90.60	72.50
Company Car (% in cat.)				
Yes	31.80	30.10	35.00	60.00
No	54.20	55.80	50.00	40.00
Sometimes	10.90	11.60	5.00	0.00
Don't Know	3.00	2.50	10.00	0.00

DAILY ACTIVITY CHARACTERISTICS

Variable	Overall	SOV	POOL	BUS
Avg. # of Days/Wk. Use Personal Car for Work Related Trips	3.57	3.56	4.02	3.32
Avg. # of Days/Wk. Use Personal Car for Own Errands	3.14	3.10	3.32	2.80
Avg. # of Days/Wk. Use Personal Car to Drive to Lunch	2.42	2.49	2.42	1.53

APPENDIX I

SUMMARY OF STATISTICALLY SIGNIFICANT DIFFERENCES — MODE CHOICE GROUPS

APPENDIX I
Summary of Differences — Mode Choice Groups

SOV compared with Carpoolers Statistically Significant Differences	SOV compared with Bus Riders Statistically Significant Differences	Carpoolers compared with Bus Riders Statistically Significant Differences
•Education •Occupation •Daycare •Household Income •Average Number of Days Car Available for Commute Trips •Morning Commute •Evening Commute	•Occupation •Average Number of Workers per Household •Household Income •Average Number of Household Vehicles •Average Number of Days Car Available for Commute Trips •Morning Commute Time •Evening Commute Time •Company Size •Parking Fee at Worksite •Availability of Company Vehicle •Average Days per Week Drive to Lunch	•Occupation •Average Number of Workers per Household •Average Numer of Household Vehicles •Morning Commute Time •Evening Commute Time •Parking Fee at Worksite •Availability of Company Vehicle •Average Days per Week Drive to Lunch

APPENDIX J

PREFERENCE ANALYSIS TABLES

APPENDIX J

MODE PREFERENCE FINDINGS

STATISTICALLY SIGNIFICANT DIFFERENCES

COGNITIVE PREFERENCE

Home Characteristics

Real Pool and Want to Pool Groups

Variable	People Who Carpool "Real Pooler"	SOV Who Rate Carpooling High "Want to Pool"	Statistical Significance of Difference
Avg#Children	0.90	0.99	0.044

Errand Characteristics

Real Pool and Want to Pool Groups

Variable	People Who Actually Carpool "Real Pooler"	SOV Who Rate Carpooling High "Want to Pool"	Statistical Significance of Difference
Avg # of Days/Wk. Use Personal Car to Drive to Lunch	1.00	2.15	0.045

Daycare Characteristics

Bus and Want to Bus Groups

Variable	People Who Actually Ride the Bus "Real Bus"	SOV Who Rate the Bus High "Want to Bus"	Statistical Significance of Differences
Drop Off Child (% in ea. cat.)			
Yes	0.00	100.00	
No	100.00	0.00	0.00
Pick Up Child (% in ea. cat.)			
Yes	0.00	80.00	
No	100.00	20.00	0.00
Day Care Closing Time	12:00 PM	6:00 PM	0.00

Workplace Characteristics

Real Bus and Want to Bus Groups

Variable	People Who Actually Ride the Bus "Real Bus"	SOV Who Rate the Bus High "Want to Bus"	Statistical Significance of Difference
Work Start Time	7:39 AM	9:20 AM	0.021
Morning Commute Time - Min.	37	28	0.029
Evening Commute Time - Min.	46	31	0.006
Parking Fee (% in cat.)			
Yes	25.00	10.80	
No	75.00	89.20	0.0352
Company Car (% in cat.)			
Yes	75.00	35.70	
No	25.00	57.20	
Sometimes	0.00	0.00	0.026
Don't Know	0.00	7.10	

Errand Characteristics

Real Bus and Want to Bus Groups

	BUS	SOV	
Variable	Cognitively Prefer Bus "Real Bus"	Cognitively Prefer Bus "Want to Bus"	Statistical Significance of Difference
Avg # of Days/Wk. Use Personal Car for Own Errands	1.50	3.16	0.032
Avg # of Days/Wk. Use Personal Car to Drive to Lunch	0.00	2.42	0.00

People who are part of "Real Bus" group are included in this analysis of errand behavior because of the way the mode choice groups were coded. Respondents were coded as bus riders if they rode the bus 2 or more days per week.

MODE PREFERENCE FINDINGS

STATISTICALLY SIGNIFICANT DIFFERENCES

AFFECTIVE ANALYSIS

Workplace Characteristics

Comparison of Real Pool and Want to Pool Groups

	POOL	SOV	
Variable	Affectively Prefer Pool "Real Pooler"	Affectively Prefer Pool "Want to Pool"	Statistical Significance of Difference
Morning Commute Time - Min	27	23	0.038
Evening Commute Time - Min.	33	27	0.02

Home Characteristics

Real Bus and Want to Bus Groups

Variable	People Who Actually Ride the Bus "Real Bus"	SOV Affectively Prefer Bus "Want to Bus"	Statistical Significance of Difference
Avg # Workers	1.38	1.94	0.03
Avg # Vehicles	2.08	2.43	0.05

Workplace Characteristics

Real Bus and Want to Bus Groups

	BUS	SOV	
Variable	Affectively Prefer Bus "Real Bus"	Affectively Prefer Bus "Want to Bus"	Statistical Significance of Difference
Morning Commute Time - Min.	34	27	0.003
Evening Commute Time - Min.	39	31	0.008
Parking Fee (% in ea. cat.)			
Yes	35.70	7.60	
No	64.30	92.40	0.0127

Errand Characteristics

Real Bus and Want to Bus Groups

	BUS	SOV	
Variable	Affectively Prefer Bus "Real Bus"	Affectively Prefer Bus "Want to Bus"	Statistical Significance of Difference
Avg # of Days/Wk. Use Personal Car to Drive to Lunch	0.36	1.92	0.00