HIGH OCCUPANCY VEHICLE LANES EVALUATION II

Traffic Impact, Safety Assessment, and Public Acceptance

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November 2004

Acknowledgements

The authors thank the Utah Department of Transportation employees for the data they furnished and their assistance with this study. The authors particularly thank the Technical Advisory Committee members for their invaluable input throughout the study. The authors are also thankful to the respondents who took the time to participate in the public opinion survey. The valuable contribution of those who helped collect data and conduct public opinion surveys is greatly appreciated.

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AFV	Alternative Fuel Vehicle
AVO	Average Vehicle Occupancy
GP	General Purpose
GVWR	Gross Vehicle Weight Rating
HERO	Highway Emergency Response Operator
HOT	High Occupancy Toll
HOV	High Occupancy Vehicle
ILEV	Inherently Low Emission Vehicle
LOS	Level of Service
MOE	Measure of Effectiveness
MPH	Miles per Hour
MUTCD	Manual on Uniform Traffic Control Devices
MVMT	Million Vehicle Miles Traveled
NCHRP	National Cooperative Highway Research Program
ODOT	Oregon Department of Transportation
PPHPL	Persons per Hour per Lane
SOV	Single Occupant Vehicle
SR	State Route
UDOT	Utah Department of Transportation
UHP	Utah Highway Patrol
UTA	Utah Transit Authority
UTL	Utah Traffic Laboratory
VPHPL	Vehicles per Hour per Lane
WSDOT	Washington State Department of Transportation
WSP	Washington State Patrol

EXECUTIVE SUMMARY

The high occupancy vehicle (HOV) lanes in the Salt Lake Valley operate between 600 North and 10600 South on Interstate 15 (I-15). They were opened on the reconstructed I-15 in May 2001. Two or more person carpools, vanpools, buses, motorcycles, alternative fuel vehicles (AFVs) and emergency vehicles are eligible to use the HOV lanes. They operate in both the northbound and southbound directions and are separated by a solid white striping that allows HOV entrance and exit. They operate 24 hours a day, seven days a week. There are inside ramps to the HOV lanes at 400 South, which is the downtown area in Salt Lake City.

A previous study of the HOV lanes was conducted before the lanes opened and continued through their first year of operation. The study recorded several HOV lane benefits. This report is based on an exhaustive evaluation of the third year of HOV lane operation in the Salt Lake Valley. The measures of effectiveness adopted were vehicle volume, average vehicle occupancy (AVO), modal split, person throughput, travel time, speed, accident rates and violation rates. Vehicle volumes and speeds were collected by video detection using the video feeds provided by the Utah Department of Transportation. The "floating car" technique was used to obtain travel time. Vehicle occupancy, modal split, person throughput and violation rates were collected manually. The findings indicate that the HOV lanes prove their value when congestion in the adjacent general purpose (GP) lanes is high. Furthermore, they are performing more effectively than they did previously. Almost all of the National Cooperative Highway Research Program (NCHRP) HOV Systems Manual standards, with respect to vehicle volume, person throughput, and travel time, were met. When compared to a GP lane, it was found that, during the a.m. peak period, the HOV lane carried just 32.69 percent fewer people with 73.17 percent fewer vehicles. During the p.m. peak period, the HOV lane carried 8.89 percent more people with 48.06 percent fewer vehicles when compared to a GP lane. HOV lanes also offer higher and more predictable speeds when compared to the GP lanes, thus offering travel time benefits. The p.m. peak period travel time saving was as high as 46.30 percent. Travel time savings during the a.m. peak period and off-peak period were 12.68 percent and 5.32 percent respectively. Thus HOV lanes are more effective during periods of high congestion. AVO has increased by 6 percent on the I-15 corridor with HOV lanes. This is an encouraging sign and needs to be further boosted by popularizing carpooling and other HOV modes. Violation rates have shown a decreasing trend and are lower than the national average of 13 percent for concurrent HOV lane facilities. The violation rate at the 400 South on-ramp is still high and needs to be curbed by more frequent and strict enforcement.

The safety of the HOV lanes was assessed in this study. Based on the accident data analysis, the HOV lanes did not appear to be inherently unsafe. The HOV lanes opened on the reconstructed I-15 along with two new GP lanes. A before/after study thereby would not have been appropriate and so the HOV lane safety evaluation was inconclusive. A public-opinion survey was conducted to determine public acceptance of the HOV lanes. The results indicate that there is strong support for the HOV lanes from both users and non-users. Those surveyed also gave useful feedback about their experience with and expectations from the HOV system. There is, however, a need for outreach programs to promote the benefits of HOV lanes. The deficiencies identified from the overall assessment were used to develop recommendations and thereby improve the operational efficiency of the HOV lanes on I-15. This study recommends stricter enforcement (especially at 400 South), construction of direct on-ramps and off-ramps and installation of prominent signs to increase public awareness.

1. INTRODUCTION

High occupancy vehicle (HOV) lanes are freeway or roadway lanes restricted to vehicles carrying a minimum number of people (typically 2, 3 or 4). Buses, vanpools, and carpools are eligible to use them. On some facilities, motorcycles with a driver only, single occupant inherently low emission vehicles (ILEV) and toll-paying single occupant vehicles (SOV) are eligible to use the HOV lanes. HOV lanes are also known as carpool, vanpool or bus lanes (*1*). The main objective of HOV lanes is to increase the average number of persons per vehicle or the people-moving capacity of a roadway. Since an HOV lane carries more people in fewer vehicles, it reduces congestion, saves travel time and reduces emissions. These benefits in turn encourage people to carpool and use buses.

HOV lanes have many advantages. They move more people in fewer vehicles, reducing the demand for new highways. HOV lanes save time for users because of lower rates of congestion and incidents, making them high-speed; in other words, travel time becomes consistent and reliable. They provide cleaner, healthier air throughout the region because of reduced emissions (*1*). They also reduce the stress of driving for passengers because they are riding in cars, vans, and buses instead of maneuvering through traffic. The lanes lead to reduced use of personal cars, thereby reducing wear and tear and fuel consumption. They are flexible and their technique, design, and operation can be tailored to meet local needs and conditions. Finally, HOV lanes benefit SOV drivers by taking carpoolers out of the General Purpose (GP) lanes (*1*).

A major disadvantage of HOV lanes is the “empty lane syndrome,” or perceived underutilization of HOV lanes. Since HOV lanes carry more persons per vehicle, they are less congested and so seem to be underused. They primarily benefit the users of the lanes and do not necessarily manage the overall traffic congestion. They need continuous enforcement and monitoring for maximum efficiency. Furthermore, the differentials in traffic speed, congestion at HOV entrance and exit points and the frequent moving in and out of vehicles from the HOV lanes create safety hazards.

1.1 Background

HOV lanes have been a part of the urban transportation scenario since the 1970s. Presently, there are about 100 HOV projects in North America. They represent nearly 1,000 route-miles of HOV lanes. Many new HOV facilities are in various stages of planning, design, and construction. With such a significant ongoing investment in carpool lane facilities, comprehensive monitoring and evaluation of the HOV lane systems’ performance is critical (*2, 3*).

Interstate 15 (I-15) is a major freeway oriented in the north-south direction in the Salt Lake Valley. Sixteen miles of HOV lane were opened on the reconstructed I-15 on May 14, 2001. HOV lanes in the Salt Lake Valley operate between 600 North and 10600 South, one in the northbound and the other in the southbound direction. They are single lanes and have a painted separation. They operate 24 hours a day, seven days a week. Buses, motorcycles, vanpools, carpools (2+), alternative fuel vehicles (AFVs), (also referred to as clean fuel vehicles which are fueled by propane or natural gas), and emergency vehicles are eligible to use them (*4*). Vehicles weighing over 12,000 lbs and vehicles towing trailers are not allowed in the HOV lanes even if they satisfy the minimum occupancy requirement. There is HOV-only on-ramp and off-ramp at 400 South (downtown Salt Lake City) to facilitate direct HOV lane entry and exit.

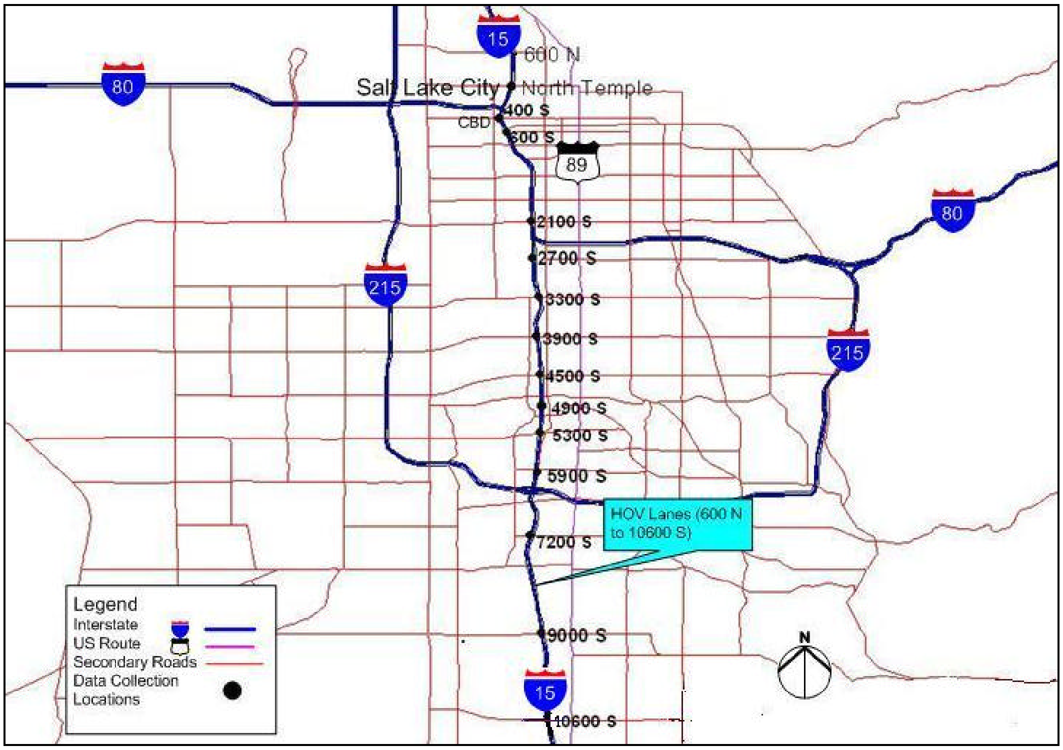

Figure 1.1: HOV Lanes in the Salt Lake Valley showing the data collection locations

The University of Utah Traffic Laboratory (UTL) evaluated the HOV lanes from 2000 to 2001 for the Utah Department of Transportation (UDOT) (*4*). The research objectives of the project were to evaluate the impact of the HOV lanes on I-15 and alternate routes and quantify the effectiveness by comparing before/after HOV lane statistics. Changes to existing HOV operation policies or procedures and educational programs for improving HOV lane acceptance and compliance were recommended. An analysis method was adopted. Measures of effectiveness (MOEs), which aid in identifying opportunities to increase the system-wide net benefits, were typical HOV evaluation measures like volume, speed, travel time, violation rate, and vehicle occupancy. Data collection included time periods before the HOV lanes opened, after they opened and recurring measures throughout the first year of operation.

Many benefits were recorded by the project. Travel time was found to be 13 percent lower in the a.m. peak period and 31 percent lower in the p.m. peak period. AVO increased from 1.12 to 1.32, that is, there was an 18 percent increase. Moreover it was found that during the p.m. peak period the average speed in the HOV lane was 63.6 miles per hour (mph) and 51.5 mph in the GP lanes. It was found that throughout the day the speeds in the HOV lanes were higher than the speeds in the GP lanes. Violation rates were 5-13 percent along the corridor and 20 percent at the ramp at 400 South, which is higher than the national average (*4*). During the 2002 Salt Lake City Winter Games, the I-15 corridor with HOV lanes played an important role, providing the greatest amount of freeway capacity in the Salt Lake Valley.

The project recommended many improvements. First, continued monitoring and evaluation are needed to adjust policy as congestion demands. Second, geometrical improvements such as providing on/off-ramp for HOVs at the 10600 South exit or extension of HOV lanes after this point would greatly improve the travel-time-savings benefit of HOV lanes. Third, frequent maintenance of traffic monitoring stations (TMS) was recommended for the continuous monitoring of HOV lanes. Additionally, rigorous violation enforcement – implementing program such as Seattle's Highway Emergency Response Operator (HERO) program – was recommended because violation rates were found to be higher than the national average. Lastly, media should be used to educate people about HOV lane restrictions. From the study it can be concluded that the HOV facility has approached its minimum pre-construction goal, which is to be able to move at least as many people as a GP lane does during the peak periods. After HOV lanes in the I-15 corridors had been in operation for one year, the AVO increased from 1.1 to 1.3. Therefore, implementation of the HOV lanes has obtained public support for ridesharing and transit. Moreover, the number of violations has decreased steadily from 24 percent in July 2001 to 18.7 percent in July 2002, which indicates that people have started accepting the system (*4*).

1.2 Problem Description

Congestion in Salt Lake City is showing an increasing trend and, as congestion reaches higher levels, benefits of the HOV lanes will also increase. It needs to be determined whether the Salt Lake Valley HOV lanes are performing effectively in terms of travel time benefits, safety and the ability to carry more people in fewer vehicles. Additional factors like public opinion about the HOV facilities also need to be considered. All these factors should be taken into account and thoroughly analyzed to track the increasing benefits, identify the problems that need to be addressed and determine the conditions that would encourage additional HOV users. In this way policy-makers can use accurate information to make informed decisions about the future management and improvement of the HOV facilities in the Salt Lake Valley.

1.3 Research Goal and Objectives

The goal of HOV Lanes Evaluation II is to evaluate the effectiveness of the HOV lanes on I-15 in the Salt Lake Valley. Traffic impact, safety implication and public acceptance of the HOV lanes will be determined.

HOV Lanes Evaluation II encompasses the assessment of the Salt Lake Valley HOV lanes. The study's research objectives are as follows:

1. Determine the efficiency of the HOV lanes
2. Assess safety
3. Identify the public's perception of the HOV lanes
4. Recommend changes to the existing HOV operations

Figure 1.2 shows a summary of the goal, objectives and measures of effectiveness of the research project.

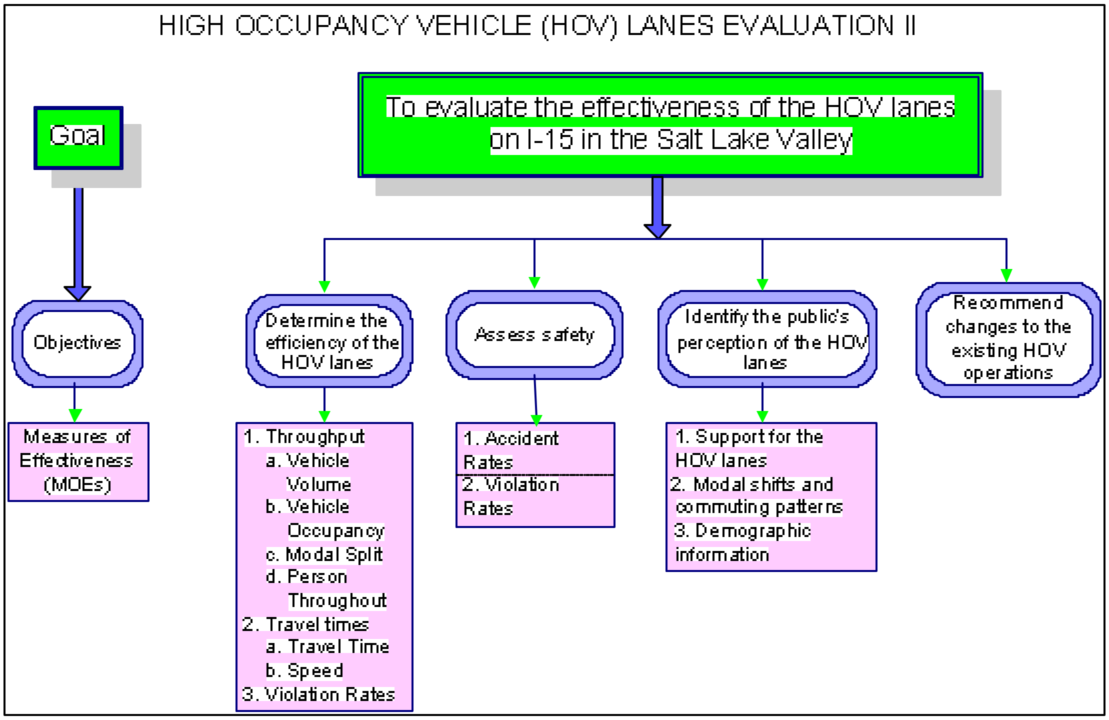

Figure 1.2: Goal, Objectives and Measures of Effectiveness

The project tasks and the actions are stated below:

1. Review success and failure of HOV lanes in the metropolitan areas.
2. Collect vehicle volume and speed data from both the HOV and GP lanes in the Salt Lake Valley.
3. Adopt the floating car method to determine speed and travel time data. Analyze travel time savings of the HOV lanes compared to the GP lanes.
4. Collect vehicle occupancy data to obtain AVOs for both the HOV and GP lanes.
5. Apply AVO to vehicle volume and obtain person throughput.
6. Identify modal split of the HOV and GP lanes.
7. Obtain violation rates at representative locations.
8. Determine accident rates along the HOV lanes.
9. Compile the data collected from the HOV and GP lanes, and compare them. Compute the changes, both numerically and as percentages for each MOE.
10. Conduct public surveys to determine the public acceptance of the I-15 HOV lanes and obtain suggestions for the improvement of HOV lanes from its users and non-users.
11. Discuss the effectiveness of the HOV lanes based on the evaluation of the data collected.
12. Recommend changes or improvements in the HOV lane system based on the analysis of the data collected.

2. LITERATURE REVIEW

HOV lane operations and evaluations have been going on in many North American states. An overview of some of the HOV lane programs is given in this section.

2.1 California Success

Caltrans operates 1,061 miles of HOV lanes and is constructing an additional 162 miles. On average, California's HOV lanes carry 2,518 persons per hour during peak hours which is much higher than that carried by a congested GP lane (*5)*. It is approximately equal to the number of people carried by a typical GP lane operating at maximum capacity. California's HOV lanes are, however, operating at only two-thirds of their capacity in terms of vehicles carried. There are some groups who say that allowing AFVs to use the HOV lanes increases alternative vehicle attractiveness. Some of California's HOV facilities allow 2+ occupancy during off-peak periods and 3+ during peak-periods. Some bridges in the San Francisco Bay region eliminate tolls for HOV vehicles during peak periods. Among California's HOV lane network, Los Angeles County's HOV lanes are extensive. In March 2000 a study was commissioned to evaluate the Los Angeles County HOV lanes. Its objectives were to enhance existing HOV data collection, analyze the travel impacts and user benefits of the HOV system, provide policy-makers with information to enable them to make decisions about the future of HOV facilities, sustain, market, and promote user and non-user acceptance of the HOV system, and develop policy recommendations to help guide future HOV investments. Market research was done as a part of the evaluation process. The general public telephone survey focused on a group of core questions to measure the public's perceptions and attitudes towards HOV facilities. It was found that, out of the HOV users, more than half use carpool lanes more than five days per week. This in turn reveals that the availability of HOV lanes plays a major role in users' decisions to access HOV lanes (*1)*.

2.2 Vancouver Evaluation

The Vancouver HOV Pilot Project Evaluation Report # 4 is the latest evaluation report that monitored the effectiveness of the Southbound Interstate 5 (I-5) HOV Lane Pilot Project in Vancouver. The Vancouver HOV lanes opened to traffic on Oct. 29, 2001 (*6)*. The three main goals of the Vancouver Project were to move more people per lane in the Vancouver HOV lane during the 2-hour a.m. period (6 a.m. to 8 a.m.) than in either of the adjacent GP lanes; to reduce peak period travel time for HOV lane users and to minimize impacts to other traffic in the corridor and on parallel facilities. During September 2002 a public opinion survey was conducted as a part of the evaluation. About 39 percent of the respondents felt the Vancouver HOV lane is an excellent or good idea. This value has decreased as compared to 58 percent of respondents in September 2001 and 47 percent in March 2002 (*6)*. Before and after traffic count data were collected from the Washington State Department of Transportation (WSDOT), City of Vancouver, Regional Transportation Council (RTC), and Clark County. A WSDOT incident response vehicle patrolled the I-5 corridor during the a.m. peak period. The vehicle collected corridor travel time data daily. Vehicle occupancy counts consisted of counting every vehicle in a single lane for 15-minute intervals and noting the number of occupants in each vehicle. The occupancy counts rotated across all lanes. Bus ridership was determined using C-TRAN counts provided for those routes using the I-5 corridor on the same dates that vehicle occupancy counts were taken. Percentages of the number of vehicles and persons for each travel mode were then applied to traffic counts, taken for each lane, by WSDOT's automated traffic recorders (*6)*.

2.3 Seattle System

In Seattle, HOV lanes exist in the major corridors around the Puget Sound area. Corridor-wide and location specific HOV performance results for the I-5, I-405, I-90, State Route 520 (SR 520), and SR 167 corridors were evaluated. The primary measures used were vehicle volume, person throughput, AVO, speed and travel reliability, and travel time. Secondary performance measures included enforcement and violation rates along the HOV lane systems (*7)*. Person and vehicle volumes were analyzed at certain locations along the major HOV corridors. The results obtained were compared with those of GP lanes for morning and afternoon periods (6:00 A.M. to 9:00 A.M. and 3:00 p.m. to 7:00 p.m.) in the direction of the heaviest traffic flow. It was found that it takes longer to travel in the GP lane (around 13 minutes) than in the HOV lane (around 10 minutes) during the afternoon peak period. In order to obtain more detail about HOV traffic performance the operation of the HOV lanes at specific locations was also examined. The principal measures used to evaluate HOV performance at a particular site included average vehicle volume, average speed at the location, and the percentage of days during which the average speed is less than 45 mph at that location. Violation rates were calculated using vehicle occupancy data collected by traffic observers at a limited number of locations throughout the region. During the year 2000, Washington State Patrol (WSP) reported 12,591 contacts with HOV violators and issued 9,045 tickets. There were 44 percent more tickets issued in 2000 than in 1998 (*7)*. Another source that provided some insight into HOV violation rates was the HERO program. It encourages motorists to report HOV violators by calling up or by sending in reports of violations electronically. The HERO program does not issue tickets because the WSP must actually observe the violation to enforce the infraction. A public opinion survey was also conducted. A major finding was that 83 percent of the respondents supported the HOV lanes (*7)*.

2.4 Houston System

In Houston, Texas, the HOV lane system consists of six corridors, namely Katy Freeway (IH 10W), North Freeway (IH 45N), Gulf Freeway (IH 45S), Northwest Freeway (US 290), Southwest Freeway (US 59S) and Eastex Freeway (US 59N). In June 2003, the total system utilization was measured at 37,173 daily vehicle trips and 121,079 daily passenger trips. Support facility utilization was measured at 16,751 daily parked vehicles. Because of construction in the vicinity of the US 59/I-10 interchange, there was a continued reduction in bus utilization of the US-59 Eastex HOV lane during the a.m. period. Buses are expected to return to the HOV lane once construction is complete. The overall AVO was 3.46 during the peak period and 2.00 during the off-peak period along the Katy Freeway (IH 10W). The accident rates (number of accidents per 100,000 vehicle trips) on the Katy, North, Gulf, Northwest, Southwest and Eastex corridors were found to be 2.54, 2.56, 0.00, 0.21, 1.51 and 0.00 respectively (*8)*.

2.5 Dallas Evaluation

HOV lanes studied in Dallas operate on I-30, I-35E, and I-635. The MOEs include vehicle volume and occupancy data, speeds and travel times, transit operation, cost-effectiveness, enforcement and violations, air quality impacts and public acceptance. Average automobile occupancy of freeways with an HOV lane increased by 8 to 12 percent, while the corresponding average of freeways without HOV lanes decreased by 2 percent (*9)*. An increase in occupancy implies that motorists are forming carpools to take advantage of the benefits offered by HOV lanes. Since the opening of the HOV lanes, there has been a significant increase in carpooling in each of the lanes, ranging from a 79 percent increase to a 296 percent increase. On incident-free days the HOV lanes monitored typically save motorists at least five minutes. Bus operating speeds have more than doubled since the HOV lanes opened. A survey of HOV lane users on I-30 indicated that carpoolers and bus riders use the HOV lane to save time and money (*9*).

2.6 Oregon System

The Oregon Department of Transportation (ODOT) conducted an evaluation of the I-5 before and after the introduction of the HOV lanes. Four follow-up evaluations have since been conducted. Performance measures such as total-person throughput, travel time, safety, enforcement, and modal impacts, which included HOV lane utilization, transit ridership, number of persons per vehicle, park-and-ride use, vanpools, and employer programs, were evaluated. Enforcement of HOV lane violators was measured in two ways: the number of observed violators based on occupancy counts (used to calculate compliance rates) and the number of citations written (warnings plus tickets). A public opinion survey was also conducted. ODOT surveyed 220 households with a margin of error of +/- 6.25 percent (*10)*. The major findings of the public survey were:

1. Seventy-four percent of the respondents favor permanent adoption of the HOV lane.
2. The most attractive carpool/bus rider incentives offered were more convenient park-and-ride locations and discounted downtown parking.

The results from the latest evaluation can be summarized as follows (*10*):

1. HOV lane drivers who drive the entire length of the corridor save an average of eight to ten minutes.
2. Overall vehicle occupancy has increased to 1.39 from the Baseline Report value of 1.37 (April 1999 information was used in the Baseline Report).
3. Occupancy compliance rates have increased to 92 percent.
4. The accident rate (number of accidents per million vehicle miles traveled or MVMT) has decreased slightly for the entire HOV lane period compared to “No-HOV Lane” conditions.

2.7 Florida Evaluation

The I-95 HOV facility extends from SR 112 in Miami-Dade County to just south of Linton Boulevard in Palm Beach County, a distance of approximately 46 miles (*11).* The objective of the monitoring effort was to collect traffic data such as volume, speed, travel time and delay, vehicle occupancy, and violation enforcement. The data were summarized, evaluated, and compared to previous reports to document the level of success of the HOV facility and to determine if operational changes should be implemented. For Miami-Dade County, vehicle counts were collected using video. This method was used because there are no imbedded loops for traffic data collection on I-95 in Miami-Dade County, and it was considered the safest technique. The videos were then analyzed to produce 15-minute interval counts and summed to hourly counts at all locations. To evaluate typical weekday conditions, 72-hour traffic volume counts were conducted between Tuesday and Thursday at various locations along the I-95 corridor. For all the data collection points along the corridor, the vehicles per hour per lane (vphpl) met the recommended criterion (400 to 800 vphpl) and in most cases the threshold was well exceeded. A level of service (LOS) analysis was performed using the latest version of the Florida Department of

Transportation LOS software. Speed data was collected via travel time and delay runs. Travel time runs were performed for the entire length of the HOV lanes using the "floating car" method. The overall travel time savings for the entire corridor in the northbound direction during the p.m. peak is approximately 9.5 minutes. In all segments except one, the speeds in the HOV lanes were significantly higher than the GP lanes. Vehicle occupancy was reported as a percentage of single occupant vehicles, two-person vehicles, and vehicles containing three or more persons within the traffic stream. AVO and traffic volume data were then used to calculate the person throughput of the HOV lane at selected locations. In all cases, the person throughput threshold of 900 to 1,800 persons per hour per lane (pphpl) was well exceeded except for one location at Glades Road southbound in the a.m. period. The vehicle occupancy surveys recorded the number of single occupant vehicles observed in the HOV lane during the enforcement periods (*11)*.

2.8 New Jersey Failure

In New Jersey, the HOV lanes on I-80 were opened with a peak-period two-person vehicle (2+) HOV designation in March 1994. The HOV lanes on I-287 were opened in January 1998, with the same 2+ and peak period operating requirements. The HOV lanes on both I-80 and I-287, however, were repealed and re-opened to all vehicles on Nov. 30, 1998. The diverse origins and destination of trips on I-287, low density suburban developments in both corridors and the absence of a major employment center or any trip-generating center made ridesharing or taking the bus more difficult. The HOV lane on I-287 was used very little with under 400 vphpl and did not do much to solve the severe congestion problem on this corridor. In contrast, the I-80 HOV lane was well used with more than 1,000 vphpl. Strong political opposition, however, encouraged the closure of I-80's HOV lane as well. Both the HOV facilities did not carry much transit service and the public was not prepared when it opened initially. The direct HOV connection between I-80 eastbound and I-287 southbound, which would have provided HOVs with significant travel time savings, was not implemented. Therefore, lack of transit service, support facilities (like park-and-ride lots), services (like rideshare programs) and policies and poor marketing were the major reasons for the failure and subsequent closure of the HOV lanes in New Jersey (*3, 12*).

2.9 System Overview

Nationwide, there are about 30 metropolitan areas with HOV lanes. Approximately 52 percent of them are enforced 24 hours a day, seven days a week. Approximately 86 percent of the HOV lanes operate as 2+ facilities with the remainder operating as 3+. The purpose of HOV lanes is to increase vehicle occupancy and reduce travel time for both private vehicles and transit services. The average peak period speed for HOV lanes as determined from the HOV lane studies across the country is 54 mph which is much higher than the average peak period speed of 28 mph for the GP lanes. The nationwide average violation rate is 9.5 percent on barrier-separated HOV lanes and 13 percent on concurrent facilities (*3, 13, 14*).

2.10 Overall Performance Summary

HOV lanes in many cities and are either meeting or exceeding the minimum effectiveness thresholds. They need continued assessment to check whether they are meeting their goals and objectives. There are many MOEs that are used in such assessments and evaluations. MOEs generally include volume, vehicle occupancy, modal split, speeds, travel times, and violation rates. Market research is also an integral part of the evaluation process. Information obtained from various evaluations and the market research indicate that support for HOV lanes has been increasing steadily. Continued evaluations and market research are key to the nationwide success of the HOV lanes.

3. METHODOLOGY

MOEs provide a way to select between alternative solutions and to know the success of a system. MOEs should be equal to or exceed the effectiveness thresholds. Any single MOE does not solely determine the achievement of the objectives. Therefore, the satisfaction of the majority of the MOEs by the HOV lanes has been considered. Data have been collected, analyzed and compared to previous data to measure the performance of the HOV lanes. Data have been compiled to develop the following MOEs:

1. Vehicle volume
2. AVO
3. Modal split
4. Person throughput
5. Travel time
6. Speed
7. Accident rate
8. Violation rate

The MOEs have been chosen to enable the fulfillment of the project's objectives. One of the major objectives of the project is to determine the efficiency of the HOV lanes. Vehicle volume has been selected as a MOE because volumes higher than the minimum threshold indicate that the HOV lanes are being used well. Vehicle volume will thus help meet the objective of determining the efficiency of the HOV lanes. Additionally, HOV lanes aim at carrying more people per vehicle. Vehicle occupancy as a MOE will provide quantitative data to evaluate occupancy and ascertain whether HOV lanes are enhancing the person-carrying capacity of the system. Moreover, modal split obtained from the AVO data will give the percentages of the various vehicle types and classify them as single-occupant vehicles, carpools, vanpools, buses, motorcycles, and trucks/trailers. HOV lanes are intended to increase the person-carrying capacity of a freeway by encouraging carpooling, vanpooling and bus ridership. Person throughput as a MOE will provide this data. Travel time as a MOE will measure and compare travel time. Travel-time data measures the effectiveness of HOV lanes in reducing commute time. With speed as a MOE it can be checked if there are any congested segments, because speeds below 45 mph are considered congested on I-15 *(4)*.

One of the major objectives of this study is to assess the safety of the HOV lanes. Accident rate as a MOE will provide quantitative data about the safety of the HOV lanes and enable their evaluation. Low violation rates are critical to ensure safe operation of the HOV facilities. Violators like trailers and heavy trucks in the HOV lanes make the HOV lanes unsafe. HOV lanes perform effectively and efficiently only with appropriate enforcement so violation rate has been selected as a MOE to evaluate HOV safety. The methodologies to be adopted for the various MOEs are described in this chapter.

3.1 Vehicle Volume

For all the data collection points along the corridor, it was checked whether the vehicle volume meets the National Cooperative Highway Research Program (NCHRP) HOV Systems Manual Report 414's standards. The NCHRP recommends a minimum operating threshold criterion of 400 to 800 vehicles per hour per lane (vphpl) during the peak hour for concurrent flow freeway HOV lanes (*15)*. When this condition was met at a specific location it was concluded that the HOV lane is well used at that location. The NCHRP's recommended maximum operating threshold criteria of 1,200 to 1,500 vphpl was checked. Additionally, 24-hour traffic volume profiles at 5900 S (both northbound and southbound) were plotted to see the variation of traffic at various times of the day for the opposing directions.

3.2 Average Vehicle Occupancy

A major objective of the HOV facility is to increase its person-moving capacity and not necessarily its vehicle-moving capacity. To meet this objective, the HOV lane should carry more people in fewer vehicles than the adjacent GP lanes. AVO is the average number of persons in a vehicle. Occupancy data from the different modes (single occupant vehicles, carpools, vanpools, buses, trailers and trucks) was collected separately during both the a.m. and p.m. peak periods. This person ridership distribution was then put into a spreadsheet for calculating the AVO of the HOV and GP lanes**.**

The following breakdown of person ridership was assumed for the different modes:

1. Carpools
   2 persons
   3 persons
   4 persons
   5+ persons

2. Vanpools
   1-5 - 3 persons
   5-10 - 7 persons
   10+ - 11 persons

3. Buses
   Empty - 1
   ½ Full - 20
   Full - 40

3.3 Modal Split

Modal changes occur when individuals switch from driving alone to carpooling, vanpooling, or riding the bus. Such modal changes indicate the popularity of the HOV lanes. To obtain modal split, the percentages of vehicles for each travel mode were calculated from the vehicle occupancy data. The effectiveness threshold for modal split is that the HOV lanes should have a higher percentage of carpools, vanpools and buses than the GP lanes. If more HOVs use the GP lanes than the HOV lanes, this may imply that HOV lanes are inconvenient to use and that on-ramps and off-ramps are needed for the HOV lanes.

3.4 Person Throughput

One of the major objectives of the HOV lanes is to increase person throughput, or person-carrying capacity. AVO and traffic volume data will be used to calculate the person throughput of the HOV lanes at the selected locations. The following formula will be used to obtain person throughput:

Person throughput = AVO * (Traffic Volume)

The NCHRP HOV Systems Manual's recommended person throughput threshold of 900 to 1,800 pphpl during the peak hours (*15)* was checked. Wherever it was satisfied it was concluded that the HOV lanes are well utilized and meeting the goal of carrying more persons than the national average. Another effectiveness threshold to be checked for person throughput is that the HOV lane should move a greater percentage of persons during the peak period than the percentage of the total directional capacity the HOV lane represents. In the Salt Lake Valley, an HOV lane represents 20 percent of the directional lane capacity and should therefore carry more than 20 percent of the total directional person trips.

3.5 Travel Time

The focus of considering travel time as a MOE is to determine peak period travel time savings for vehicles in the HOV lane as compared to those in the GP lane. According to the NCHRP HOV Systems Manual Report 414, HOV facilities should provide an overall travel time savings of at least 5 minutes during the peak hour (*15)*. An overall travel time saving of 7 minutes is desirable. It was checked whether travel times for the HOV lanes were lower than for the GP lanes. Moreover, travel time savings for the a.m. peak direction, p.m. peak direction and off-peak direction were tabulated. Average running speed of the test vehicle was also collected to complement the speed data collected using video detection. Travel speed profiles were developed using this data. Higher speeds in the HOV lanes, as compared to the GP lanes, indicate that the HOV lanes have lower congestion levels.

3.6 Speed

Speed as a MOE helps in determining congested segments. Speeds less than 45 mph are considered congested on I-15 (*4*). It was checked if the HOV lane speeds were less than 45 mph. It was also checked whether the HOV lane speeds are higher than 54 mph which is the average peak period speed for HOV lanes as determined from other studies across the country (*14)*. The speed limit in the Salt Lake Valley HOV and GP lanes on I-15 is 65 mph. If the speeds collected from the HOV lanes were found to be much higher than 65 mph, it was concluded that HOV lanes encourage illegal speeds.

3.7 Accident Rate

Accident information analysis evaluates the safety of the HOV lanes and identifies accident-prone locations or segments, if any. Safety in the HOV lanes is indicated by lower accident rates. The effectiveness threshold is that the accident rate of the HOV lanes should be lower than that of the GP lanes and the HOV lanes should not have an increasing trend of accident rates. Accident rate has been measured in terms of the number of accidents per million vehicle miles traveled (MVMT). An accident which occurred in the HOV lane or involved a vehicle entering or exiting the HOV lane has been considered as an HOV lane accident.

The entire HOV lane was divided into 8 segments for comparison of the accident rates. The exit locations were taken as the end points of each segment. The segments considered for accident rate comparison were:

1. 600 North to 400 South
2. 400 South to 2100 South
3. 2100 South to 3300 South
4. 3300 South to 4500 South
5. 4500 South to 5300 South
6. 5300 South to 7200 South
7. 7200 South to 9000 South
8. 9000 South to 10600 South

The following UDOT severity codes were considered:

No injury - 1
Possible injury - 2
Bruises and abrasions - 3
Broken bones or bleeding wounds - 4
Fatal - 5

3.8 Violation Rate

Violation is defined as the percentage of the total HOV lane volume that is comprised of single-occupant vehicles and prohibited vehicles, such as those weighing over 12,000 lbs and those towing trailers. Lower violation rates indicate public awareness and acceptance of the HOV lanes. Since the nationwide average violation rate is 13 percent on concurrent HOV lanes (*14)*, it was determined whether the violation rate in the Salt Lake Valley is higher than 13 percent. The effectiveness threshold is that the violation rate should be lower (that is, less than 10 percent) and should decline over time. If this threshold is not met, appropriate enforcement steps like stronger patrolling are recommended.

4. DATA COLLECTION

Data was collected only on Tuesdays, Wednesdays and Thursdays to evaluate typical weekday conditions. The a.m. peak period was considered from 6:30 a.m. to 8:30 a.m. The a.m. peak direction was taken as southbound from 600 North to 400 South and northbound from 400 South to 10600 South. The p.m. peak period was considered from 4:00 p.m. to 6:00 p.m. The p.m. peak direction was taken as northbound from 600 North to 400 South and southbound from 400 South to 10600 South. The directional split has been determined, taking into consideration the northern dense employment district (400 South being a major trip-generating center) as compared to the southern residential areas. For a particular location data was collected during both the a.m. and p.m. peak periods and for both the HOV and GP lanes, unless otherwise stated. Data was collected manually and by video detection using the video feeds provided by UDOT. Video data collection was done in late January 2004, whereas manual data collection was done in March 2004. Manual data collection locations were chosen that were safe, and favorable for visual observation while providing representative data. Locations with an overpass running over the freeway corridor were first selected. To ensure safety it was checked whether they had a sidewalk and a fence. The overpass at 2700 South did not have a sidewalk or a fence facing the southbound traffic, so southbound (p.m. peak) traffic data was not collected. Additionally, northbound (a.m. peak) traffic data could not be collected at 10600 South as the HOV lanes begin much after the overpass. A list of the data collection locations is provided in Appendix A.

4.1 Vehicle Volume

Vehicle volume was collected as a.m. and p.m. Peak volume in 15-minute intervals along the peak directions. Vehicle volume was obtained by video detection (Autoscope Solo System®) using UDOT's video feeds. A snapshot of the video data collection is provided in Appendix A. It was checked periodically whether the camera position and alignment were constant. The data collection locations were:

1. North Temple
2. 400 South
3. 2100 South
4. 4500 South
5. 5900 South
6. 7200 South
7. 10600 South

At 5900 South, 24-hour traffic volume data was collected for both the northbound and southbound directions. Data at 400 South, 7200 South and 10600 South were taken before the exits, whereas data at 2100 South and 4500 South were taken after the exits.

4.2 Average Vehicle Occupancy

Occupancy data collection was done manually. The counts consisted of noting the number of occupants in each vehicle in a single lane for 15-minute intervals in datasheets. Only peak periods and peak directions were considered. AVO data was collected at the following locations:

1. 400 South HOV on-ramp and off-ramp
2. 2700 South (a.m. peak period only)
3. 3900 South
4. 4900 South
5. 10600 South (p.m. peak period only)

Data was collected manually by standing on the overpasses at the locations (except at 400 South where data was collected by standing on the sidewalks).

4.3 Modal Split

The AVO datasheet was prepared so that modal split, vehicle volume and person throughput could be obtained in addition to AVO. Modal split was collected at the following locations:

1. 400 South HOV on-ramp and off-ramp
2. 2700 South (a.m. peak period only)
3. 3900 South
4. 4900 South
5. 10600 South (p.m. peak period only)

4.4 Person Throughput

Person throughput data was collected at the following locations:

1. 400 South HOV on-ramp and off-ramp
2. 2700 South (a.m. peak period only)
3. 3900 South
4. 4900 South
5. 10600 South (p.m. peak period only)

4.5 Travel Time

Travel time is the time it takes a vehicle to traverse a given section of a road. 400 South is a Central Business District area and is very congested, especially during the peak periods. If the GP lane study segment includes 400 South, it might lead to skewed travel time data. For this reason the starting point for the GP lanes for the southbound direction was the Little America Hotel (500 South, Main Street) and the end point was 10600 South on I-15. For the northbound direction in the GP lanes the starting point was 10600 South on I-15 and the end point was 600 South on I-15. The Southbound HOV lane travel time run was taken from the intersection of 400 South and Main Street to 10600 South on I-15. The HOV-only on-ramp was used at 400 South. The Northbound HOV lane run was taken from 10600 South to 400 South on I-15 and the HOV-only off-ramp was used at 400 South. These have provided more representative data. The travel time runs were done only on Tuesdays, Wednesdays and Thursdays in the a.m. peak direction, p.m.

peak direction and off-peak direction. The floating car technique was adopted to determine travel time. In the floating car technique the vehicles in the HOV and GP lanes are driven at the median speed in the respective lane. The vehicle running in the GP lane can change lanes.

The distance between two consecutive control points was considered a segment. The control points which were taken as the on/off-ramp locations were 600 South, 2100 South, 3300 South, 4500 South, 5300 South, 7200 South, 9000 South, and 10600 South. The time taken to traverse the entire study stretch and each of its segments was recorded. Additional data was obtained by recording the average running speed of the test vehicle.

Usually the number of test runs is less than 30. If t-distribution is assumed, the number of test runs to be conducted is given by the formula (*16*)

$$N = \left(\frac{t_{a,(N-1)} * s}{d} \right)^2$$

(1)

where:

N = minimum number of test runs
$t_{a,(N-1)}$ = value of the student's t-distribution with (1- a /2) confidence level and (N-1) degrees of freedom
s = standard deviation (in mph)
d = limit of acceptable error in the speed estimate (mph)

Since d is generally assumed between ± 2.0 to ± 4.0 mph (*16*) for traffic operations, economic evaluations, and trend analysis, d = ± 2 mph was assumed. An average value of s = 2.32 mph was determined from the previous study of the I-15 HOV lanes. Since a 95 percent confidence level is assumed, (1- a /2) = .95 or, a = 0.1. N values were assumed and then t values were found from the student's t-distribution table. N value was then calculated for that particular value of $t_{a,(N-1)}$. The assumed and computed values of N were compared. If they were almost equal, then that value of N was chosen as the minimum number of test runs. From Table 4.1 the minimum number of test runs required was found to be 6. The runs in the HOV and GP lanes were conducted simultaneously. They were performed twice during the a.m. peak, p.m. peak and off-peak directions. In this way the number of runs for HOV and GP lanes totals 6.

Table 4.1: Calculation of number of test runs

$N_{assumed}$	$t_{.1,N-1}$	$N_{calculated}$
5	2.132	6.12
6	2.015	5.46
7	1.943	5.08

4.6 Speed

Speed data in the HOV and GP lanes was collected using video detection simultaneously with the volume data collection. Data was collected only along the peak directions during the peak periods. Additionally average time headway and level of service were obtained using video detection.

Variation of speed along the HOV and GP lanes was collected at the following locations:

1. North Temple
2. 400 South
3. 2100 South
4. 4500 South
5. 5900 South
6. 7200 South
7. 10600 South

At 5900 South, 24-hour speed data was collected for both the northbound and southbound directions.

4.7 Accident Rate

The accident records are stored in the State of Utah Investigating Officer's Report of Traffic Accidents. They were obtained from UDOT's Traffic and Safety Division. At first, the accident control numbers, accident dates, and milepoints were obtained for all the accidents that occurred from May 14, 2001, (that is, the day on which the HOV lanes were opened on I-15) to Dec. 31, 2003, between 600 North and 10600 South on I-15. Corresponding to these accident control numbers, the description and diagram of each accident was examined. Based on this it was determined whether the accident occurred in the HOV lane, GP lane or a ramp. If it occurred in the HOV lane, the date, time, location, direction of travel, cause and severity code of the accident and the collision type were noted. The Utah Highway Patrol (UHP) accident records were available in the database maintained by the Utah Law Enforcement Data Center and the rest were in the form of microfilms. About 3,517 accident records were examined. It should be noted that these accident records corresponded to the following time periods (the rest being unavailable):

1. UHP accident records from May 2001 to December 2003
2. Non- UHP accident UHP accident records from May 2001 to May 2002

UDOT's accident records refer to an accident location using the milepoint system. For the year 2001, the milepoints were 309.81 for 600 North and 293.78 for 10600 South. For the years 2002 and 2003, the milepoints were 309.99 for 600 North and 294.25 for 10600 South. The change is due to the reconstruction and realignment of curves along I-15 and the subsequent renumbering of the milepoints. Corresponding to the milepoint of an accident in the HOV lanes, the segment in which it fell was determined.

4.8 Violation Rate

Violations were monitored for two hours during the a.m. and p.m. peak periods on typical weekdays (Tuesday, Wednesday and Thursday). Observers stood on an overpass or other suitable place where violations could be easily detected. The license plates of AFVs have a letter C painted in black on a blue background. To detect vehicles weighing more than 12,000 lbs. the Gross Vehicle Weight Rating (GVWR) displayed on the vehicle identification number (VIN) plate or on the side of the vehicle was noted. Generally trucks larger than a pickup have a GVWR over 12,000 lbs. Data collection locations for violation rates were:

1. 400 South HOV on-ramp and off-ramp
2. 2700 South (a.m. peak period only)
3. 3900 South
4. 4900 South
5. 10600 South (p.m. peak period only)

5. MARKET RESEARCH

5.1 Measures of Effectiveness (MOEs)

The MOEs were framed to identify the public's perception of the HOV lanes and to aid in determining the conditions that would encourage additional HOV users.

The MOEs for market research were:

1. Support for the HOV lanes from both the HOV users and SOV drivers

   Support for the HOV lanes from both the users and non-users indicates that the HOV lanes are functioning effectively.

   Questions:
   Q11 a. HOV lanes are unfair to those taxpayers who drive alone. ___
   Q11 f. HOV lanes are convenient to use. ___
   Q11 g. HOV lanes should be expanded. ___

2. Modal shifts and commuting patterns

   Modal shifts to high occupancy vehicles imply public acceptance of the HOV lanes. Factors affecting carpool mode choice, transit use and carpooling characteristics can be obtained to improve the HOV facilities.

   Questions:
   Q5. Have you changed your mode of travel (e.g. carpooling, motorcycle, etc) to allow you to use the HOV lanes?
   Q9. What, in your opinion, most influences a driver's decision to carpool?

3. Demographic information

   Demographic information like gender, age, education level, and household size help to know potential differences among the respondents.

   Questions:
   Q12. Gender: Male ___ Female ___
   Q13. Age: under 20 ___ 21-30___31-40 ___ 41-50 ___ 51-60 ___ 61-70___71-80___81-90___91+___
   Q14. What is your highest level of education?
   Q15. How many people live in your household, including yourself?

Public surveys were conducted to find how users and non-users rate the performance of the HOV lanes and whether there have been modal shifts. They consisted of a random sample of area travelers and the method adopted was face-to-face personal interviews (86 percent) and email surveys (14 percent). Personal interviews are better than alternative methods (telephonic surveys, mail-out surveys, web-based surveys) in many ways. The researcher can interact directly with the respondent and ask follow-up questions. Moreover, the respondents find it easier because mainly opinions are sought and the respondent can clarify his/her doubts (*17*). Email surveys are fast and can cover a wide range of people. It was checked whether there were comparable samples of SOV drivers (non-users) and carpoolers and bus riders (users) so that different viewpoints and unbiased opinions were obtained.

5.2 Sample Size Calculation

The number of participants needed for statistically significant results is found by using the formula (*18*):

$$n = \frac{(4*Z^2*p*q)}{B^2} \quad (2)$$

where:
n = sample size required to estimate p
Z = test statistic for a standard normal distribution.
p = either .5 (conservative value) or the proportion favoring HOV lanes in any previous research surveying the same population. Here p = 0.5 is considered to give the highest value of n.
q = (1.00 - p) the best estimate that can be made of the proportion opposed to HOV
B = bound on the error of estimation or the confidence interval (two times the confidence interval for two tailed tests). It has been assumed that the actual value may be ±7 percent off from the true value. Since it is a two-tailed test, B=2*(±7 percent) = ±0.14

A 95 percent confidence level was assumed. Hence, Z = 1.96 and Z^2 = 3.84

$$n = \frac{(4*1.96^2*.5*.5)}{(.14)^2} \approx 200$$

This sample size of 200 is statistically valid with an error margin of +/-7 percent with a 95 percent confidence level.

5.3 Questionnaire Design

A questionnaire is a tool to draw forth, collect, and record information. Well-framed questionnaires start off a process of analysis and discovery in the respondent's mind (*19*). Questionnaire design, unlike sampling and data analysis, is not guided by rules. It is best guided by intuition about how to script a natural conversation between a researcher and a respondent. If a questionnaire is reliable, then the feedback from a population sample can be considered a reflection on the attitudes of the entire population. Furthermore, questionnaires are usually quick and a lot of data can be gathered. The main disadvantage, however, is that a questionnaire tells only the respondent's reaction as he/she perceives the situation (*19*).

There is generally a tendency of respondents to try to please an interviewer by answering "yes" whenever possible. Moreover there is a tendency to prefer answers listed earlier (or later) or to number the options serially. Most of these problems were overcome by rotation, that is, by changing the order in which the questions and options were presented to the respondents. Also, the questionnaire was pre-tested to detect misleading or confusing questions. The questions were kept simple and short. Complex symbols and terminology were avoided.

In the questionnaire, mainly factual and opinion-type questions were asked. The filter question was that the respondents should have traveled on the I-15 stretch between 600 North and 10600 South in the Salt Lake Valley. The questions were then grouped by content, namely commute trip, opinions, and information about the respondent. In the commute trip section, respondents were asked to describe their commuting pattern, that is, whether they use the HOV lane, their mode when using the HOV lane, and why they may sometimes choose not to use the HOV lane. The opinions section asked respondents about their viewpoints on a variety of issues. Respondents were asked to rate a list of options that would make HOV lanes more attractive and also asked to indicate a degree of agreement or disagreement to a series of propositions. The propositions addressed usage, safety, enforcement, and other issues associated with HOV lanes. The third section of the survey asked respondents to provide information about themselves. This demographic data helped develop a profile of the region's commuters and to control potential differences among respondents. In other words, it enabled the comparison of responses based on demographic data such as gender, age, and education level. The questionnaire is included in Appendix E.

5.4 Results and Discussion

Responses of Salt Lake Valley commuters were obtained through public opinion surveys and they complemented the traffic and travel time analysis findings. The respondents were randomly selected mainly at the Salt Lake City Downtown Library and at the University of Utah. Results in which the respondents expressed degrees of their agreement to a particular view have been presented as scores in a certain scale. The other results have been expressed as percentages of respondents who supported or opposed a particular view. The results obtained were then analyzed.

5.4.1 Section A: Commute Trip

Figure 5.1 shows that the most popular travel mode when using I-15 is SOV, followed closely by carpools. Forty-nine percent of the respondents drive alone on the I-15, 46.5 percent carpool, 3 percent use the bus, 1 percent ride motorcycles and the remaining 0.5 percent vanpool. Representatives from all the travel modes were covered in the public opinion survey.

Figure 5.2 shows that most of the respondents (82 percent) have used the HOV lanes at one time or another which also implies their familiarity with the system.

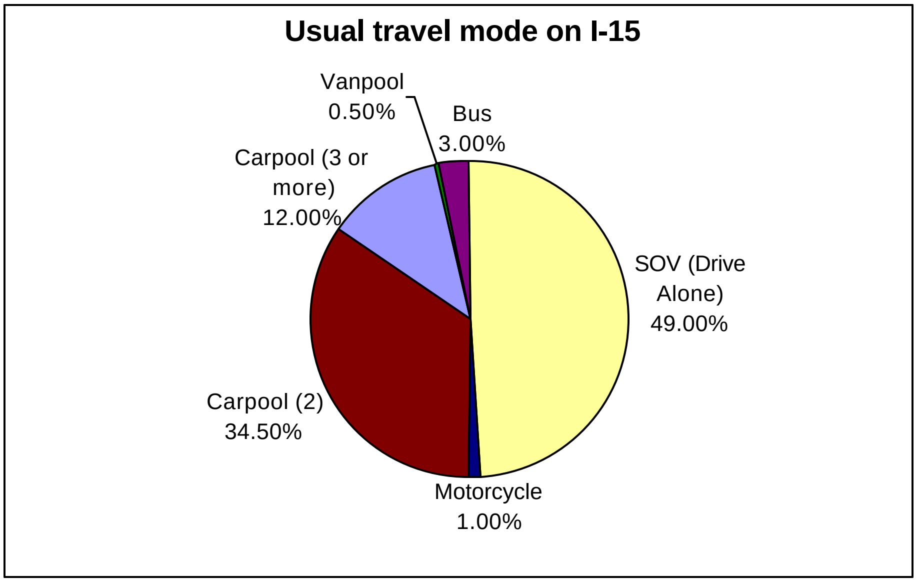

Figure 5.1: Usual Mode when using I-15

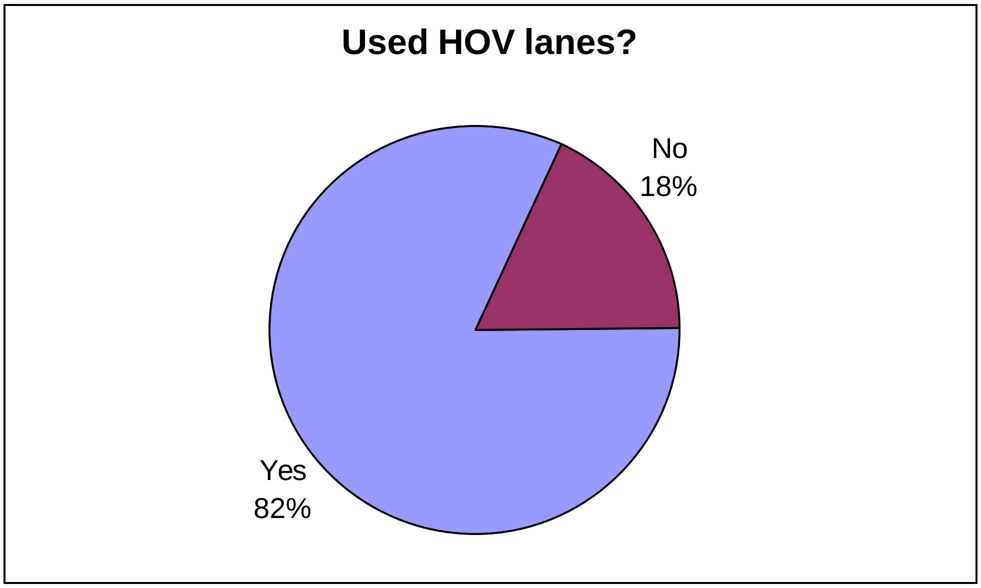

Figure 5.2: Percentage who have/have not used the HOV lanes

Figure 5.3 illustrates that, when using the HOV lanes, the majority of the respondents have a 2-person carpool (68.29 percent), followed by 3 or more person carpool (25.61 percent), bus (4.27 percent), motorcycle (1.22 percent) and vanpool (0.61 percent). The reason for the greatest popularity of 2-person carpools is probably because 2+ carpools are relatively easy and convenient to form. This is supported by the manual data collection for modal split, which found that 2-person carpools constituted the highest percentage of all the modes in the HOV lane, followed by 3 or more person carpools. From Figure 5.3 it is also seen that vanpooling needs to be encouraged and popularized so that there is a further increase in the average vehicle occupancy of the HOV lanes.

Figure 5.4 shows the number of round trips made by the respondents, in the HOV lanes per week. It is seen that most of the respondents, (88.41 percent), use the HOV lanes less than 3 times per week, 10.37 percent use them less than 6 times per week and only 1.22 percent use them more than 5 times per week.

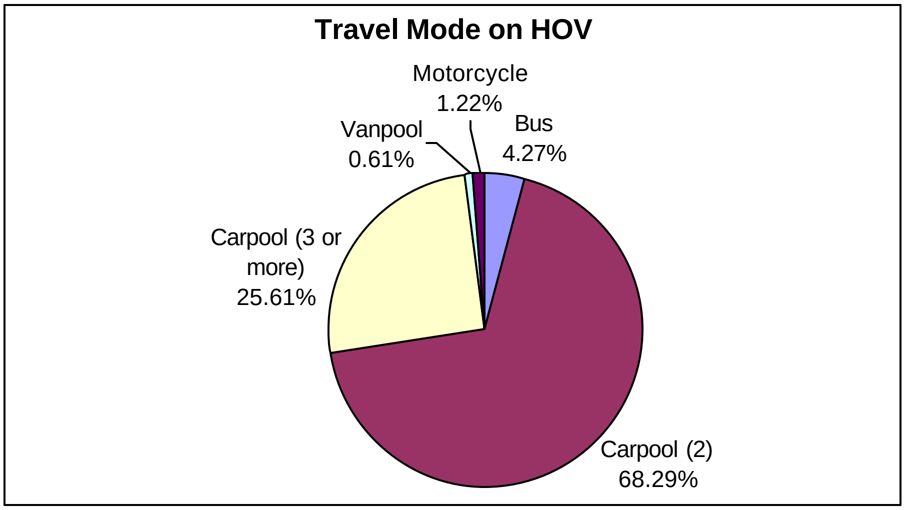

Figure 5.3: Mode when using the HOV lanes

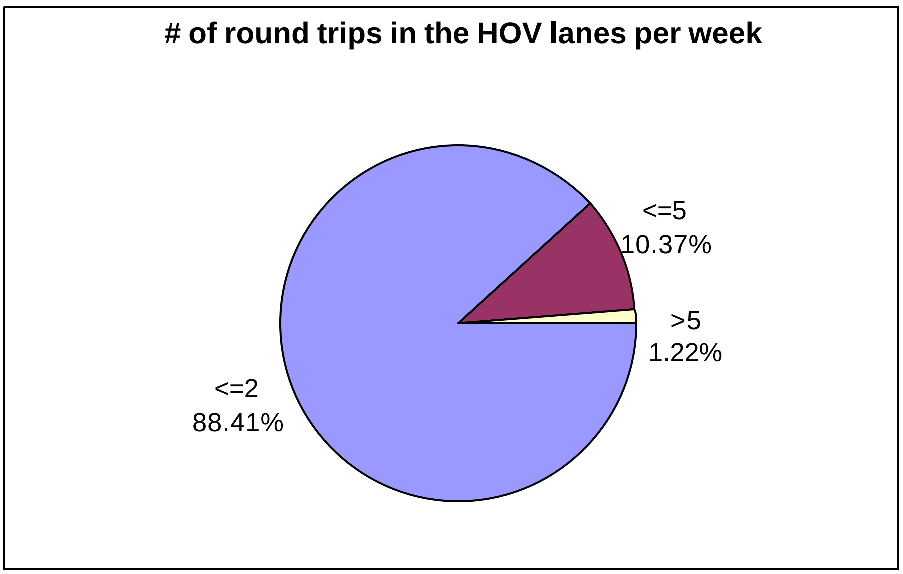

Figure 5.4: Number of round trips in the HOV lanes per week

Figure 5.5 presents the respondents' ratings of the advantages offered by the I-15 HOV lanes. The respondents were asked to rate the 4 factors that would make the HOV lanes more attractive. The scale was from 1 to 4, where 1 meant "least important" and 4 meant "most important." Using this scale, an overall score was determined for each factor. A higher overall score (maximum possible overall score was 4) meant a more advantageous factor. The overall rating was 2.70 for "less traffic," 2.60 for "saves time," 2.51 for "benefits carpoolers," and 2.20 for "better for the environment." Therefore, according to the responses, no particular advantage of the HOV lanes was much more important than the others.

When the respondents were asked to compare their present commute times to those before the HOV lanes were constructed in the Salt Lake Valley, 41 percent could not distinguish between the two situations, followed by another 38 percent who believed that the commutes have become faster, another 18 percent who felt that it was the same and the remaining 3 percent who thought that it had become slower. This is illustrated in Figure 5.6.

Figure 5.7 shows that 69 percent of the respondents generally use the HOV lanes when traveling with someone else and the remaining 31 percent do not do so.

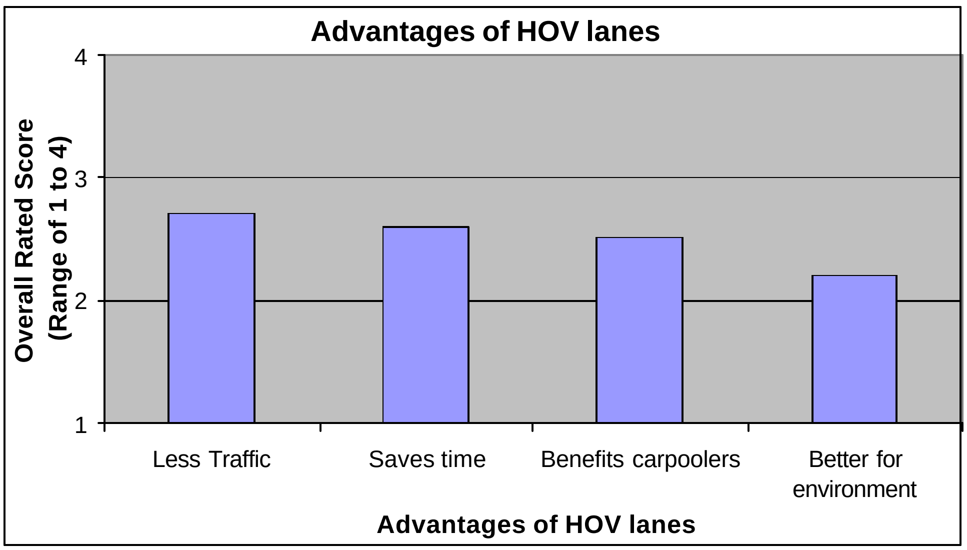

Figure 5.5: Advantages of HOV lanes

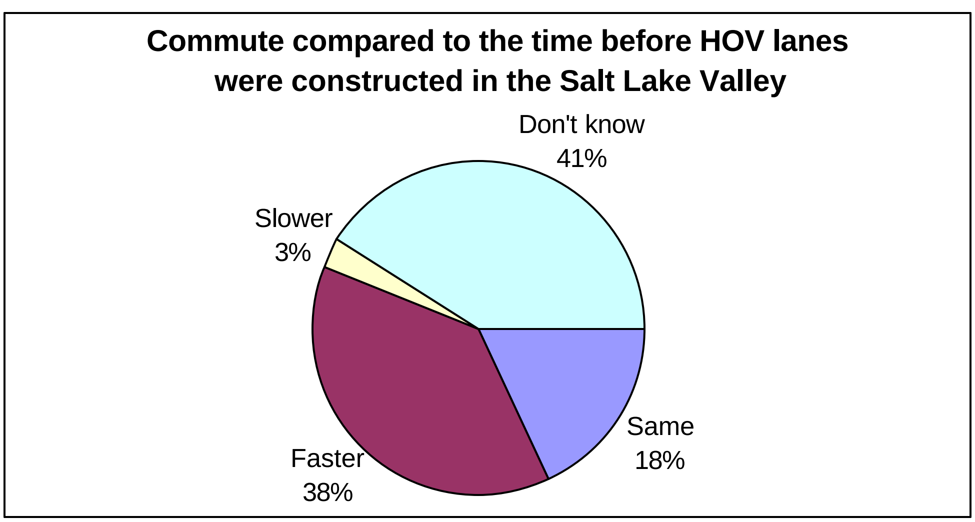

Figure 5.6: Comparison of the commutes before/after HOV lane construction

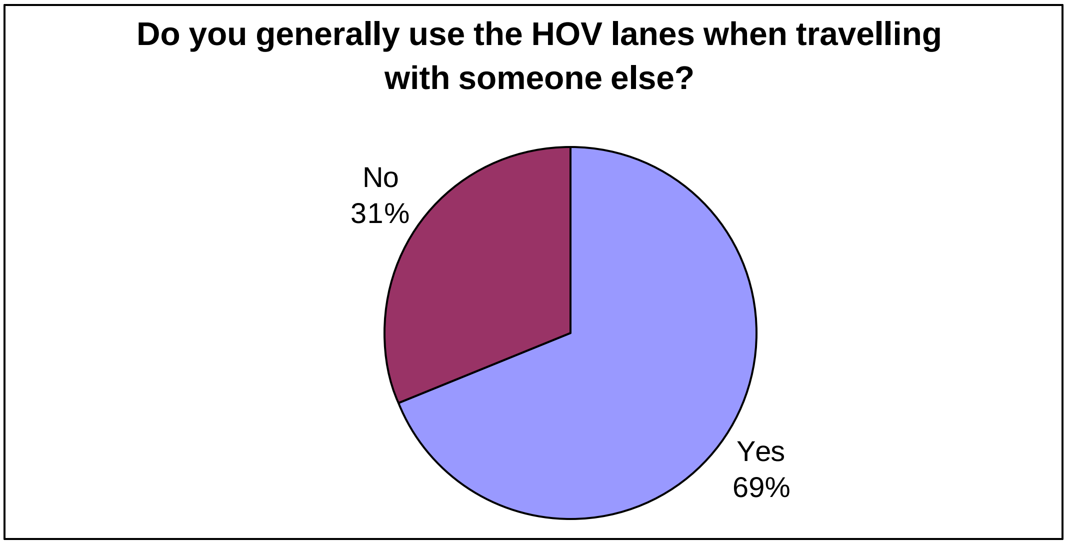

Figure 5.7: Percentage of respondents who have used the HOV lanes when eligible

Figure 5.8 lists the reasons for people not using the HOV lanes when they are eligible to use them. The major reason mentioned was that during the off-peak period traffic moves fast enough in all the lanes, so there is not much advantage in using the HOV lanes. Lack of direct HOV exit/entrance ramps, which leads to trouble in changing lanes, was found to be the second reason for qualified people not using the HOV lanes. The other reasons cited were signs and markings being unclear or unreadable, the HOV lane being slower than the GP lanes and the HOV lanes being unsafe. Southbound HOV lanes were observed to be slower than the GP lanes during Friday evenings when the number of carpoolers is higher. Some people feel that HOV lanes are unsafe because vehicles dart in and out of the HOV lanes frequently.

About 5 percent of the respondents admitted that they had changed their travel mode to use the HOV lanes, as seen in Figure 5.9. This percentage in modal shift is not high and needs to be improved by making the lanes more attractive to users.

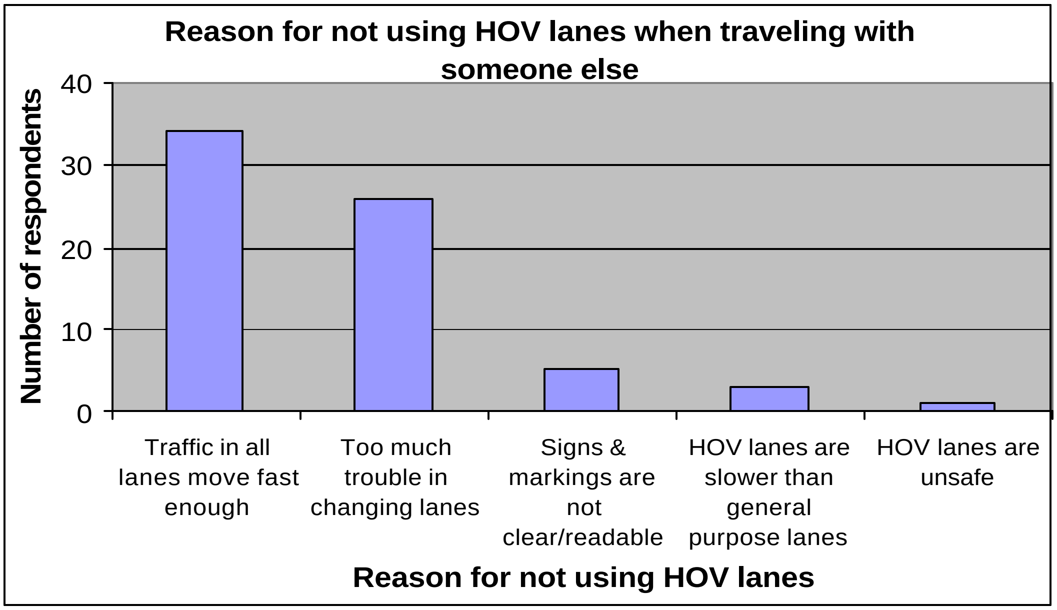

Figure 5.8: Reason for not using the HOV lanes when traveling with someone else

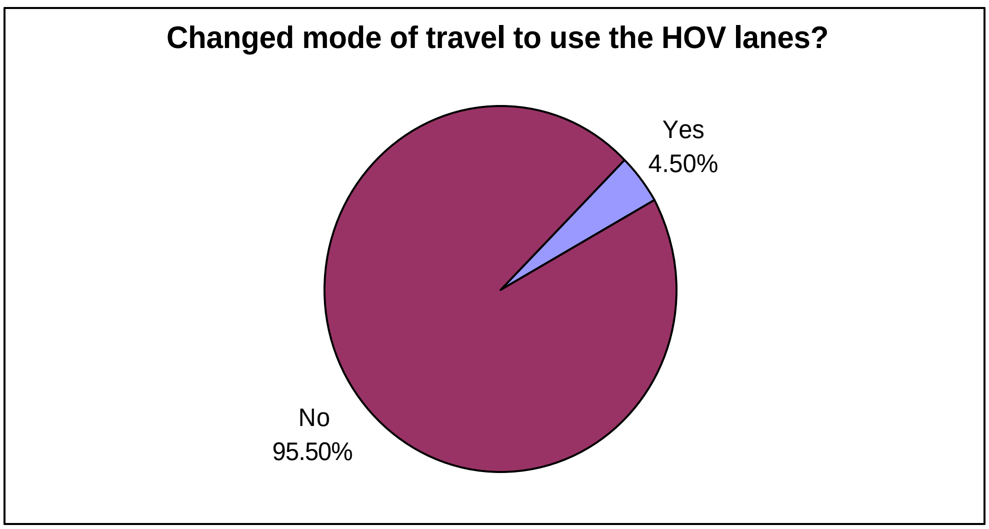

Figure 5.9: Change of mode of travel to use the HOV lanes

Figure 5.10 shows that people find the HOV lanes preferable over light rail. Most of the respondents (71 percent) will continue using the HOV lanes even if light rail is available for the same route. The reason is that people can access the HOV lanes even with their personal cars, which is more convenient.

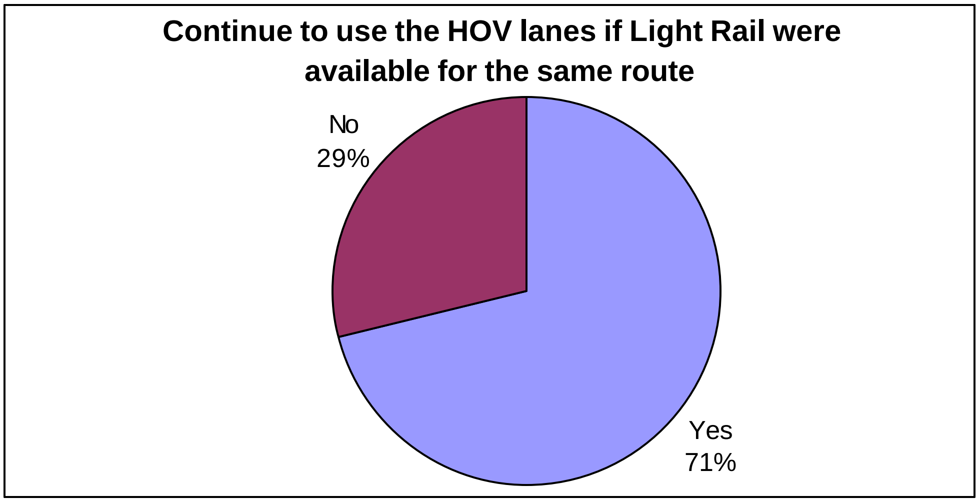

Figure 5.10: HOV lanes Vs Light Rail

5.4.2 Section B: Opinions

Comments about the Salt Lake Valley HOV lanes were obtained from the respondents. The comments offered are included in Appendix F.

When asked if some sections of the I-15 HOV lanes were too congested, 17.5 percent of the respondents replied in the affirmative. They were further asked to mention the segments which they felt were congested. Figure 5.11 shows the congested HOV segments on I-15 as mentioned by the respondents. The majority of them mentioned the segment from 9000 South to 10600 South, (especially the 10600 South bottleneck where the HOV lane merges into GP lanes and one GP lane is subtracted) to be a major congested segment.

Figure 5.12 presents the respondents' rating of the factors that would make the HOV lanes more attractive. The rating scale was from 1 to 6, where 1 meant "least attractive" and 6 meant "most attractive." Using this scale, an overall score was determined for each factor. A higher score (maximum possible overall score of 6) meant a more attractive factor. The major factor determined was direct entrance and exit ramps to the inside HOV lanes with a score of 4.36, followed by more park and ride lots and discounted parking (score of 3.84), employers' incentives (score of 3.66), better bus service (score of 3.29), assistance in finding a compatible carpool partner (score of 3.25), and fee-based access for SOV drivers (score of 2.61). Thus, among the options to improve HOV lane usage, the direct access issue outweighed the transportation demand management measures such as additional park & ride lots and employers' incentives for ridesharing. There does not seem to be much support for high occupancy toll (HOT) lanes which permit SOV drivers to use HOV lanes for a fee.

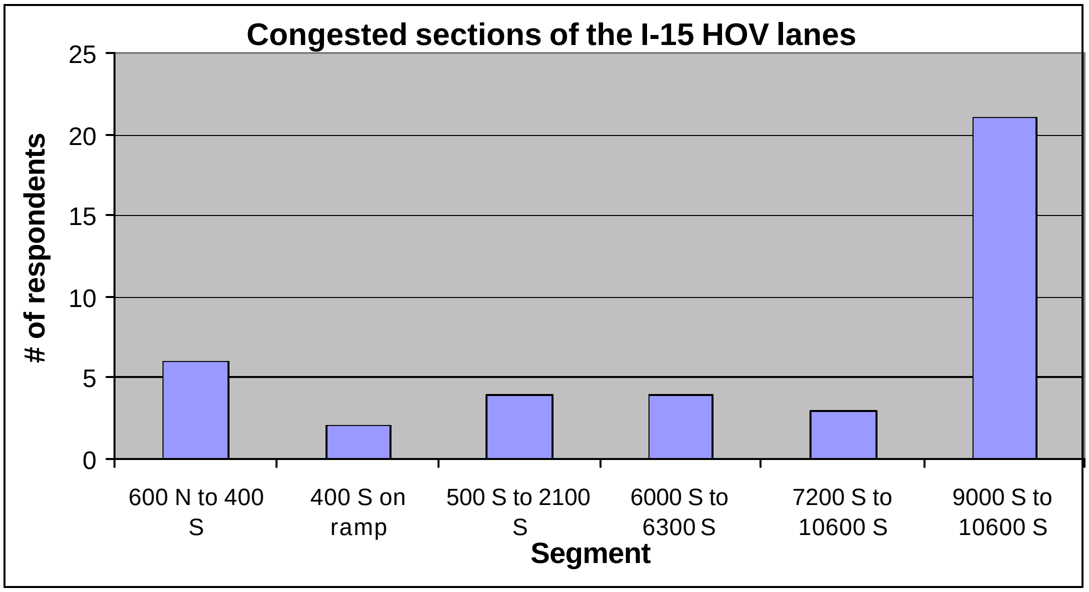

Figure 5.11: Congestion in the I-15 HOV lanes

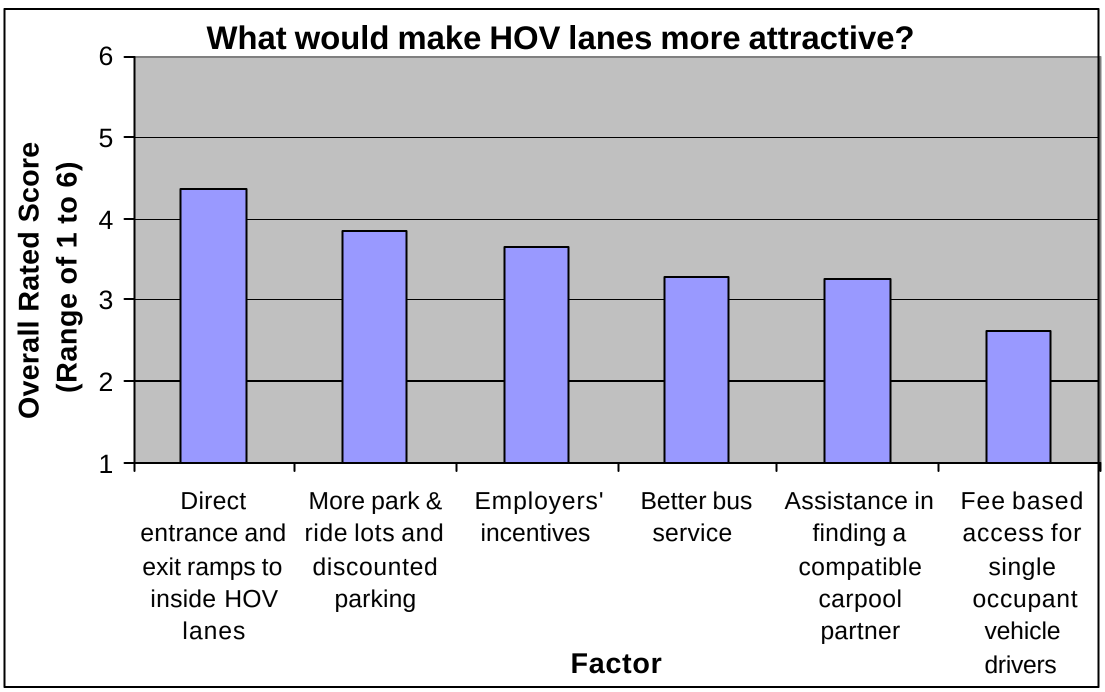

Figure 5.12: Factors that would make HOV lanes more attractive

The respondents were asked to rate the factors that affect a driver's decision to carpool. The rating scale was from 1 to 6, where 1 meant "least influential" and 6 meant "most influential." Using this scale, an overall score was determined for each factor. A higher score (maximum possible score of 6) meant a more influential factor. The major deciding factor was found to be reduced cost of driving and parking with a score of 4.31, followed by reduced stress of commuting (score of 3.91), access to carpool or vanpool (score of 3.47), incentives from employers (score of 3.47), regular/irregular work hours (score of 3.17), and concern for environment (score of 2.69). Figure 5.13 presents these results.

Figure 5.14 shows how the respondents rate the HOV lanes. There is a strong public support of 86.5 percent, with 49.50 percent stating it to be an excellent idea followed by another 37 percent who believe it is a good idea. Another 11.5 percent felt that it was a fair idea and the remaining 2 percent felt that it was a poor idea. This widespread popularity is consistent with the traffic and travel time data analysis which concludes that HOV lanes are effective and thereby popular. The reason for some people rating it as a fair idea or a poor idea may be due to the fact that the HOV lanes in Salt Lake Valley still need improvement in their operation.

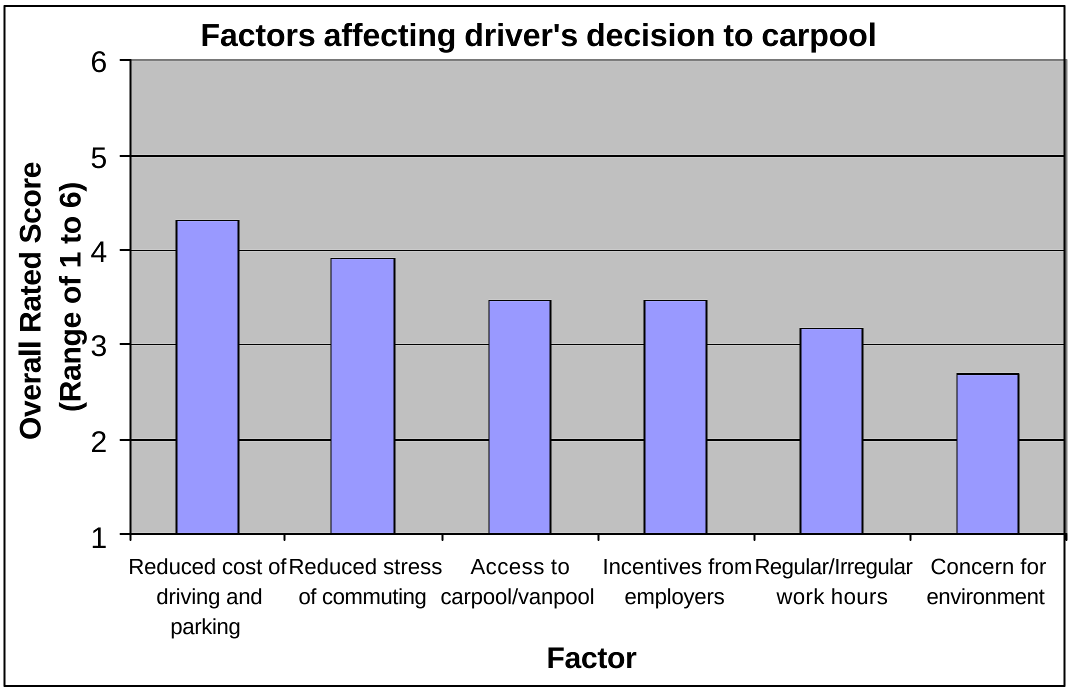

Figure 5.13: Factors influencing carpooling

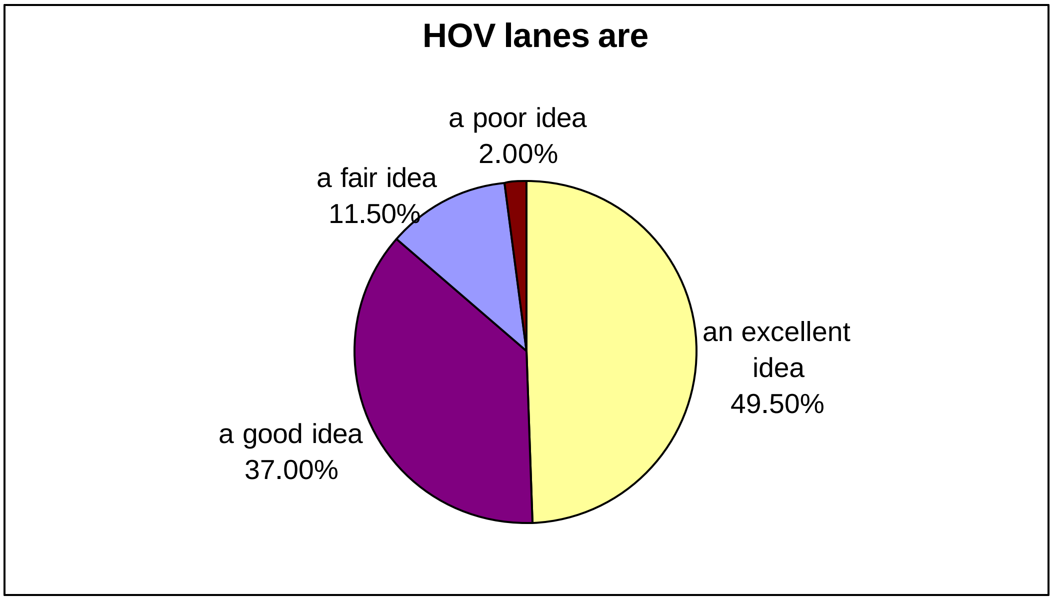

Figure 5.14: Rating of the HOV lanes

Table 5.1 shows the proportion of respondents favoring the HOV lanes at various locations. In the Salt Lake Valley, support for HOV lanes is quite high, second only to Los Angeles.

To evaluate the rating of the non-HOV users, the responses of the SOV drivers were separately analyzed. It was found that about 42 percent of those who drive alone believed that HOV lanes are an excellent idea; 39 percent felt it was a good idea whereas 15 percent thought it to be a fair idea and the remaining minority of 4 percent felt it to be a poor idea. Among HOV lane users 57 percent believed that HOV lanes are an excellent idea; 35 percent thought they are a good idea and the remaining 8 percent termed them a fair idea. The difference in the view that the HOV lanes are either an excellent or a good idea expressed by those who drive alone and the HOV lane users is not significantly different at the 0.05 significance level. This shows that the Salt Lake Valley HOV lanes have support from those who drive alone too. Figure 5.15 shows the SOV drivers' rating of the HOV lanes.

Table 5.1: Support for HOV lanes

HOV lanes location	Proportion favoring HOV lanes (%)
Los Angeles, California	88.0
Salt Lake City, Utah	86.5
Seattle, Washington	83.0
Houston, Texas	70.0
Oregon I-5	66.0
Vancouver, Washington	58.0

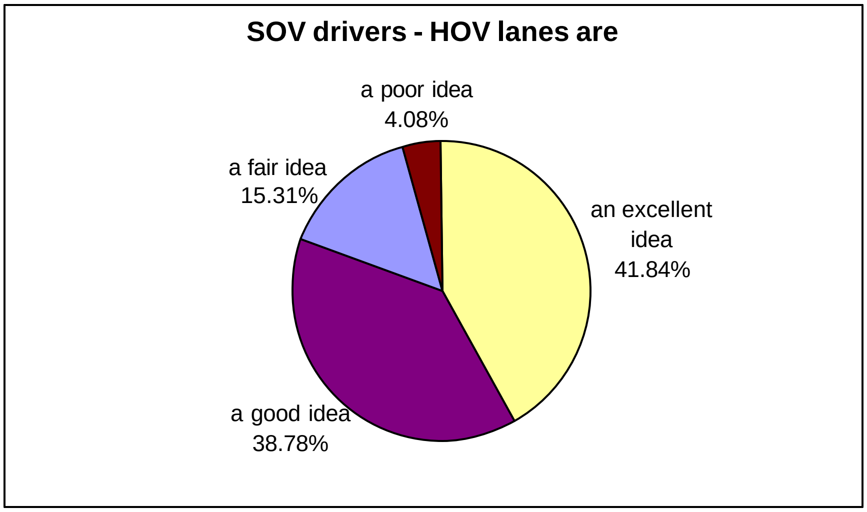

Figure 5.15: Rating of the HOV lanes – SOV drivers

A series of eight statements about the HOV lanes was presented to the respondents. They were then asked whether they strongly agreed, agreed, were neutral, disagreed or strongly disagreed with each statement. An overall score was determined for each statement using a 1 to 5 scale where "strongly disagree" was assigned a value of 1, "neutral" was assigned a value of 3 and "strongly agree" was assigned a value of 5. Thus the closer a score is to 5, the greater the level of agreement and the closer a score is to 1, the greater the level of disagreement. The statement that "HOV lanes are convenient to use" received the highest score of 3.87 whereas "HOV lanes are unfair to those taxpayers who drove alone" received the lowest score of 2.23. The latter statement implies that people realize the fact that HOV lanes benefit the SOV drivers by taking the high-occupancy vehicles out of the GP lanes. As a whole, respondents gave above-average scores to the other statements like "HOV lanes should be expanded" (score 3.54); "HOV lane violations are common during peak hours" (score 3.51); "HOV lane violation is a serious traffic violation" (score 3.45); "Existing HOV lanes are being adequately used" (score 3.15); "HOV lanes should be opened to all traffic during non-peak hours" (score 2.98) and "Vehicles move in and out of HOV lanes too often and so they are safety hazards" (score 2.64) as shown in Figure 5.16.

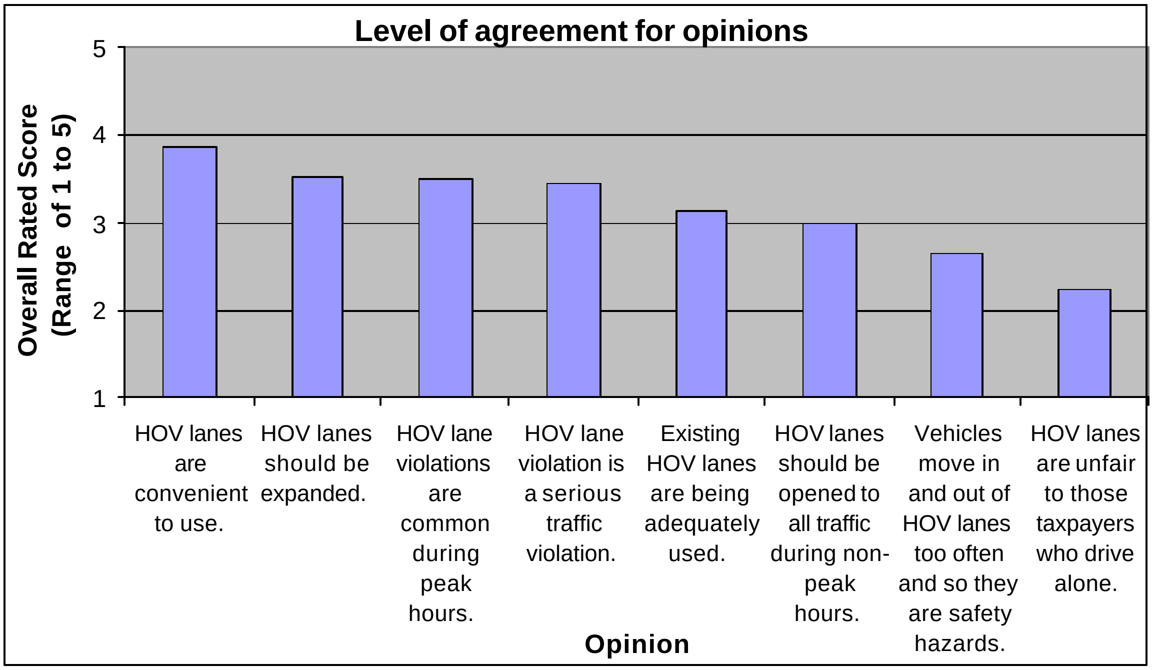

Figure 5.16: Level of agreement for opinions

5.4.3 Section C: Demographics

Figure 5.17 shows that there were more male respondents (56 percent) than female respondents (44 percent) in the random public opinion survey.

Figure 5.18 presents the split of respondent age in various age groups. There were representatives from all age groups. The dominant age group was 21-30 years (42 percent), followed by 41-50 years age group (17.5 percent), 51-60 years age group (16 percent), 31-40 age group (13.5 percent), under 21 years age group (9 percent) and 61-70 years age group (2 percent). The reason for about 90 percent of the respondents being from the age group of 21 to 60 years is that people who belong to this groups own vehicles and drive to work, school, businesses etc.

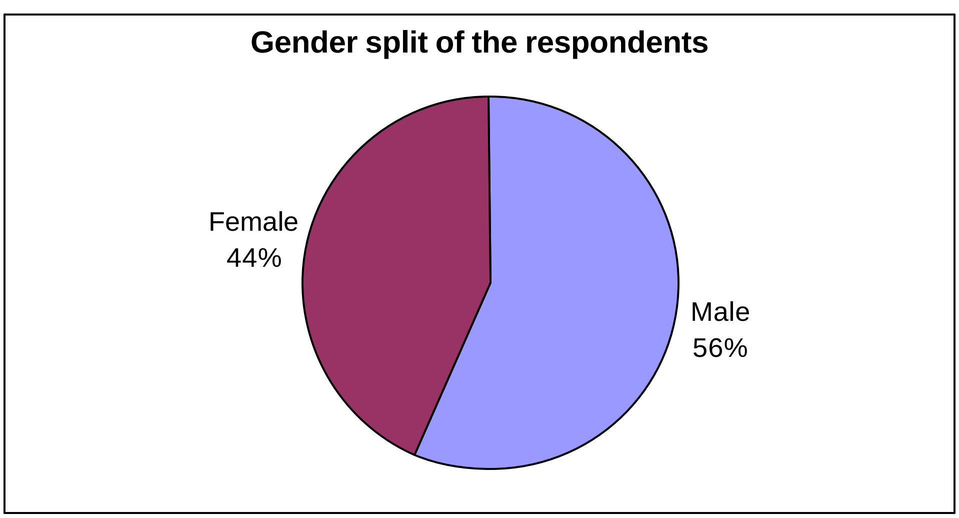

Figure 5.17: Gender Split of the respondents

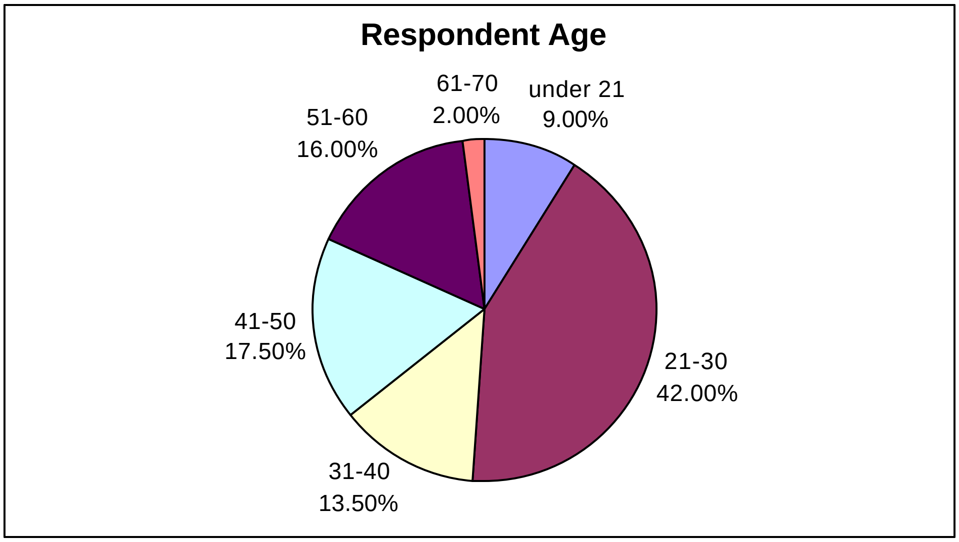

Figure 5.18: Respondent Age

Figure 5.19 shows that most respondents had a college education (42.5 percent), followed by those who finished high school/diploma (37.5 percent), those with a post-graduate degree (19.5 percent) and a very small minority of those who did not finish school (0.5 percent). In other words, the majority of the respondents (62 percent) were well-educated with either a college or a post-graduate degree.

Figure 5.20 shows the variation of the household size of the respondents. On average the respondents had a household size of 4 people.

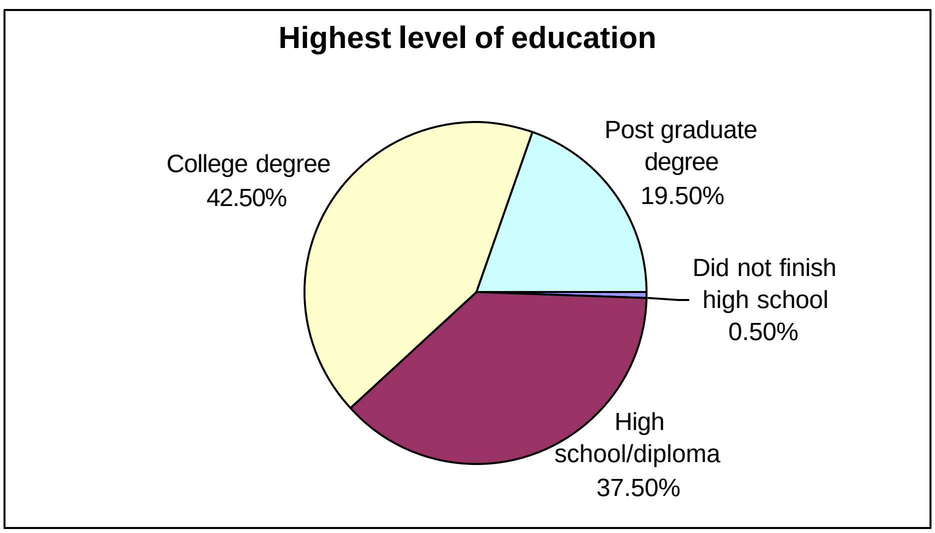

Figure 5.19: Educational qualification

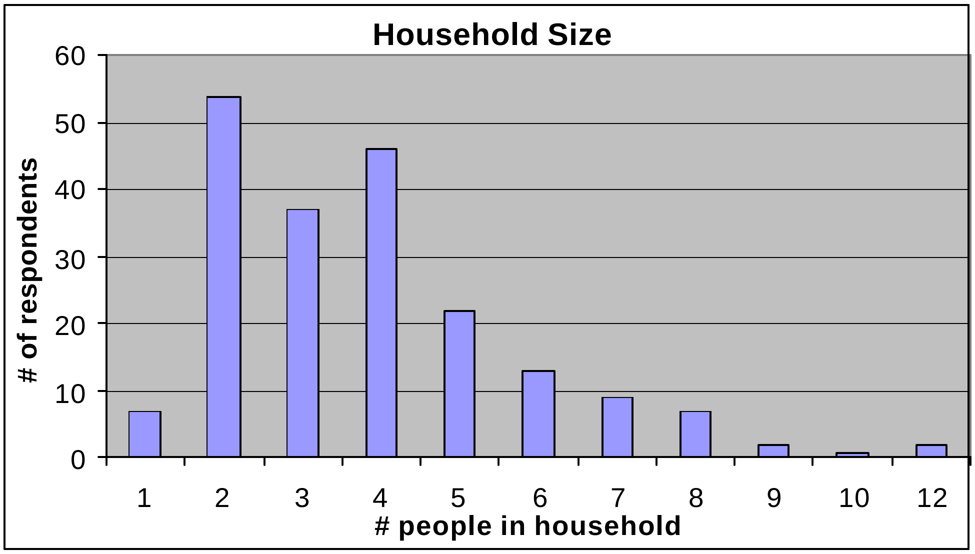

Figure 5.20: Household Size

Forty-seven percent of the respondents sometimes carpool with their household members, 27.5 percent carpool frequently with their household members and 7 percent carpool every day with their household members. The remaining 18.5 percent never carpool with their household members. Figure 5.21 illustrates these results.

Most of the respondents had 2 household members working outside home, followed by those who had 3 or 1 member(s) working outside home. This is illustrated in Figure 5.22.

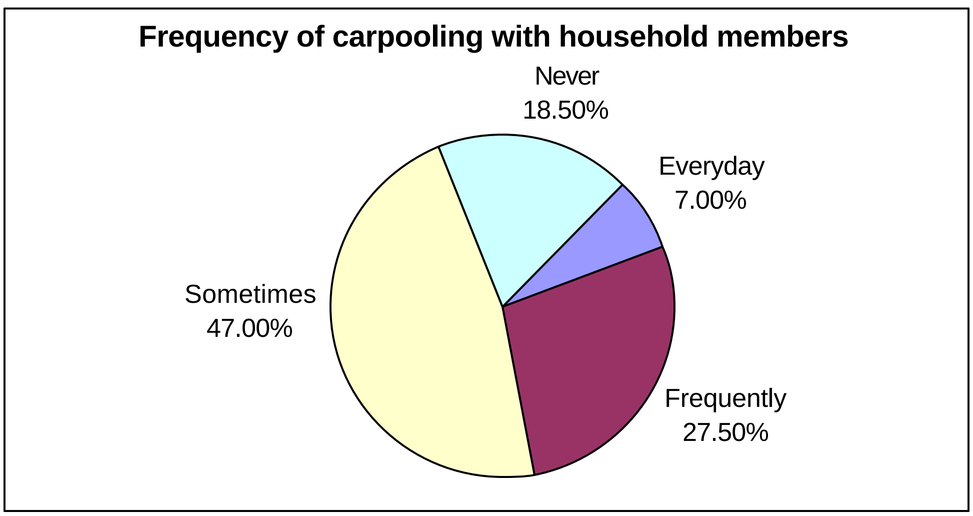

Figure 5.21: Frequency of carpooling with others in the household

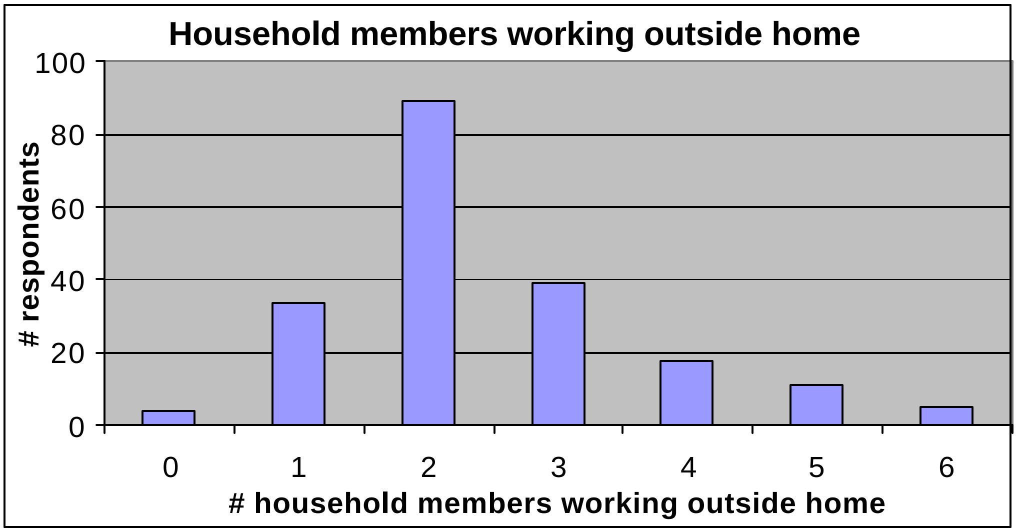

Figure 5.22: Household members working outside home

Figure 5.23 shows that most of the respondents have two or more vehicles in their household. Thus, there was a high level of automobile availability among the respondents with an average of 2.71 ($\approx$ 3) vehicles per household.

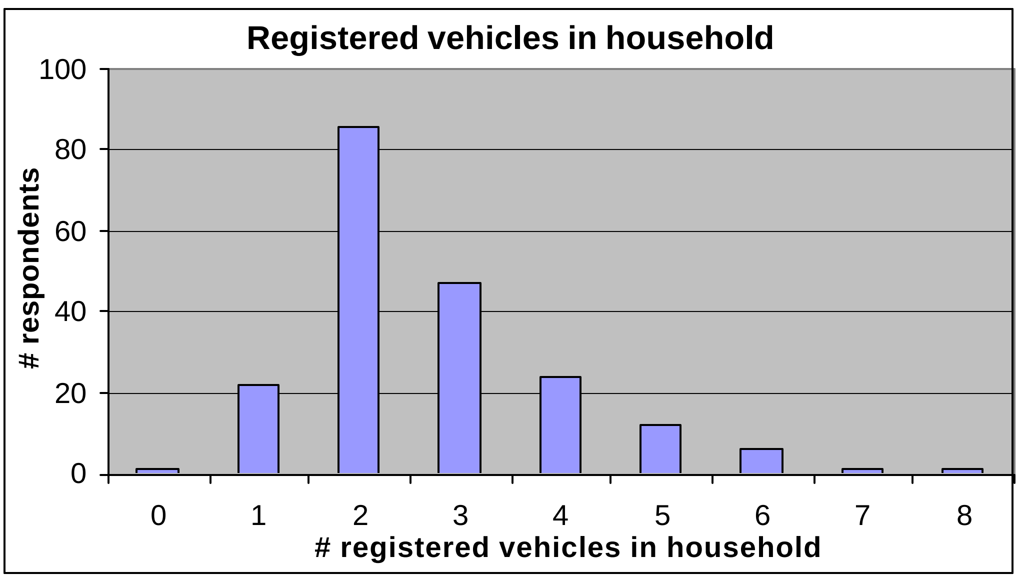

Figure 5.23: Number of registered vehicles in the household

6. RESULTS AND DATA ANALYSIS

Regular data analysis, system monitoring and adjustment in the operation of the HOV lanes are required because, even after HOV lanes are opened, changes occur in land use, levels of traffic congestion, and commuting patterns. Hence travel impacts and user benefits of the HOV system need to be analyzed periodically. This chapter presents the results and determines whether the MOEs have met and/or crossed the effectiveness thresholds. Deficiencies identified from these assessments have been taken as direct input into developing the recommendations for improving the operational efficiency and safety of the HOV lanes.

6.1 Vehicle Volume

Figure 6.1 shows the a.m. peak hour traffic volume by location. The NCHRP's recommended minimum vehicle volume of 400 to 800 vehicles/peak hour for the HOV lane is satisfied at all locations during the a.m. peak hour except at North Temple where it was short 43 vehicles. Around 400 South the GP lane volume increases because 400 South is the downtown area (where most offices are located) and many people get to the downtown area by getting off I-15. One possible reason for the decrease in the a.m. peak hour volume from 10600 South to 2100 South in the GP lanes could be that traffic enters I-15 around 10600 South and then traffic volume decreases northwards as people start taking the exits.

Figure 6.2 presents the p.m. peak hour traffic volume by location. The NCHRP's recommended minimum vehicle volume for an HOV lane (400 to 800 vehicles/peak hour) is satisfied at all locations during the p.m. peak hour. This implies that HOV lanes are well used. Also, p.m. peak hour volume is higher than the a.m. peak hour volume in both the GP and HOV lanes. Graphs showing the a.m. and p.m. peak hour volumes of the HOV and GP lanes at the various data collection locations are provided in Appendix B.

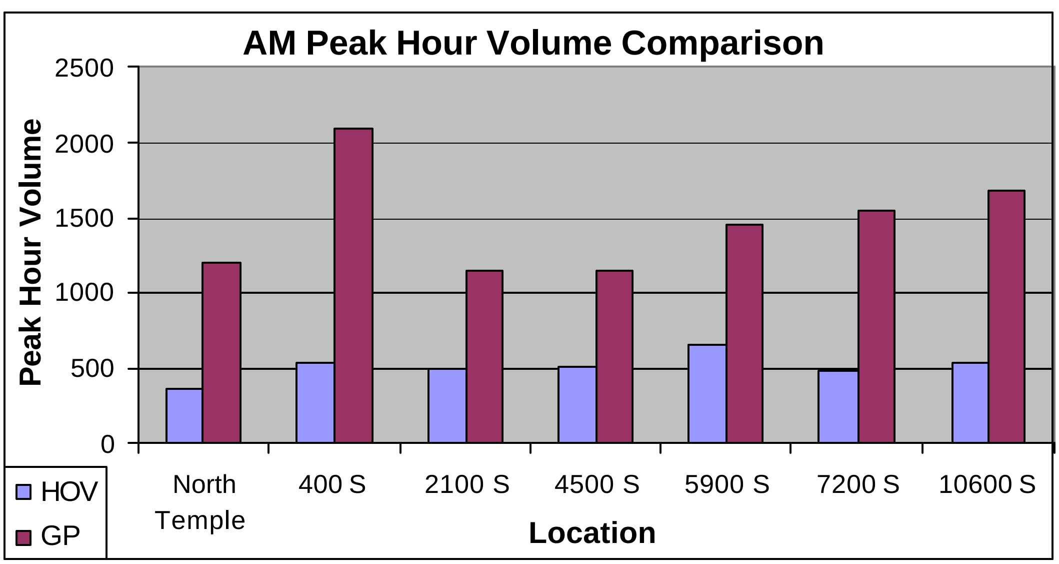

Figure 6.1: a.m. Peak Hour Vehicle Volume by location

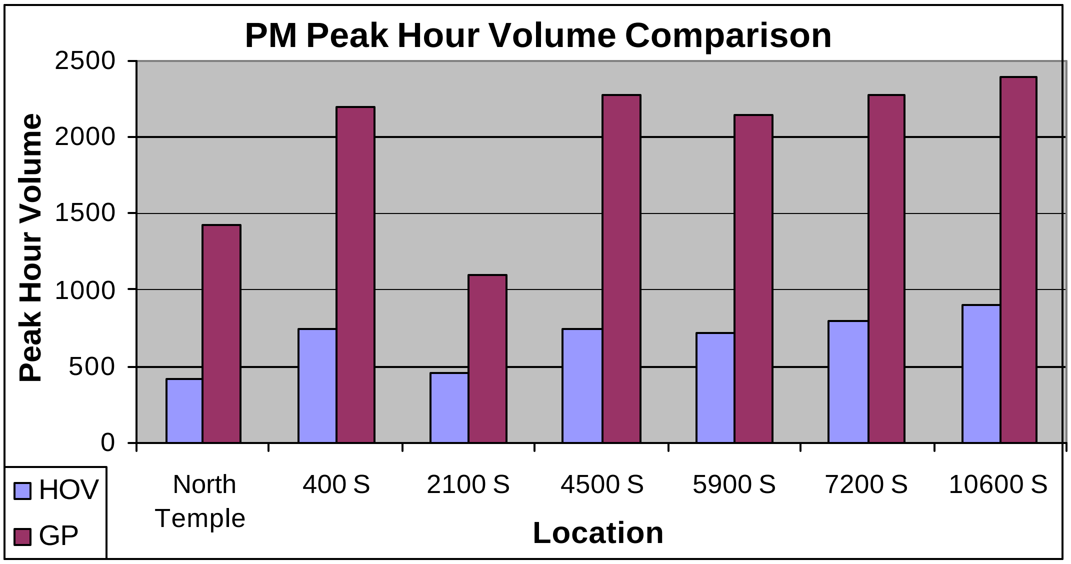

Figure 6.2: p.m. Peak Hour Vehicle Volume by location

The NCHRP's recommended maximum operating threshold criterion of 1200 to 1500 vphpl was not exceeded at any of the locations during either the a.m. or p.m. peak periods.

Figure 6.3 illustrates the 24-hour northbound traffic volume variation at 5900 South. GP 1 refers to the GP lane next to the HOV lane and GP 4 refers to the rightmost GP lane. The reason for the highest volume during the morning for the northbound vehicles is that the a.m. peak direction is northbound. This is consistent with the fact that the downtown area is in the northern part of the HOV lanes and the residential areas are in the southern part. The traffic volume profile at 5900 South also gives site-specific operational performance and identifies the a.m. peak period to be from 6:30 a.m. to 8:30 a.m.

Figure 6.4 illustrates the 24-hour southbound traffic volume variation at 5900 South. The reason for the highest volume during the afternoon for the southbound vehicles is that the p.m. peak direction is southbound. The traffic volume profile at 5900 South provides site-specific operational performance and identifies the p.m. peak period to be from 4:00 p.m. to 6:00 p.m.

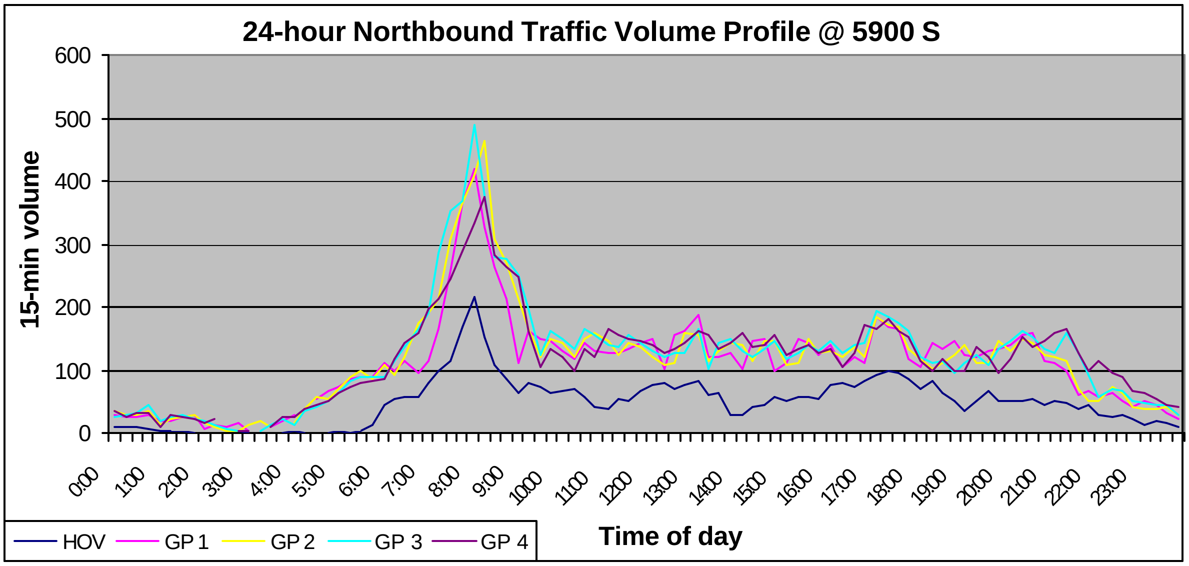

Figure 6.3: Traffic Volume Profile at 5900 South (Northbound)

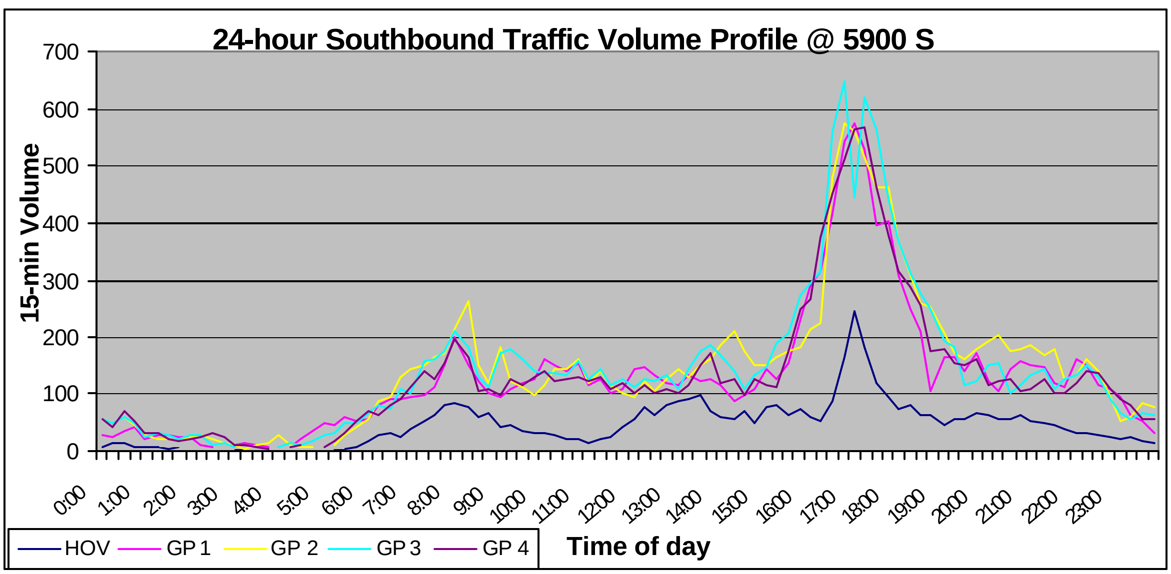

Figure 6.4: Traffic Volume Profile at 5900 South (Southbound)

6.2 Average Vehicle Occupancy

As seen in Figures 6.5 and 6.6 the AVO in the HOV lanes is much higher than the AVO in the GP lanes during both the a.m. and p.m. peak periods. The overall AVO in the HOV lanes decreases from 2.71 in the a.m. peak period to 2.39 in the p.m. peak period. On the other hand, the AVO in the GP lanes increases from 1.08 in the a.m. peak period to 1.14 in the p.m. peak period. The overall AVO in the GP lane is 1.11 whereas the overall AVO in the HOV lane is 2.55. This is a strong indication of the HOV lane's effective performance. The overall AVO before May 2001 (before the HOV lanes were opened on the reconstructed I-15) was 1.12 and the AVO within one year of their opening increased to 1.32 (*4*). Hence there was an 18 percent increase in the AVO on I-15 after the HOV lanes opened. Furthermore, as found in this study, the overall AVO on I-15 is 1.40 as of March 2004. Thus, as a result of the HOV system there has been a 6 percent increase in AVO from its first year of operation to its third year of operation.

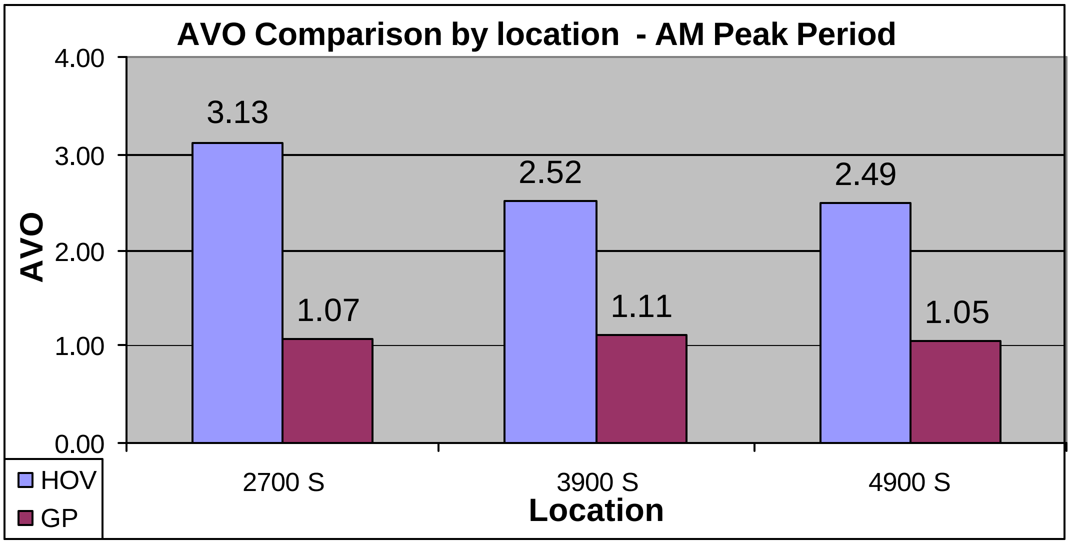

Figure 6.5: a.m. Peak Period AVO by location

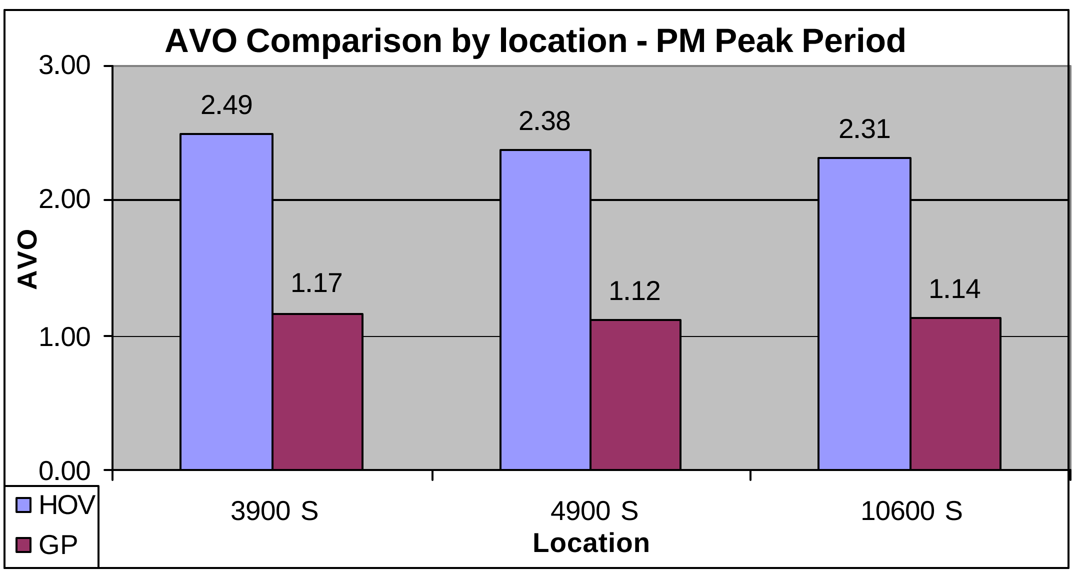

Figure 6.6: p.m. Peak Period AVO by location

6.3 Modal Split

Figures 6.7 and 6.8 present the peak period vehicle classification percentages of the HOV lane and a GP lane at 4900 South on I-15. In the GP lane SOVs were the major mode, constituting 96.45 percent of all modes. In the HOV lane, carpools were dominant, constituting 90.63 percent of all modes. In fact, the HOV lanes had a higher percentage of carpools, vanpools, motorcycles and buses than the GP lanes. The express buses operated by the Utah Transit Authority (UTA) and Greyhound buses were observed using the HOV lanes during the peak periods. Vanpools and buses, however, constituted only a small portion of the total vehicles (3.28 percent and 1.18 percent respectively) in the HOV lane and therefore need to be encouraged to further increase the person-carrying capacity of the HOV lanes. Moreover, AFVs constituted only 0.27 percent of all modes. They also need to be popularized as they are environmentally-friendly. Graphs showing the a.m. and p.m. peak period modal split of the HOV and GP lanes at the various data collection locations are provided in Appendix C.

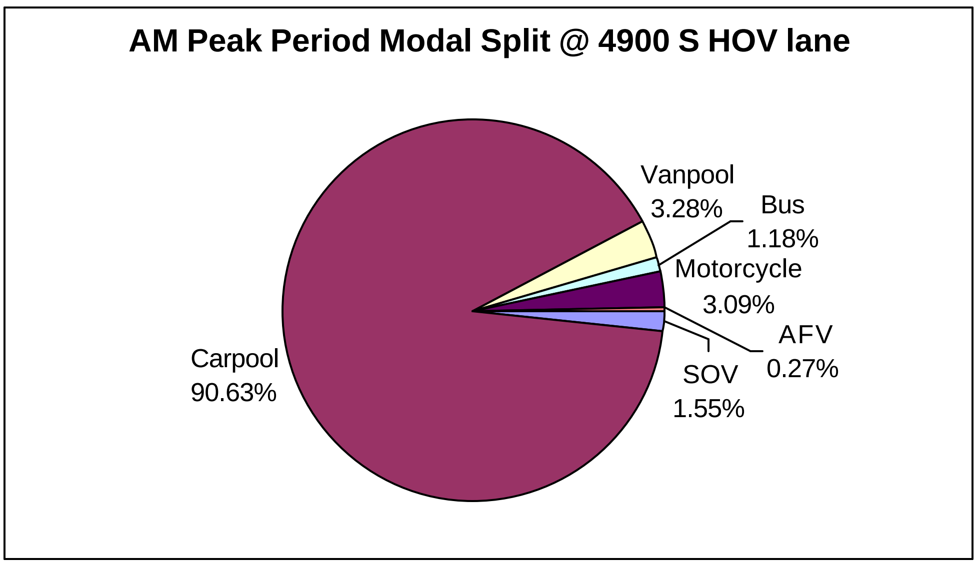

Figure 6.7: a.m. Peak Period Modal Split @ 4900 South HOV lane

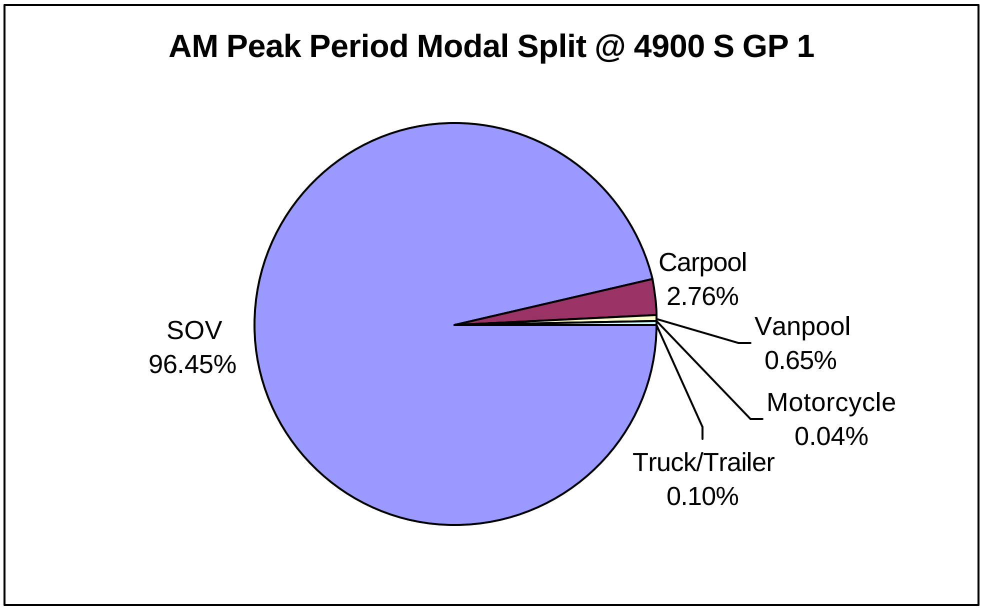

Figure 6.8: a.m. Peak Period Modal Split @ 4900 South GP 1

6.4 Person Throughput

Person throughput helps determine how well utilized the HOV lanes are. Person throughput at a particular location was obtained by multiplying AVO by the traffic volume at the corresponding location.

The NCHRP HOV Systems Manual recommends a minimum HOV lane person throughput threshold of 900 to 1,800 pphpl during the peak hours (*15*). Table 6.1 shows the a.m. and p.m. peak hour person throughput of the HOV lanes at various locations. All the locations not only met the NCHRP standards but exceeded them, especially during the p.m. peak hour. Exceeding the minimum threshold range is an indication of the effective use of the HOV lanes because as person throughput increases, HOV system performance effectiveness also increases.

Figure 6.9 shows that the person throughput per lane per vehicle of the HOV lane is much higher than that of a GP lane. Overall a.m. peak period vehicle volume and person throughput of a typical GP lane and the HOV lane were compared. It was found that compared to a GP lane the HOV lane carried 32.69 percent fewer people with 73.17 percent fewer vehicles during the a.m. peak period.

Table 6.1: Person Throughput of HOV lanes during a.m. and p.m. peak hours

Location	a.m. Peak Hour			p.m. Peak Hour		
	AVO	Peak Hour Volume	Person Throughput	AVO	Peak Hour Volume	Person Throughput
400 South Ramp	2.95	310	915	2.46	456	1122
I-15 2700 South	3.13	516	1615	NA	NA	NA
I-15 3900 South	2.52	656	1653	2.49	1062	2644
I-15 4900 South	2.49	665	1656	2.38	1059	2520
I-15 10600 South	NA	NA	NA	2.31	1001	2312

NA – Not Available

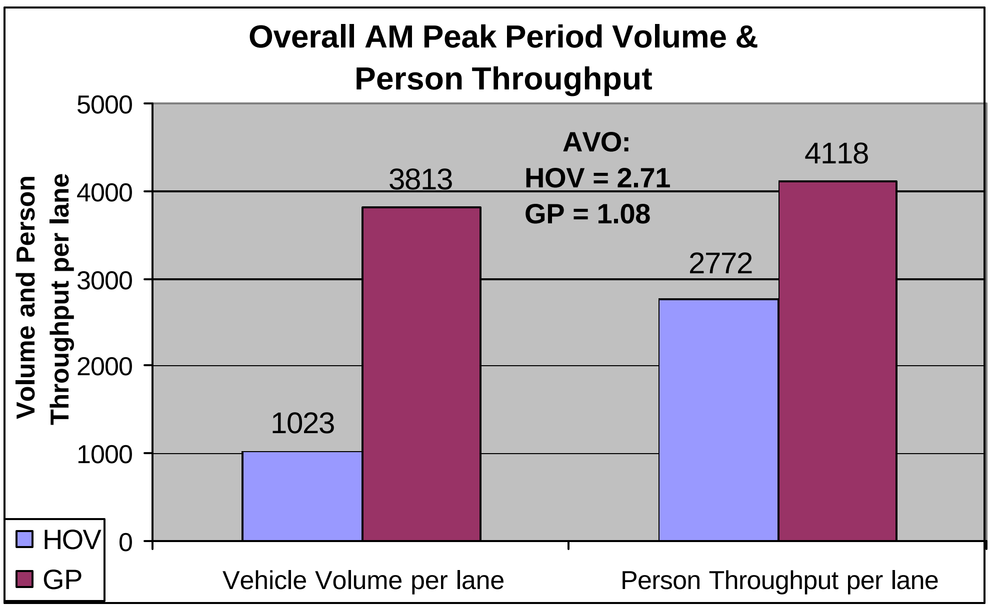

Figure 6.9: Overall a.m. Peak Period Volume & Person Throughput

Figure 6.10 presents the overall p.m. peak period vehicle volume and person throughput of a typical GP lane and the HOV lane. Compared to a typical GP lane the HOV lane carried 8.89 percent more people with 48.06 percent fewer vehicles during the p.m. peak period. HOV lanes thus carry more people in fewer vehicles and are more effective during the more congested p.m. peak period than during the a.m. peak period when the congestion level is low.

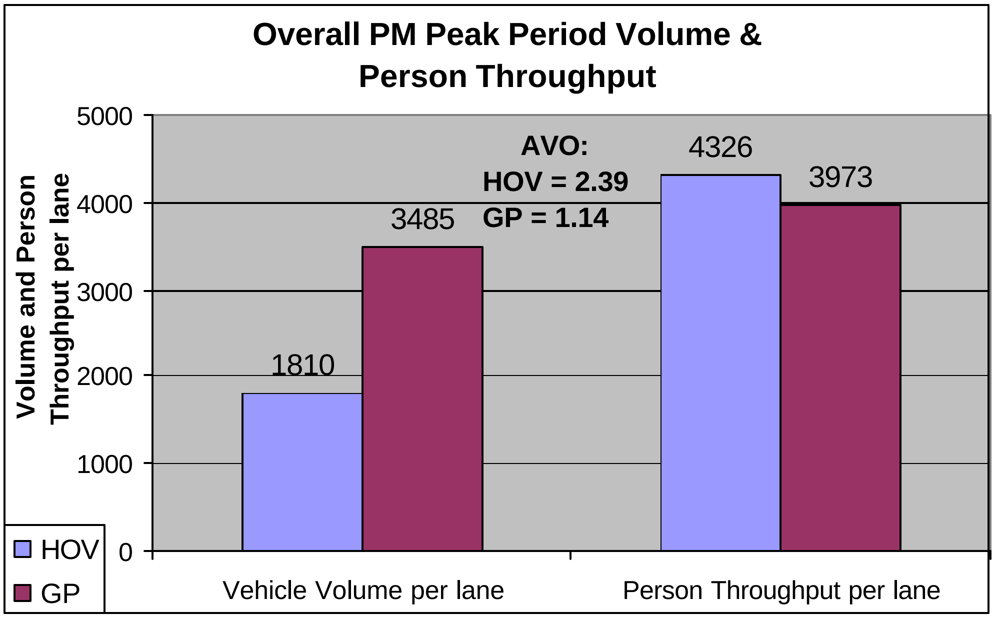

Figure 6.10: Overall p.m. Peak Period Volume & Person Throughput

Overall, there has been a 35 percent increase in the HOV lane peak period vehicle volume and 31 percent increase in its person throughput since the first year of its operation. In the Salt Lake Valley, an HOV lane represents 20 percent of the total directional lane capacity. During the p.m. peak period the HOV lane carries 21.40 percent of the total directional person trips, whereas, during the a.m. peak period, it carries 14.40 percent of the total directional person trips. Hence HOV lanes in the Salt Lake Valley work more effectively during the p.m. peak period. Graphs showing the a.m. and p.m. peak period vehicle volume and person throughput of the HOV and GP lanes at the various data collection locations are provided in Appendix D.

6.5 Travel Time

Table 6.2 summarizes the results of the travel time runs on the arterial streets and the HOV and GP lanes on I-15. Throughout the day the HOV lane speeds were higher than the GP lane speeds; thereby they offered travel time savings throughout the day. During the p.m. peak period, however, the HOV lane offers a much higher travel time savings of about 40 percent. Thus, the maximum HOV time savings are during the p.m. peak period when congestion in the GP lanes reaches high levels.

Table 6.3 presents the results of the travel time runs in the HOV and GP lanes between 600 South and 10600 South on I-15. From 9000 South to 10600 South, with only 16 percent of the entire road length, about 25 percent and 26 percent of the total travel time were spent in the HOV and GP lanes respectively in the p.m. peak period. This is because of the spillback from congestion at the 10600 South bottleneck. The NCHRP's recommended overall peak hour travel time savings of at least 5 minutes and the desirable overall travel time savings of 7 minutes *(15)* were met and exceeded during the p.m. peak period when the travel time savings was 13.45 minutes. During the a.m. peak period, however, these standards were not met although there was travel time savings of about 2 minutes. The average running speed in the HOV lane remained higher than the GP lane speed throughout most of the day. The previous HOV study recorded travel time benefits of 13.4 percent during the a.m. peak period, 30.7 percent during the p.m. peak period and 4.7 percent during the off-peak period (*4*). During the p.m. peak period, there has been an increase in the travel time savings from 30.7 percent in 2001-02 to 46.3 percent in 2004. Travel time savings during the a.m. peak period and off-peak period have remained nearly the same at about 13 percent and 5 percent respectively.

Figure 6.11 presents the speed profiles of the HOV and GP lanes with the variation of speed at the control points on I-15. It was seen that in general, the HOV lane speed was higher than the GP lane speed throughout most of the day. Congested speeds (that is, speed less than 45 mph), however, were recorded from 9000 South to 10600 South in both the HOV and GP lanes. Figure 6.11 also shows that there is little advantage in using the HOV lanes during the a.m. and off-peak periods. HOV lane users, however, have a definite advantage during the p.m. peak period when they travel at more stable speeds than the GP lane users.

Table 6.2: Average Running Speed and Travel Time on Arterial Street and I-15

	Average Running Speed (mph)		Average Travel Time (min.)		Time Savings (min.)	Percentage (HOV Time Savings)
	HOV	GP	HOV	GP		
a.m. Peak	65.37	62.88	12.20	13.57	1.37	10.10
Off-Peak	63.76	64.67	13.49	14.45	0.96	6.64
p.m. Peak	52.33	43.08	20.12	33.67	13.55	40.24

Table 6.3: Average Running Speed and Travel Time on I-15

	Average Running Speed (mph)		Average Travel Time (min.)		Time Savings (min.)	Percentage (HOV Time Savings)
	HOV	GP	HOV	GP		
a.m. Peak	66.25	62.88	11.85	13.57	1.72	12.68
Off-Peak	66.98	66.36	11.39	12.03	0.64	5.32
p.m. Peak	55.00	45.96	15.60	29.05	13.45	46.30

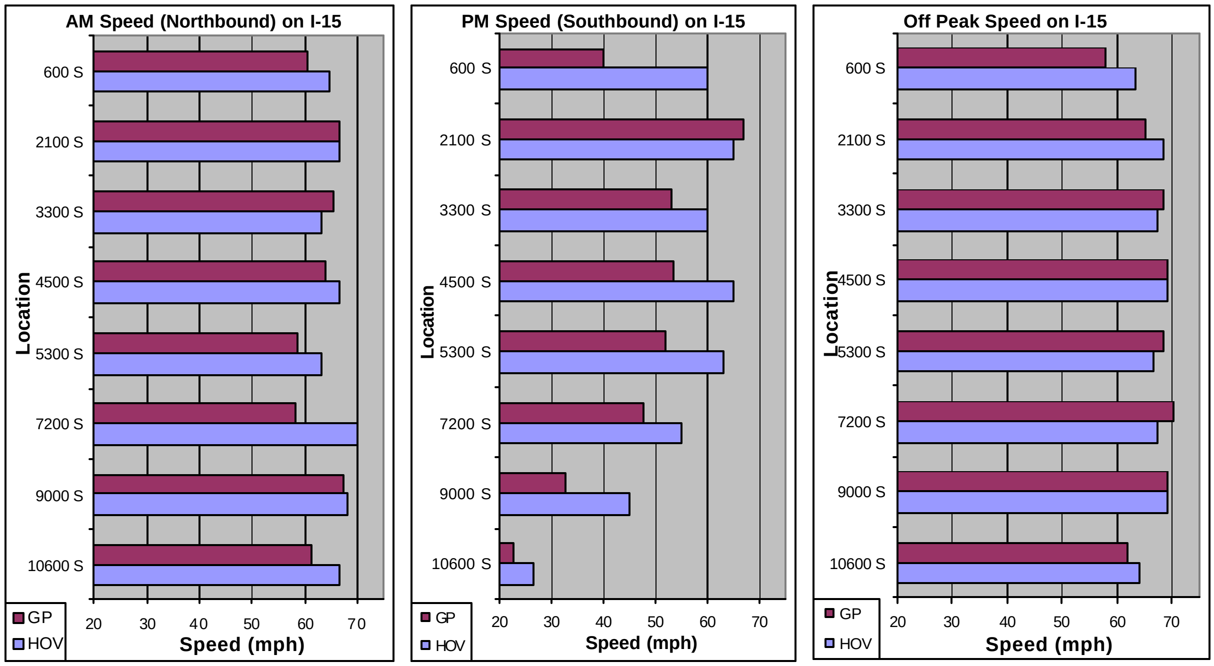

Figure 6.11: Speed Variation in the HOV and GP lanes

6.6 Speed

Figures 6.12 and 6.13 show the a.m. and p.m. peak period mean speed comparison at various locations. Higher speeds in the HOV lanes as compared to the GP lanes indicate that the HOV lanes have less or no congestion. The HOV lane mean speeds are much higher than 45 mph which means that the HOV lane was not congested at the data collection locations. Furthermore, the Salt Lake Valley HOV lane mean speed is higher than the national HOV lane mean speed of 54 mph during the peak periods. The mean peak period speeds for the HOV and GP lanes were 68.18 mph and 58.60 mph respectively in 2001-02 (*4*). They were 65.47 mph and 58.50 mph respectively during the year 2004. This difference in the mean speeds of the HOV and GP lanes is statistically significant at the 95 percent confidence level. The 4 percent decrease in HOV lane speed since the first year of its operation is not statistically significant at the 95 percent confidence level and is probably due to the increased use of the HOV lanes. Also there seems to be no negative impact of the HOV lanes on the GP lanes as the GP lane mean speed has remained almost constant during the peak periods. Graphs showing the a.m. and p.m. peak period mean speeds of the HOV and GP lanes at the various data collection locations are provided in Appendix B.

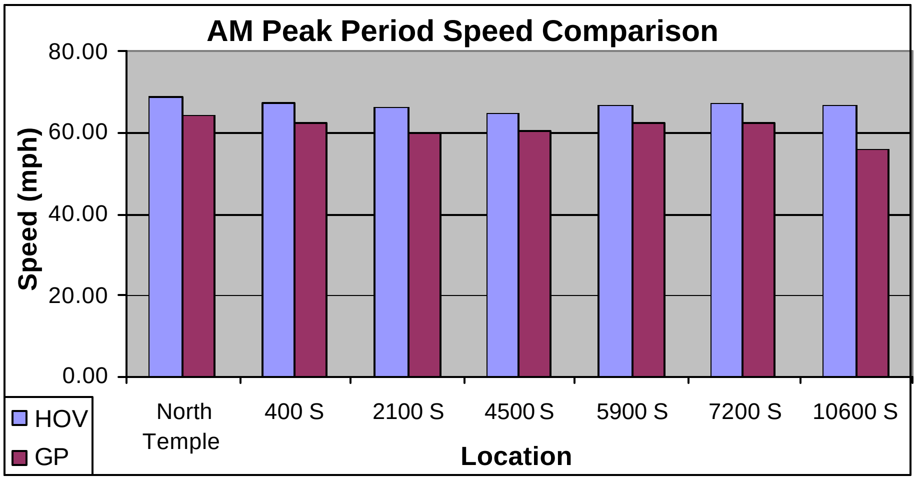

Figure 6.12: a.m. Peak Period Speed Comparison

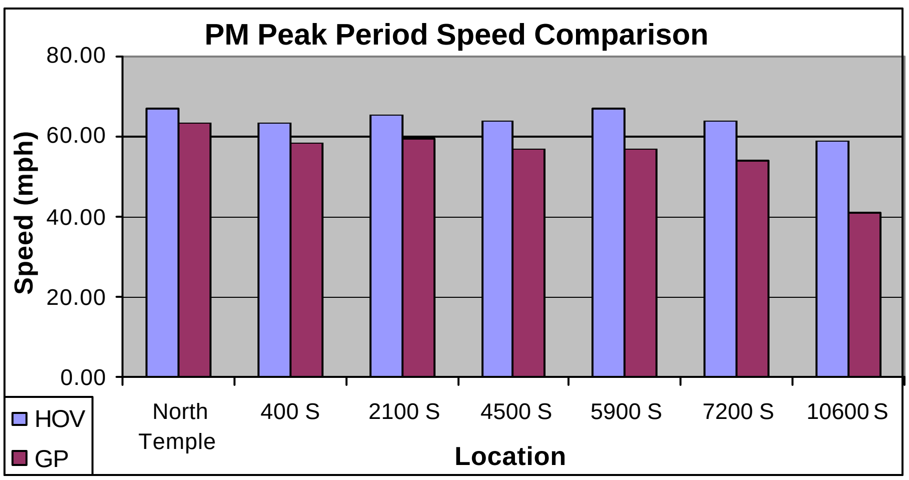

Figure 6.13: p.m. Peak Period Speed Comparison

Figure 6.14 illustrates the 24-hour speed variation at 5900 South for the northbound traffic. Breaks in the graph indicate that there were no vehicles and therefore no speeds were recorded. The reason for the lowest speeds during morning for the northbound vehicles is that the a.m. peak direction is northbound. In both the HOV and GP lanes, speed decreases during the peak periods because of higher vehicular volume but speed is relatively higher in the HOV lanes than in the GP lanes. The speed profile at 5900 South also gives site-specific operational performance and shows that the HOV lanes have higher speed throughout the day when compared to the GP lanes.

Figure 6.15 illustrates the 24-hour speed profile at 5900 South for the southbound traffic. The reason for the lowest speeds during the afternoon for the southbound vehicles is that the p.m. peak direction is southbound. The speed profile at 5900 South also provides site-specific operational performance.

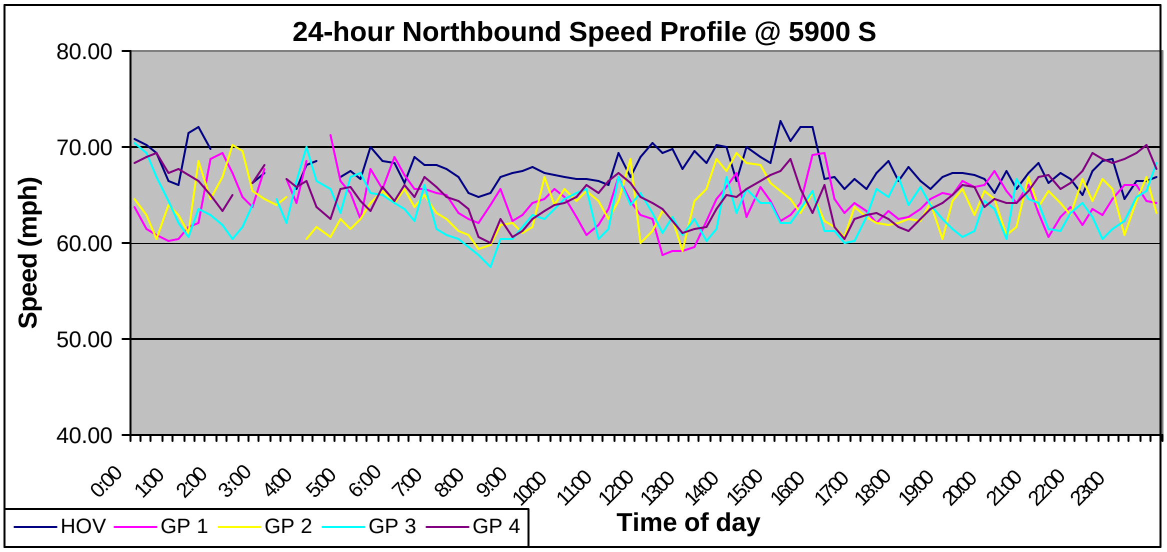

Figure 6.14: Traffic Speed Profile at 5900 South (Northbound)

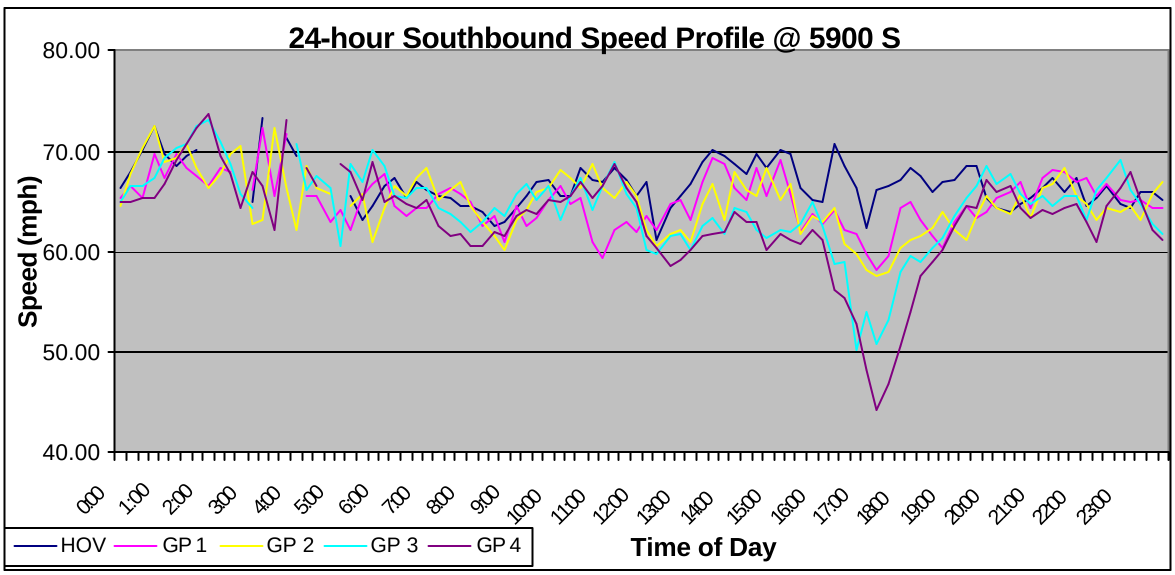

Figure 6.15: Traffic Speed Profile at 5900 South (Southbound)

6.7 Accident Rate

There were 48 HOV lane accidents from May 14, 2001, to Dec. 31, 2001. In 2002 there were 61 HOV lane accidents and in 2003 there were 78 HOV lane accidents. In total there have been 187 HOV lane accidents from May 14, 2001 to December 2003. The overall accident rate per MVMT was found to be 1.35.

Figure 6.16 shows there were more accidents in the winter because of snowy and icy conditions and also because the duration of natural light is shorter in the winter months. The overall accident rate was the highest in 2001 (1.58 accidents per MVMT), followed by 2003 (1.26 accidents per MVMT) and then 2002 (1.20 accidents per MVMT).

Figure 6.17 shows the variation of accidents at different times of the day. The a.m. peak period has been considered from 6:30 a.m. to 8:30 a.m., p.m. peak period from 4:00 p.m. to 6:00 p.m. and off-peak period from 8:30 a.m. to 4:00 p.m. and then again from 6:00 p.m. to 6:30 a.m.. It is observed that the p.m. peak period had the highest number of accidents per MVMT followed by the off-peak period and the a.m. peak period. The high accident rate in the p.m. peak period may be due to the high congestion levels during that period.

Figure 6.18 shows that the number of accidents per MVMT was the highest in the southbound direction for all the years when compared to the northbound direction. The reason is that the southbound direction is the p.m. peak direction during which congestion levels are high.

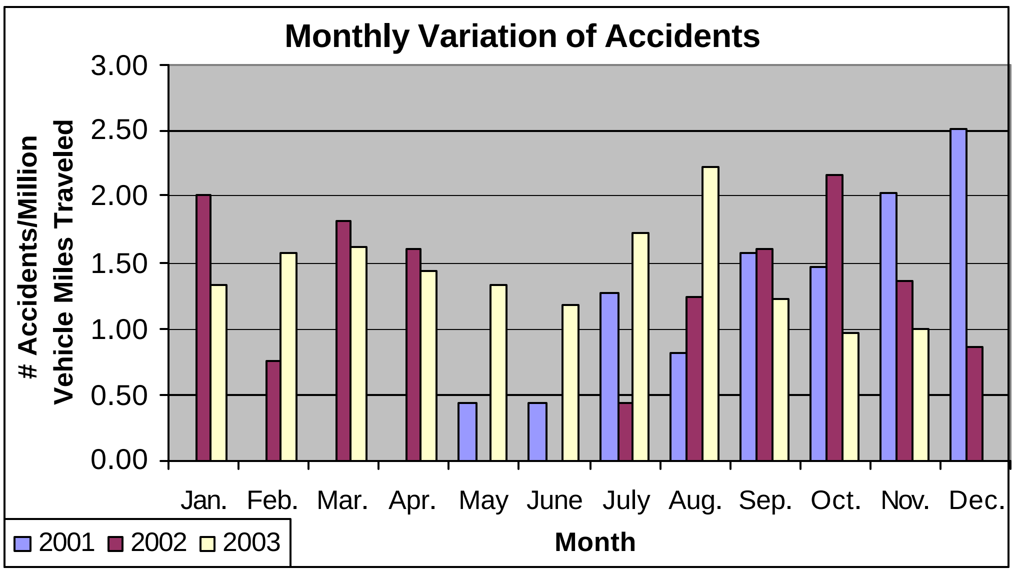

Figure 6.16: Monthly Variation of the HOV lane Accidents

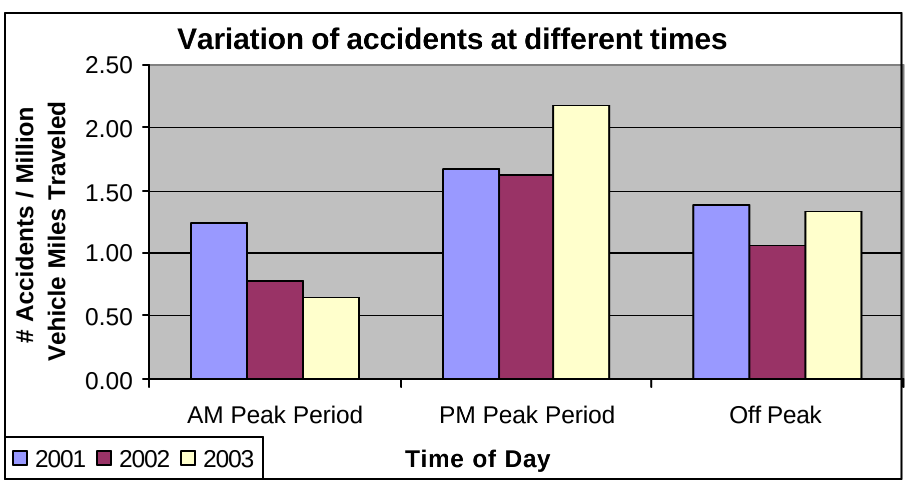

Figure 6.17: Variation of accidents at different times of the day

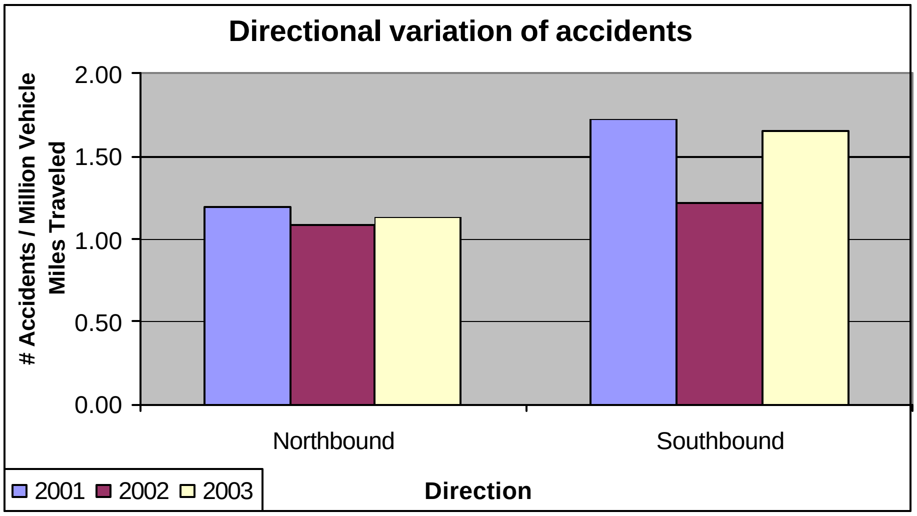

Figure 6.18: Directional Variation of the HOV lane accidents

Figure 6.19 presents the segmental distribution of HOV lane accidents. The number of accidents per MVMT was the highest from 600 North to 400 South in 2001 with 3.48 accidents per MVMT and also in 2002 with 1.95 accidents per MVMT. The highest number of accidents per MVMT in 2003 was from 4500 South to 5300 South with 1.84 accidents per MVMT. This pattern in accident rates is not readily apparent and is probably due to the randomness of accident occurrence.

From Figure 6.20 the directional and segmental distribution of HOV lane accidents is seen. The highest number of accidents per MVMT in the northbound direction was recorded from 600 North to 400 South with 2.65 accidents per MVMT. The highest number of accidents per MVMT in the southbound direction was recorded from 4500 South to 5300 South (1.88 accidents per MVMT) and 9000 South to 10600 South (1.86 accidents per MVMT).

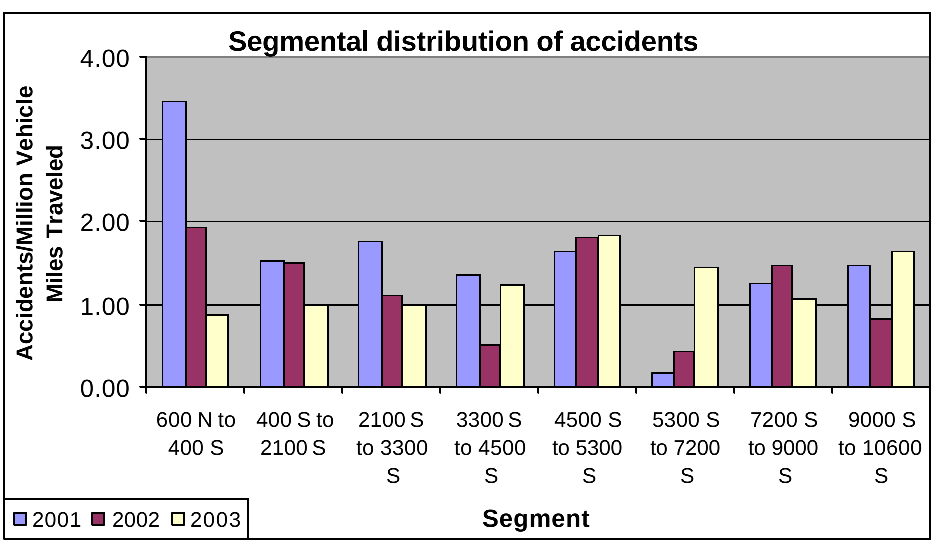

Figure 6.19: Segmental distribution of the HOV lane accidents

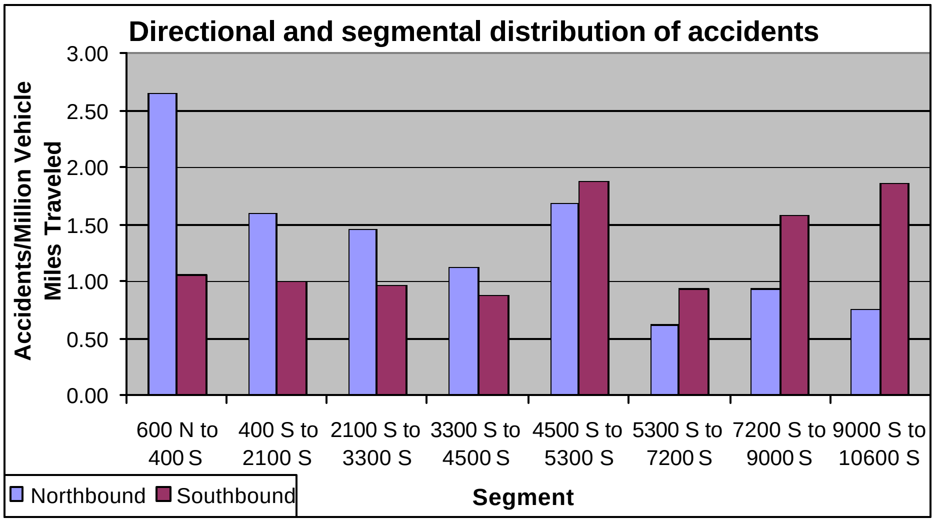

Figure 6.20: Directional and segmental distribution of the HOV lane accidents

Figure 6.21 presents the major causes of accidents. The major causes of accidents were improper lane travel, excessive speeds, following too close and improper lookout. Improper lane travel includes not displaying the indicator on time or trying to change lanes when there is not a big enough gap available. Excessive speeds are not necessarily speeds above the speed limit (65 mph) but also include speeds that are too fast for the conditions (such as rainy, snowy or icy conditions). Improper lookout was another major cause of accidents and includes not looking back before changing lanes or not looking properly in the rear-view mirror. Driving under the influence, talking to a co-passenger, defective vehicle conditions, etc., constituted the "others" category.

Figure 6.22 shows the major collision types for the HOV lane accidents. The major collision types were found to be motor vehicle to motor vehicle side swipe, motor vehicle to motor vehicle rear end, and motor vehicle to fixed object collisions. Other collisions like motor vehicle to other object (non-fixed object, like a snow pile), motor vehicle to motor vehicle head on, non-collision, etc., made up the "others" category.

Figure 6.23 presents the severity of HOV lane accidents. It was found that the major type was no injury, followed by possible injury, bruises and abrasions, and broken bones or bleeding wounds. One significant finding was that there were no fatalities among the HOV lane accidents. The percentages of accidents with no injury, possible injury, bruises and abrasions, and broken bones or bleeding wounds respectively were 72.73 percent, 15.51 percent, 6.95 percent and 4.81 percent of the total HOV lane accidents.

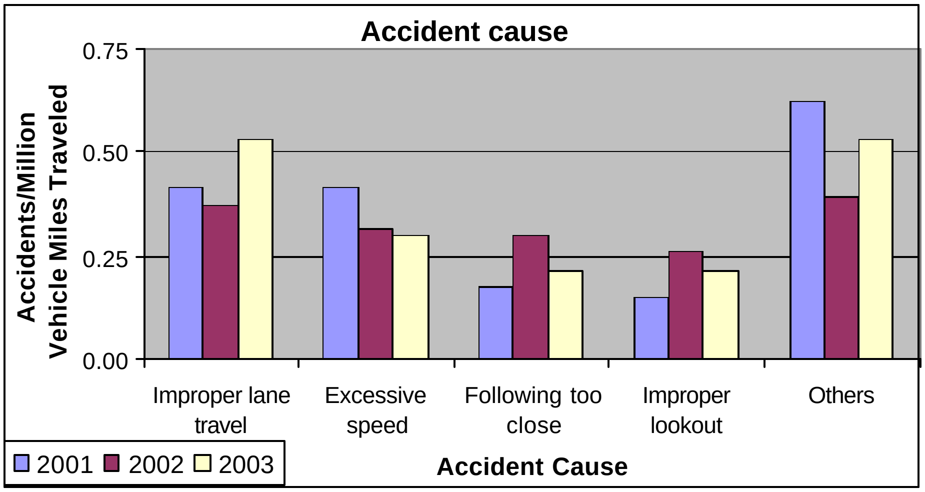

Figure 6.21: Major Accident Causes of the HOV lane accidents

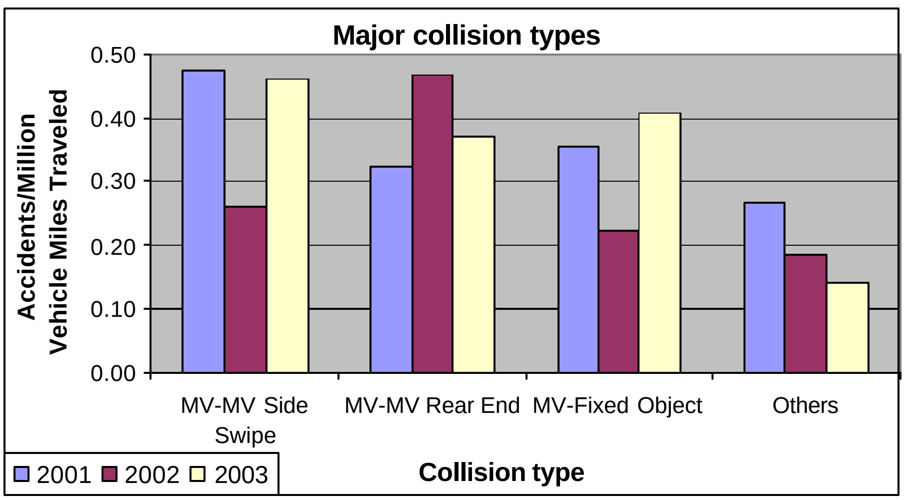

Figure 6.22: Major Collision Types of the HOV lane accidents

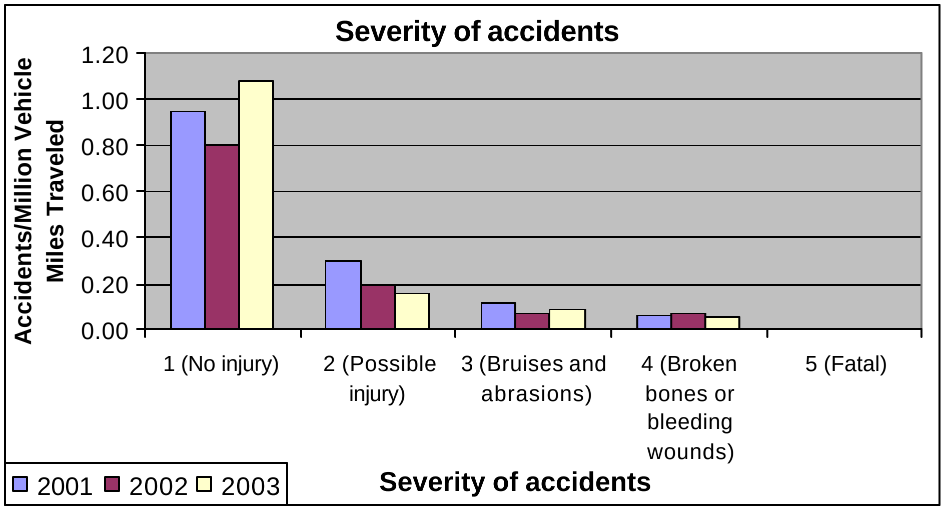

Figure 6.23: Severity of HOV lane accidents

It was checked whether motorcycles created safety hazards because of their small size and different operating characteristics. Motorcycles account for about 2 percent of all the vehicles in the HOV lane. They were, however, involved in only 1 percent of all the accidents. Based on this analysis it can be concluded that motorcycles do not pose a safety hazard in the HOV lane.

The accident analysis indicates no adverse effect on safety conditions that could be attributed to the HOV lane operation. No before/after study was done because the HOV lanes were opened on the reconstructed I-15 in May 2001. As a result of the reconstruction, I-15 in the Salt Lake Valley was expanded from a facility with three GP lanes to a five-lane facility with four GP lanes and one HOV lane. Furthermore, the time period used in this study is shorter than that typically used for an accident study. A minimum of three years before and after data should be collected to draw conclusions and make recommendations for future courses of action (*10*). No definite trend could be established about the accident rates or accident severity due to the opening of the HOV lanes. HOV lane impact on safety was therefore inconclusive.

6.8 Violation Rate

Figures 6.24 and 6.25 show the comparison of violation rates during the a.m. and p.m. peak periods respectively. There was no clear distinction between the violation rates during the a.m. and p.m. peak periods. The overall violation rates along the I-15 corridor are quite low whereas the violation rates at the 400 South on-ramp and off-ramp are much higher. The violation rates at all the locations, however, are much lower than the national average of 13 percent for concurrent HOV lane facilities (*14*). From the split of the violations it is seen that occupancy violations (SOV drivers using the HOV lanes) were the most common type of violation. Trailer violation is quite low when compared to occupancy violation. The other type of prohibited vehicles, that is, trucks weighing over 12,000 lbs were not seen in the HOV lanes during the data collection period. HOV lane violation rates along the I-15 corridor and at the 400 South ramps decreased from 9 percent and 17 percent respectively in the year 2002 (*4*) to 2 percent and 10 percent respectively in 2004. This decrease in violation rates is probably because of increased awareness about the HOV lanes, strong and frequent patrolling and heavy fines ($70 minimum and up to $1,800 depending on the type of violation) imposed on HOV lane violators. The low violation rates reflect high compliance with HOV lane requirements and ensure that the maximum possible HOV lane capacity is available for those eligible to use it.

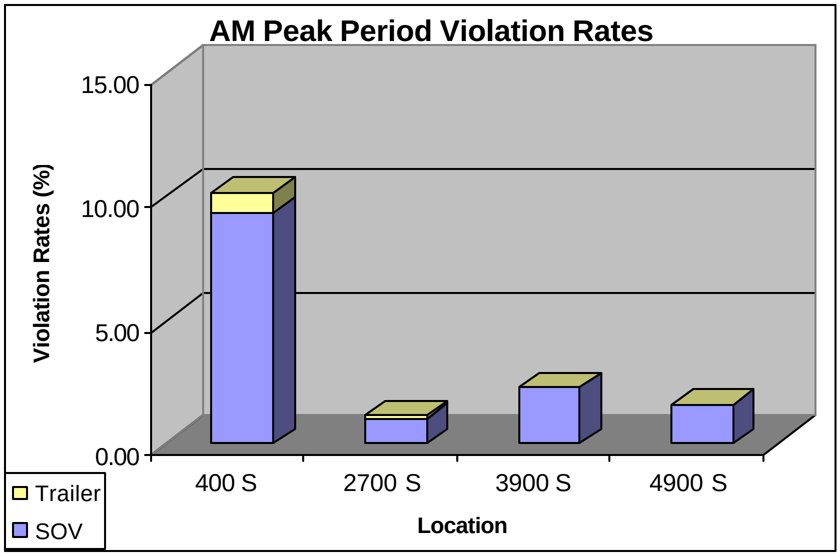

Figure 6.24: a.m. Peak Period Violation Rates

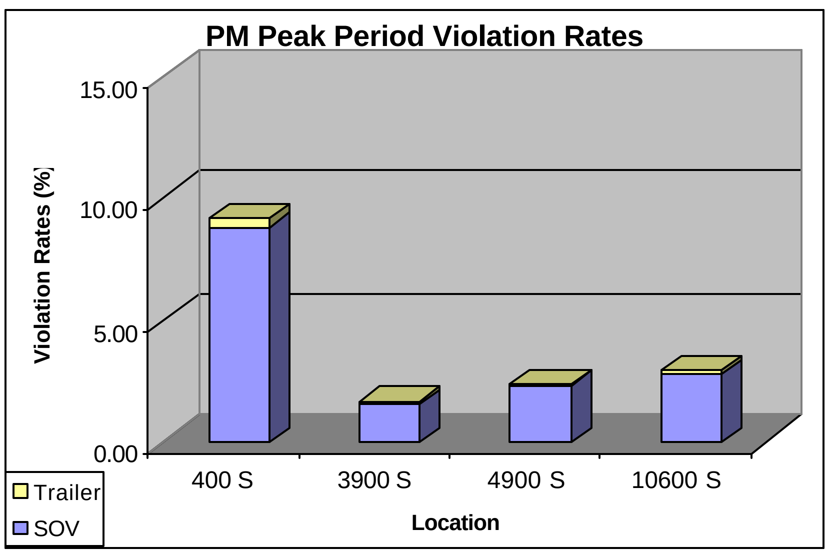

Figure 6.25: p.m. Peak Period Violation Rates

Figure 6.26 shows the on-ramp and off-ramp violation rates at 400 South. Violation rates are relatively higher on the 400 South on-ramp and off-ramp than along the I-15 corridor. One possible reason could be that violators want to get on or off I-15 quickly using the HOV on-ramp and off-ramp. Violation rates at 400 South ramps have decreased during the a.m. and p.m. peak periods from 18 percent and 15 percent respectively during the year 2002 (*4*) to 10 percent and 9 percent respectively during the year 2004. Although the overall violation rates are lower than the national average, the on-ramp violation rates at 400 South (16 percent and 13 percent during the a.m. and p.m. peak periods respectively) are higher than the national average of 13 percent. On-ramp violations are higher as violators can take advantage of being able to merge with traffic once they are on I-15. Enforcement thus needs to be more frequent and rigorous at 400 South, especially on the on-ramp.

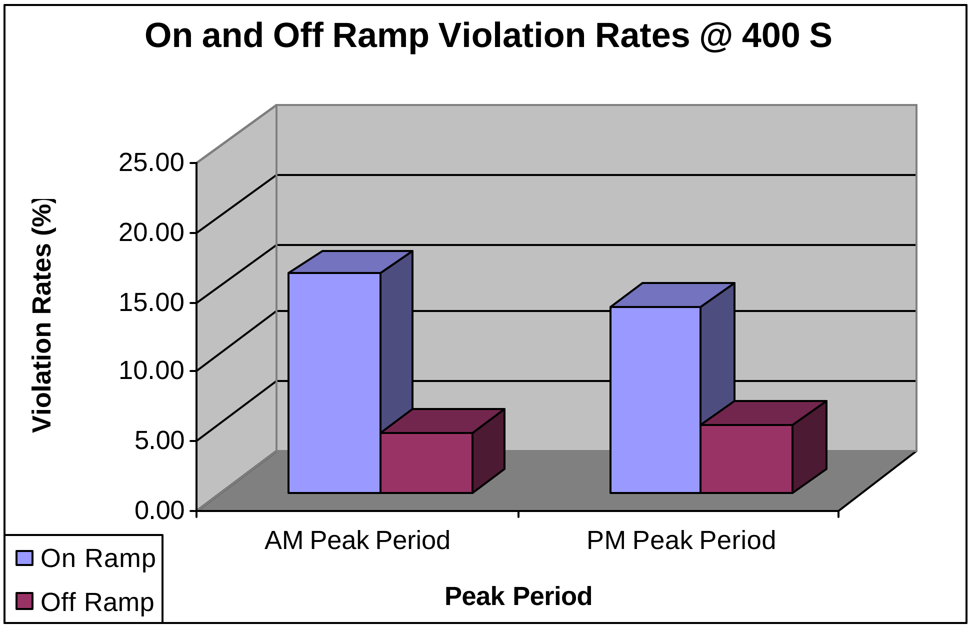

Figure 6.26: On- and off-ramp Violation Rates at 400 South

Additional MOEs (Average Time Headway and Level of Service) were obtained using video detection. The results are summarized in the following sections.

6.9 Average Time Headway

Figures 6.27 and 6.28 show the average time headway of the vehicles in the HOV and GP lanes during the a.m. and p.m. peak periods. Average time headway is the average time gap between two consecutive vehicles. It was obtained using video detection. It was found that the average time headway during both the a.m. and p.m. peak periods was in the HOV lanes when compared to that in the GP lanes. The reason is that there were fewer vehicles in the HOV lane than in each GP lane.

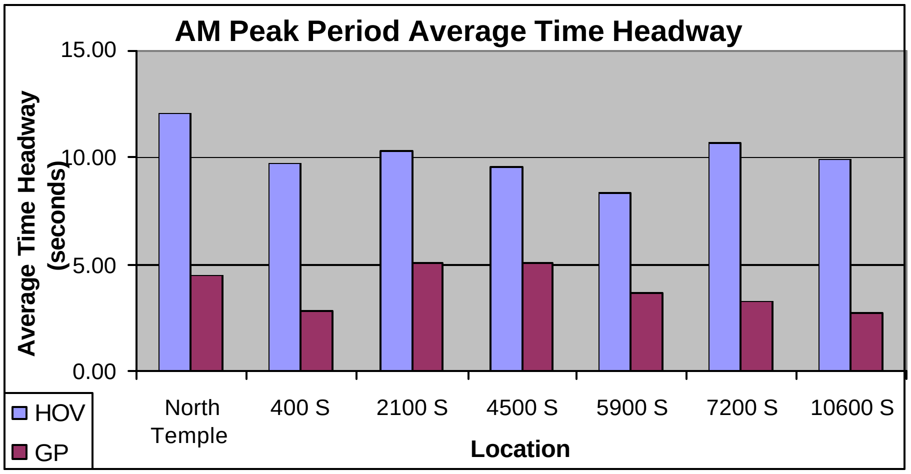

Figure 6.27: A.M. Peak Period Average Time Headway Comparison

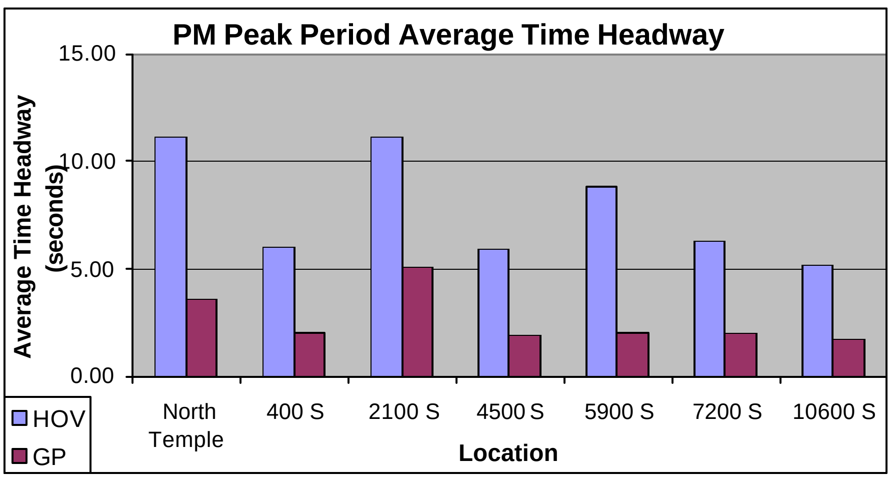

Figure 6.28: P.M. Peak Period Average Time Headway Comparison

6.10 Level of Service

Level of Service (LOS) is the operating condition that occurs on a lane or roadway when accommodating various traffic volumes (*16*). It is a qualitative measure of the effect of traffic flow factors like speed, travel time, freedom to maneuver, and driver comfort. It is expressed as LOS A through F. LOS A is a free-traffic-flow condition where there is little or no restriction in speed or maneuverability because of the presence of other vehicles. LOS F, on the other hand, corresponds to forced-flow operation at low speed with many stops. LOS of the HOV and GP lanes was obtained using video detection. Table 6.4 presents this comparison. It is seen that the HOV lanes operate mainly at LOS A and sometimes at LOS B, whereas the GP lanes operate at various LOS ranging from LOS A to LOS F. At almost all the locations, the LOS drops in the p.m. peak period.

Table 6.4: HOV and GP Lanes LOS Comparison

Location	a.m. Peak Period		p.m. Peak Period	
	HOV Lane LOS	GP Lanes LOS	HOV Lane LOS	GP Lanes LOS
North Temple	A	B, C	A	B, C
400 South	A	B, C, D, E, F	A, B	D, E
2100 South	A	A, B, C	A	B, C
4500 South	A	A, B, C	A, B	D, E, F
5900 South	A	A, B, C	A	D, E
7200 South	A	B, C, D	A, B	D, E, F
10600 South	A	B, C, D	A, B	D, E, F

7. CONCLUSIONS

HOV lanes in the Salt Lake Valley are performing effectively in several MOEs such as vehicle volume, person throughput, AVO and speed benefits. This study reports the third year of performance. The data collected was compared with the NCHRP standards and national averages. It was found that vehicle volume satisfies the NCHRP's recommended minimum vehicle volume of 400 to 800 vehicles/peak hour for the HOV lane at almost all the seven representative locations during both the a.m. and p.m. peak periods (except at North Temple during the a.m. peak period).

The NCHRP's minimum HOV lane person throughput threshold of 900 pphpl during the peak hours was not only met but was exceeded at all data collection locations, especially during the p.m. peak hour. It was found that, compared to a GP lane, the HOV lane carried 32.69 percent fewer people with 73.17 percent fewer vehicles during the a.m. peak period. Furthermore, during the p.m. peak period, the HOV lane carried 8.89 percent more people with 48.06 percent fewer vehicles and had a higher LOS when compared to a GP lane. This is reasonable as HOV lanes are more effective during the more congested periods (p.m. Peak Period in the Salt Lake Valley).

The Salt Lake Valley HOV lane mean speeds are higher than the national average HOV lane speed of 54 mph during the peak periods. In both the HOV and GP lanes speeds decrease during the peak periods, because of higher vehicular volume. However, speeds are relatively higher and more stable in the HOV lanes than in the GP lanes. Because of the higher speeds, HOV lanes offer travel time benefits. The NCHRP's recommended overall peak hour travel time saving of at least five minutes was met and exceeded during the p.m. peak period. During the a.m. peak period, however, this standard was short three minutes to meet the minimum standard. The p.m. peak period travel time saving was 46.30 percent. Travel time savings during the a.m. peak period and off-peak period were 12.68 percent and 5.32 percent respectively.

The HOV system has resulted in an increase in AVO levels in the I-15 corridor in the Salt Lake Valley. The overall AVO on I-15 has increased by 6 percent from 1.32 during the first year of HOV lane operation to 1.40 during its third year of operation. It was inferred from this that HOV lanes have encouraged carpooling in the Salt Lake Valley. Another indicator of the effective performance of the HOV lanes is that the overall AVO in the HOV lane is 2.55 whereas in the GP lane it is 1.11.

HOV lane violation rates in the I-15 corridor and at the 400 South ramps were found to be 2 percent and 10 percent respectively. The Salt Lake Valley HOV lane system experiences a low violation rate when compared to other cities nationally, although the on-ramp violation rate of 14.6 percent at 400 South is higher than the national average of 13 percent.

There were a total of 187 HOV lane accidents from May 14, 2001, to Dec. 31, 2003. The overall accident rate per MVMT was found to be 1.35. Accidents were influenced by traffic congestion and roadway conditions. Higher accident rates were recorded in the p.m. peak period and in the southbound direction. This was probably because of the high congestion levels during the p.m. peak periods in the peak direction. The other patterns in accident rates (segmental and monthly variation of accidents) were not readily apparent and were probably due to the randomness of accident occurrence. The major accident causes were improper lane travel, excessive speeds, following too close and improper lookout. One important finding was that there were no fatalities among the HOV lane accidents. The percentages of accidents with no injury, possible injury, bruises and abrasions, and broken bones or bleeding wounds respectively were 72.73 percent, 15.51 percent, 6.95 percent and 4.81 percent of the total HOV lane accidents. The timeframe considered was not adequate to analyze changes in accident rates. Future data, however, may be analyzed to establish a definite trend in accident rates.

Impacts to other freeway users seem to be within acceptable levels, based on public feedback. There is widespread support for the HOV lanes from both its users and non-users with 49.50 percent of the respondents stating it to be an excellent idea followed by another 37 percent who believed it was a good idea. This widespread popularity is consistent with the traffic and travel time data analysis which concludes that HOV lanes are effective and thereby popular. The major factor that would make HOV lanes more attractive was found to be direct entrance and exit ramps to the inside HOV lanes with a score of 4.36/6.00. There was not much support for HOT lanes which permit SOV drivers to use HOV lanes for a fee (score of 2.61/6.00). The statement that HOV lanes are unfair to taxpayers who drive alone received a low score of 2.23/5.00. Some of the respondents wanted the HOV lanes to be extended to Utah County and Davis County.

The results were also compared to the first year of operation. Overall, there has been a 35 percent increase in the HOV lane peak period vehicle volume and 31 percent increase in its person throughput since the first year of its operation. HOV lane speeds have decreased by just 4 percent which is not statistically significant at the 95 percent confidence level. GP lane speeds have remained almost the same. Travel time savings have increased from 30.7 percent to 46.30 percent during the p.m. peak period although during the a.m. and off-peak periods they have remained the same. HOV lane violation rates in the I-15 corridor and at the 400 South ramps have decreased from 9 percent and 17 percent respectively to 2 percent and 10 percent respectively. Effective enforcement, however, is still required, especially at the 400 South on-ramp.

The I-15 South Project will add an HOV lane in each direction and a GP lane in the southbound direction from 10600 South to the Salt Lake/Utah County Line (*22*). It is then expected to provide more travel time benefits to HOV lane users. Other improvements like direct on-ramps and off-ramps to the inside HOV lanes and prominent ILEV and carpool information signs are needed along the I-15 corridor. All these will enhance the popularity of the HOV lanes and lead to increased HOV lane use.

HOV lane use in Salt Lake Valley is continuing to grow. As traffic volume in the Salt Lake Valley increases and congestion reaches higher levels, the benefits of the HOV lanes will likely increase.

8. RECOMMENDATIONS

Salt Lake Valley HOV lane performance continues to meet or exceed nationwide HOV lane performance. Moreover, there seems to be a widespread public support for the HOV lanes. The HOV lanes should not be closed, but should remain open to allow people to continue to benefit from them. Although this study found that high occupancy vehicle lanes are becoming increasingly effective, a few shortcomings were noted and were used to develop recommendations.

Violation rates, especially at the 400 South ramps, need stricter enforcement. The on-ramp violation rate of 14.6 percent at 400 South is higher than the national average of 13 percent for concurrent HOV lane facilities.

Signage along the I-15 corridor also needs to be improved. Proper signage needs to be posted informing drivers that AFVs are allowed in the HOV lanes. On the signs along the I-15 HOV lanes there are some signs with the letter C painted in black on a blue background. Many people, however, are not aware of what that symbol stands for. The Manual on Uniform Traffic Control Devices (MUTCD) recommends the use of the Inherently Low Emission Vehicle (ILEV) sign (MUTCD Code R3-10b) when it is permissible for a labeled and certified ILEV to use an HOV lane even if it is a SOV. ILEV signs are ground-mounted and placed in advance of and at intervals along the HOV lane based on engineering judgment (*20*). There needs to be carpool and rideshare information signs along the I-15 corridor so that people become aware of UTA's carpool programs. The signs may display UTA's rideshare phone number 533-RIDE. Vanpooling also needs to be encouraged by popularizing UTA's interest free van purchasing and van leasing programs. Vanpooling needs to be emphasized to encourage increased vehicle occupancy in the HOV lanes. Figure 7.1 displays the ILEV and carpool information signs recommended by MUTCD (*20, 21*).

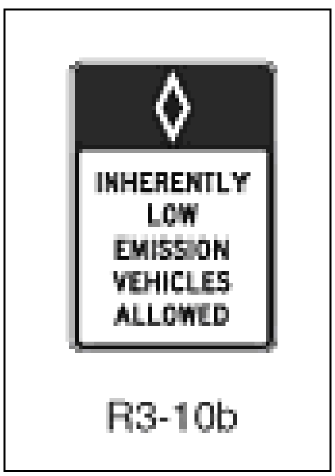

Figure 7.1: MUTCD's ILEV and Carpool Information signs

HOV lane accidents were found by examining 3,517 accident records. These accidents occurred between 600 North and 10600 South on I-15 from May 14, 2001, to Dec. 31, 2003. It is recommended that investigating officers identify the HOV lane accidents while reporting them. They may write G (which is the code for an HOV lane) as the traffic control type under the second section of the State of Utah Investigating Officer's Report of Traffic Accident (DI-9 form). Then all the HOV lane accidents can be retrieved easily. There will be no need to go through the other accident records and it will provide better data for future HOV lane accident analysis and safety evaluation.

Direct entrance and exit ramps to the inside HOV lanes are needed so that it is more convenient for people to enter and exit the HOV lanes. Direct ramps would provide travel time savings for the HOV users and enhance the safe operation of both the HOV and GP lanes. Many potential HOV lane users do not use the HOV lanes for short freeway trips because they have to cross four GP lanes to exit the freeway. This could have been overcome had there been inside ramps to the HOV lanes. Additionally, there is a need for more park and ride lots and discounted parking charges for HOV users.

People need to be educated about HOV lane restrictions and benefits, particularly the potential travel time savings. Hence there is a need for the implementation of public outreach programs to promote HOV facilities. It needs to be emphasized that HOV lanes do not have to look full to be effective and backed up traffic on GP lanes does not mean that HOV lanes are ineffective. The concept that a single-occupant AFV is allowed in the HOV lanes needs to be popularized. Furthermore, public opinion surveys should be made an integral part of the ongoing project operations. Public feedback can then be used as a direct input to the facilities management so that the HOV lanes operate more efficiently and hence become more popular.

As congestion in the Salt Lake Valley increases, the benefits of the HOV lanes are also expected to increase. There is a need for continued monitoring to identify and keep track of these benefits and proactively manage the HOV lanes. The periodic monitoring programs may be conducted every two or three years. They may be performed on a small-scale and include MOEs like vehicle volume, person throughput, travel time, and violation rate.

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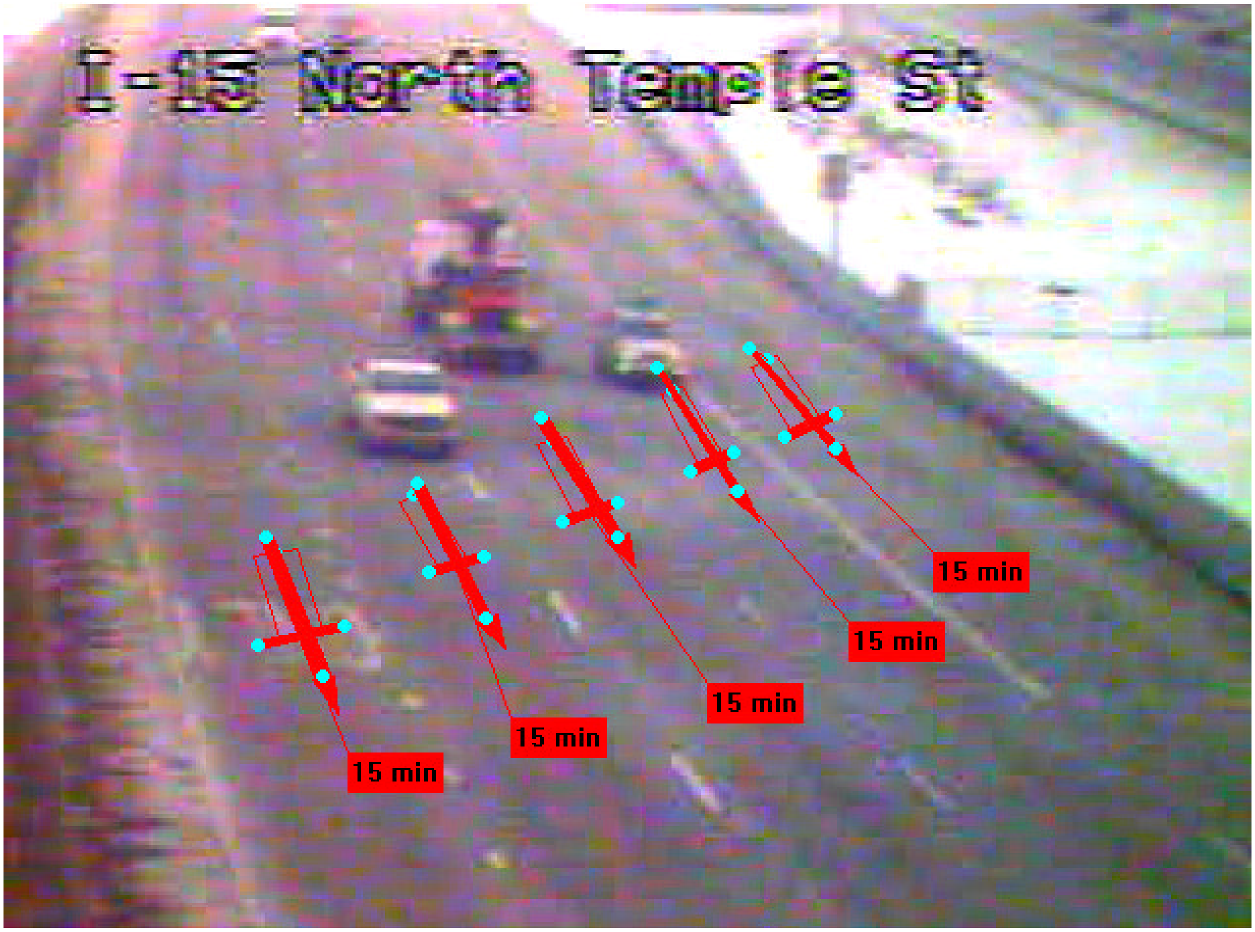
APPENDIX A. DATA COLLECTION LOCATIONS

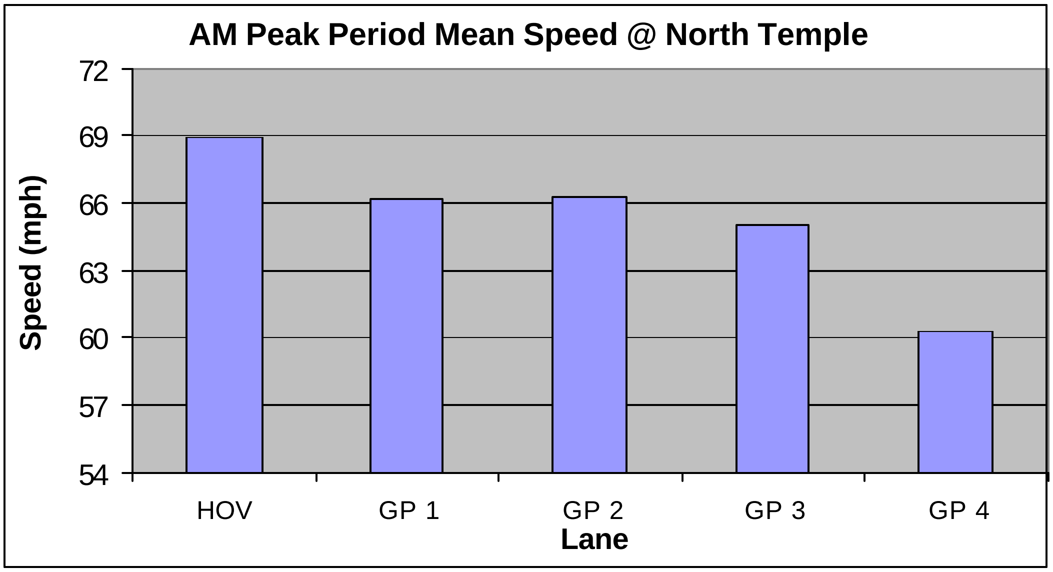
Location	Vehicle Volume, Speed (Video Detection)	AVO, Modal Split, Person Throughput (Manual)	Violation Rates (Manual)
North Temple	◆		
400 South	◆	◆ (HOV)	◆
2100 South	◆		
2700 South		◆ (a.m.)	◆ (a.m.)
3900 South		◆	◆
4500 South	◆		
4900 South		◆	◆
5900 South	◆		
7200 South	◆		
10600 South	◆	◆ (p.m.)	◆ (p.m.)
Total	7	5	5

* Data Collection was done for both the HOV and GP lanes during both the a.m. and p.m. peak periods unless otherwise stated.

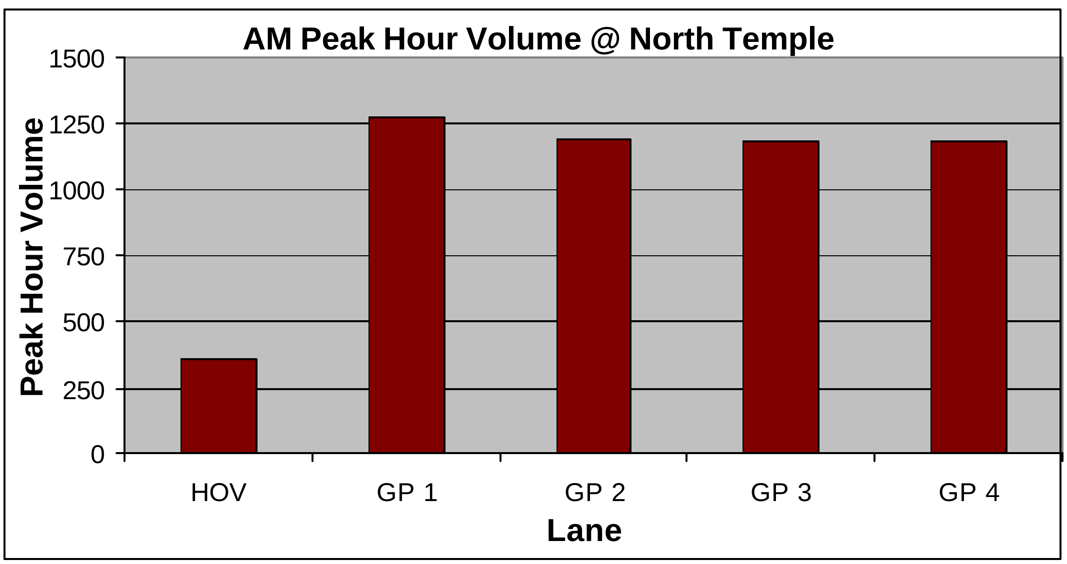
A SNAPSHOT OF VIDEO DATA COLLECTION AT NORTH TEMPLE, I-15



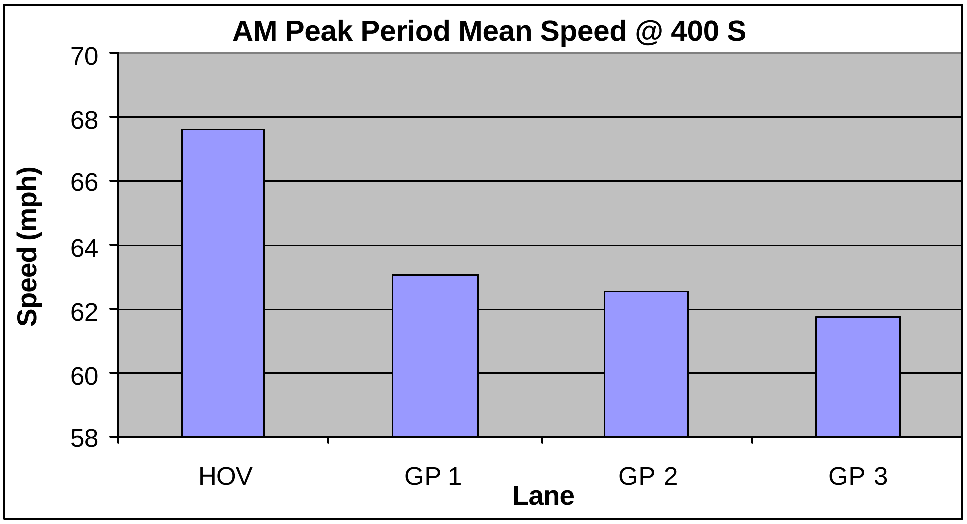
APPENDIX B. PEAK PERIOD MEAN SPEED AND PEAK HOUR VOLUME



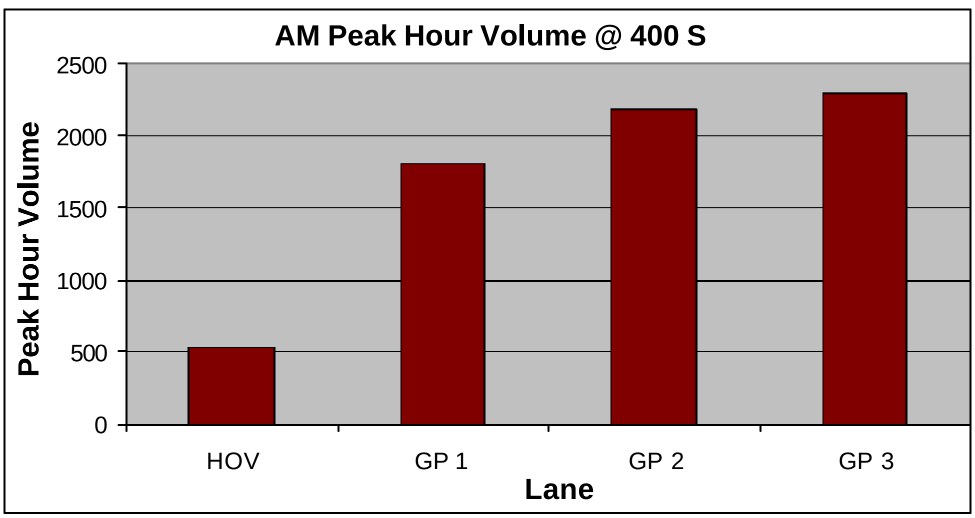
A.M. Peak Period Mean Speed Variation at North Temple



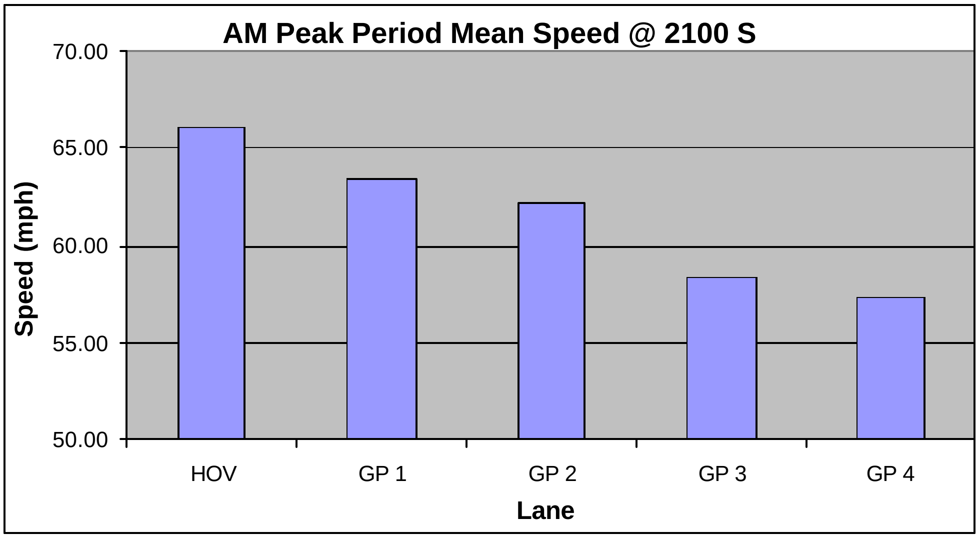
A.M. Peak Hour Volume Variation at North Temple



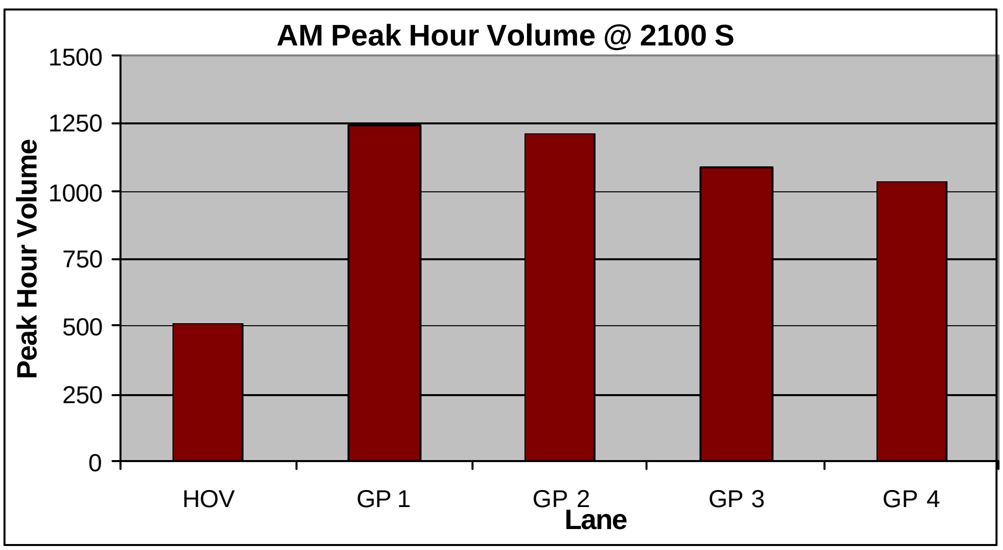
A.M. Peak Period Mean Speed Variation at 400 South



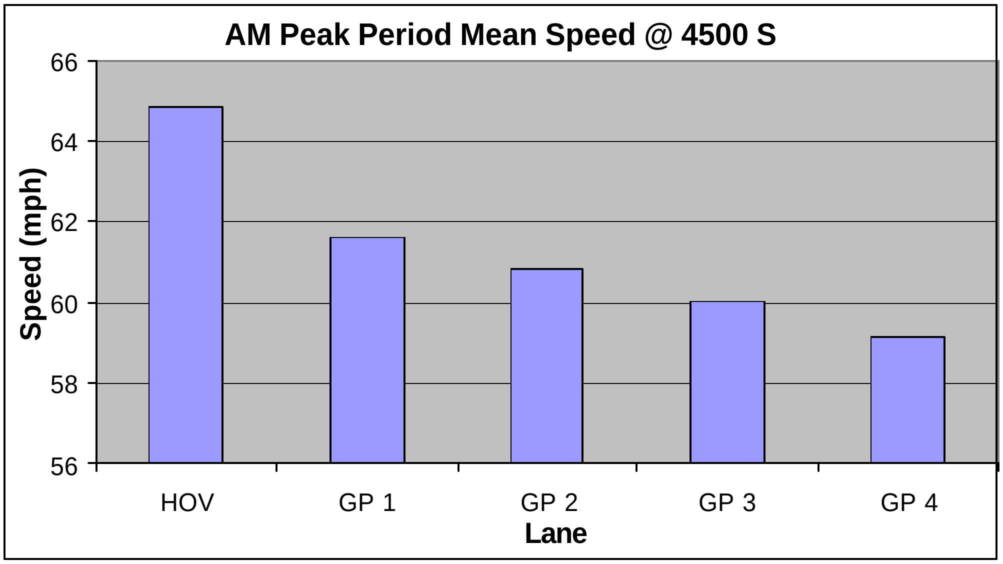
A.M. Peak Hour Volume Variation at 400 South



A.M. Peak Period Mean Speed Variation at 2100 South



A.M. Peak Hour Volume Variation at 2100 South



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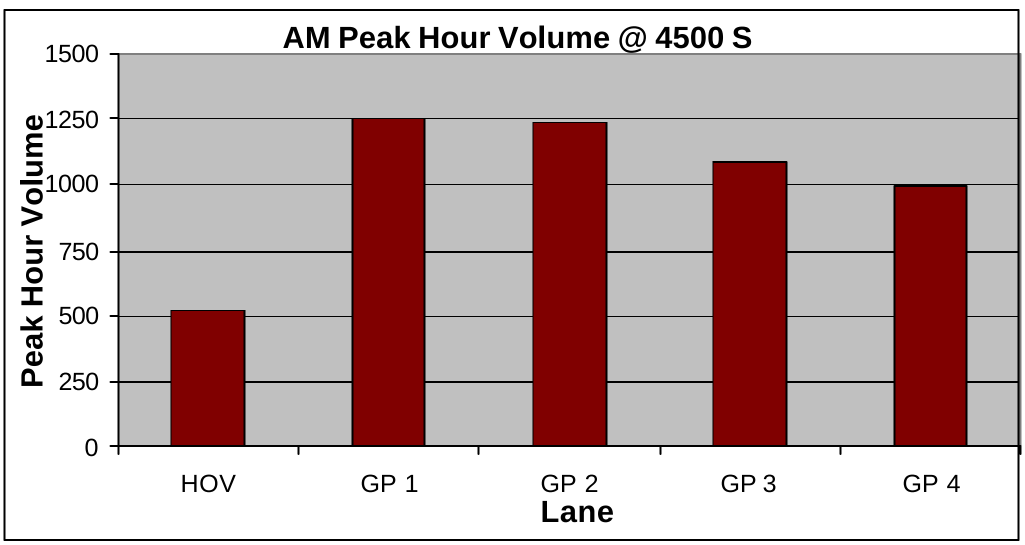
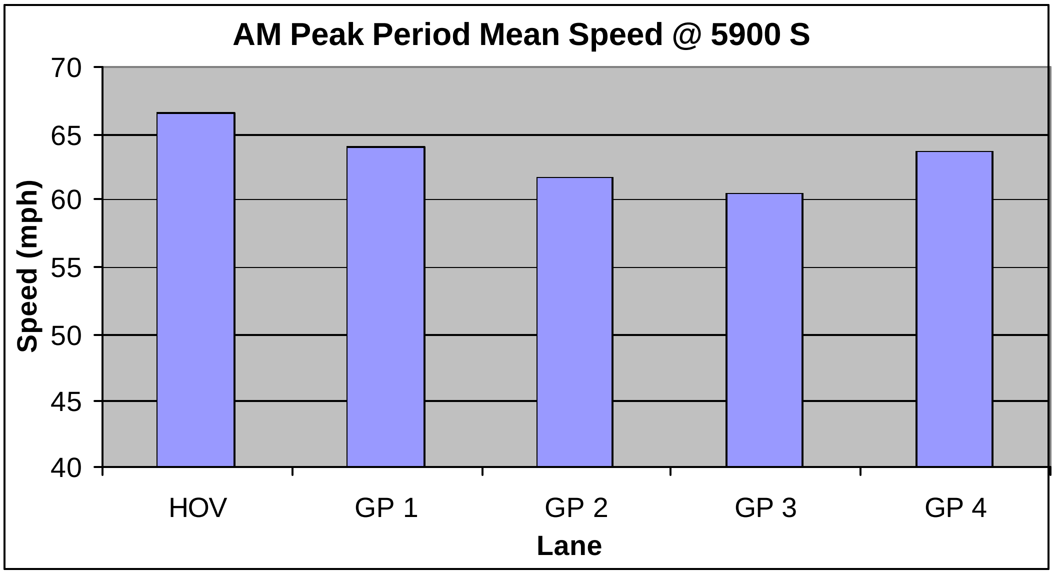
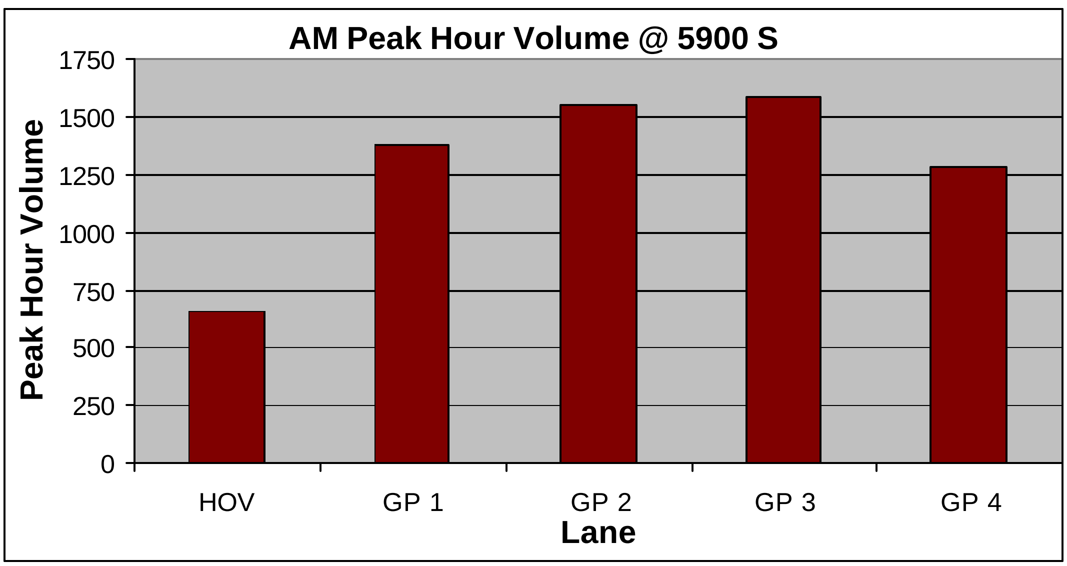


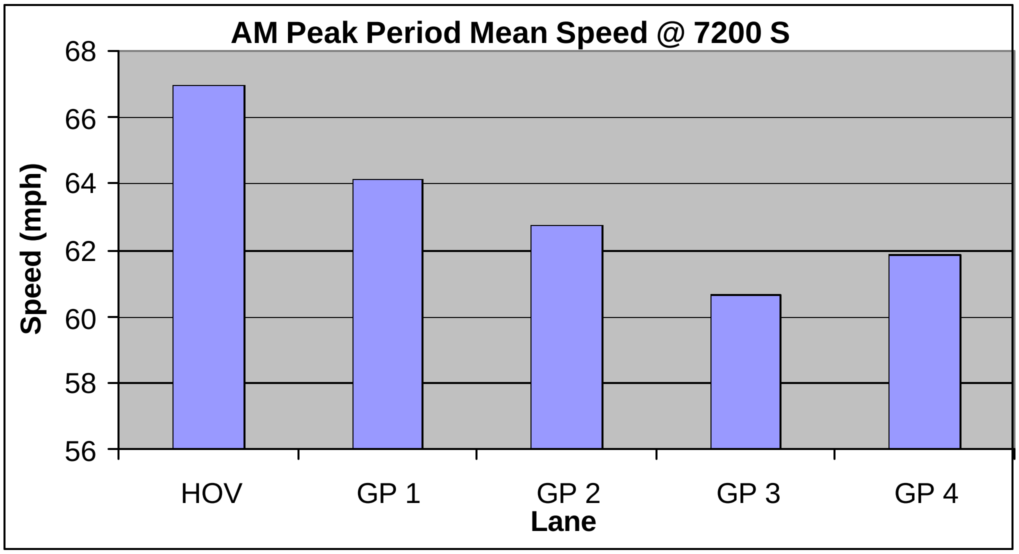
A.M. Peak Hour Volume Variation at 4500 South



A.M. Peak Period Mean Speed Variation at 5900 South



A.M. Peak Hour Volume Variation at 5900 South



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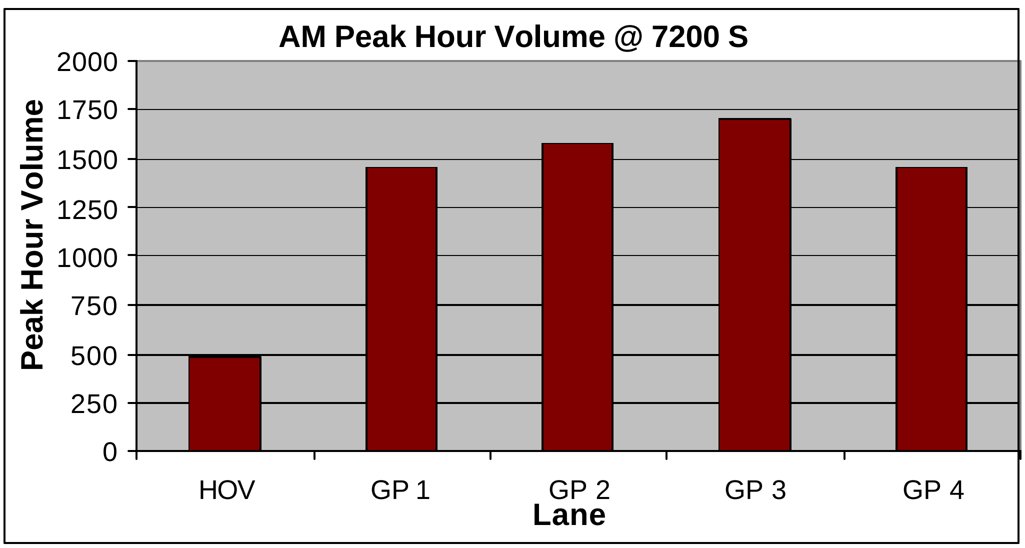
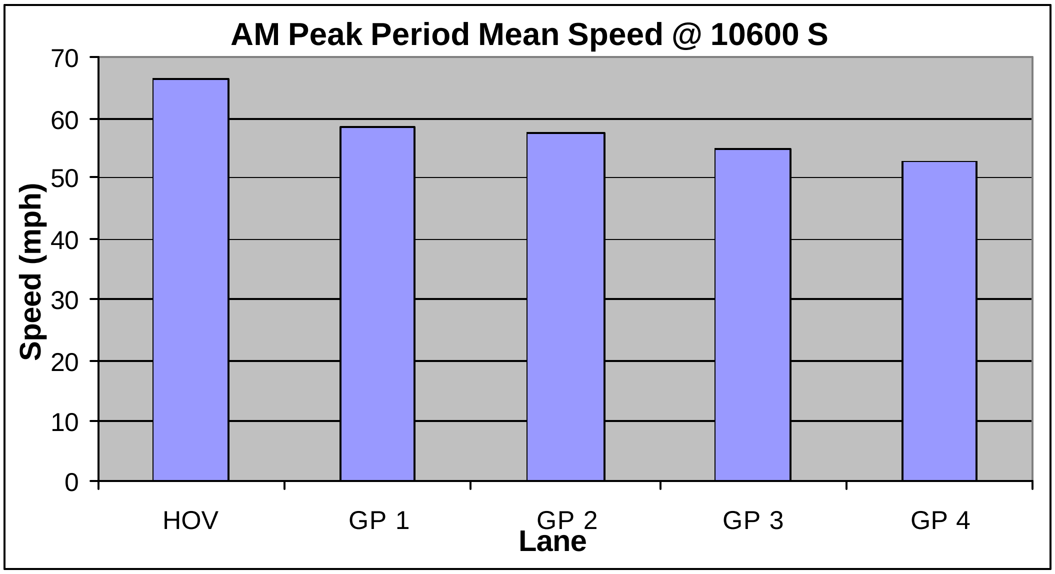
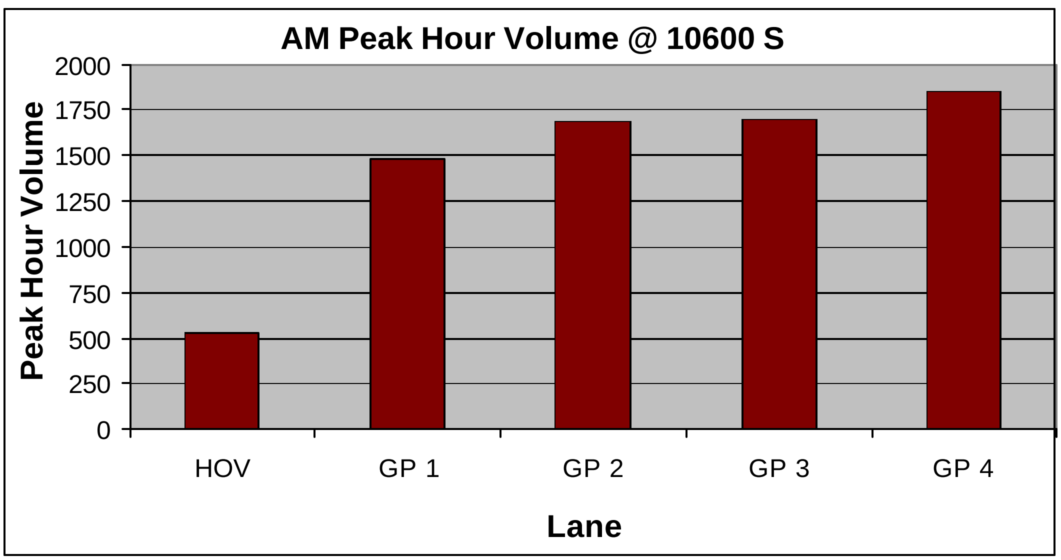


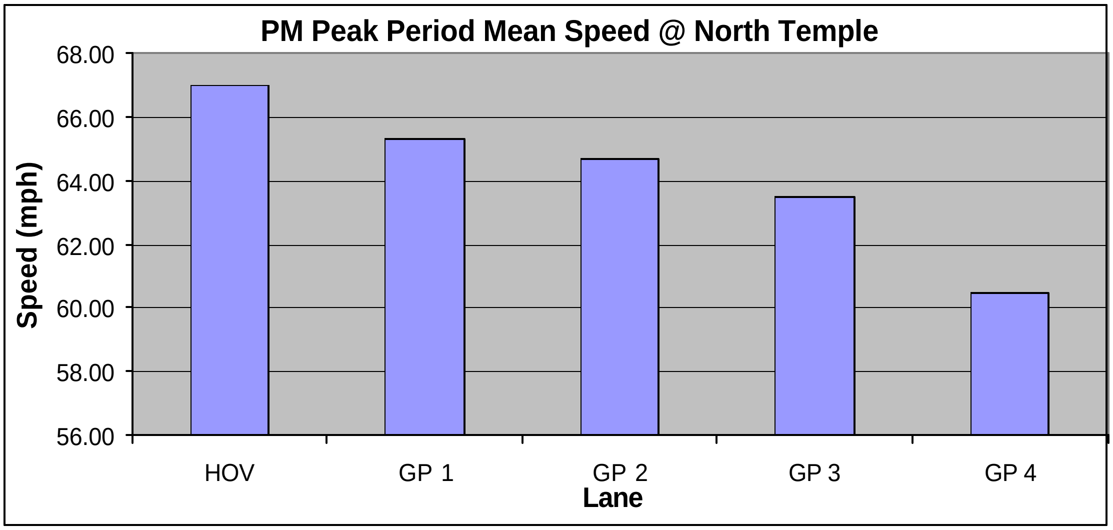
A.M. Peak Hour Volume Variation at 7200 South



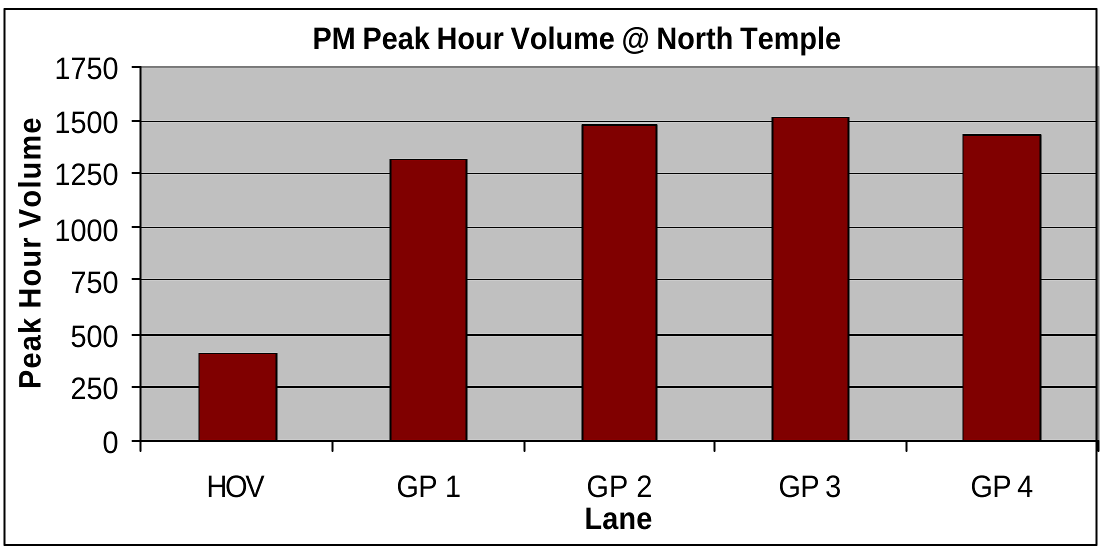
A.M. Peak Period Mean Speed Variation at 10600 South



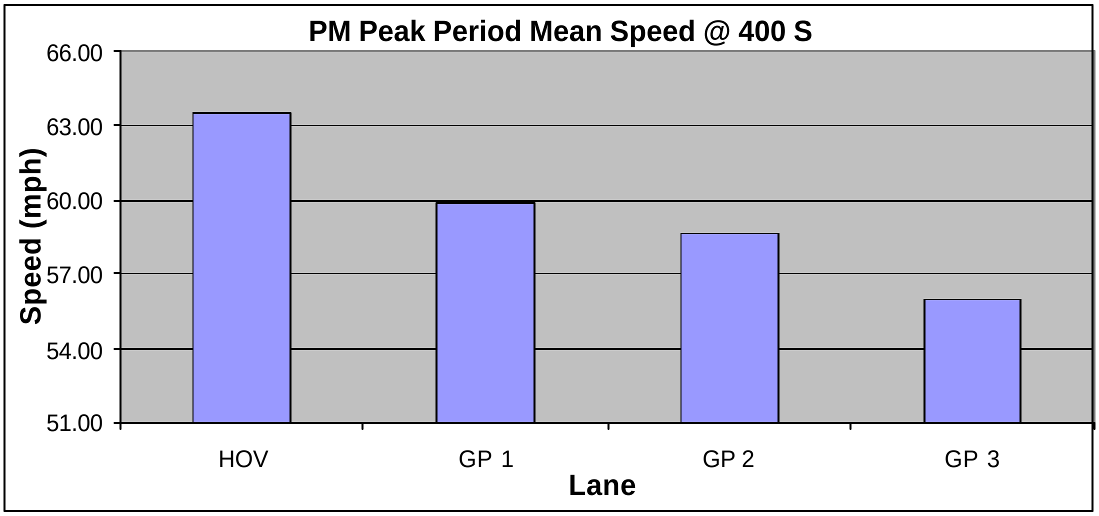
A.M. Peak Hour Volume Variation at 10600 South



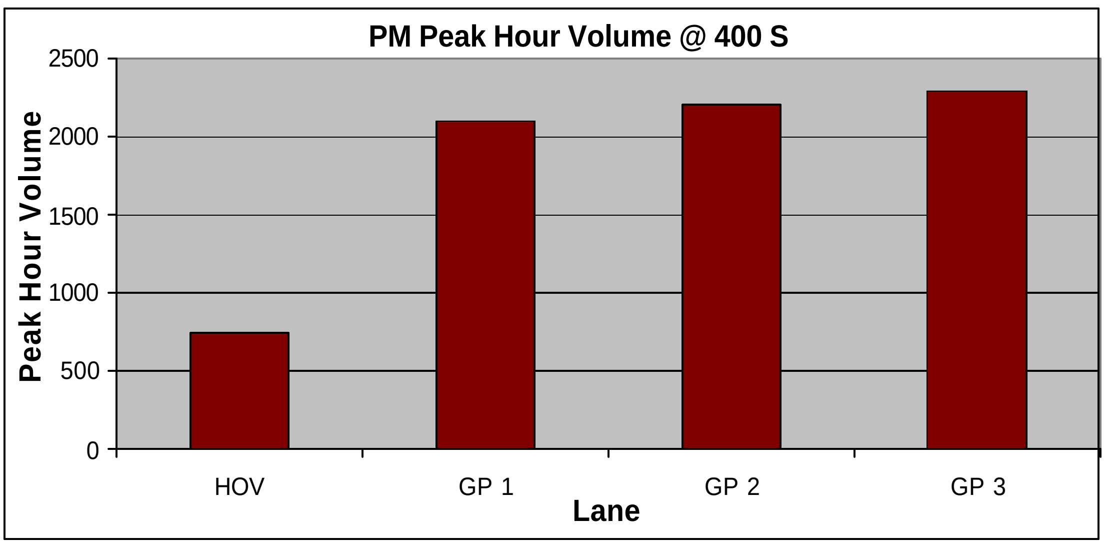
P.M. Peak Period Mean Speed Variation at North Temple



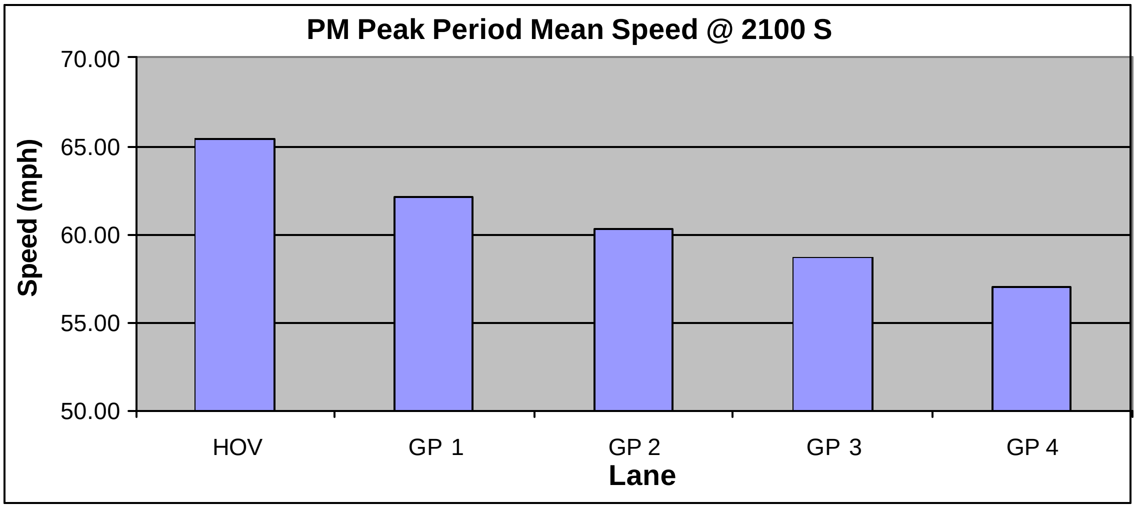
P.M. Peak Hour Volume Variation at North Temple



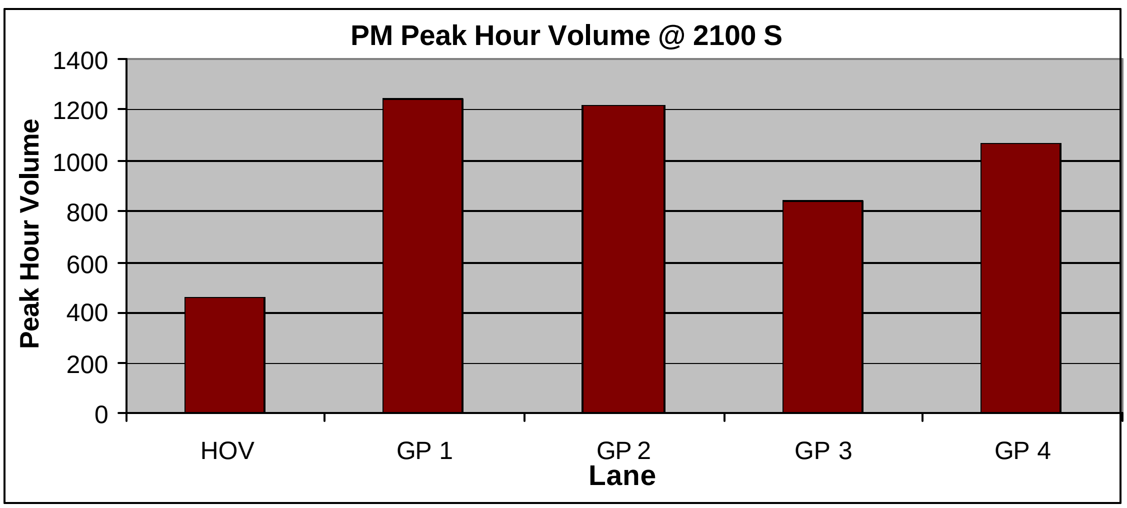
P.M. Peak Period Mean Speed Variation at 400 South



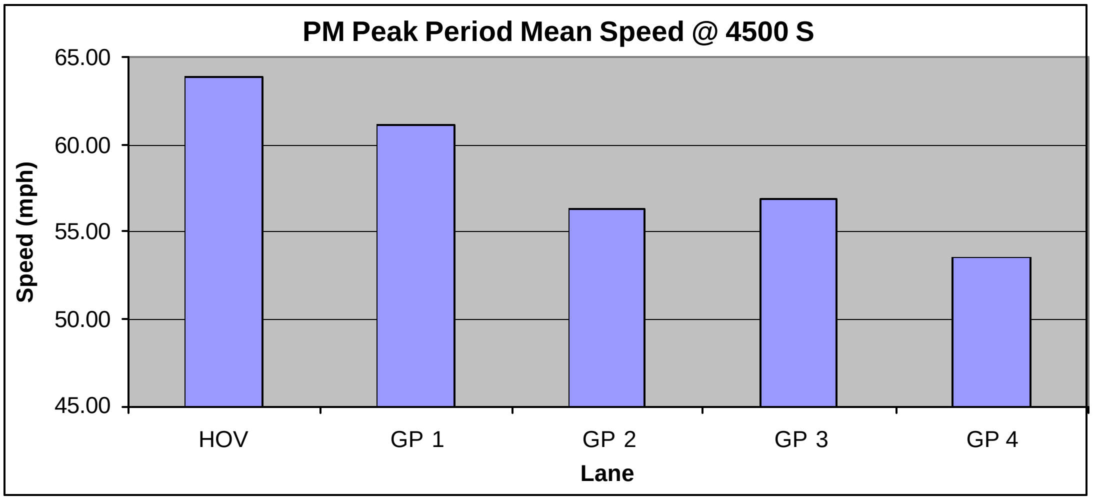
P.M. Peak Hour Volume Variation at 400 South



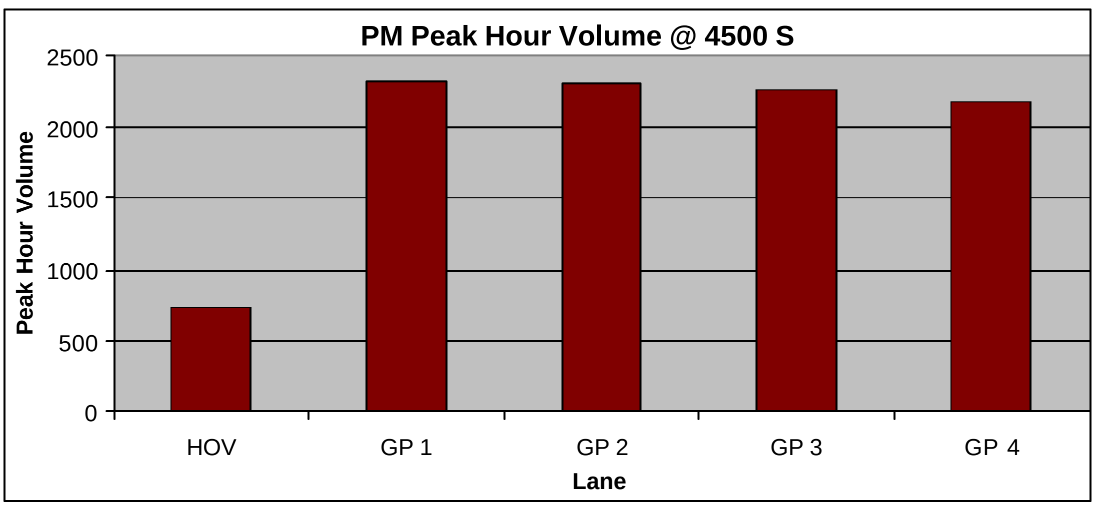
P.M. Peak Period Mean Speed Variation at 2100 South



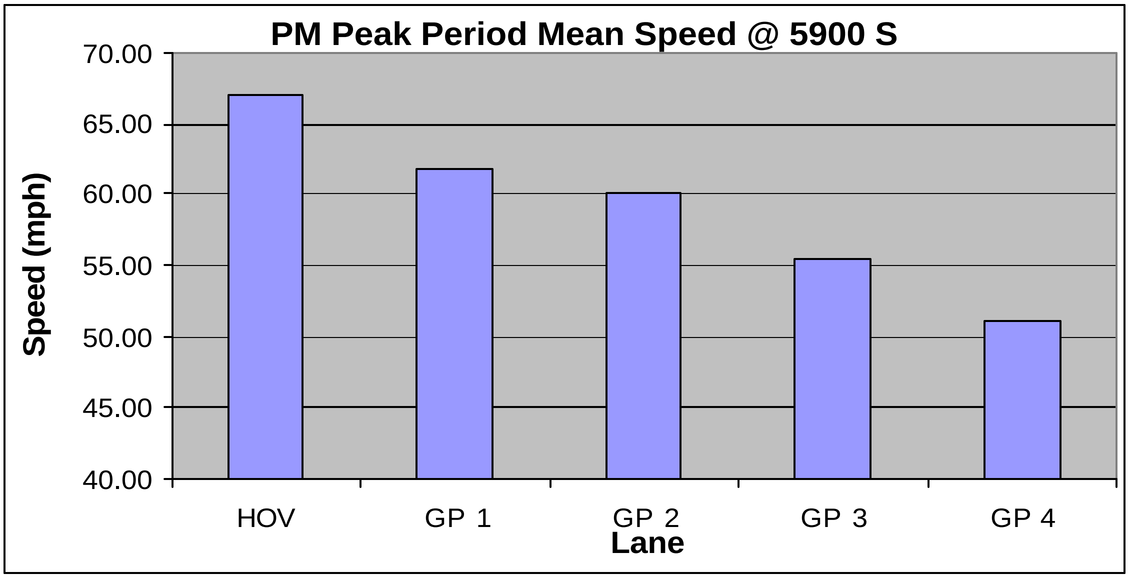
P.M. Peak Hour Volume Variation at 2100 South



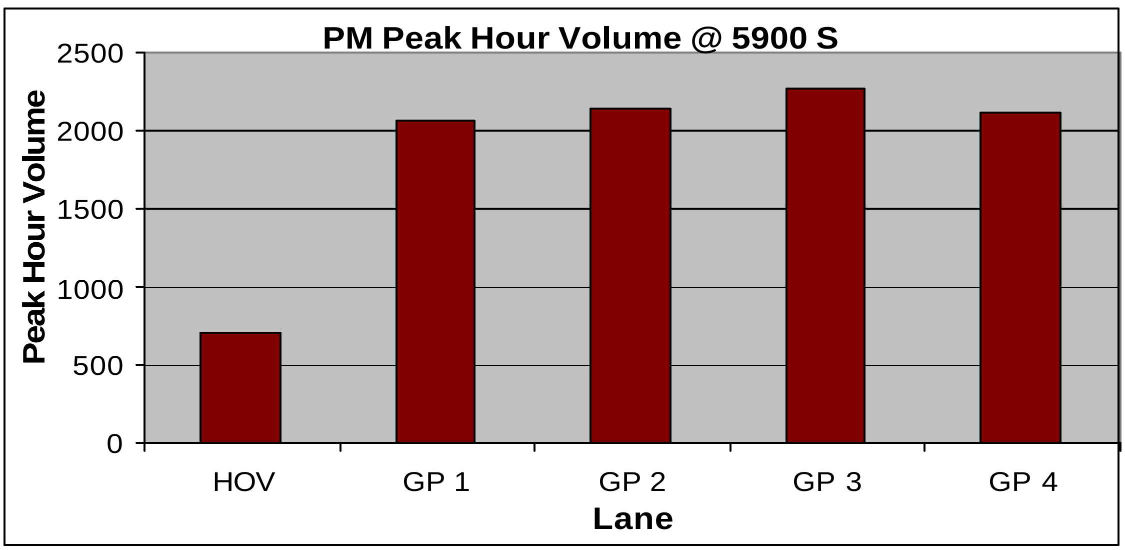
P.M. Peak Period Mean Speed Variation at 4500 South



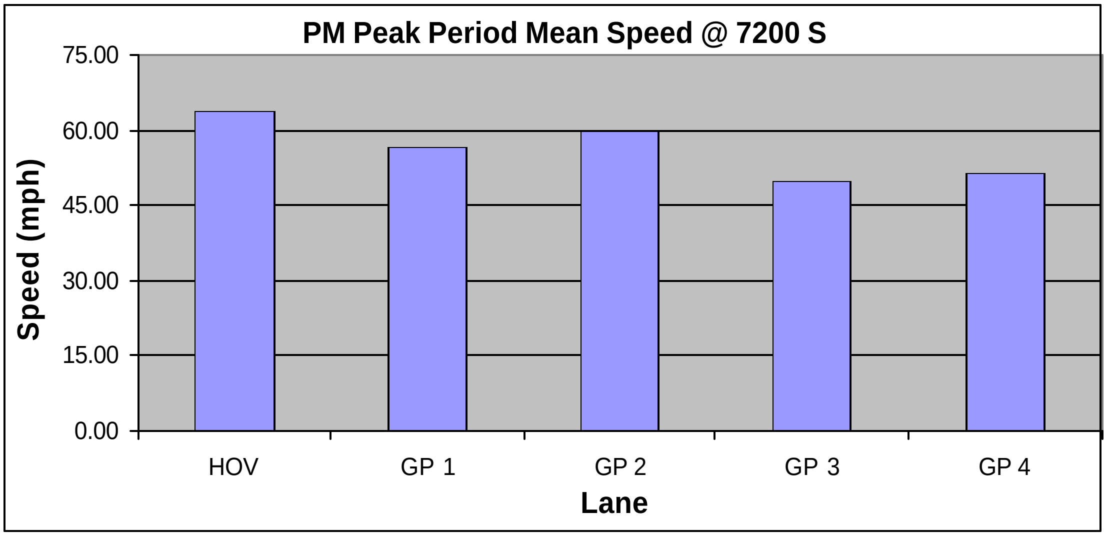
P.M. Peak Hour Volume Variation at 4500 South



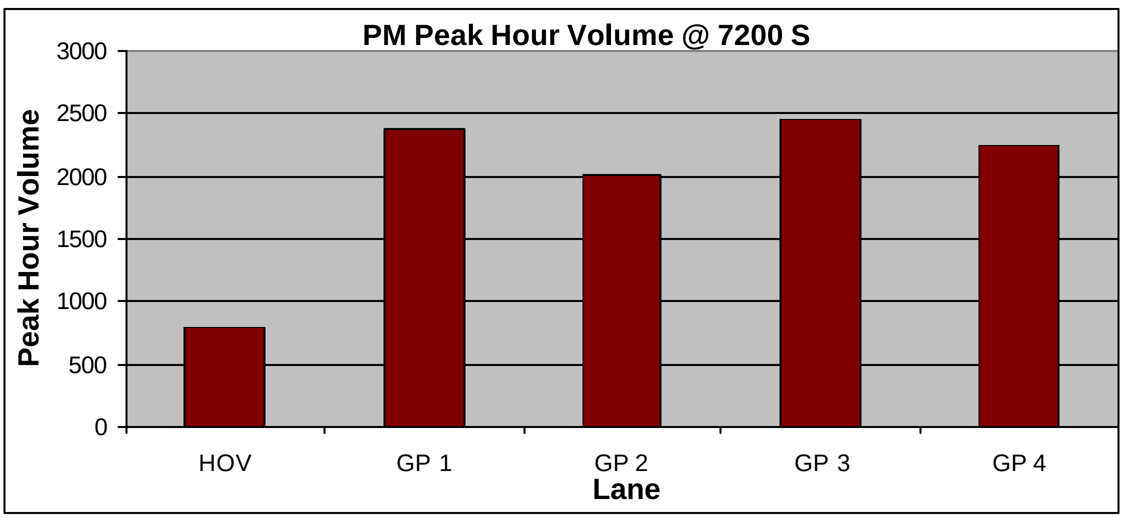
P.M. Peak Period Mean Speed Variation at 5900 South



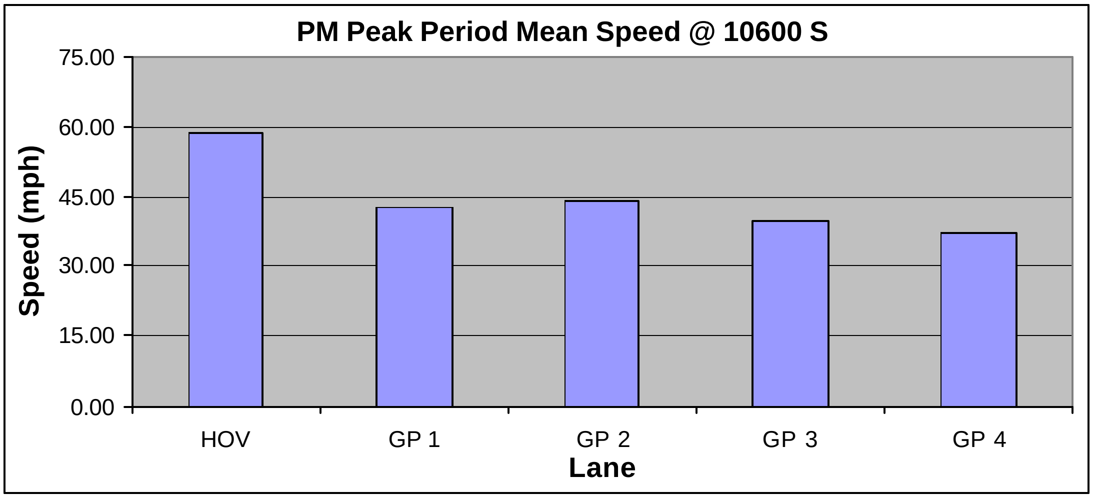
P.M. Peak Hour Volume Variation at 5900 South



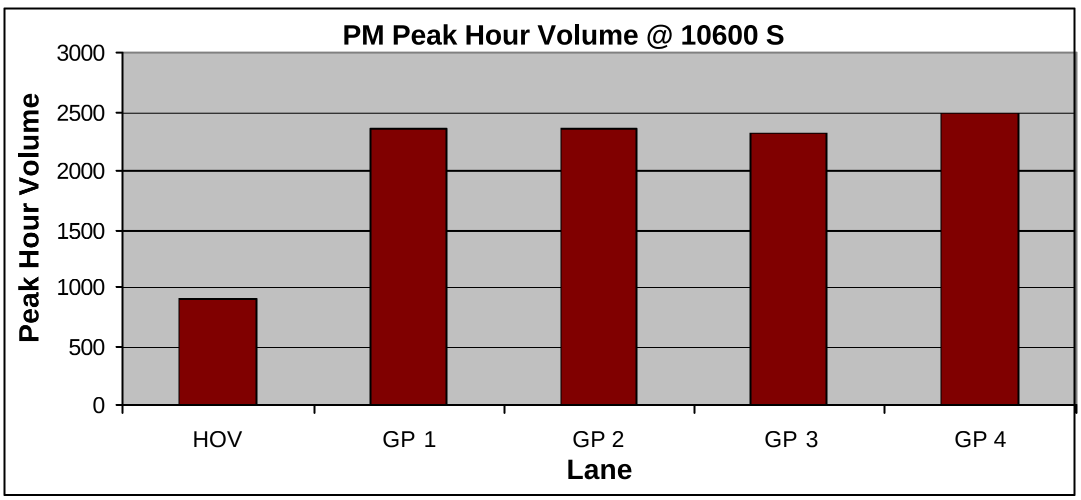
P.M. Peak Period Mean Speed Variation at 7200 South



P.M. Peak Hour Volume Variation at 7200 South

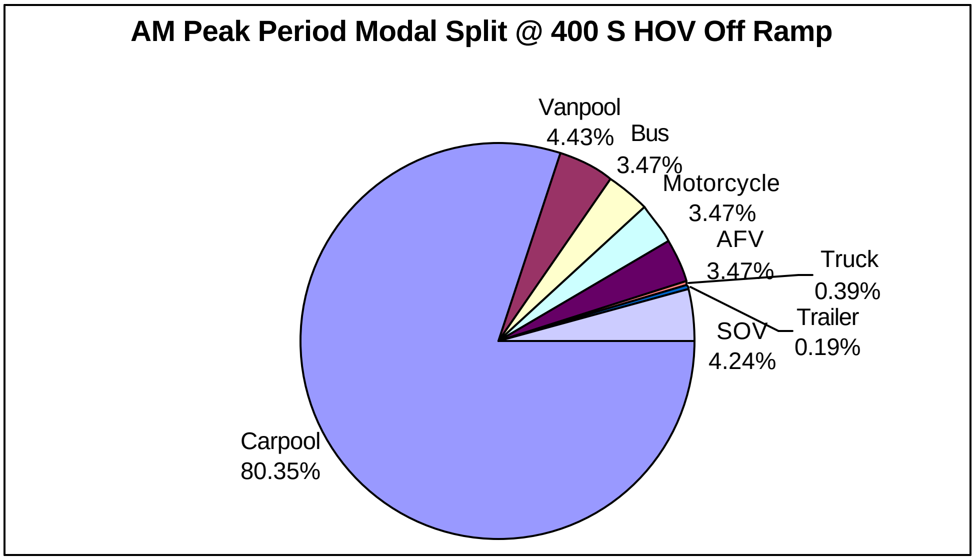


P.M. Peak Period Mean Speed Variation at 10600 South

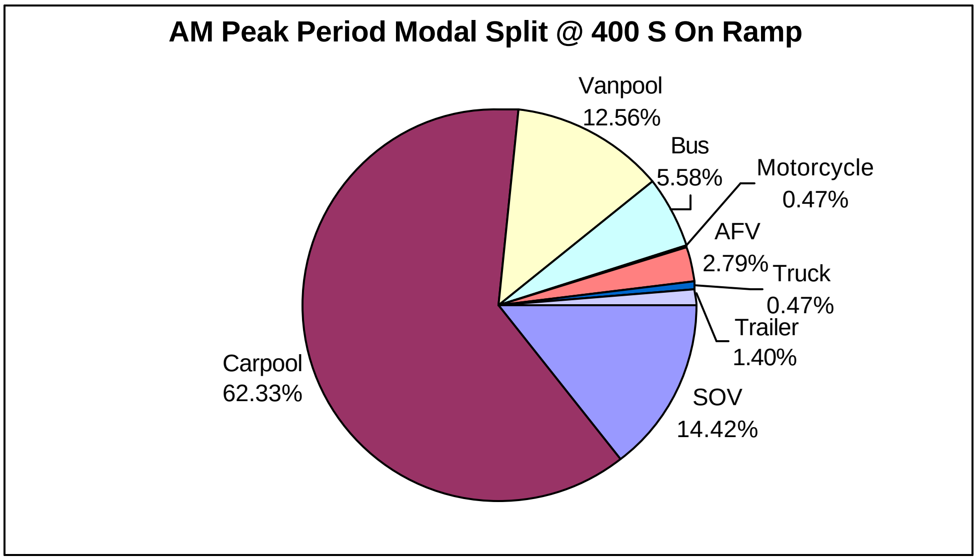


P.M. Peak Hour Volume Variation at 10600 South

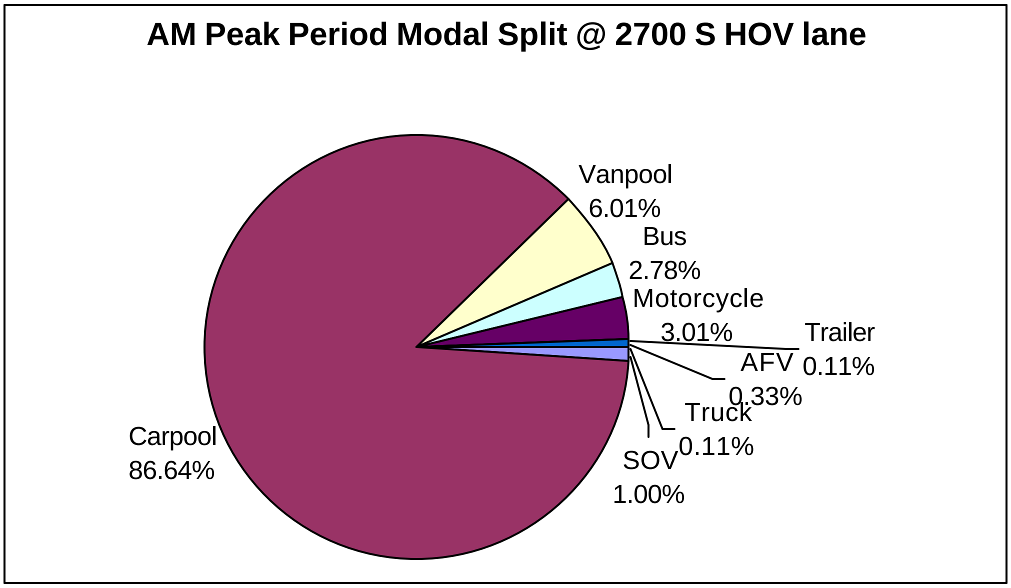
APPENDIX C. PEAK PERIOD MODAL SPLIT



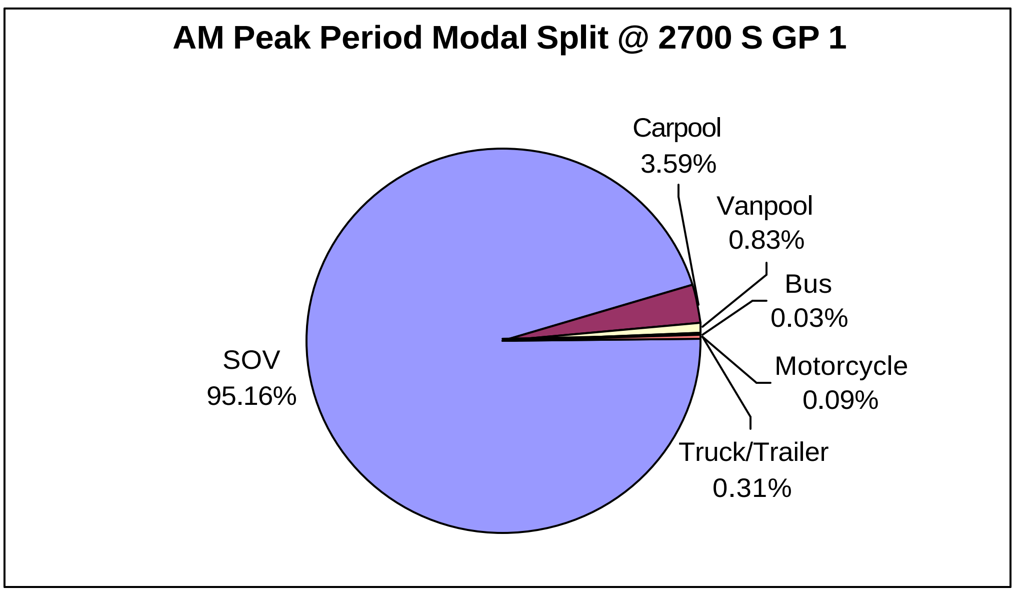
A.M. Peak Period Modal Split at 400 South HOV Off-Ramp



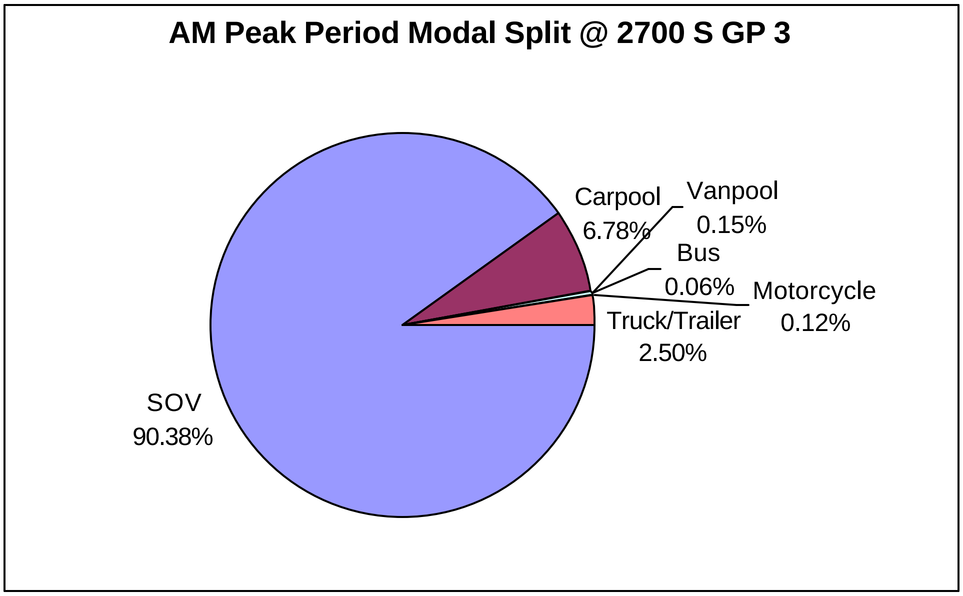
A.M. Peak Period Modal Split at 400 South HOV On-Ramp



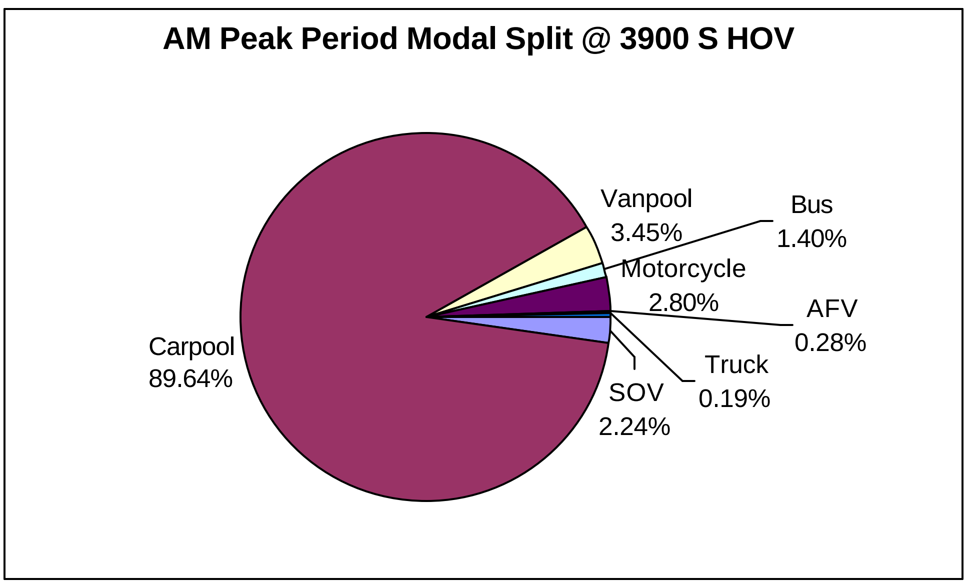
A.M. Peak Period Modal Split at 2700 South HOV Lane



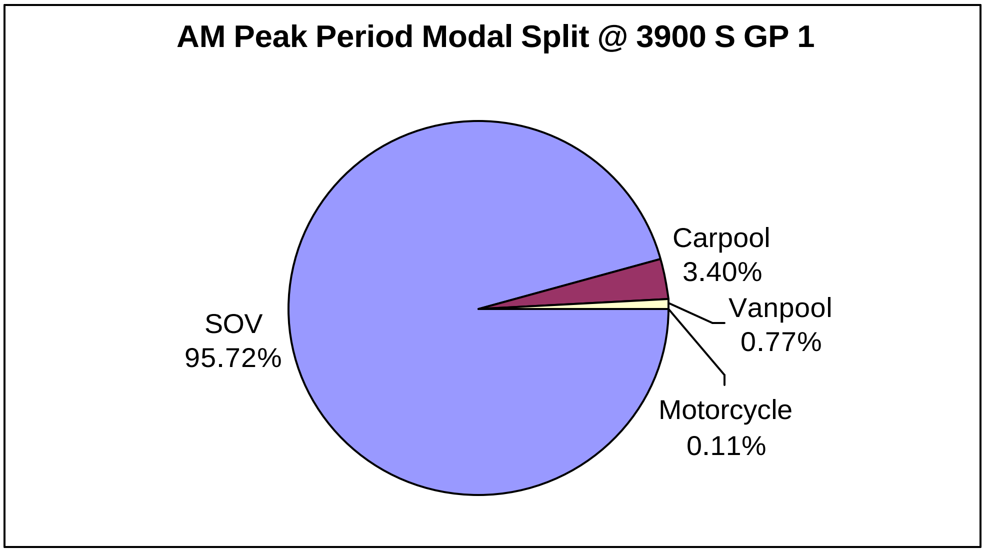
A.M. Peak Period Modal Split at 2700 South GP 1



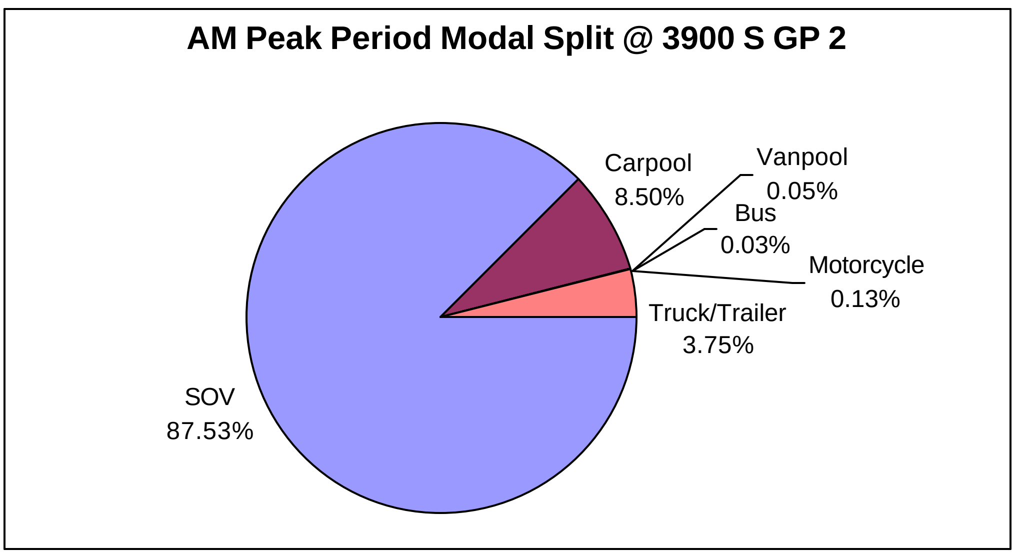
A.M. Peak Period Modal Split at 2700 South GP 3



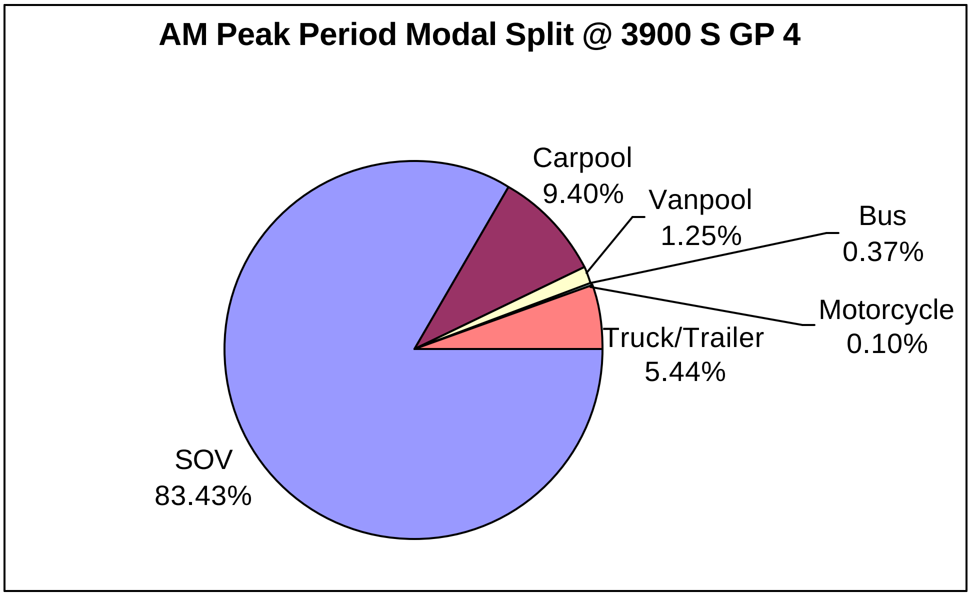
A.M. Peak Period Modal Split at 3900 South HOV Lane



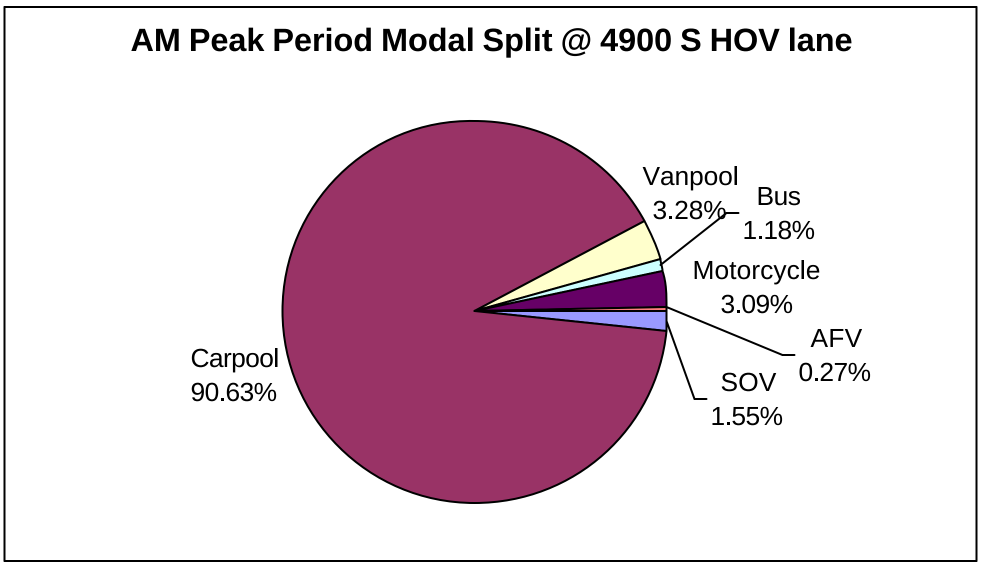
A.M. Peak Period Modal Split at 3900 South GP 1



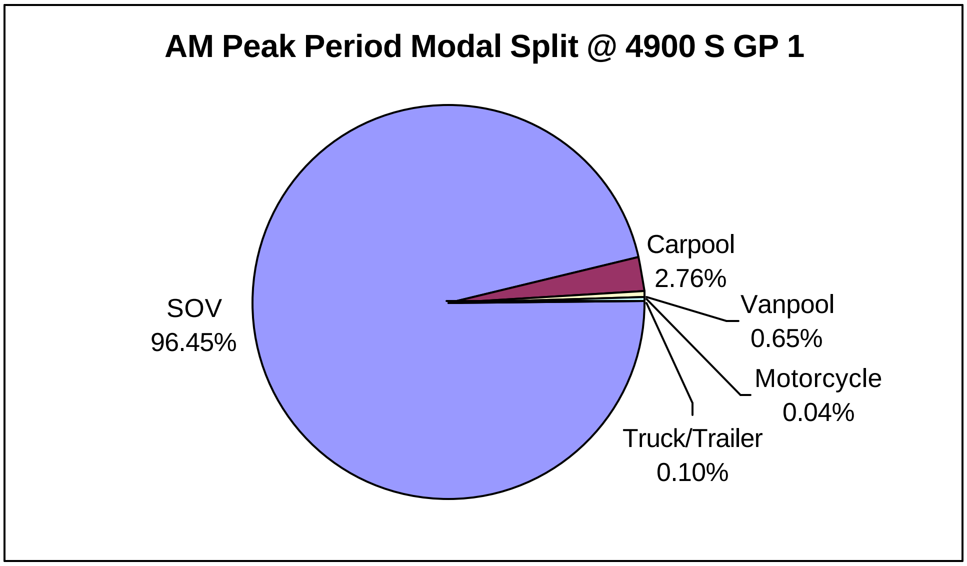
A.M. Peak Period Modal Split at 3900 South GP 2



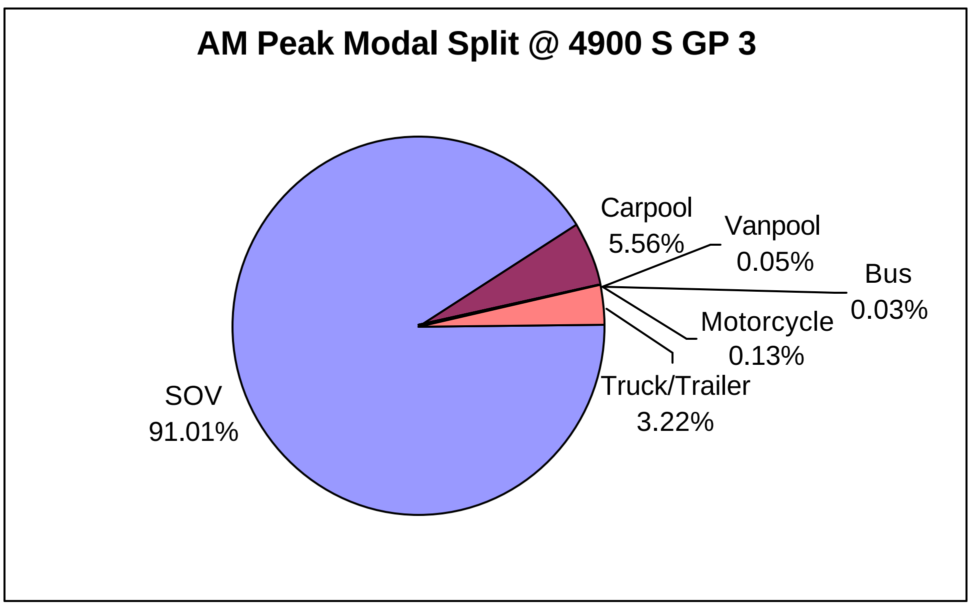
A.M. Peak Period Modal Split at 3900 South GP 4



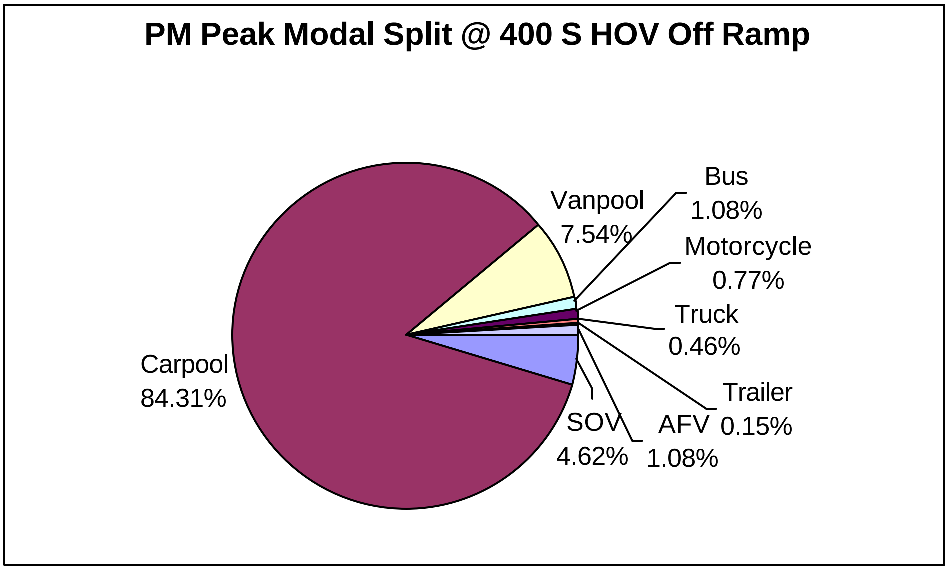
A.M. Peak Period Modal Split at 4900 South HOV Lane



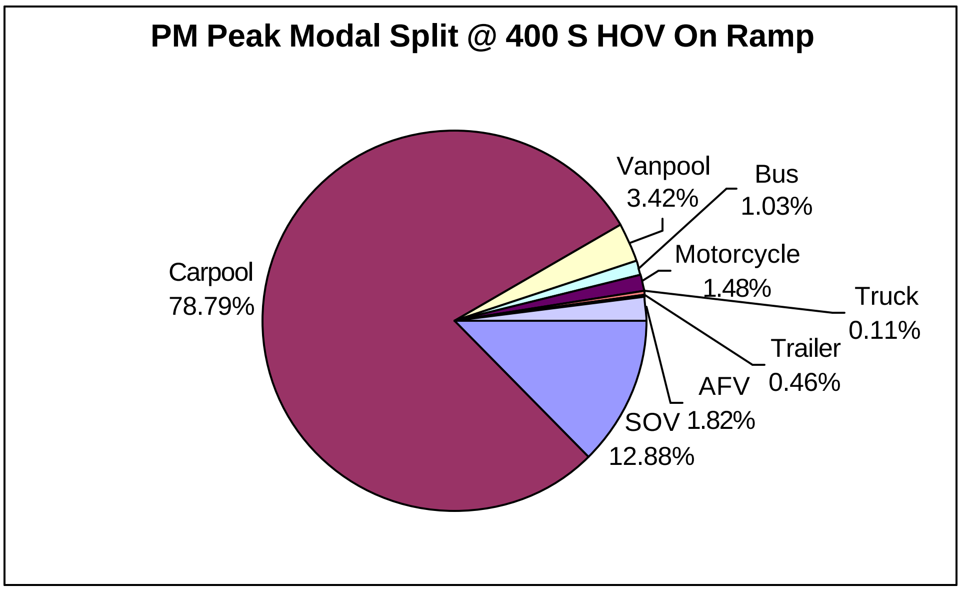
A.M. Peak Period Modal Split at 4900 South GP 1



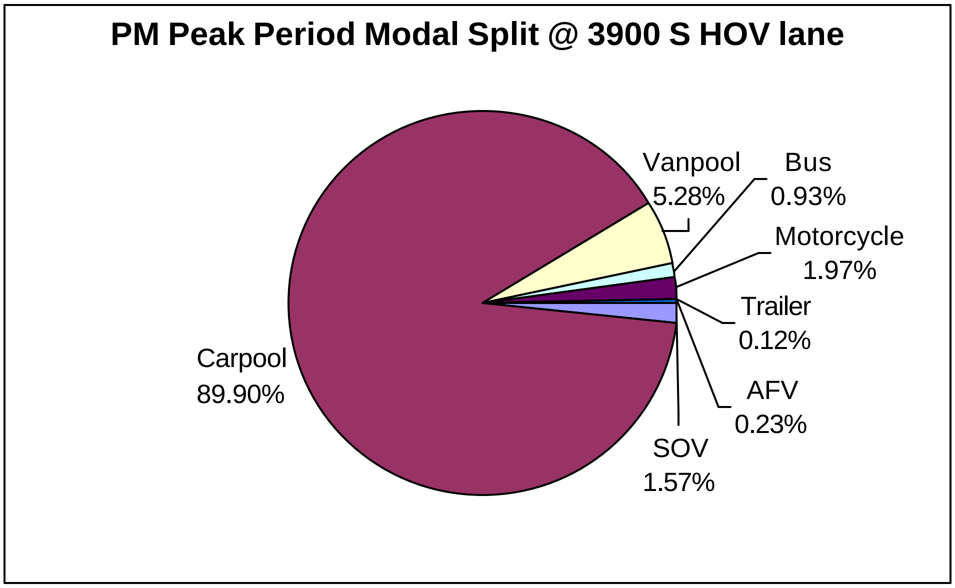
A.M. Peak Period Modal Split at 4900 South GP 3



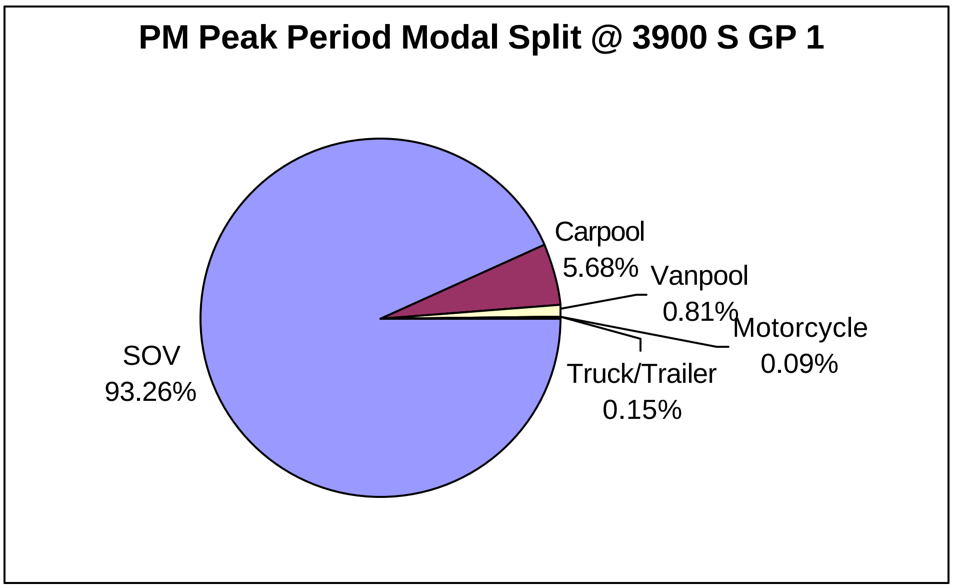
P.M. Peak Period Modal Split at 400 South HOV Off-Ramp



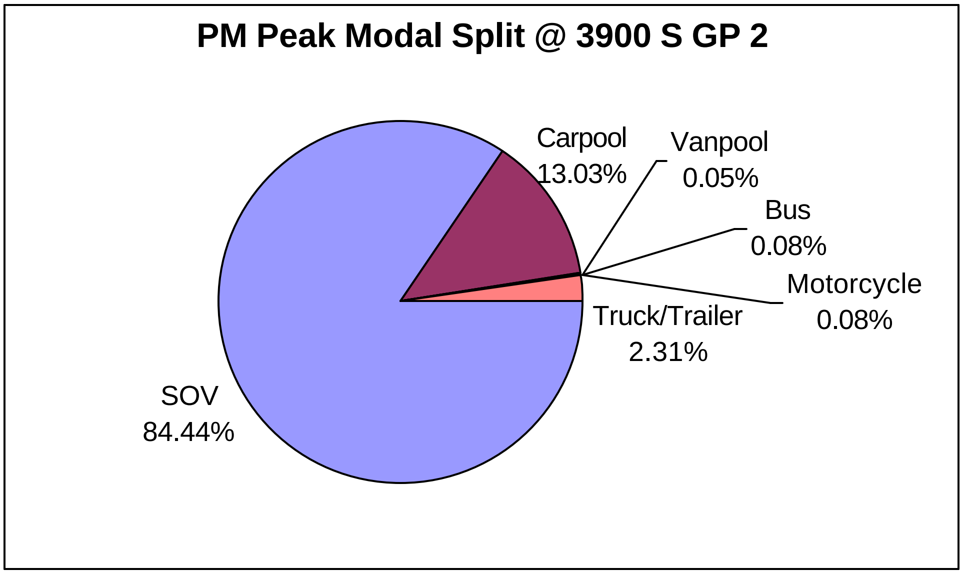
P.M. Peak Period Modal Split at 400 South HOV On-Ramp



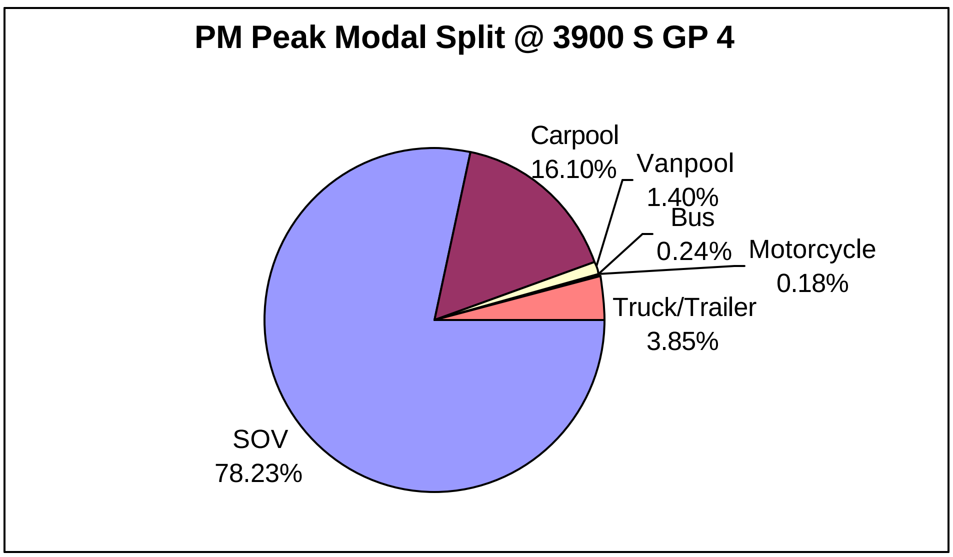
P.M. Peak Period Modal Split at 3900 South HOV Lane



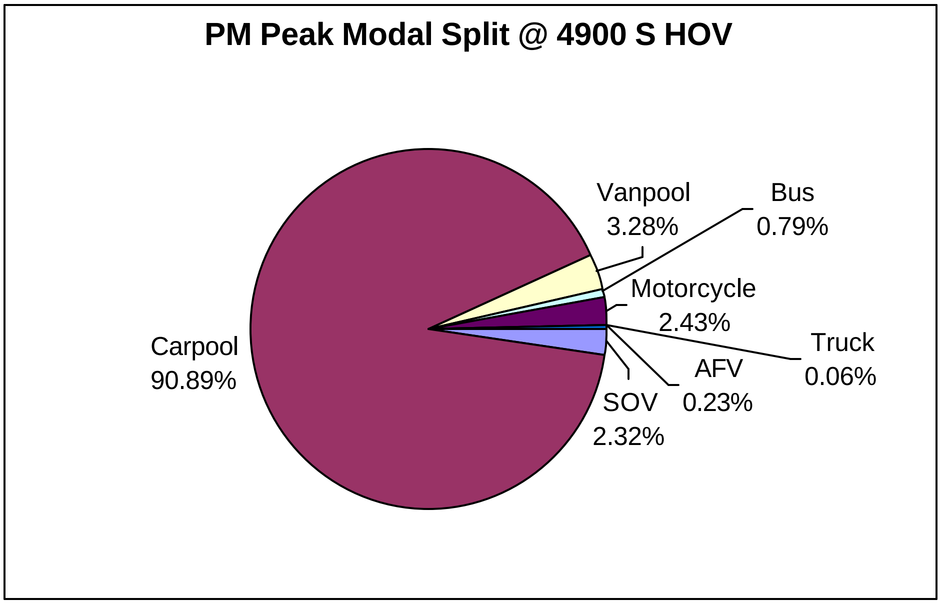
P.M. Peak Period Modal Split at 3900 South GP 1



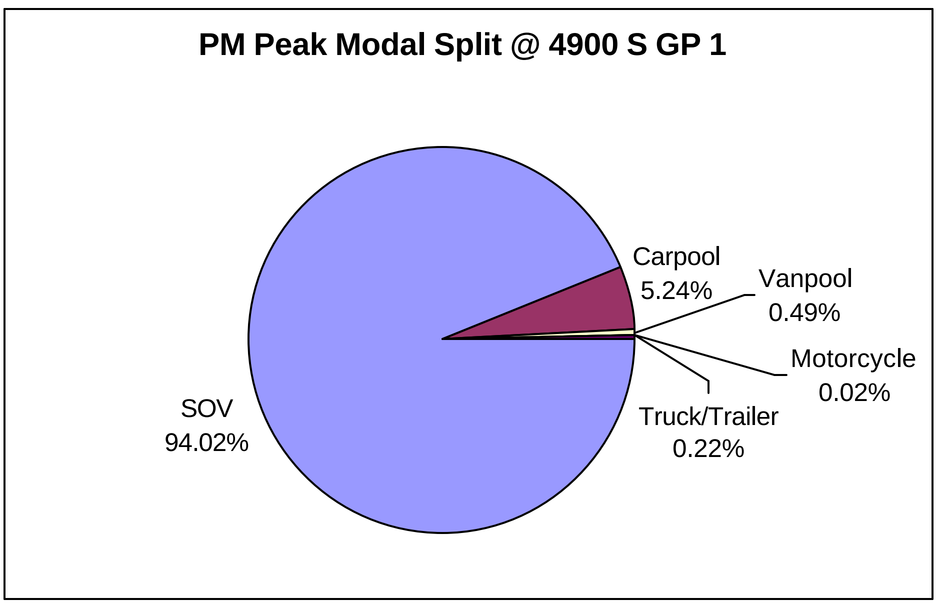
P.M. Peak Period Modal Split at 3900 South GP 2



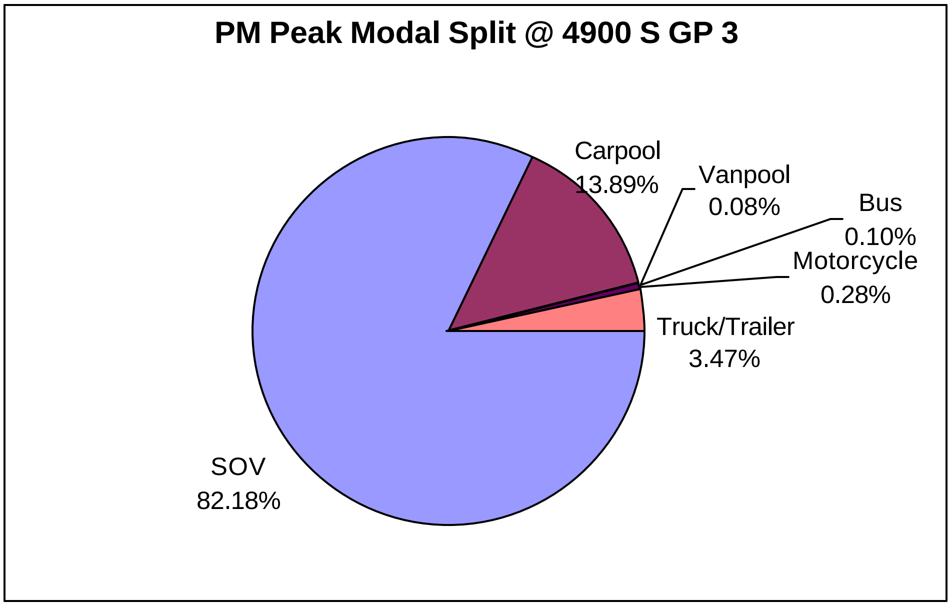
P.M. Peak Period Modal Split at 3900 South GP 4



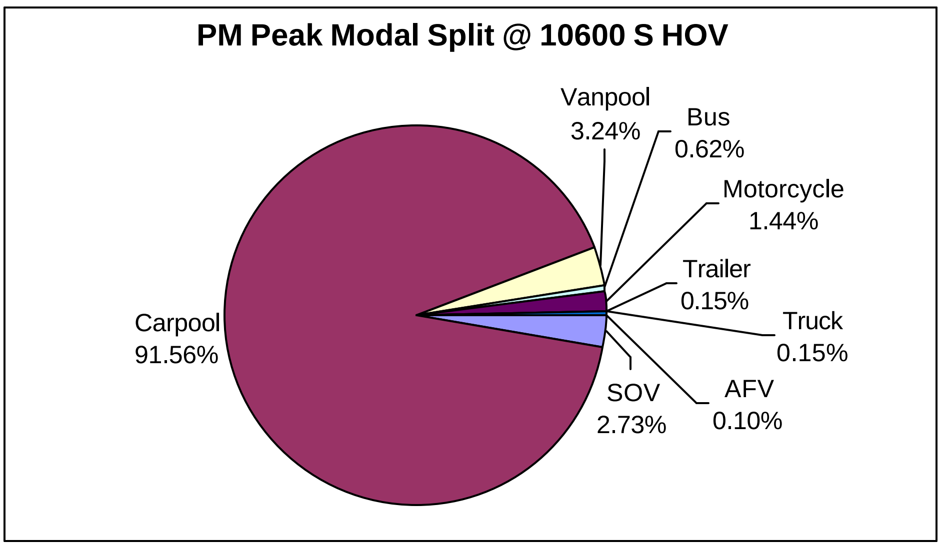
P.M. Peak Period Modal Split at 4900 South HOV Lane



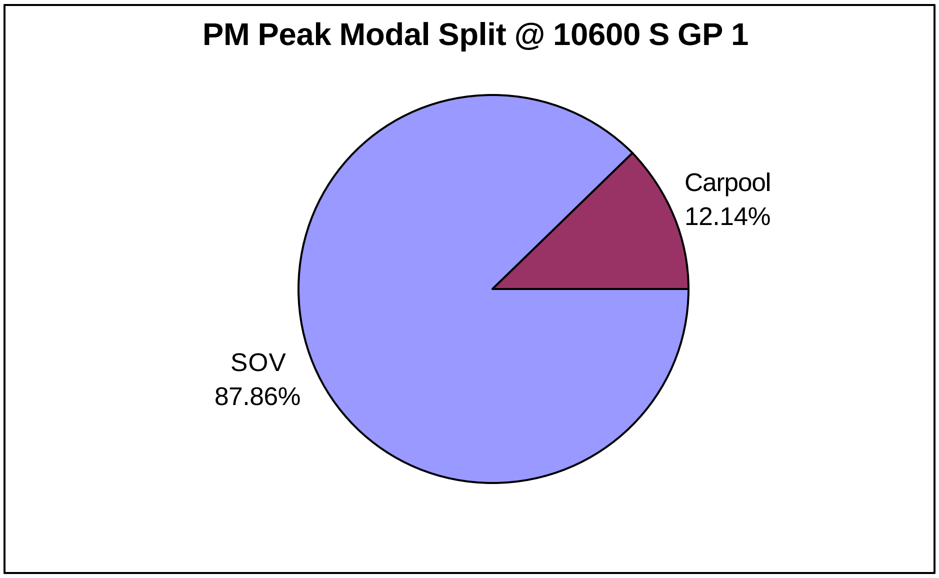
P.M. Peak Period Modal Split at 4900 South GP 1



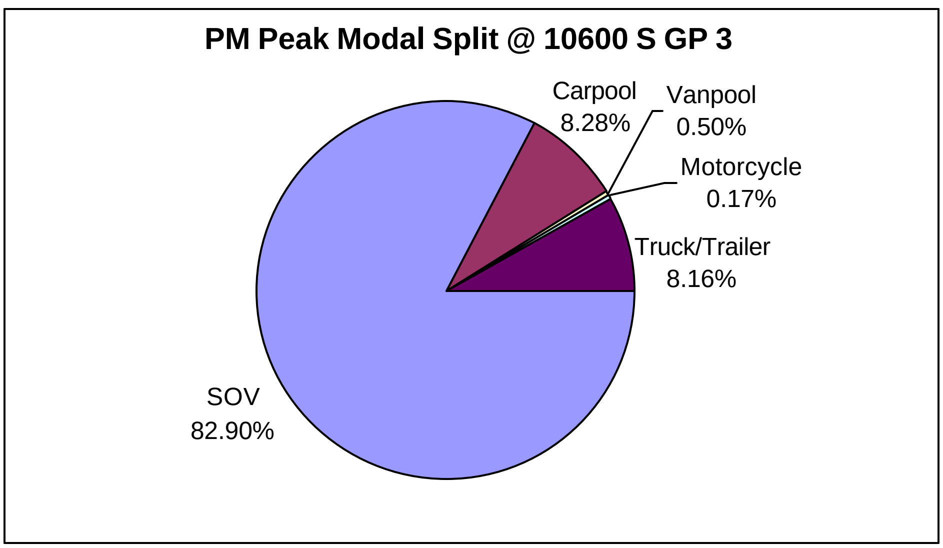
P.M. Peak Period Modal Split at 4900 South GP 3



P.M. Peak Period Modal Split at 10600 South HOV Lane

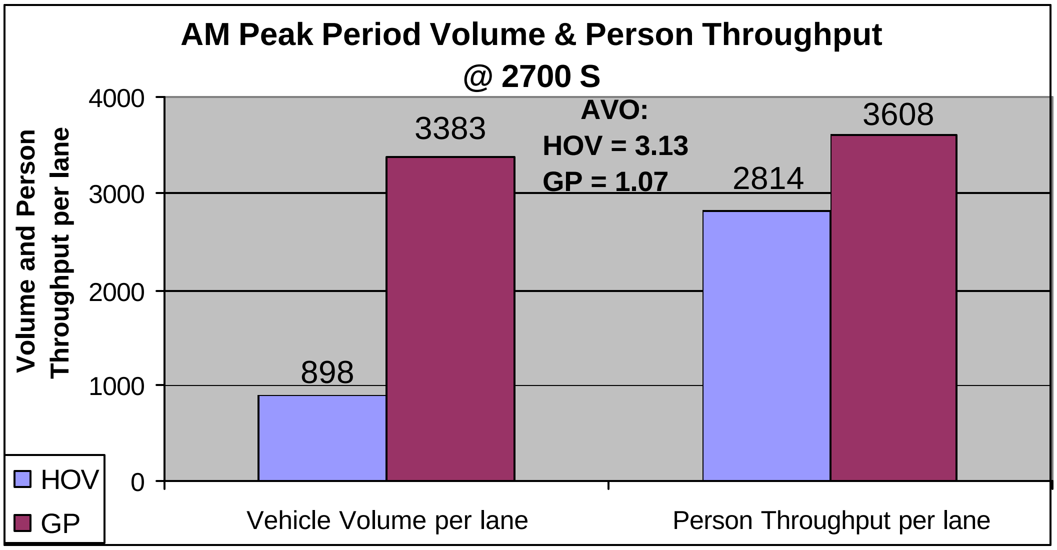


P.M. Peak Period Modal Split at 10600 South GP 1

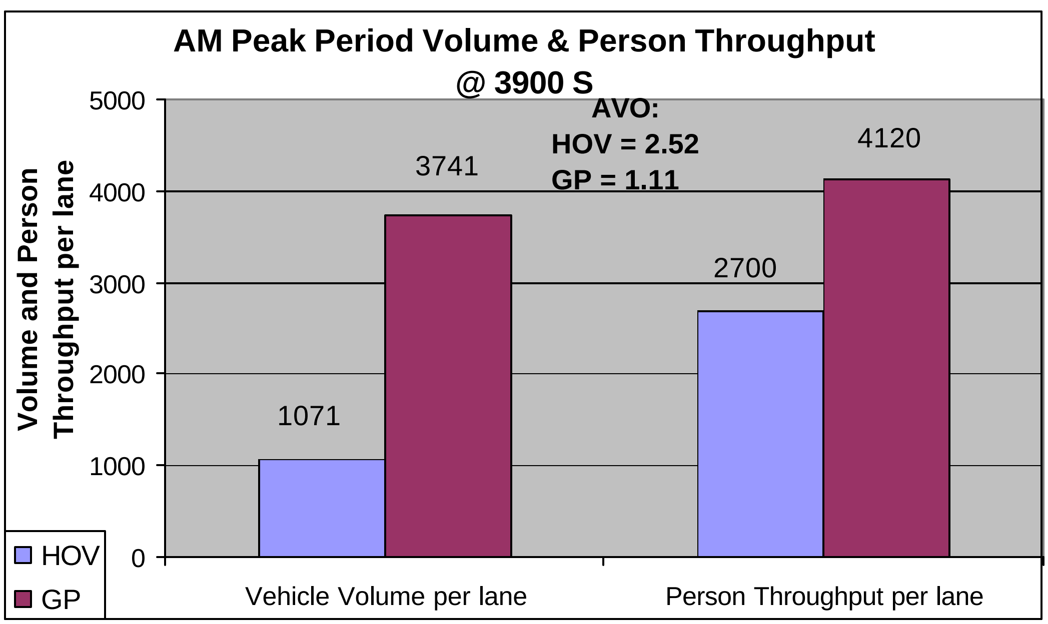


P.M. Peak Period Modal Split at 10600 South GP 3

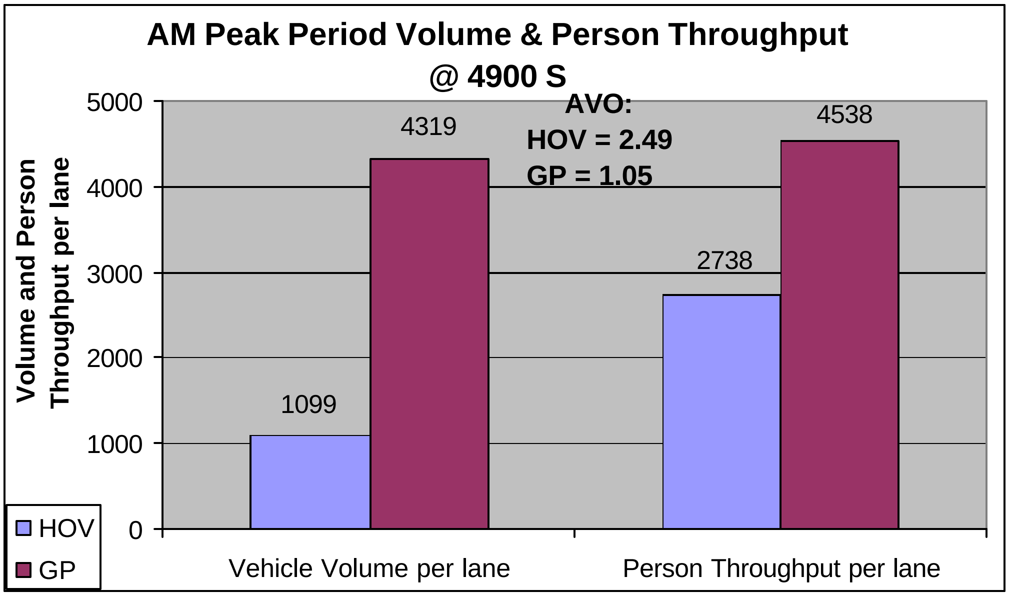
APPENDIX D. PEAK PERIOD VOLUME & PERSON THROUGHPUT



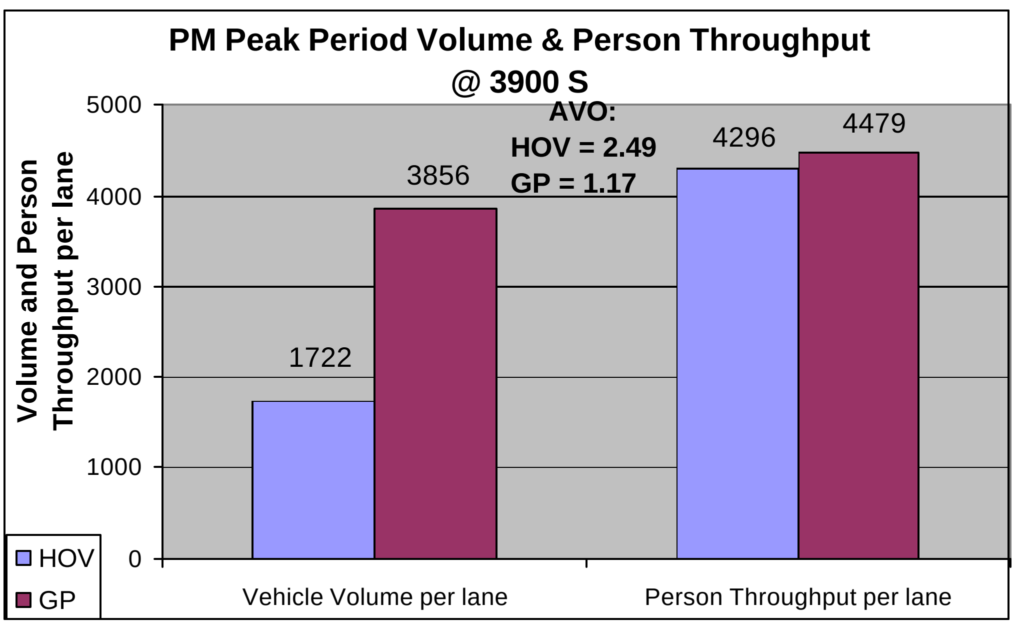
A.M. Peak Period Volume & Person Throughput at 2700 South



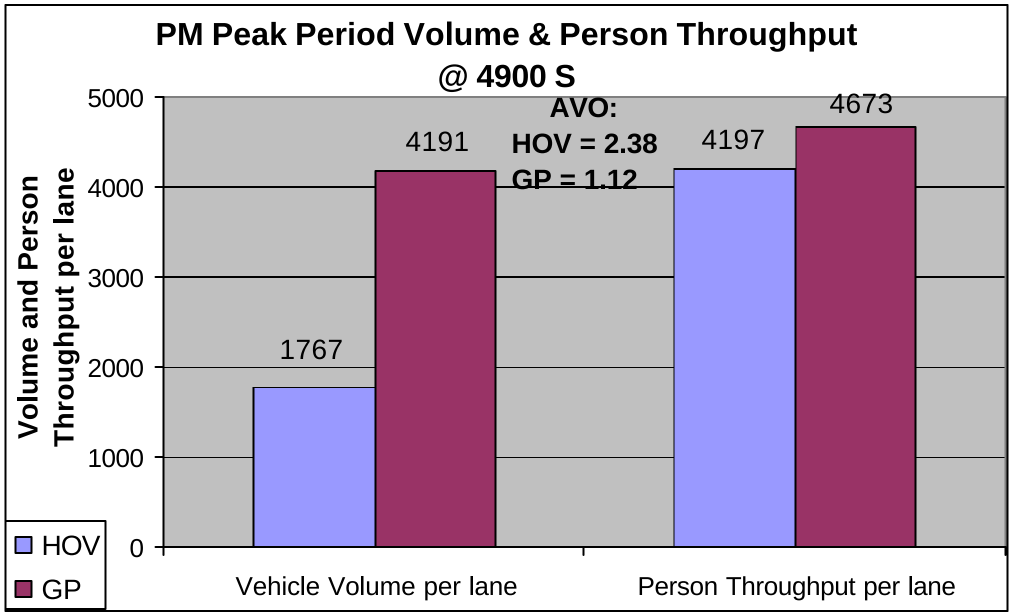
A.M. Peak Period Volume & Person Throughput at 3900 South



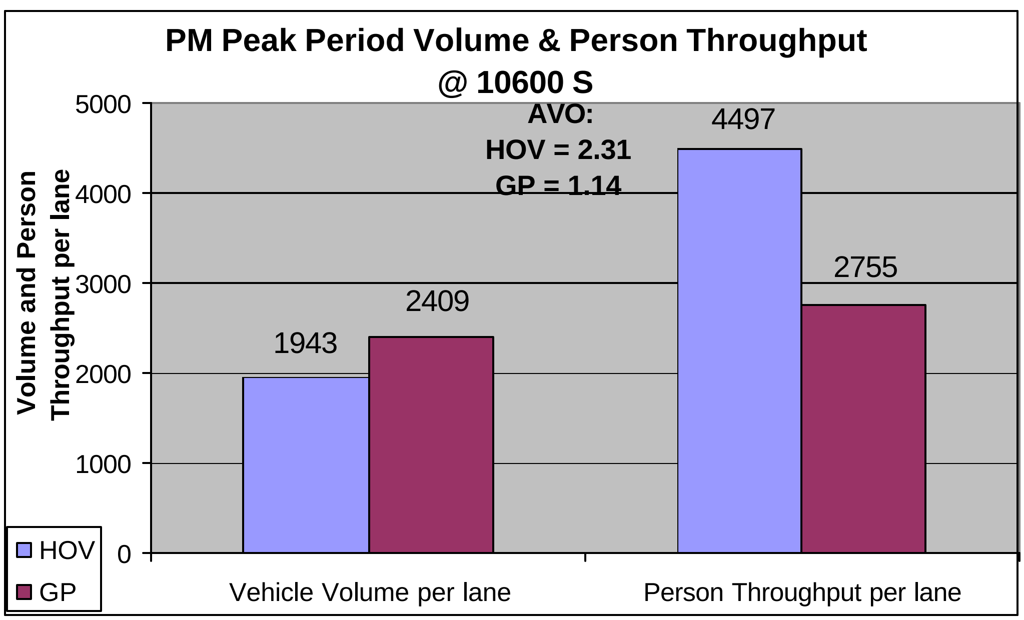
A.M. Peak Period Volume & Person Throughput at 4900 South



P.M. Peak Period Volume & Person Throughput at 3900 South



P.M. Peak Period Volume & Person Throughput at 4900 South



P.M. Peak Period Volume & Person Throughput at 10600 South

APPENDIX E. HIGH OCCUPANCY VEHICLE (HOV) LANES PUBLIC SURVEY

(This questionnaire is for research purposes only. It takes about 5 minutes. All answers are confidential.)

Have you traveled on the I-15 stretch between 600 North and 10600 South in the Salt Lake Valley?
____Yes. Please proceed to question #1.
____No. Thank you for your interest, but this survey only applies to those who have traveled on this section of I-15.

Section A: Commute Trip

1. Indicate your usual travel mode when using I-15.

Drive alone ___
Motorcycle ___
Carpool (you and 1 more person) ___
Carpool (you and 2 or more persons) ___
Vanpool ___
Bus ___
Other (Please specify) ___________________

2. Have you ever used the High Occupancy Vehicle (HOV) or carpool lanes while traveling on I-15?

Yes___ No___ (If your answer is No, skip to question 3)

a) How do you travel on the HOV Lanes? Please check all that apply.
Bus ___
2-person carpool ___
3 or more person carpool ___
Vanpool ___
Motorcycle ___

b) How many round trips do you make in the HOV lanes per week?
less than or equal to 2 ___
less than or equal to 5 ___
greater than 5 ___

c) What are the advantages offered by the I-15 HOV lanes? (Rate from 1 to 4, 1 being the least important)
a. Less traffic/more reliable ___
b. Saves time ___
c. Benefits carpoolers ___
d. Better for environment ___
e. Other (Please specify) ________________________

3. How does your commute compare to the time before HOV lanes were constructed in the Salt Lake Valley?

Same_____ Faster_____ Slower_____ Don't know_____

4. Do you generally use the HOV lanes when you travel with someone else?

Yes____ No____ If No, why? (Check all that apply)
The HOV lanes are slower than general purpose lanes. ___
Too much trouble in changing lanes. ___
The HOV lanes are unsafe. ___
Traffic in all lanes move fast enough. ___
Signs & markings are not clear/readable. ___
Other (Please specify) ___________________

5. Have you changed your mode of travel (e.g. carpooling, motorcycle, etc) to allow you to use the HOV lanes?

Yes_____ No_____

6. Would you continue to use the HOV lanes if Light Rail were available for the same route?

Yes_____ No_____

Section B: Opinions

7. Are some sections of the I-15 HOV lanes too congested? If so, where?

____

8. What would make HOV lanes more attractive? Rate from 1 to 6, 1 for the least attractive and 6 for the most attractive.

a. Assistance in finding a compatible carpool partner. ___
b. Direct entrance and exit ramps that connect with inside HOV lanes. ___
c. More park & ride lots (especially near freeway entrances/exits) and discounted parking. ___
d. Employers' incentives like paying for part or all of bus passes, vanpooling fares, or parking for carpoolers. ___
e. Better bus service. ___
f. Fee based access for single occupant vehicle drivers. ___

9. What, in your opinion, most influences a driver's decision to carpool? Rate from 1 to 6, 1 being the least influential.

a. Reduced stress of commuting ___
b. Reduced cost of driving and parking ___
c. Access to carpool/vanpool ___
d. Incentives from employers ___
e. Regular/Irregular work hours ___
f. Concern for environment ___

10. HOV lanes are (Check one)

an excellent idea ___
a good idea ___
a fair idea ___
a poor idea ___

11. Rate the following as:

1 (Strongly Disagree), 2 (Disagree), 3 (Neutral), 4 (Agree), 5 (Strongly Agree)

a. HOV lanes are unfair to those taxpayers who drive alone. ___
b. Vehicles move in and out of HOV lanes too often and so they are safety hazards. ___
c. Existing HOV lanes are being adequately used. ___
d. HOV lane violation is a serious traffic violation. ___
e. HOV lane violations are common during peak hours. ___
f. HOV lanes are convenient to use. ___
g. HOV lanes should be expanded. ___
h. HOV lanes should be opened to all traffic during non-peak hours. ___

Section C: About Yourself

12. Gender: Male ___ Female ___

13. Age: under 21 ___ 21-30___31-40 ___ 41-50 ___ 51-60 ___ 61-70___71-80___81-90___91+___

14. What is your highest level of education?

a. Did not finish high school ___
b. High school/diploma ___
c. College degree ___
d. Post graduate degree ___

15. How many people live in your household, including yourself? ____

16. How frequently do you carpool with others in your household?

Everyday ____Frequently___ Sometimes ____Never ___

17. How many people living in your household (including yourself) work outside the home? ____

18. How many registered vehicles do you have in your household? ____

19. What is your work place Zip Code? _________ home Zip Code?__________

20. Comments:
____

Thank you for taking time to complete this survey!

APPENDIX F. RESPONDENTS' COMMENTS

1. "Put some HOV lanes in Utah County."
2. "HOV awareness is not very high. Needs to be improved but overall a good concept."
3. "Need HOV or Light Rail or Commuter Rail in Davis County."
4. "Compared to California HOVs Utah HOV lanes are difficult to enter and exit."
5. "I think I-215 should have light rail along the East side of the valley to the University of Utah."
6. "You need to make it easier to get off freeway with the HOV lanes."
7. "HOV lanes are OK. Good Survey!"
8. "Travel on I-15 is continually congested-Legacy Highway needs to be finished ASAP."
9. "More carpools will be good."
10. "I think they should expand/make lanes on I-15."
11. "I love HOV lanes."
12. "I love the HOV lane - but we still need a commuter rail from Weber/Davis Counties through Salt Lake and Utah counties."
13. "HOV lane is the quieter lane."
14. "No Legacy Highway - Rail Only."
15. "Light Rail & HOV lanes for Davis County are needed soon!"
16. "I use the HOV lanes when traveling through SLC to other places."
17. "HOV lanes are good and reduce the need for single cars."
18. "HOV lanes do work but system needs tweaking."
19. "Difficult to cross lanes to reach the off-ramps in all cases except 400 South exit. I think additional HOV lanes should be constructed along I-215."
20. "SLC does not have the volume yet like the other cities."
21. "Include Heavy Rail."
22. "HOV lanes would have been attractive if an SUV could pull trailer. The 4th South on ramp HOV is a dumb idea."
23. "I would enjoy the HOV lanes better if those that drive alone don't use it! Not fair!"
24. "HOV lanes should be opened during non-peak hours."
25. "I use the carpool lane on weekends or road trips."
26. "I ride public transit for most of my local travel. When I have a passenger I use the HOV lane."
27. "We need HOV lanes in Davis County. HOV lanes have fewer cars and fewer crazy drivers switching lanes."
28. "I would like to know the results of this survey."
29. "Carpool lane is a good idea, but needs to be more accessible."
30. "Extend HOV lanes to Davis County."
31. "HOV lanes would be useful if they extended up into Davis County. Carpool lanes would be easier to use if they were on the right instead of left."
32. "HOV lanes remind me of the Beatles song 'Lucy in the lane with diamond'"
33. "People should carpool more or use Trax."

34. “Saving the environment is the most important reason for me for HOV lanes. I hope the city expands light rail too.”
35. “I have a diesel car and hope that I can drive in the HOV lane as a way to incentivize me further- have to pay a little bit extra but it’s worth it if you get the added bonus of being able to drive in the HOV lane.”
36. “HOV lanes are a safety issue as vehicles from the slow peak traffic change into the HOV lanes, causing accidents.”
37. “No alternative to I-15. Thanks.”

APPENDIX G. PERSONS INVOLVED WITH THE PROJECT

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