Southbound I-680 Express Lane Performance Evaluation

An After Study

FINAL

June 2013

ALAMEDA County Transportation Commission

Prepared by:

Kittelson & Associates, Inc.

Transportation Engineering/Planning

SOUTHBOUND I-680 EXPRESS LANE

PERFORMANCE EVALUATION – AN AFTER STUDY

ALAMEDA COUNTY TRANSPORTATION COMMISSION

June 2013

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EXECUTIVE SUMMARY

The Southbound Interstate 680 (I-680) Express Lane Performance Evaluation or the "After" Study evaluated the effectiveness of the Express Lane using a set of performance measures compared to the goals of the Express Lane Demonstration Program (Program), under which this Express Lane is authorized. The "After" study results, from the data collected in the Fall of 2012, were compared to the conditions identified in a "Before" study conducted in 2008 before construction of the Express Lane.

The "After" study indicates that implementation of the Express Lane improved the performance of general purpose lanes and the Express Lane and overall corridor performance.

This executive summary describes the background for the study, includes highlights of data analysis and findings and conclusions for each performance measure in comparison with the results from the "Before" study, and summarizes how the Express Lane meets the objectives of the Program as identified in the "Before" study.

The report following the Executive Summary provides a detailed account of where, how, and why the data was collected, as well as interpretations on what this data reflects in terms of the overall performance of the Express Lane and the corridor.

ES-1 STUDY BACKGROUND

The southbound I-680 Express Lane was the first High Occupancy Toll lane project implemented in northern California. It was opened to traffic in September, 2010. The evaluation of the Express Lane performance was prepared to fulfill the legislative mandate that requires an evaluation report within three years of opening. The Express Lane "study corridor" (see Figure ES-1) is southbound I-680 from the State Route 84 (SR 84) interchange in Alameda County to the State Route 237 (SR 237) interchange in Santa Clara County.

The "Before" study report was prepared in April 2009 based on data collected in the Fall of 2008 prior to construction of the southbound I-680 Express Lane. It establishes the baseline traffic conditions for comparison for the "After" study.

Transportation data were also collected on a control corridor, northbound I-680 between Alcosta Boulevard in San Ramon and Livorna Road in Alamo. The control corridor helps to determine if changes in Express Lane performance measures may be due to external factors that impact travel trends in the area as opposed to changes related to implementation of the Express Lane.

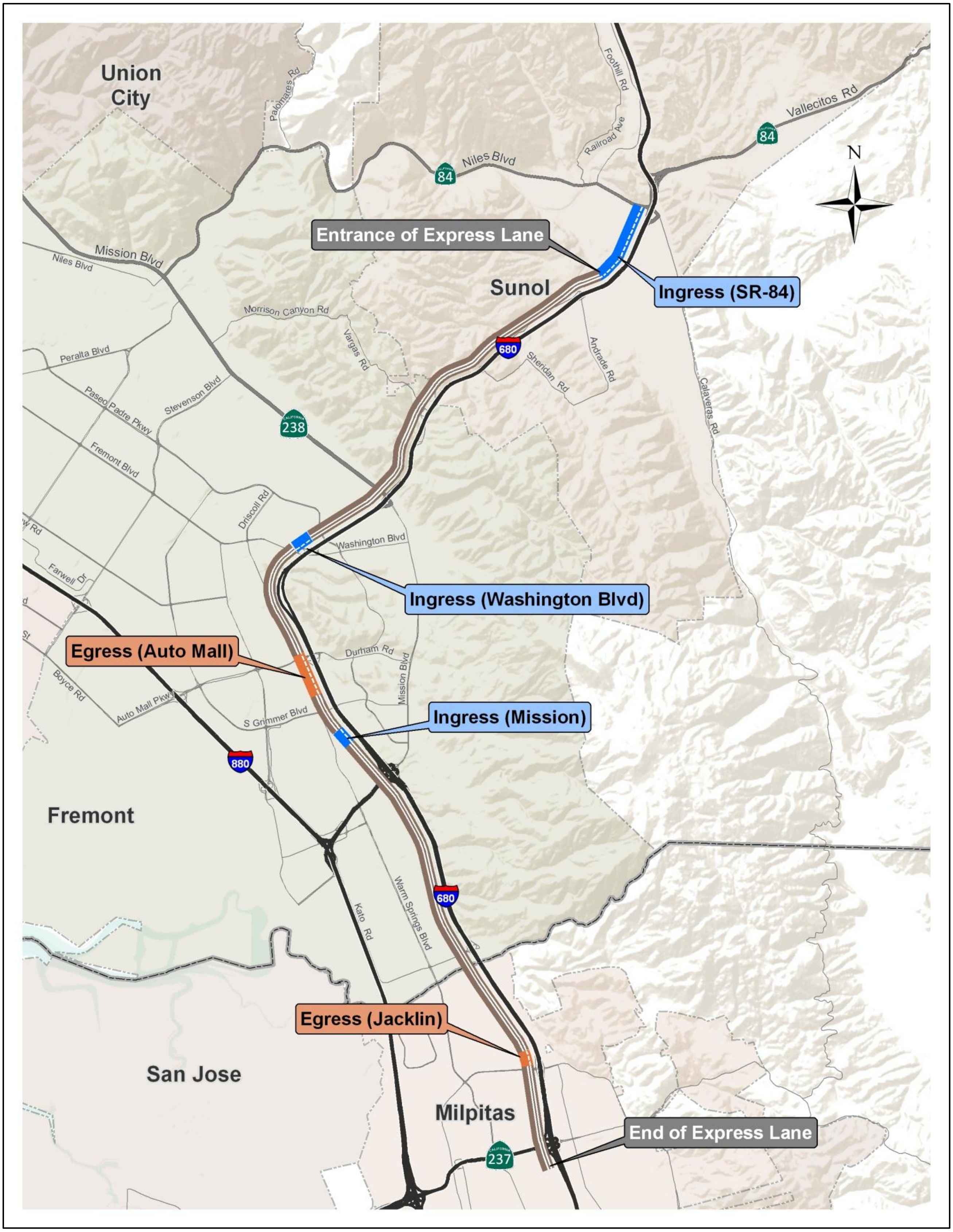
Input from the project partners and the local jurisdictions were received and used to inform the study development. Results from the study were shared with the project partners and comments received from Caltrans will be responded to and incorporated into the final report.

ES-2 DATA COLLECTION

The data collection for the "After" study was completed in October and early November, 2012, the same time of year as the data collection for the "Before" study in 2008. The data collection conducted for this study in 2012 included:

- Traffic counts;
- Travel time surveys using "floating car" runs;
- Manual counts of vehicle classification and occupancy at selected locations (four in the study corridor and two in the control corridor);
- Aerial photography; and
- Video recordings at selected locations.

Figure ES-1: Southbound I-680 Express Lane Study Corridor



Based on California Highway Patrol input regarding the safety of locating surveyors on the side of the road, three out of four study corridor survey locations and one out of two control corridor survey locations used for the "Before" study were relocated for the "After" study. As a result and in order to obtain comparable "Before" and "After" data, available data were also compiled from:

- Installed traffic and toll reader detectors;
- California collision records;
- California Highway Patrol citation history;
- Transit agency ridership statistics;
- Express Lane toll revenue records;
- Travel time data from the Caltrans Freeway Performance Monitoring System (PeMS) and the Metropolitan Transportation Commission (MTC) 511.org program; and
- American Community Survey data from the United States Census.

ES-3 PERFORMANCE MEASURES AND DATA ANALYSIS

The following performance measures were used to help evaluate the effectiveness of the Express Lane:

1. Travel Time
2. Travel Speeds
3. Vehicle and Person Throughput
4. Bottlenecks and Queues
5. Vehicle Occupancy
6. Level of Service
7. Transit Ridership
8. Safety
9. HOV/Express Lane Violations and Enforcement

All of these measures were used in the "Before" study to establish an existing conditions baseline on the study corridor prior to the implementation of the Express Lane. Analyses were performed for three distinct time periods, where applicable (primarily for Measures 1 through 7 above) for the study and control corridors. The three time periods were AM peak period (5 AM to 9 AM), PM peak period (3 PM to 7 PM) and daytime (7 AM to 7 PM). These time periods were selected based on the HOV operation hours in the study corridor during the "Before" conditions. The Control Corridor HOV operations during the "Before" conditions were between 6 AM and 9 AM in the morning and between 3 PM and 6 PM in the afternoon, and therefore these three-hour periods were used for the AM and PM peak periods respectively for the control corridor. For Throughput and Vehicle Occupancy, a two-hour AM peak period (7 AM to 9 AM) was analyzed due to visibility constraints in the earlier hours (5 AM to 7 AM). Since the AM peak period is the commute direction on the study corridor, focused analyses were performed for the AM peak period compared to the other two time periods analyzed. The performance measure results based on the data collection and analyses are summarized below.

Travel Times

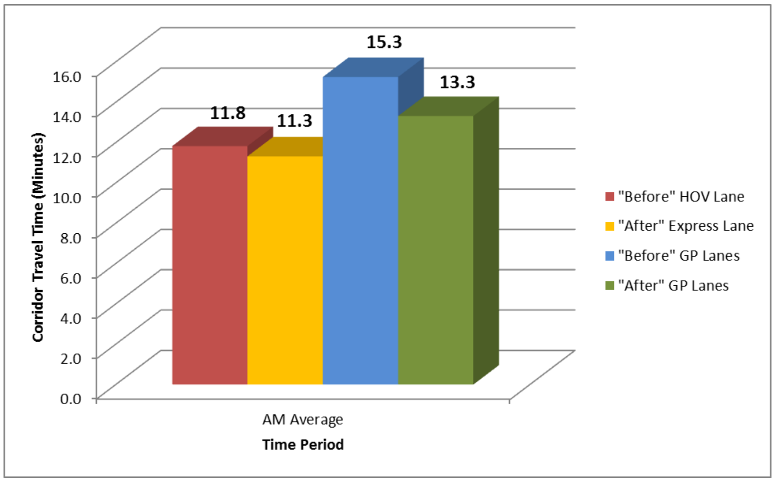
Travel times to travel from the beginning to the end of the corridor were evaluated. They were primarily measured by floating car travel time runs using Geographic Positioning System (GPS) equipment.

***Findings**:* As shown in Figure ES-2, on the Express Lane, the average travel times in the "After" study show slight improvement compared to average travel times measured on the HOV lane in the "Before" study. The average travel time improvement was 4 percent (0.5 minutes) in the AM peak period.

*Average **travel times** during the AM peak period in the "After" study reduced by less than 1 minute in the Express Lane and 2 minutes in the general purpose lanes compared to the "Before" study.*

The average travel times in the general purpose lanes were reduced by 13 percent (2 minutes) during the AM peak period. The highest reduction of 22 percent (4.4 minutes) was experienced during the 8:00 to 9:00 AM time period. The average travel times in the general purpose lanes during the PM peak period showed no significant change compared to 2008 conditions.

Figure ES-2: Southbound I-680 AM Peak Period Average Travel Times



The HOV lane in the "Before" study provided up to 7.5 minutes of travel time savings compared to the general purpose lanes in the AM peak period. The Express Lane provided less travel time savings compared to the general purpose lanes, a maximum of 4.2 minutes of travel time savings in the "After" study, because travel conditions had improved on the general purpose lanes.

Conclusions: After implementation of the Express Lane, travel times in the adjacent general purpose lanes were reduced by up to 22 percent during the AM peak period and were similar to the "Before" conditions for the PM peak period. The Express Lane provides modest improvements in travel times compared to the HOV lane in the "Before" study even after allowing toll-paying single occupant vehicles (SOV) to use the lane.

Travel Speeds

Travel speeds were evaluated for the overall corridor and for the individual segments of the corridor. They were based on the same floating car travel time runs as the travel time measurements.

***Travel speeds** during the AM peak period in the "After" study increased by up to 6 mph in the Express Lane and by up to 11 mph in the general purpose lanes compared to the "Before" study.*

***Findings**:* On the Express Lane, average travel speeds in the "After" study increased by 3 mph in the AM peak period and by 1 mph in the PM peak period compared to the "Before" study. The highest increase in average travel speed was 6 mph for the 8:00 to 9:00 AM peak hour, from 60 mph to 66 mph.

Average travel speeds in the general purpose lanes increased by an average of 6 mph during the AM peak period and 2 mph during the PM peak period. The highest increase occurred during the 8:00 to 9:00 AM time period, when the average travel speed increased by 11 mph, from 38 mph to 49 mph.

Conclusions: Implementation of the Express Lane improved the travel speeds, particularly in the general purpose lanes, compared to the "Before" study. Travel speeds in the Express Lane are the same or faster than travel speeds in the prior HOV lane.

Vehicle and Person Throughput

Corridor throughput was measured in two different ways: vehicle throughput and person throughput. Vehicle throughput measures the number of vehicles counted at four survey locations along the corridor. Person throughput is the number of persons at the same four locations, accounting for vehicle occupancy.

*Overall **vehicle throughput** increased in the corridor in most locations. The 12-hour daytime period showed a maximum increase of 20% while the AM and PM peak periods showed increases of 11% and 38% respectively.*

Findings: Comparing "Before" and "After" conditions, vehicle throughput showed modest to notable increases ranging between 0.6 percent and 11 percent at all 4 survey locations in the AM peak period. For the PM peak period and the 12-hour daytime period, improvements were observed at the three northern locations ranging between 1.4 percent and 37.9 percent for the PM peak period and 3.2 percent and 19.8 percent for the daytime period. The one location showing reductions during both the PM peak and daytime periods is at SR 237/Calaveras Boulevard. It is important to note that the improved I-880/SR 262/Mission Interchange opened in 2009 after completion of the "Before" study. This improved interchange combined with the implementation of the Express Lane appeared to have mostly contributed to the decrease in volume in the southern section of the study corridor due to trips from the City of Fremont using southbound I-880 through the improved interchange to go to Santa Clara County rather than using southbound I-680. This diversion would also include trips that normally would have used I-880 to go Santa Clara County but used I-680 instead for the last few years because of the construction at the SR 262/Mission Boulevard interchange on I-880. This is also shown in the decrease in average daily traffic volumes of 9% on the southbound I-680 and corresponding increase of 11% on the southbound I-880 at the Alameda and Santa Clara County Line experienced between 2008 and 2011 while volumes on southbound I-880 at northern Fremont showed a decline of 2% for the same period.

Person throughput showed slight declines to modest increases (-1.0 percent to 2.4 percent) during the AM peak period, and increased by 19 percent to 38 percent at 2 locations during the PM peak and daytime periods. Similar to the vehicle throughput, person throughput showed notable decreases at the southern survey location, due to the same reasons.

Conclusions: Overall, the implementation of the Express Lane increased the corridor vehicle and person throughput. The recently improved I-880/SR 262-Mission interchange combined with the implementation of the Express Lane appeared to have contributed to reductions in throughput in the southern section of the corridor.

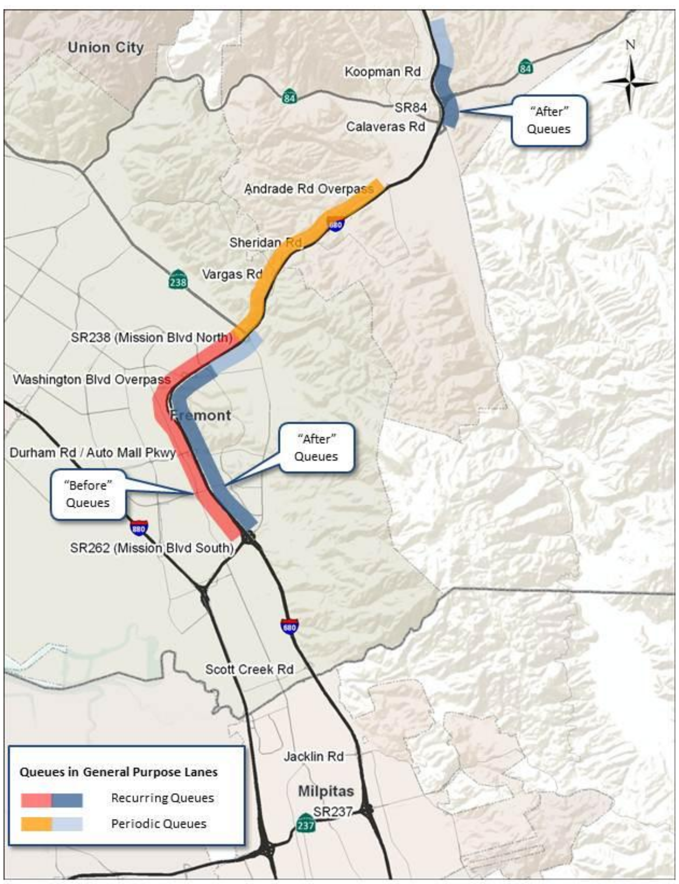
Bottlenecks and Queues

Bottlenecks and queues show the location and length of congestion on the corridor. They were identified based on floating car travel time surveys and verified using aerial photography.

***Queues** in the general purpose lanes north of SR 262/Mission Boulevard reduced from 7.4 miles in the "Before" conditions to 2.9 miles in the "After" conditions.*

Findings: Overall, in the general purpose lanes, the "Before" study identified AM peak period congested queues from Andrade Road all the way to SR 262/Mission (7.4 miles), while queues in the "After" study extended from Washington Boulevard to SR 262/Mission (2.9 miles). Figure ES-3 shows the length and location of the queues. Slow speeds and queuing were observed in the "After" conditions during the early part of the AM peak period on the segments just north of SR 84 (from Koopman Road) and just south of the SR 84 on-ramp merge, near the entry to the Express Lane. These locations did not have slow speeds and queuing during the "Before" study, and are appeared to be caused by weaving to enter the Express Lane. Later in the AM peak period, queues and slow speeds occurred approaching the Auto Mall Parkway/Durham Road interchange and in the right lane approaching the SR 262/Mission Boulevard interchange. These two congestion locations were consistent with observations during the 2008 "Before" study. Congestion at these locations appears to be caused by backups from the signalized intersections at or adjacent to the southbound off-ramps, rather than conditions on the freeway mainline.

Figure ES-3: Southbound I-680 AM Peak Period Queues in General Purpose Lanes



No queues were observed during the PM peak period in either the "Before" or "After" conditions

Conclusions: The "After" conditions showed slow speeds and queuing for a shorter distance (7.4 vs. 2.9 miles) north of SR 262/Mission compared to "Before" conditions. Implementation of the Express Lane introduced slow speeds north and south of the SR 84 on-ramp, near the entry to the Express Lane, due to weaving to enter the Express Lane, and did not eliminate existing queues from the southbound off-ramps at Auto Mall Parkway and SR 262/Mission Boulevard.

Vehicle Occupancy

Vehicle occupancy was analyzed based on the numbers of vehicles of each type (auto, bus, motorcycle, truck) and numbers of occupants manually counted at four survey locations along the study corridor and two locations on the control corridor.

Findings: The "Before" study reported 27 percent to 35 percent single-occupant vehicles (SOVs) in the I-680 HOV lane. These SOVs would either have been eligible clean-air vehicles or were in violation of the HOV restrictions. The "After" conditions showed 54 percent to 61 percent SOVs in the HOV lane, including toll vehicles, eligible clean air vehicles and potential violations.

The average HOV percentages and volumes in all lanes decreased by 32 percent in the AM peak period and by 7 percent in the PM peak period. The decrease may be attributable to an overall declining trend in carpool use, changes in employment in the sub-region and improved operating conditions in the general purpose lanes.

The total number of HOVs on the study corridor (Express Lane and general purpose lanes) decreased by an average of 32 percent in the AM peak period, 7 percent in the PM peak period and 11 percent for the 12-hour daytime period in the "After" study compared to the "Before" study conditions. This pattern is also seen in the control corridor, where the average HOV percentage decreased by 24 percent for the AM peak period and 20 percent for the PM peak period between the "Before" and "After" studies with no changes in HOV lane operations.

The overall decline in carpool usage is corroborated using the American Community Survey data which shows that the percentage of commuters using carpools declined 4 percent between 2000 and 2012 in Alameda County. These same data show that, between 2008 and 2011, carpool work trips declined in Alameda County by 0.3 percent and in Contra Costa County by approximately 2 percent. Further, the change in employment due to the economic downturn, approximately 80,000 jobs in Santa Clara County and 60,000 jobs in Alameda County, since 2008 may have contributed to some shift in modal preferences in work trips.

Conclusions: The "After" study showed a decrease in HOV usage in the study corridor and the control corridor. The decreases in HOV usage could be due to a combination of factors such as a general decline in carpooling, overall changes in employment in the sub-region, and improvements in speed and travel time in the general purpose lanes for the study corridor.

Level of Service and Related Measures

*The **level of service** on the Express Lane stayed at LOS A or B, above the required service level of LOS C.*

The level of service (LOS) of each segment was evaluated using freeway analysis procedures from the 2000 *Highway Capacity Manual*, similar to the "Before" conditions. The LOS analysis was based on freeway mainline and ramp traffic counts and used the FREQ analysis software. This analysis also estimated corridor-wide performance measures such as vehicle miles traveled (VMT) and vehicle hours of travel and delay (VHT and VHD). VMT is a measure of the total density of traffic while VHT and VHD indicate the overall delay due to congestion.

Findings: In the Express Lane, AM peak period LOS was similar in the "Before" and "After" studies, varying between LOS A and LOS B, and improved from LOS B to LOS A in the PM peak period. In the general purpose lanes, LOS improved from LOS F to D in a number of segments in the middle of the corridor, between Sheridan Road and Auto Mall Parkway/Durham Road, while new LOS F segments appeared in the north end of the corridor near the entry to the Express Lane and at the southern section approaching SR 262/Mission Boulevard. Within the study corridor limits, VMT increased by 24 percent and VHD reduced by 16 percent for the AM peak period compared to the "Before" conditions.

> ***Vehicle Miles of Travel*** *increased by 24% and* ***Vehicle Hours of Delay*** *reduced by 16% for the AM peak period compared to the "Before" conditions.*

Conclusions: Conditions after the implementation of the Express Lane showed that LOS in the Express Lane either improved or stayed the same. The general purpose lanes showed improved LOS in the mid portion of the corridor, and LOS F conditions at the north end of the corridor and approaching SR 262/Mission Boulevard. The analyses show significant increases in VMT and reductions in delay mostly due to the improved corridor travel conditions.

Transit Ridership

Transit ridership in the corridor was identified based on data from transit operators on average ridership for each bus line that uses the I-680 corridor.

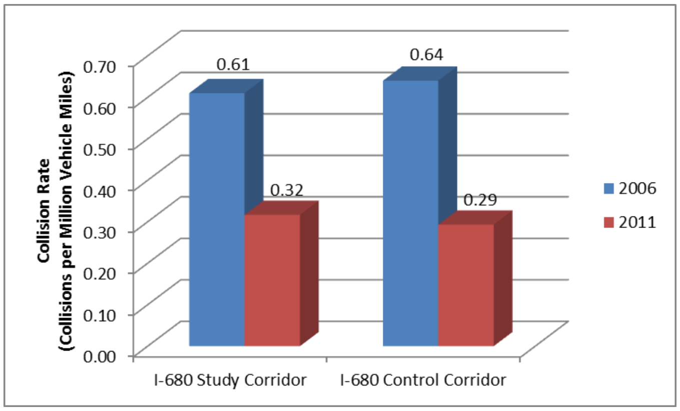
Findings: The average weekday transit ridership decreased in the study corridor by 6 percent and in the control corridor by 5 percent. Transit services were reduced in both the study and control corridors compared to the "Before" conditions. In the study corridor, out of a total of 10 lines that operated during the "Before" conditions, 5 lines were not operating and one new line was added in the "After" study. In the control corridor, out of a total of 9 lines operating during the "Before" study, 4 lines were eliminated in the "After" study. The ridership decreases experienced in both corridors were related to service reductions by the transit operators. It is likely that the service reduction is part of larger level trends and not related to Express Lane operations.

Conclusions: The amount of transit service operating in the study corridor was significantly reduced between 2008 and 2012, and therefore decreases in transit ridership were not related to implementation of the Express Lane.

Safety

Safety is measured by the number of collisions on the corridor and the collision rate, which is calculated by dividing the number of collisions by the amount of total travel measured as annual million vehicle miles of travel.

Figure ES-4: Average Collision Rates



Findings: Between 2006 and 2011, the collision rates on the I-680 study and control corridors both dropped by 50 percent. Reasons for such significant changes could not be obtained from the CHP at the time of report development.

Conclusions: Since the control corridor also experienced a decrease in collision rate, it cannot be inferred that the decrease in collision rate on the study corridor can be directly attributed to the Express Lane. However, it may be concluded that the Express Lane did not cause an increase in accident rates on the study corridor.

Violations and Enforcement

Violations on the Express Lane were measured based on the estimation of single-occupant vehicles not paying tolls, observation of illegal crossings of the solid double white line separating the Express Lane from the general purpose lanes, and calculation of vehicles illegally using an ingress as egress and vice versa. Based on observations and stakeholder comments, the Washington Boulevard ingress to the Express Lane was analyzed for its use as an illegal egress from the Express Lane. Enforcement is measured by the number of citations issued by the California Highway Patrol.

*The estimated toll **violation rate** (single-occupant vehicles not paying a toll) observed on the Express Lane was 20% of single-occupant vehicles or 11% of all vehicles in the Express Lane.*

Findings: The percentages of single-occupant vehicles that were not recorded as paying a toll were approximately 25 percent of single-occupant vehicles or 13 percent of all vehicles in the Express Lane. A portion of these vehicles could be qualified clean air vehicles or vehicles with legal transponders that were not working properly. The approximate volume of eligible clean air vehicles is estimated as 2.4 percent of all vehicles in the Express Lane, based on prior surveys and clean air vehicle registration totals. Therefore, the estimated toll violation rate on the Express Lane is estimated to be approximately 20% of single-occupant vehicles or 11% of all vehicles in the Express Lane.

Video recording surveys from 8 locations along the study corridor indicated a very low (less than 1 percent of all Express Lane vehicles in each location) violation rate for illegal crossings of the double white line between the Express Lane and general purpose lanes. These surveys represent observations in just the 8 specific locations in the corridor, and additional illegal crossings may occur in other portions of the corridor. However, the percentage of drivers performing illegal movements in each portion of the corridor is expected to be similar to the observed driver behavior.

A minimum violation rate of 6 percent was estimated for vehicles using the Washington Boulevard Express Lane ingress as an egress. This is likely due to the vehicles that needed to use the Auto Mall

Parkway off ramp for which there is no legal egress available from the Express Lane, and therefore using the Washington Boulevard ingress as egress.

The number of California Highway Patrol citations for HOV lane violations in the study corridor increased during the first full year of Express Lane operation from 205 citations in 2009, and 400 citations in 2010 to 478 in 2011, but then decreased significantly in 2012 to 223 citations.

Conclusions: The maximum toll violation rates on the Express Lane are approximately 20 percent of single occupant vehicles or 11 percent of total vehicles in the Express Lane, and are higher than the 3 to 5 percent auto occupancy violation rates reported by Caltrans on the HOV lane in prior years. The number of CHP citations increased initially and reduced later, indicating that increased enforcement for the Express Lane likely is resulting in reduced citations. License plate readers and self-identification of carpools (using switchable toll tags or web-based applications) are being explored for use in the Bay Area region to improve enforcement and potentially reduce violations.

ES-4 OTHER FACTORS AFFECTING STUDY CORRIDOR

Other factors potentially affecting the study corridor “After” study results include economic conditions, gasoline prices and the implementation of ramp metering, completion of nearby major roadway improvements, and general travel trends in the area.

Economic Conditions

Findings: The California unemployment rate was 8 percent at the time of the “Before” studies in Fall 2008, and rose to 12 percent between 2009 and 2012. During the time of the “After” study in Fall 2012, it was at 10 percent. During this period, Alameda and Santa Clara counties lost about 60,000 and 80,000 jobs respectively while recovering to 2008 employment levels by 2011.

Conclusions: While the unemployment rate or employment levels are comparable between 2008 and 2012, the significant drop in employment that occurred in the years in between due to the economic downturn may have created some changes in the types of employment and number of workers by employment type, and therefore resulted in shifts in modal preferences.

Gasoline Prices

Findings: Gasoline prices during the Fall 2012 “After” study were very similar to gasoline prices during the Fall 2008 “Before” studies.

Conclusions: Travel demand characteristics should not have been affected by gasoline price differences between the “Before” and “After” conditions.

Ramp Metering

Ramp metering was implemented along the southbound I-680 corridor on July 25, 2011. The Metropolitan Transportation Commission (MTC) prepared a I-680 Southbound Ramp Metering “Before and After” Study***.***

Findings: Average southbound traffic volumes increased by 2 percent between the “Before” and “After” ramp metering conditions, with most of the increase occurring in the Express Lane (18 percent increase in traffic volume). Two “After” ramp metering studies prepared by MTC showed that while ramp metering initially reduced travel times, by up to 8 percent during the AM peak period, at a later time in May 2012 average travel times had increased by 2.5 minutes. The ramp metering "After" studies concluded that increased travel times were likely contributed by a combination of increased traffic volumes and travelers adjusting their travel patterns in response to ramp metering and ramp metering adjustments to the north at Bernal Avenue.

Conclusions: The implementation of ramp metering in the study corridor slightly increased traffic volumes and travel times in the Express Lane. Even with these increases, a comparison of the Express Lane "Before" and "After" studies travel times showed overall modest to notable improvements in both the general purpose lanes and Express Lane as discussed earlier.

Major Roadway Improvements

The I-880/SR 262-Mission interchange improvements in Fremont were completed in Spring 2009 after the "Before" study was completed.

Findings: The interchange improvements provided an improved connection between I-680 and I-880 for trips going to Santa Clara County, providing an alternative to using I-680. Volumes at the three major on-ramps from the City of Fremont to southbound I-680 showed decreased volumes of about 800 vehicles in the 2-hour AM peak period compared to "Before" conditions.

Conclusions: The reduction in throughput volumes experienced at the southern end of the I-680 study corridor is appeared to be mostly contributed by a combination of trips using I-880 through the improved I-880/Mission interchange to travel to Santa Clara County and implementation of the Express Lane.

Other Related Trends

The American Community Survey from the United States Census showed that the percentage of commute trips using carpooling declined in Alameda County between 2000 and 2012 by 4 percent from 14 to 10 percent.

Findings: Between 2008 and 2011, carpooling work trips alone decreased in Alameda County by 0.3 percent and in Contra Costa County by approximately 2.0 percent. Alameda and Contra Costa Counties along with San Joaquin County make up the majority of the trips on the southbound I-680 study corridor during the morning commute.

Conclusions: Decreases in vehicle occupancy in the study and control corridors are affected by the overall larger declining trend in carpool trips.

ES-5 EXPRESS LANE REVENUES

Toll revenues collected on the I-680 Southbound Express Lane have been fully utilized to pay for operations and maintenance of the Express Lane facility. In the current facility ramp-up period, the revenues do not exceed operating costs. The operating cost has been subsidized by the unspent grant funds available in the Project. When the Express Lane becomes financially sustainable (i.e., the toll revenues exceed the operations and maintenance costs), the Sunol Smart Carpool Lane JPA Board will determine how to reinvest these funds into the project corridor.

ES-6 CONCLUSIONS

Both “Before” and “After” studies identified key objectives related to performance of the Express Lane in meeting the legislative mandate. Based on the results summarized above for various performance measures, the following summary describes how the objectives are met:

- ***Objective:*** Optimize the HOV lane usage to improve traffic throughput in the corridor
  Results: Overall vehicle and person throughput in the corridor increased, average travel times decreased by 2 minutes (13 percent) in the general purpose lanes and I minute (4%) in the Express Lane, and average speeds increased by 6 mph in the general purpose lanes and 3 mph in the Express Lane.

- ***Objective:*** Maintain LOS C or better for all Express Lane users
  Results: Express Lane LOS levels did not go below LOS B

- ***Objective:*** Use net revenue to improve highway and transit in the corridor
  Results: Currently all toll revenues are being used towards the Express Lane operations. When net revenue becomes available over and above covering the Express Lane operations, it will be used to improve highway and transit in the corridor

- ***Objective:*** Employ new intelligent transportation system (ITS) technologies
  Results: Dynamic pricing is currently being deployed to optimize the throughput. Working with the regional partners, technology options for other purposes are being explored including switchable toll tags and automated license plate reading for enforcement purposes.

ES-7 RECOMMENDATIONS

Analysis of performance measures for the “Before” and “After” Studies shows that some improvements can be implemented to further improve the corridor performance in both the Express Lane and general purpose lanes. These improvements will aim to improve occupancy (carpool use), transit ridership, level of service and related bottlenecks, and toll violations. Recommendations regarding these potential improvements are presented below:

- Increased HOV usage and transit ridership for trips within Alameda County could be achieved through focused implementation of a Transportation Demand Management program that includes tools to promote use of alternate modes. The implementation of the Travel Demand Management program will be done in coordination with the large employers in Alameda, Santa Clara and Contra Costa Counties and with MTC’s Regional Ride Share program.
- Toll violation rates could be reduced through implementation of new technologies such as automated license plate reading combined with the switchable toll tag capabilities that are currently being explored.
- To improve the new bottleneck at SR 84 and the two existing bottlenecks at the southern portion of the Express Lane at the Auto Mall Parkway/Durham Road and SR 262/Mission Boulevard interchanges, and to address the access issues experienced at the Washington Boulevard and Auto Mall Parkway/Durham Road interchanges, further studies could be performed to identify potential improvement options.
- Alameda CTC will work with the Legislature regarding the need for increased California Highway Patrol enforcement and related resources along the Express Lane to reduce the toll and access violations.

1 INTRODUCTION

The southbound I-680 Express Lane was the first High Occupancy Toll lane project in northern California, which was approved as part of the Express Lane Demonstration Program. It was opened to traffic in September, 2010. It is operated by the Sunol Smart Carpool Lane Joint Powers Authority through the Alameda County Transportation Commission.

The intent of the Express Lane Demonstration Program is to improve the efficiency of the carpool lanes and the freeway corridor through providing options for single occupant vehicles to use the carpool lane for a fee and optimizing the capacity of the carpool lane, which will in turn reduce congestion and improve travel time reliability in the corridor. The state legislation that approved the implementation of the Express Lane requires an evaluation of the performance of the Express Lane within three years of its opening. This report was prepared to fulfill that requirement. It provides feedback on the performance of the system in relation to the Demonstration Program's overall goals. The evaluation was done in comparison to a "Before" Study that was developed in April 2009, which established a benchmark for the operations of the corridor prior to the implementation of the Express Lane. The evaluation results, highlighted in the Executive Summary, are presented in detail in the report.

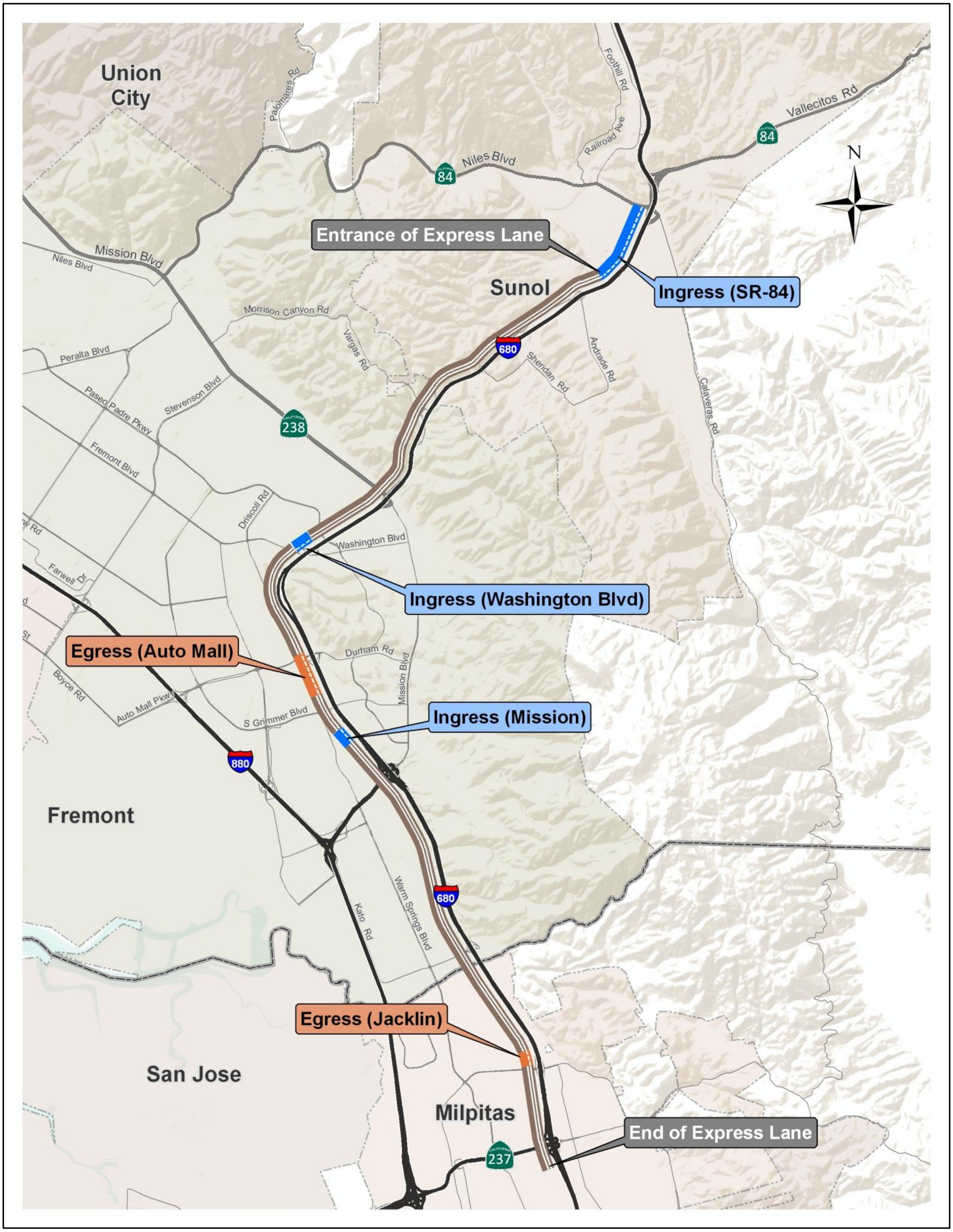
1.1 ORGANIZATION OF THE REPORT

- Chapter 1 describes the overview and purpose of the "After" study, the southbound I-680 Express Lane project, and background legislative requirements.
- Chapter 2 provides information on the goals and objectives and criteria used.
- Chapter 3 describes the study methodology including performance measures.
- Chapter 4 includes information on the data collection schedule and various types of data collected.
- Chapter 5 provides the detailed data analysis and results for each performance measures and identifies key findings and conclusions.
- Chapter 6 discusses other factors that may have likely impacted the performance of the study corridor other than the implementation of the Express Lane.
- Chapter 7 provides information on the revenue collection from the Express Lane.
- Appendices include supportive analysis or technical documentation for the information provided in the main report.

1.2 THE STUDY CORRIDOR

The southbound I-680 Express Lane corridor ("study corridor") is southbound Interstate 680 (I-680) from the State Route 84 (SR 84) interchange in Alameda County to the State Route 237 (SR 237) interchange in Santa Clara County (Figure 1). The study corridor is the primary commuter route serving the Tri-Valley area in Alameda and Contra Costa Counties and San Joaquin County and serves as the major connection to Santa Clara County and Silicon Valley. This freeway corridor generally has four lanes, consisting of three general purpose lanes and one Express Lane.

Figure 1: Southbound I-680 Express Lane Configuration



Prior to implementation of the I-680 Express Lane, there were three general purpose lanes and one high occupancy vehicle (HOV) lane in the study corridor. The HOV lane was converted into the Express Lane and opened for operation in September 2010.

Express Lane Configuration

The I-680 Express Lane is separated from the general purpose lanes by double solid white lines, except at the designated entry and exit locations.[1] It begins at the SR 84 (Valecitos Road) on-ramp with an ingress that extends 1.0 mile south. A second ingress to the Express Lane is located at the Washington Boulevard off-ramp followed by an Express Lane egress approximately 1.25 miles downstream at the Durham Road off-ramp. Another half mile downstream, an Express Lane ingress is located approximately 0.25 miles north of the Mission Boulevard (SR 262) off-ramp. The final Express Lane egress is located at the Jacklin Road off-ramp approximately 0.6 mile before the Calaveras Boulevard (SR 237) off-ramp and approximately 1.25 miles from the southern end of the Express Lane.

Express Lane Operations

The Express Lane provides drivers of single occupancy vehicles (SOV) the option to use the lane for a fee that can be paid using FasTrak transponders. Regular carpool users, buses, motorcycles and eligible clean air vehicles continue to use the lane at no cost. Tolls are estimated by a computerized dynamic pricing model based on the traffic flow in the Express Lane to manage congestion and to ensure smooth flow of traffic. Tolls are collected from the SOVs based on the published toll rate and the length of their trip.

The southbound I-680 Express Lane includes three toll zones for toll estimation and assessment purposes: Andrade Road to Washington Boulevard, Washington Boulevard to Mission Boulevard, and Mission Boulevard to SR 237. Tolls are collected from the SOVs from their FasTrak® accounts, with their FasTrak® transponders read by the automated vehicle identification readers mounted on overhead gantries. Five FasTrak® readers are located in the Express Lane, one at each of the three toll zones and one at each of the two enforcement zones. Readers at the toll zone are linked to the Toll Data Center and transponder readings are related to the FasTrak® accounts.

The Express Lane enforcement is in effect on weekdays between 5:00 AM and 8:00 PM. At nights and on weekends, the Express Lane is open to all vehicles.

1.3 PURPOSE OF THE STUDY

As described above, the evaluation of the newly implemented Express Lane is required by the California Streets and Highways Code Section 149.5 (g), which states:

Not later than three years after the administering agency first collects revenues from the program authorized by this section, the administering agency shall submit a report to the Legislature on its findings, conclusions, and recommendations concerning the demonstration program authorized by this section. The report shall include an analysis of the effect of the HOT Lanes on the adjacent general

[1] Express Lane factsheet: http://www.680expresslane.org/I-680_Fact_Sheet.asp

purpose lanes and any comments submitted by the Departments of Transportation and California Highway Patrol regarding operation of the lane.

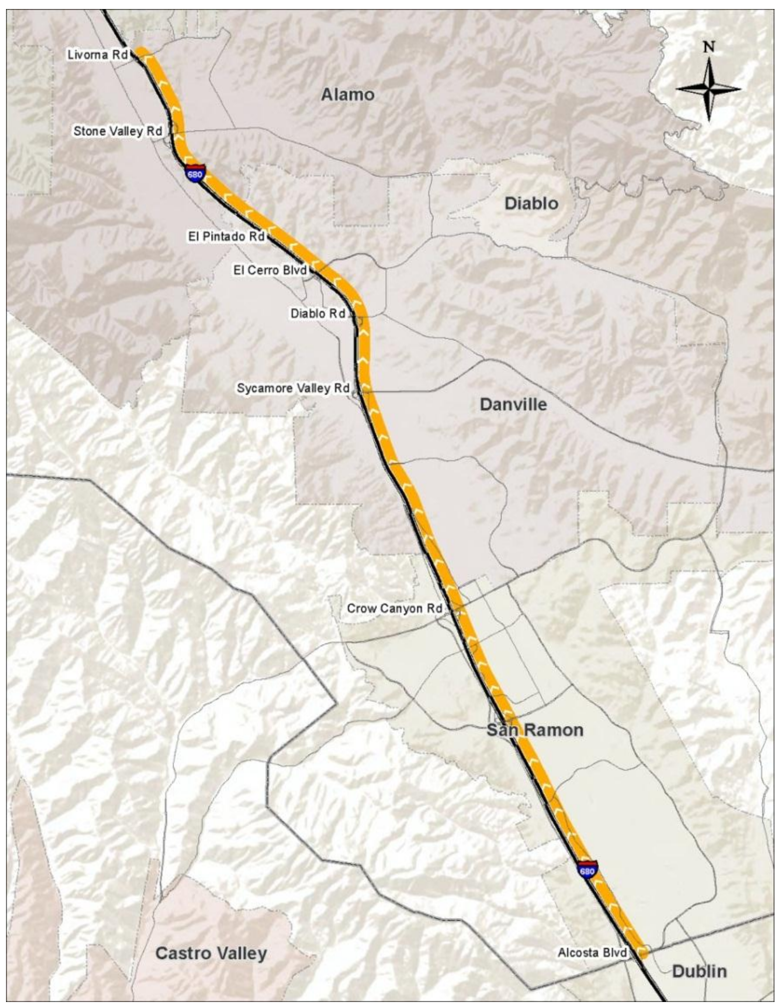
"Before" Study

To perform an evaluation of the Express Lane performance after its implementation, a study on existing conditions prior to implementation of the Express Lane, a "Before" study, was conducted. The "Before" study report was prepared in April 2009 based on data collected in the fall of 2008 prior to implementation of the southbound I-680 Express Lane. The "Before" study established a benchmark for the operation of the existing southbound general purpose lanes and HOV lane on I-680 prior to implementation of the Express Lane.

1.4 CONTROL CORRIDOR

A control corridor (Figure 2) was defined in addition to the study corridor, and used in the "Before" study. The same control corridor is used in the "After" study. The control corridor will help determine if any changes in travel behavior observed are due to the opening of the Express Lane or other external factors that would normally influence the travel trends within the San Francisco Bay Area. The control corridor was selected based on two criteria: 1) it should have a similar configuration as the study corridor in the "Before" condition (freeway with HOV lane), and 2) the similar conditions wouldn't change between the "Before" and "After" studies.

Figure 2: Northbound I-680 Control Corridor



The selected control corridor was northbound I-680 between Alcosta Boulevard in San Ramon and Livorna Road in Alamo. This segment was selected for the following reasons:

- Traffic demand and travel characteristics would be similar except that the direction of the peak commute is reversed between morning and afternoon hours.
- Length of HOV lane corridor is similar.
- There were no planned major improvements along the corridor between 2008 and 2013.
- This corridor serves similar suburban area traffic as the study corridor.

1.5 THE AFTER STUDY PROCESS

The "After" Study collected various types of transportation data on the study and control corridors. In addition, input from the project partners and the local jurisdictions were received and used to inform the study development. Two meetings were held with project stakeholders including Caltrans, California Highway Patrol (CHP), Metropolitan Transportation Commission and Santa Clara Valley Transportation Authority, the first on December 12, 2012 during the data collection and the second one on May 28, 2013 to share the draft results. Comments received generally from all stakeholders and specifically from Caltrans and the CHP were incorporated into the report. In addition, comments from local jurisdictions, including Alameda County and the Cities of Fremont and Pleasanton, were received in December, 2012.

2 EVALUATION GOALS AND OBJECTIVES

The goal of the "After" study is to provide feedback on the performance of the Express Lane corridor in relation to the legislative requirements of the Express Lane Demonstration Program.

2.1 EXPRESS LANE DEMONSTRATION PROGRAM

California Assembly Bill (AB) 2032, High-Occupancy Toll (HOT) Lanes Demonstration Projects, authorized the Sunol Smart Carpool Lane Joint Powers Authority to conduct, administer, and operate a value pricing high-occupancy vehicle program on the Sunol Grade segment of Interstate 680 in Alameda and Santa Clara Counties. The legislation included the following findings that outline the purpose of the HOT (Express) Lane Demonstration Program:

- Provide an additional choice for users on occasions when saving time is of value to them.
- Create an alternative mechanism for financing transportation projects by using revenue generated from HOT (Express) lanes for transit services, highway maintenance, and other improvements within the HOT (Express) lane corridor.
- Establish an equitable means of assessing a fee that is directly related to the burden placed on the transportation system by providing the consumer a choice of paying a direct user fee for utilizing the unused capacity of the transportation system during peak periods.
- Toll collection for HOT (Express) lanes should be entirely by electronic means, and in accordance with Section 27565 of the Streets and Highways Code, which requires the use of equipment that is interoperable with electronic toll collection systems currently operating in California.
- Increase the efficiency of the transportation system by taking advantage of existing capacity without forfeiting the congestion mitigation and air quality benefits provided by HOV lanes.
- Revenue from HOT (Express) lane operations would be reinvested in projects and services that provide traffic congestion relief in the HOT (Express) lane corridor.

2.2 EVALUATION OBJECTIVES

The Southbound I-680 Express Lane "After" study, consistent with the "Before" study and the requirements of AB 2032, identified the following performance objectives that will help evaluate the performance of the Express Lane and the Express Lane corridor:

- Optimize the high occupancy vehicle (HOV) lane usage to improve traffic throughput in the corridor;
- Maintain Level-of-Service (LOS) C or better for all Express Lane users;
- Use net revenue to improve highway and transit in the corridor; and
- Employ new intelligent transportation systems (ITS) technologies such as dynamic pricing and in-vehicle electronic enforcement, and identify the benefits of these ITS deployments.

2.3 PERFORMANCE MEASURES

The following performance measures were established to evaluate the performance of the Express Lane and the Express Lane corridor, and to determine whether the stated goals and objectives of the southbound I-680 Express Lane project have been met:

- Time and Speed
    - Travel times, corridor
    - Travel speeds by segment
- Throughput
    - Vehicle throughput at selected locations
    - Person throughput at selected locations
- Bottlenecks and queues
- Vehicle occupancy
    - Vehicle occupancy in HOV/Express Lane
    - Vehicle occupancy in all lanes
- Level of service
    - Level of service, HOV/Express Lane
    - Level of service, general purpose lanes
    - Vehicle-miles traveled
    - Vehicle-hours of delay
- Transit ridership
- Safety measured by collision rates
- Violations and enforcement
    - Violations, toll payment
    - Violations, illegal crossings
    - Citations

All of these measures were used in the “Before” Study to establish an existing conditions baseline on the study corridor prior to the implementation of the Express Lane. In addition to these measures, other external factors that may have impacted the performance of the Express Lane were also studied in the “After” study. The methodologies for evaluating these performance measures are described in the next chapter.

3 STUDY METHODOLOGIES

Analysis of corridor performance for a majority of the performance measures was developed directly from the data collected, including travel times, freeway speeds, throughput, vehicle occupancy, transit ridership, collision data, and violations. Additional analysis for measures such as level of service and total corridor delay was based on traffic operations modeling. This chapter describes the methodologies used to evaluate each performance measure.

3.1 ANALYSIS TIME PERIODS

Analyses were performed for three distinct time periods, where applicable, for the study and control corridors. The three time periods were AM peak period (5:00 AM to 9:00 AM), PM peak period (3:00 PM to 7:00 PM) and daytime (7:00 AM to 7:00 PM). These peak period times were selected based on the HOV operation hours in the study corridor during the “Before” conditions. For the “After” study conditions, the Express Lane and HOV enforcement is in effect for 15 hours, from 5:00 AM to 8:00 PM, Monday through Friday. For the control corridor, the HOV operations during the “Before” conditions were between 6:00 AM and 9:00 AM in the morning and between 3:00 PM and 6:00 PM in the afternoon, and therefore these three-hour periods were used for the AM and PM peak periods respectively for the control corridor. For Throughput and Vehicle Occupancy, a two-hour AM peak period (7:00 AM to 9:00 AM) was analyzed due to visibility constraints in the earlier hours (5:00 AM to 7:00 AM). Since the AM peak period is the commute direction on the study corridor, focused analyses were performed for the AM peak period compared to the other two time periods analyzed.

3.2 PERFORMANCE MEASURE ANALYSIS METHODOLOGIES

The analysis methodologies for the performance measures are described below. The data collection used to support the analysis is described in the following chapter.

Travel Times and Speeds

The travel times and speeds in the HOV/Express Lane and general purpose lanes from the “Before” and “After” studies were compared. The comparisons of travel time and speed are based primarily on GPS-equipped “floating car” travel time surveys. The floating car surveys were conducted for two survey days on each corridor. The reported travel times and speeds represent the average of all travel time survey runs on both survey days wherever possible. In some cases, an incident or other anomaly occurred that made the data from one day not representative of average conditions. In those cases, the data from the non-representative survey day was not used and the reported travel times represent the results from one survey day.

Travel times and speeds could also be estimated or verified with other sources of continuous travel time data available for the study and control corridors. These include Caltrans’ Freeway Performance Monitoring System (PeMS) database, the Metropolitan Transportation Commission (MTC)’s 511.org database, and speed detectors installed along the Express Lane. Although each of these sources have limitations to providing more detailed data required for segment evaluation or separate evaluation of Express Lane and general purpose lane operations, they are able to provide useful control totals for comparison and were therefore used for verification where needed.

PeMS data were used to estimate and supplement corridor travel times for the time periods where floating car travel surveys were not available. The floating car travel time surveys were conducted from 7:00 to 9:00 AM and from 3:00 to 6:00 PM on both the study and control corridors. Travel speeds for other hours (5:00 to 7:00 AM and 6:00 to 7:00 PM) of the peak periods were derived from available PeMS data. Because the PeMS data are not available for individual segments, these average speeds were reported for the entire corridor.

Statistical Analysis and Hypothesis Testing

Travel time data from the "After" study period were compared against "Before" study data sets. Statistical tests were conducted at a 90 percent confidence interval.

The significance of the differences in mean travel times for the "Before" and "After" studies was tested using the Student's t test. The specific Student t-test to be used depends on whether the variances of the sample distributions are the same. For each analysis set, the F-test was conducted first, the results of which were used to select the appropriate Student t-test. Either the "equal variance" t-test or "unequal variance" t-test was selected based on the results of the F-test.

The null hypothesis for each scenario was that the mean travel time for the "After" condition was less than or equal to the mean travel time from the "Before" condition at a 10 percent significance level. The null hypothesis would be:

Ho: $\mu 2 \leq \mu 1$

Where:

$\mu 1$ = mean travel time for the Express/HOV or general purpose lanes from the "Before" study

$\mu 2$ = mean travel time for the Express/HOV or general purpose lanes from the "After" study

The assumption is that the mean travel time has a normal distribution and will perform an equal-tail test of the null hypothesis that $\mu 2 \leq \mu 1$. Rejection of the null hypothesis would indicate a significant increase in travel time between the "Before" and "After" conditions.

The statistical analyses were conducted using tools available within Microsoft Excel software.

Travel Time Variability

Travel time variability is used in this study to provide information on the reliability of travel times in the corridor. The following statistics for travel time are computed by time of day to measure travel time variability on the study and control corridors:

- Mean travel time by time of day
- Standard deviation of travel time by time of day
- Coefficient of variation of travel time by time of day

These statistics were also calculated for the "Before" study.

A high number of observations are required to measure travel time variability. Therefore, the relatively limited number of floating car travel time surveys conducted specifically for the "After" study could not be used for this purpose. The evaluation instead uses the travel time data from FasTrak transponders and roadway sensors available from 511.org. This system calculates the average of all travel times on all lanes of the freeway since it does not distinguish between the Express/HOV lane and the general purpose lanes.

The data were evaluated for a total of 24 days, including every Tuesday, Wednesday, and Thursday from September 8 to November 1, 2012. The mean of the 511.org travel time data for each hour was computed based on the travel time observations for each minute (60 computations per hour). For each day, a total of 1,440 (=24×60) computations were used.

The Coefficient of Variation was calculated as the ratio of the standard deviation to the mean. It is a dimensionless number.

Vehicle and Passenger Throughput

The throughput measures include vehicle throughput and person throughput at selected survey locations.

Vehicle Throughput

The vehicle throughput based on traffic counts is reported at four survey locations along the study corridor and two survey locations along the control corridor.

For the study corridor, the “Before” study traffic counts were from the manual vehicle occupancy counts conducted at four survey locations. The “After” study manual vehicle occupancy counts could not all be conducted in the identical locations due to changes in California Highway Patrol (CHP) policy regarding surveyor locations, as described in the next chapter. Therefore, the traffic counts used to determine “After” throughput were from the detectors installed as part of the Express Lane implementation. The detectors identified for data collection were selected to be as close as possible to the manual count locations used for the “Before” study.

Traffic counts on the study corridor were also verified against traffic counts from two other sources, loop detectors installed by Caltrans as part of the implementation of ramp metering, and Wavetronix traffic counts conducted specifically for this study at two locations.

For the control corridor, the “Before” study traffic counts were from the manual vehicle occupancy counts conducted at two survey locations. One of the “After” study manual vehicle occupancy counts could not be conducted in the same location due to changes in CHP policy regarding surveyor locations.. The traffic counts used to determine the “After” throughput on the control corridor were from Wavetronix detectors set up specifically for this study as the Wavetronix counts were conducted at locations same as the manual survey locations used for the “Before” study.

Two days of traffic count data were used wherever possible for each location, for both the “Before” and “After” studies. In some cases, an incident or other anomaly occurred that made the data from one day not representative of average conditions. In those cases, the data from the non-representative survey day was not used and the reported traffic counts represent the results from one survey day.

Based on the vehicle occupancy surveys, estimates of total vehicle/passenger throughput from the “After” study are compared to the estimates from the “Before” study, for both the study and control corridors. These estimates do not include transit riders.

Person Throughput

The person throughput was calculated based on the vehicle throughput traffic counts multiplied by average vehicle occupancies. The average vehicle occupancies were based on the manual vehicle occupancy surveys and calculated separately for each location, type of lane (HOV/Express or general purpose) and time period (7:00-9:00 AM peak period, 3:00-7:00 PM peak period, 7:00 AM-7:00 PM daytime 12 hours).

The average vehicle occupancy calculations assumed vehicle occupancies for various vehicle classifications. One person per vehicle was assumed for single-occupant vehicles, motorcycles and trucks, and two persons were assumed for vehicles identified as two-person carpools. In order to be consistent with the passenger throughput evaluation performed during the “Before” study, an average occupancy rate of 3.5 was assumed for vehicles identified as carpools with 3 or more passengers. This estimate of average auto occupancy for 3+ person vehicles is derived from the Bay Area Travel Survey (BATS) compiled by the Metropolitan Transportation Commission (MTC). For the purposes of this study, vanpools were assumed to carry an average of 5 persons per vehicle and buses were assumed to carry an average of 20 persons per vehicle in the study and control corridors, based on transit ridership data collected for this study.

Bottleneck and Queue Identification

Bottlenecks and queues were identified using the floating car travel time surveys, and aerial photographs taken at approximately 15 minute intervals. The speeds of the survey vehicles were plotted by corridor location using the GPS coordinates. Speeds less than 35 mph were noted as potential queue locations. These locations were verified by examining aerial photographs for the same time periods and identifying segments with high vehicle densities. Segments with slow speeds and high densities for more than 30 minutes were considered to be in “recurring queues.” Segments with slow speeds and high densities for 30 minutes or less were considered to be in “periodic queues.”

Locations of congestion and potential causes were confirmed through field inspection by engineers driving the corridors during peak periods.

Vehicle Occupancy Analysis

The vehicle occupancy analysis was based on the manual counts of vehicle classification and occupancy conducted at four locations on the study corridor and two locations on the control corridor. Two days of traffic count data were reviewed for each location, for both the “Before” and “After” studies. The reported vehicle occupancies represent the average of the vehicle occupancy counts on both survey days wherever possible. In some cases, an incident or other anomaly occurred that made the data from one day not representative of average conditions. In those cases, the data from the non-representative survey day was not used and the reported vehicle occupancies represent the results from one survey day.

Vehicles classified as “unknown” during the manual counts were allocated to the other classification categories in proportion to the known vehicle classifications. The percentages of “unknown” vehicles ranged from zero to eight percent and averaged two percent at the survey locations.

Motorcycles are eligible to ride in HOV or express lanes and were counted as HOVs in summary tables and graphs, whether they were observed in the HOV/Express Lane or in the general purpose lanes. Trucks observed in the HOV lane during the “Before” study were assumed to be eligible HOVs if they were observed during the enforced peak periods, but were not assumed to be HOVs if they were observed during midday non-enforcement hours (9 AM to 3 PM). Trucks observed in the Express Lane during the “After” study were assumed to be eligible HOVs during all of the observation hours (7 AM to 7 PM). This classification system is consistent with the classification system used by Caltrans for HOV violation surveys.

Level of Service

Level of Service Definition

Traffic operations performance is evaluated in terms of "level of service" (LOS), which is a measure of driving conditions and vehicle delay. Levels of service range from A (best) to F (poorest). Levels of service A, B and C indicate conditions where traffic can move relatively freely. Level of service D describes conditions where delay is more noticeable. Level of service E describes conditions where traffic volumes are at or close to capacity, resulting in significant delays and unstable traffic flow. Level of service F characterizes conditions with unstable flow, where freeway operations break down, traffic demand exceeds available capacity, with very slow speeds (stop and go), long delays, and queuing.

The LOS for freeway segments was evaluated based on the methodology outlined in the 2000 *Highway Capacity Manual*, which was the most recent HCM during the “Before” study. The LOS is determined based on density, which is the number of vehicles occupying a given length of a lane or roadway at a particular instant. The HCM states that density characterizes the quality of traffic operations because it describes the proximity of vehicles to one another and reflects the freedom to maneuver within the traffic stream. In the HCM, an estimate of density is calculated based on various inputs, such as flow rate and lane geometry. Table 1 shows the density thresholds based on the HCM, which are consistent in the 2000 and 2010 versions of the HCM.

Table 1: Highway Capacity Manual Freeway Level of Service Criteria

Level of Service	Density (passenger cars/mile/lane)
A	≤11.0
B	>11.0 – ≤18.0
C	>18.0 – ≤26.0
D	>26.0 – ≤35.0
E	>35.0 – ≤45.0
F	> 45.0

Source: Transportation Research Board, Highway Capacity Manual 2000 and 2010, Washington, DC, 2010

The HCM bases level of service on traffic density rather than speed, so LOS results are not directly comparable to speed-based LOS estimates such as those reported in the Alameda CTC LOS Monitoring report.

FREQ Model

The FREQ software, developed by the Institute for Transportation Studies at the University of California at Berkeley, can generate speeds, densities, levels of service (based on the *HCM* criteria), bottleneck locations, and queue lengths and delays for each segment. The FREQ software has more capabilities than a simple segment-by-segment LOS calculation, as it can consider the effects of bottlenecks and queues on downstream and upstream traffic conditions. However, it is not as detailed as a full microsimulation model such as CORSIM, Paramics, or VISSIM, which consider the behavior of individual vehicles in individual lanes. The FREQ model considers segments including all lanes, and evaluates time slices of vehicle flow rather than individual vehicles.

The FREQ models for the southbound study corridor (from SR 84 to SR 237) and the northbound control corridor were developed and calibrated during the Express Lane "Before" study. During the "Before" conditions, drivers were able to enter or exit the HOV lane freely at any point along the entire southbound corridor. The FREQ model for the "Before" study was coded with no barrier between the general purpose and HOV lanes. Since the opening of the Express Lane, the geometry of the southbound study corridor has changed, and the Express Lane has limited ingress and egress points. Therefore, the FREQ model developed for the "Before" study could not be used for the "After" study of the corridor.

One of the FREQ software limitations is that a limited access HOV/Express Lane can only be represented with simultaneous ingress and egress; any access point is assumed to operate in both directions. To address this FREQ software limitation, the project team, which also worked on the I-680 Southbound Ramp Metering "Before and After" Study in 2011-2012 for Caltrans, developed a solution based on discussions with staff from Caltrans and MTC. The agreed-upon solution was to code the Express Lane ingress and egress as left-side on and off "ramps" rather than a parallel lane, so that the operational impacts on the general purpose lanes could be modeled accurately and effectively.

For the "After" study evaluation, it was decided to use the more detailed FREQ model developed for the I-680 ramp metering analysis rather than using the exact FREQ model used for the Express Lane "Before" study analysis, so that it would better represent the "After" study conditions on the study corridor. An additional benefit of using the FREQ model from the ramp metering study is the extended study area. The original FREQ model for the "Before" conditions started at SR 84 and ended at SR 237. The ramp metering FREQ model starts from the Stoneridge Drive interchange and ends at SR 237, so the model can evaluate traffic operations on the freeway segments north of SR 84 where needed.

Because the main FREQ model does not explicitly include the Express Lane as a parallel lane (it is represented by ramps at the ingress and egress points), the level of service for the Express Lane was evaluated based on a separate parallel FREQ model set up specifically for the Express Lane.

The "After" evaluation of the I-680 northbound control corridor uses the same FREQ model as the "Before" study, as the operating conditions on the control corridor remain unchanged. The FREQ model for the control corridor was calibrated and validated during the "Before" study based on the observed corridor-wide travel times, and data and observations indicating general bottleneck and queuing locations at the time of the "Before" study. The "Before" study control corridor FREQ model was used for the "After" control corridor evaluation.

Corridor Performance Measures from FREQ

The FREQ model can generate additional corridor performance measures including vehicle-miles of travel (VMT), vehicle-hours of travel (VHT), and vehicle hours of delay (VHD).

Vehicle-miles of travel were calculated by multiplying the traffic volume on each freeway segment (between each on or off ramp) by the length of the segment. A set of balanced traffic volumes were calculated for each corridor for each hour of the four-hour AM and PM peak periods and used as input to the FREQ model. The balanced traffic volumes were based on Wavetronix counts of freeway mainline traffic conducted for this study at each end of the corridors, with individual segment volumes calculated by adding or subtracting traffic counts at each on or off ramp. The volumes used for the VMT calculation are actually the output throughput volumes from FREQ, which include the effects of bottlenecks that may restrict flow in some segments.

Vehicle-hours of travel are calculated by multiplying the volume on each segment by the congested travel time on the segment. Vehicle-hours of delay are estimated by multiplying the volume on each segment by the difference between the congested travel time and the estimated travel time without congestion (generally the travel time at the posted speed limit).

The average corridor speed is estimated by dividing total vehicle miles of travel by total vehicle hours of travel.

Transit Ridership Methodology

Transit operators and routes that run on the study and control freeway corridors were identified from transit operator websites. The on- and off-ramps used by the relevant bus routes were identified from the route maps. The peak-period and off-peak headways were identified from route schedules posted on the transit operator websites. In almost all cases, the bus routes that run on the freeway corridors are commuter routes that only operate during the peak periods.

The following transit service providers were contacted to get current information:

- Santa Clara Valley Transit Authority (VTA)
- San Joaquin Regional Transit District (RTD)
- Livermore-Amador Valley Transit Authority (LAVTA/Wheels)
- The County Connection (Central Contra Costa Transit Authority)

The most recent available data for all route maps, ridership tables and time schedules were obtained from these transit agencies or their websites.

Safety Evaluation Methodology

The safety evaluation of the southbound I-680 Express Lane is based on a comparison of collision records before and after the implementation of the Express Lane. Collision data were obtained from the Statewide Integrated Traffic Records System (SWITRS) maintained by the California Highway Patrol Data Services Department.

Typically, collision records are evaluated for a three-year period. For the “Before” study, the collision records for the three full years prior to the 2008 study (2005, 2006 and 2007) were evaluated, as the collision data for 2008 were not available at the time of the “Before” study analysis. For the “After” study, the full records for 2012 were not yet available, and the 2009 or 2010 records could not be used to represent Express Lane operations, because the Express Lane opened during 2010. Therefore, the "After" study focuses on collision records from 2011.

In order to calculate the collision rates based on the collision data obtained from SWITRS, data on traffic volume and length of roadway segments were required. Both the length of the roadway segments and traffic volumes for comparable time periods and locations were obtained from the California Department of Transportation Traffic Volumes website. The traffic volumes were multiplied by corresponding segment lengths to calculate vehicle-miles of travel (VMT), the standard divisor for collision rates.

Violation Evaluation Methodology

Three types of Express Lane violations were evaluated for the study corridor:

1. Single-occupant vehicles not paying tolls;
2. Illegal crossings of the solid double line into or out of the Express Lane; and
3. Illegal use of an Express Lane ingress as an egress (Washington Boulevard ingress)

Toll Violation Methodology

Toll violations were estimated by comparing the number of toll-paying vehicles with the number of single-occupant vehicles at a specific location on the same day and during the same time period. The selected segment was between Washington Boulevard and Auto Mall Parkway/Durham Road, where both electronic toll data and manual vehicle occupancy data were available. In addition, there is no Express Lane ingress or egress between the toll reader and the manual occupancy survey locations, therefore the volume differences for single occupant vehicles can be estimated to show the toll violation. The difference between counted single-occupant vehicles and recorded toll-paying vehicles was calculated during the AM peak period for a selected day when all data types were available (October 25, 2012, 7:00 to 9:00 AM).

Estimate of Clean Air Vehicle Percentage

Some single occupant vehicles could be clean air vehicles with eligible white or green stickers. These vehicles were not specifically counted. The percentage of clean air vehicles was estimated based on prior vehicle classification counts and vehicle registration information. Caltrans HOV Violation studies for the I-680 study corridor from 2007 to 2010 specifically counted eligible clean air vehicles. The percentage of clean air vehicles in the HOV lane ranged from 7 percent to 9 percent of total vehicles in the HOV lane and averaged 8 percent. During those years, vehicles with yellow stickers (hybrids) were eligible to travel in the HOV lane. This eligibility ended in 2011, after which only vehicles with green (advanced partial zero-emission vehicles) or white stickers (electric and natural gas vehicles) were eligible to travel in HOV lanes or in an Express Lane without payment. The green stickers became available January 1, 2012 and were not in effect at the time of the "Before" surveys.

Information on the number of stickers issued of each type were obtained from the legislative analysis of Assembly Bill 266, which extended the clean air vehicle HOV lane eligibility program, and from information obtained from the Department of Motor Vehicles by the San Jose Mercury News[2]. By 2007, the number of yellow stickers issued had reached the maximum allowable quantity of 85,000. The number of white stickers issued was less than 20,000 as of May, 2012 and was 23,000 as of March, 2013. The number assumed at the time of the “After” surveys is 22,000. The number of green stickers issued was 9,000 as of May, 2012 and 11,000 as of March, 2013. The number assumed at the time of the “After” surveys is 10,000.

The number of clean air vehicles statewide with stickers allowing them to use HOV lanes prior to 2011, consistent with the “Before” conditions, would have been 85,000 yellow stickers plus 20,000 white stickers or 105,000 total vehicles. The number of eligible clean air vehicles after 2011 would have been 22,000 white stickers plus 10,000 green stickers, or 32,000 vehicles. The number of eligible clean air vehicles in California after 2011 would be 30 percent (32,000/105,000) of the number of eligible clean air vehicles prior to 2011.

The Caltrans HOV counts on I-680 identified 8 percent of all vehicles in the HOV lane as eligible clean air vehicles prior to 2011. It is estimated that the percentage of clean air vehicles in the Express Lane after 2011 would be 2.4 percent (30% of 8%) of Express Lane vehicles. This estimate is used to adjust the percentage of SOVs identified as non-paying vehicles in the Express Lane.

Illegal Crossing Violation Methodology

The illegal crossing violation rate was calculated by dividing the number of vehicles observed illegally crossing the double line by the total number of vehicles counted in the corresponding segment of the Express Lane during the same period.

The illegal crossing violations were based on the video surveys recorded for several days from the. video cameras that were mounted at four locations along southbound I-680: Andrade Road interchange, Vargas Road interchange, Washington Boulevard interchange and Auto Mall Parkway/Durham Road interchange. Two video cameras were mounted at each of the four locations, one facing north and the other facing south. These surveys represent observations in just the 8 specific locations in the corridor, and additional illegal crossings may occur in other portions of the corridor. However, the percentage of drivers performing illegal movements in each portion of the corridor is expected to be similar to the observed driver behavior.

The illegal crossings could only be identified by detailed manual observation, and therefore it was impractical to summarize all of the hours of video recordings within the scope of the “After” study. The manual compilation of illegal crossing data was completed for the single survey date of October 11, 2012 and for two hours of the AM peak period, from 7:00 to 9:00 AM.

Washington Boulevard Illegal Egress Violation Methodology

Based on the input from the stakeholders and from the field observations, Washington Boulevard ingress was analyzed to determine the number of vehicles using this ingress as an egress illegally. The numbers of vehicles using the Express Lane ingress at Washington Boulevard as an illegal egress point were estimated by comparing traffic counts before and after the ingress location. Traffic volumes in the

[2] San Jose Mercury News, “Plenty of green carpool stickers remain available,” January 21, 2013

Express Lane are available from loop sensors installed by Caltrans as part of the ramp metering implementation. Express Lane traffic counts from the upstream SR 238/Mission interchange were compared with traffic counts at the downstream Washington Boulevard interchange. The difference between these two traffic counts represents the potential number of vehicles exiting the Express Lane at Washington Boulevard.

3.3 "AFTER" STUDY ADDITIONAL EVALUATION

In addition to the identified performance measures, the "After" study also analyzed other factors that may have potentially impacted the performance of the Express Lane and the Express Lane corridor. These factors analyzed include employment, gasoline prices, ramp metering implementation, other major roadway improvements and general changes in travel trends. Relevant data for these factors were compiled and analyzed for both "Before" and "After" conditions, and impacts to the performance of the Express Lane and the study corridor were evaluated.

In addition, selected ITS technologies that are currently on the market, (dynamic pricing and in-vehicle electronic enforcement), as well as new technologies that may be considered for future implementation, are summarized in the Appendices as additional resources. The potential benefits resulting from the deployment of these ITS technologies are also summarized.

4 DATA COLLECTION

The data used for the "After" study included new data collected specifically for this study, as well as data compiled from available sources. The new data collection conducted for this study included:

- Traffic counts;
- Travel time surveys using "floating car" runs;
- Manual counts of vehicle classification and occupancy at selected locations;
- Aerial photography; and
- Video recordings at selected locations.

In order to obtain comparable "Before" and "After" data, available data were also compiled from:

- Installed traffic and toll reader detectors;
- California collision records;
- California Highway Patrol citation history;
- Transit agency ridership statistics;
- Express Lane Toll revenue records;
- Travel time data from the Caltrans Freeway Performance Monitoring System (PeMS) and the Metropolitan Transportation Commission (MTC) 511.org program; and
- American Community Survey data from the United States Census.

4.1 DATA COLLECTION SCHEDULE

The field surveys and data collection for the "After" study were primarily conducted during October 2012. Details of the data collection schedule, including dates are shown in Table 2.

Table 2: Data Collection Schedule

Date	Tuesday	Date	Wednesday	Date	Thursday
10/9	n/a	10/10	First day of Study Corridor radar counts, ramp tubes, floating car runs, video cameras.	10/11	Second day of Study Corridor radar counts, ramp tubes, floating car runs, video cameras.
10/16	First day of Control Corridor radar counts, ramp tubes, floating car runs.	10/17	Second day of Control Corridor radar counts, ramp tubes, floating car runs.	10/18	First day of occupancy counts at Pico Road (near Vargas Road) and Washington Blvd. overpass.
10/23	Second day of occupancy counts at Pico Road (near Vargas Road) and Washington Blvd. overpass. First day of Study Corridor aerial photo survey.	10/24	First day of occupancy counts at Auto Mall Parkway/Durham Road Interchange and Research Avenue (north of SR 262). Second day of Study Corridor aerial photo survey.	10/25	Second day of occupancy counts at Auto Mall Parkway/Durham Road Interchange and Research Avenue (north of SR 262).
10/30	First day of Control Corridor occupancy counts at Alcosta Blvd. overpass and Crow Canyon Road overpass.	10/31	n/a	11/1	Second day of Control Corridor occupancy counts at Alcosta Blvd. overpass and Crow Canyon Road overpass.

4.2 TRAFFIC COUNTS

Traffic counts for the study and control corridors were collected in a number of locations, with additional sources used for verification on these data collected specifically for the "After" study. Traffic volumes for each segment of the I-680 freeway were determined using counts of the mainline freeway in two locations, and counts of each freeway ramp to identify the volume of traffic entering or exiting the freeway in each location.

Freeway Mainline Counts

Continuous volume counts were collected using Wavetronix radar units at four locations (two locations on the study corridor and two locations on the control corridor) for two full weekdays (48 hours of data):

Study Corridor

- I-680 SB near Andrade Road Interchange
- I-680 SB near SR 237 Interchange

The locations of manual vehicle counts and electronic toll readers are shown in Figure 3.

Control Corridor

- I-680 NB near Alcosta Boulevard Interchange
- I-680 NB near Livorna Road Interchange

Freeway Ramp Counts

Freeway ramp counts were collected for both the study corridor and the control corridor. Tube counts were collected at the ramp locations for two full weekdays (48 hours), scheduled to coincide with the mainline Wavetronix counts. Counters were set up to collect data at the 42 ramps shown in Table 3.

PeMS Counts

The University of California at Berkeley maintains a Freeway Performance Measurement System (PeMS) database based on detectors on roads throughout the Bay Area. The PeMS data were utilized primarily to verify the consistency of field surveys (floating car travel time/speed surveys, volume surveys, etc.) along the study and control corridors.

Caltrans Ramp Metering Equipment Counts

Caltrans installed ramp metering equipment, including loop detectors, as part of the I-680 ramp metering implementation. Metered on-ramp and mainline volumes for October, 2012 were obtained from Caltrans in coordination with Alameda CTC.

Table 4 lists the interchange locations where southbound mainline and on-ramp counts from the installed ramp metering detector equipment were collected. These 24-hour mainline and ramp counts were compiled for a total of four weeks. The mainline volumes were collected just upstream of the on-ramp gores.

Figure 3: Data Collection Locations

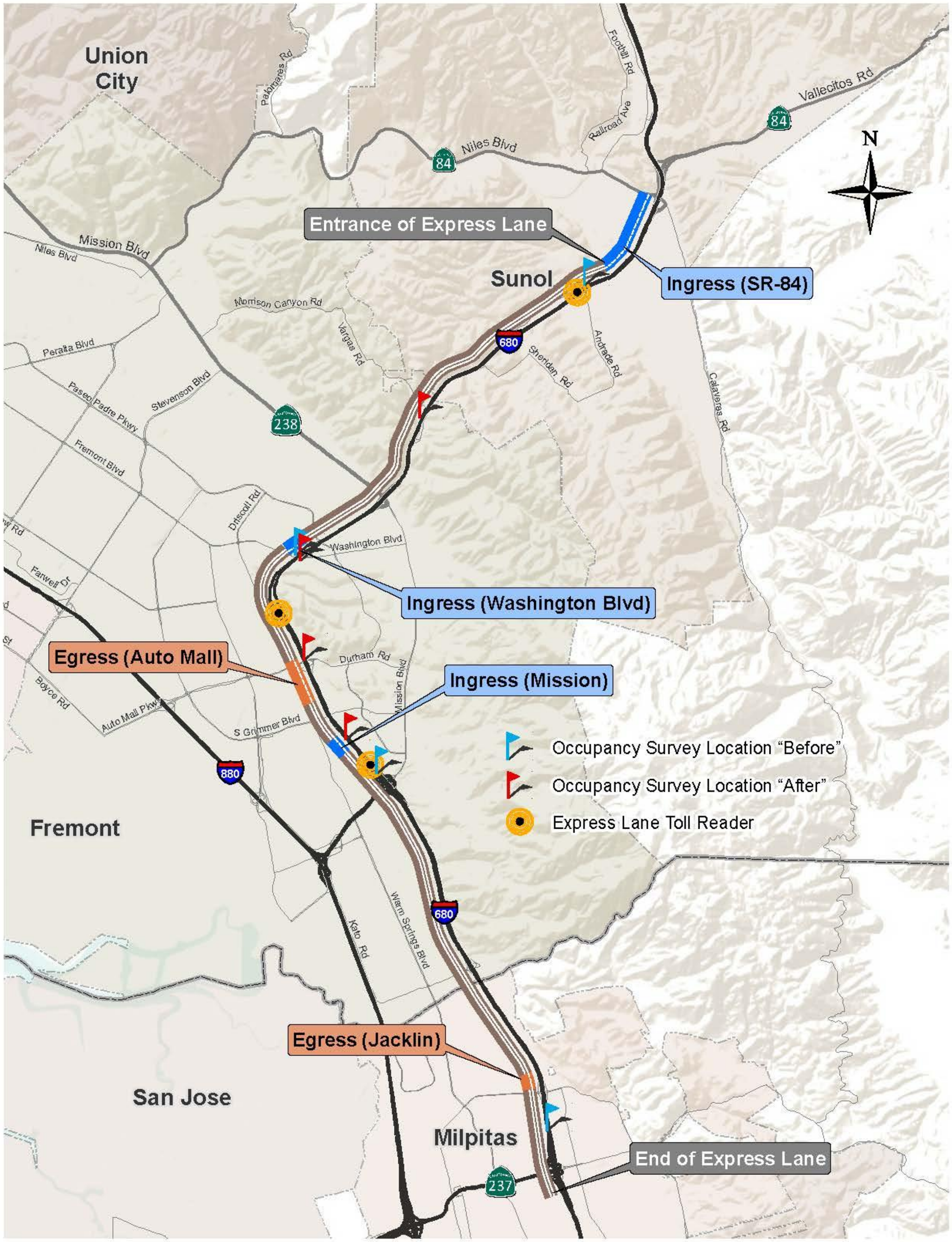


Table 3: Freeway Ramp Count Locations

STUDY CORRIDOR	CONTROL CORRIDOR
Southbound I-680	Northbound I-680
Paloma Rd Off-Ramp	Alcosta Blvd Off-Ramp
RTE-84 SB On-Ramp	Alcosta Blvd On-Ramp
Paloma Rd On-Ramp	Bollinger Canyon Rd Off-Ramp
Andrade Rd Off-Ramp	Bollinger Canyon Rd EB Off-Ramp
Andrade Rd On-Ramp	Bollinger Canyon Rd WB Off-Ramp
Sheridan Rd On-Ramp	Crow Canyon Rd Off-Ramp
Vargas Rd Off-Ramp	Crow Canyon Rd EB On-Ramp
Vargas Rd On-Ramp	Crow Canyon Rd WB On-Ramp
Mission Blvd (North)/RTE 238 Off-Ramp	Sycamore Valley Rd Off-Ramp
Mission Blvd (North)/RTE 238 On-Ramp	Sycamore Valley Rd On-Ramp
Washington Blvd Off-Ramp	Diablo Rd Off-Ramp
Washington Blvd On-Ramp	Diablo Rd EB On-Ramp
Auto Mall Pkwy Off-Ramp	Diablo Rd WB On-Ramp
Auto Mall Pkwy On-Ramp	El Cerro Blvd Off-Ramp
Mission Blvd (South)/RTE 262 Off-Ramp	El Cerro Blvd Off-Ramp
Mission Blvd (South)/RTE 262 On-Ramp	El Pintado Rd On-Ramp
Scott Creek Rd Off-Ramp	Stone Valley Rd Off-Ramp
Scott Creek Rd On-Ramp	Stone Valley Rd On-Ramp
Jacklin Rd Off-Ramp	Livorna Rd Off-Ramp
Jacklin Rd On-Ramp	Livorna Rd On-Ramp
Calaveras Blvd/RTE 237 Off-Ramp	
Calaveras Blvd/RTE 237 On-Ramp	

Table 4: Caltrans Ramp Metering Traffic Detector Locations

Ramp Metering Detector Location
Bernal Avenue
Sunol Boulevard
SR 84 (SR 84 Connector Ramp and Paloma Way)
Andrade Road
Sheridan Road
Vargas Road
Mission Boulevard SR 238
Washington Boulevard
Durham Road / Auto Mall Parkway
Scott Creek Road
Jacklin Road
Calaveras Boulevard (Loop Ramp)

Express Lane Traffic Volumes

Express lane traffic count data sets were obtained from the Sunol Smart Carpool Lane Joint Powers Authority (SSCLJPA) in coordination with Alameda CTC. These traffic counts were obtained from roadside detectors associated with the Express Lane operation.

4.3 TRAVEL TIME SURVEYS

Travel time data (collected by Quality Counts) were primarily based on floating car surveys during the peak periods. The probe vehicles were equipped with Geographic Positioning System (GPS) equipment so that vehicle trajectories could be recorded at frequent time intervals.

Study Corridor

Seven survey vehicles were used for the I-680 study corridor during the AM peak period during each of the two weekdays. Four probe vehicles surveyed the general purpose lanes and three surveyed the Express Lane. During the PM peak period, there were a total of five survey vehicles; three vehicles surveyed the general purpose lanes and two surveyed the Express Lane.

For the two-day survey period, the total numbers of study corridor travel time runs were:

- AM peak period, Express Lane: 16 travel time runs
- AM peak period, general purpose lanes: 16 travel time runs
- PM peak period, Express Lane: 13 travel time runs
- PM peak period, general purpose lanes: 17 travel time runs

Control Corridor

For the I-680 control corridor, two probe vehicles surveyed the general purpose lanes and another two probe vehicles surveyed the carpool (HOV) lane, for a total of four survey vehicles during each peak period.

For the two-day survey period, the total numbers of control corridor travel time runs were:

- AM peak period, HOV lane: 16 travel time runs
- AM peak period, general purpose lanes: 12 travel time runs
- PM peak period, HOV lane: 22 travel time runs
- PM peak period, general purpose lanes: 18 travel time runs

Additional Data Sources

Three additional data sources were used to verify and augment the travel time data collected in the floating car surveys: the Alameda CTC LOS Monitoring study, 511.org, and PeMS websites.

Alameda CTC LOS Monitoring Study

The floating car travel time data from Alameda CTC's LOS Monitoring Reports were used as additional references. These surveys were conducted using a similar methodology as the floating car surveys conducted specifically for the Express Lane "Before" and "After" studies. This LOS Monitoring information was available for the study corridor only, as the control corridor is located in Contra Costa County.

511.org Transponder Travel Time Data

The Metropolitan Transportation Commission (MTC) compiles continuous travel time data on freeways based on transponders in vehicles through the 511.org program. Travel time data provided by this source represent the average travel time of all vehicles with FasTrak transponders across all travel lanes. Therefore, the general purpose lane data and Express Lane data are grouped together. For this study, the average travel time data for the study and control corridors for the months of September through October 2012 from the 511.org was used. These data were primarily used to assess travel time variability.

PeMS

The Caltrans Freeway Performance Monitoring System (PeMS) database can provide limited travel speed data at selected locations where reliable loop detectors are operating. Particularly, PeMS data were used to estimate and supplement corridor travel times for the time periods where floating car travel surveys were not available. The floating car travel time surveys were conducted from 7:00 to 9:00 AM and from 3:00 to 6:00 PM on both the study and control corridors. Travel speeds for other hours (5:00 to 7:00 AM and 6:00 to 7:00 PM) of the peak periods were derived from available PeMS data. Because the PeMS data are not available for individual segments, these average speeds were reported for the entire corridor.

4.4 VEHICLE CLASSIFICATION AND OCCUPANCY SURVEYS

Vehicle classification and occupancy data were collected through manual observation of each freeway lane, from 7:00 AM to 7:00 PM. One surveyor was assigned to one lane of travel to collect occupancy data. The vehicle classification categories included separate counts of drive-alone vehicles, carpool with two passengers, carpool with three or more passengers, vanpool, buses, motorcycles, and trucks. Vehicle occupancy and classification data were collected for both the study and control corridors.

For the study corridor, the occupancy surveys were conducted at four locations: Andrade Road interchange, Washington Boulevard interchange, Auto Mall Parkway/Durham Road, and near SR 262/Mission. For the control corridor, the surveys were conducted at two locations: Alcosta Boulevard interchange and Crow Canyon Road. Observations were performed on the overpass bridge at these locations.

Some of the "After" study occupancy survey locations are different than the "Before" study locations (Table 5). The "After" study manual occupancy surveys could not be conducted around the same locations as the "Before" study due to change in changes in CHP policy regarding surveyor locations on the roadside. In particular, there were safety concerns about surveyors using the freeway shoulders as observation points, so surveys were relocated to the nearest possible north-facing overpass or adjacent frontage road with good visibility for all lanes.

On the study corridor, the "After" study Pico Road survey location is comparable to the "Before" study Andrade Road location, and the Washington Boulevard location is the same in both studies. The "Before" survey locations at SR 262/Mission and SR 237/Calaveras could not be replicated in the "After" study, and the "After" survey locations at Auto Mall Parkway/Durham Road and Research Avenue cannot be directly compared to any of the "Before" study locations. The "After" study Research Avenue location was adequate for viewing vehicle occupancies during survey trials and setup, but provided inadequate viewing angles during peak periods when there was more congestion on the freeway. Therefore, data from this survey location could not be directly used in the comparative analysis.

Table 5: Vehicle Classification and Occupancy Survey Locations

Study Corridor (I-680 SB): four locations		Control Corridor (I-680 NB): two locations	
Before Study	After Study	Before Study	After Study
Andrade Rd. shoulder	Pico Rd. (service road south of Vargas Rd. interchange)	Alcosta Blvd. overcrossing	Alcosta Blvd. overcrossing
Washington Blvd. overcrossing	Washington Blvd. overcrossing	Livorna Rd. shoulder	Crow Canyon Rd. overcrossing
Mission Blvd. (SR 262) shoulder	Auto Mall Pkwy./Durham Rd. overcrossing		
Calaveras Blvd. (SR 237) shoulder	Research Ave. (service road north of SR 262/Mission)		

On the control corridor, the south survey location at Alcosta Boulevard is the same in the "Before" and "After" studies, allowing direct comparison of data. However, the Crow Canyon survey location used for the "After" study is seven miles south of the Livorna Road location used for the "Before" study, and cannot be directly compared. There were no acceptable occupancy survey locations available for the "After" study between Livorna Road and Crow Canyon Road.

4.5 AERIAL SURVEYS

Aerial photography for the study corridor was obtained by flying a helicopter along the corridor between the peak commute hours of 7:00 AM to 9:00 AM and 4:00 to 6:00 PM. Photos were taken along the entire corridor. These photos provide an additional source to determine existing bottleneck locations, as well as lengths of queues associated with those bottleneck locations. Considering weather conditions, (fog and overcast skies on earlier dates) the aerial photography survey was conducted on October 23rd and 24th, 2012.

4.6 VIDEO RECORDINGS

Quality Counts used video cameras to record traffic operations on the study corridor. The video cameras were mounted in four locations along the corridor, including the area near the entrance to the Express Lane at SR-84. Two cameras were mounted at each location, one facing upstream and one downstream, for a total of eight sets of recordings. The data collection was performed for three weekdays during the month of October, 2012. Selected portions of these recordings, representing two hours during the AM peak period for a single weekday, were reviewed to assess additional issues not observed directly in the field, such as illegal crossings into or out of the Express Lane.

4.7 VIOLATIONS AND ENFORCEMENT

Summaries of the HOV/Express Lane enforcement actions were obtained from the CHP Violation data as they cannot automatically be collected based on Express Lane detectors, as vehicles without transponders could be carpools or authorized clean air vehicles.

Citation data were provided by the CHP Information Services Section. Relevant freeway patrol "beats" and the numbers of annual citations for the HOV lane violation citation code (21655.5) were obtained from the Dublin, Contra Costa, and San Jose CHP offices. This citation code is also used for Express Lane violations, which can occur if a CHP officer identifies a single-occupant vehicle in the Express Lane without a valid transponder for toll payment. Each CHP patrol beat includes both sides (northbound and southbound) of the freeway within the beat boundaries.

4.8 TRANSIT USAGE

The transit operators were contacted to obtain ridership data for the routes in the study and control corridors. The transit operators and the routes that run on the study and control freeway corridors were identified from the transit operator websites. The on- and off-ramps used by the relevant bus routes were identified from the route maps. The peak-period and off-peak headways were identified from route schedules posted on the transit operator websites. In almost all cases, the bus routes that run on the freeway corridors are commuter routes that only operate during the peak periods.

4.9 ACCIDENT DATA

The CHP keeps a database of accident reports for collisions that occur on California roadway facilities, called the Statewide Integrated Traffic Records System (SWITRS). An electronic database of SWITRS data for collisions that occurred on the study and control corridors during 2011 and a portion of 2012 were provided by the CHP Data Services Department.

4.10 EXPRESS LANE REVENUE

The revenue data for the I-680 Express Lane were provided by the Alameda CTC.

5 DATA ANALYSIS AND EVALUATION

The southbound I-680 Express Lane corridor performance was evaluated based on the data collected in the fall of 2012 as described in the previous chapters. Data collected were analyzed for the following performance measures to determine the performance of the Express Lane, general purpose lanes and the entire corridor, as appropriate:

1. Travel Time
2. Travel Speeds
3. Vehicle and Person Throughput
4. Bottlenecks and Queues
5. Vehicle Occupancy
6. Level of Service
7. Transit Ridership
8. Safety
9. HOV/Express Lane Violations and Enforcement

The "After" study results were compared to the "Before" study results for these performance measures to determine the improvement in performance of the study corridor after implementation of the Express Lane. This chapter presents the data analysis based on the data collected for each of these measures including results in the following sections.

5.1 TRAVEL TIME EVALUATION

Travel times were evaluated based on the total time to travel from the beginning to the end of the corridor. The travel times are based on the floating car surveys, supplemented by detector information from the PeMS system. Corridor travel times are compared between "Before" and "After" conditions, and also for travel in the HOV or Express Lane compared to the general purpose lanes.

After implementation of the Express Lane, travel times in the adjacent general purpose lanes were reduced by up to 22 percent during the AM peak period and were similar to the "Before" conditions for the PM peak period. The Express Lane provides modest improvements in travel times compared to the HOV lane in the "Before" study even after allowing toll-paying single occupant vehicles (SOV) to use the lane. Average travel times during the AM peak period in the "After" study reduced by less than 1 minute in the Express Lane and 2 minutes in the general purpose lanes compared to the "Before" study.

Study Corridor Travel Time Comparison

Table 6, Figure 4 and Figure 5 show a comparison of the "Before" and "After" study average travel times for the study corridor. The travel times are shown separately (Table 6) for the HOV/Express Lane and general purpose lane for each hour in the study period.

Table 6: Study Corridor Travel Time Comparison

TIME	"Before" Travel Time (minutes)			"After" Travel Time (minutes)			Change in Travel Time (minutes)	
	HOV	General Purpose Lanes	HOV Lane Savings	Express Lane	General Purpose Lanes	Express Lane Savings	HOV/ Express Lane	General Purpose Lanes
AM PEAK PERIOD								
5:00-6:00 AM	11.2	12.4	1.2	10.6	11.8	1.2	-0.6	-0.6
6:00-7:00 AM	11.4	12.7	1.3	11.2	12.5	1.3	-0.2	-0.2
7:00-8:00 AM	11.8	15.5	3.7	11.5	12.9	1.4	-0.3	-2.6
8:00-9:00 AM	12.9	20.4	7.5	11.8	16.0	4.2	-1.1	-4.4
AM Average	11.8	15.3	3.5	11.3	13.3	2.0	-0.5 (-4.2%)	-2.0 (-13.1%)
PM PEAK PERIOD								
3:00-4:00 PM	11.2	12.4	1.2	11.1	11.7	0.6	-0.1	-0.7
4:00-5:00 PM	11.3	12.1	0.8	10.8	11.9	1.1	-0.5	-0.2
5:00-6:00 PM	11.1	12.1	1.0	11.0	11.8	0.8	-0.1	-0.3
6:00-7:00 PM	11.7	12.6	0.9	11.5	12.9	1.4	-0.2	+0.3
PM Average	11.3	12.3	1.0	11.1	12.1	1.0	-0.2 (-1.8%)	-0.2 (-1.6%)

Study Corridor Express Lane Travel Times

Corridor travel times on the Express Lane in the "After" study were similar to the corridor travel times on the HOV lane in the "Before" study, showing a modest decrease. The average "After" Express Lane travel times were 0.5 minutes (4 percent) less in the AM peak period and 0.2 minutes (2 percent) less in the PM peak period compared to the "Before" travel times in the HOV lane.

Study Corridor General Purpose Lane Travel Times

Significant travel time improvements were experienced on the general purpose lanes. The average AM peak period travel time was reduced by 13 percent from the "Before" to the "After" conditions. The maximum travel time reduction in the general purpose lanes was during the 8:00 to 9:00 AM time period, when corridor travel times in the general purpose lanes were reduced by over 4 minutes (22 percent improvement) in the "After" study compared to the "Before" study. During the PM peak period, average travel times in the general purpose lanes were similar between the "Before" and "After" conditions, showing modest improvement.

Figure 4: Southbound I-680 Study Corridor Travel Times, AM Peak Period

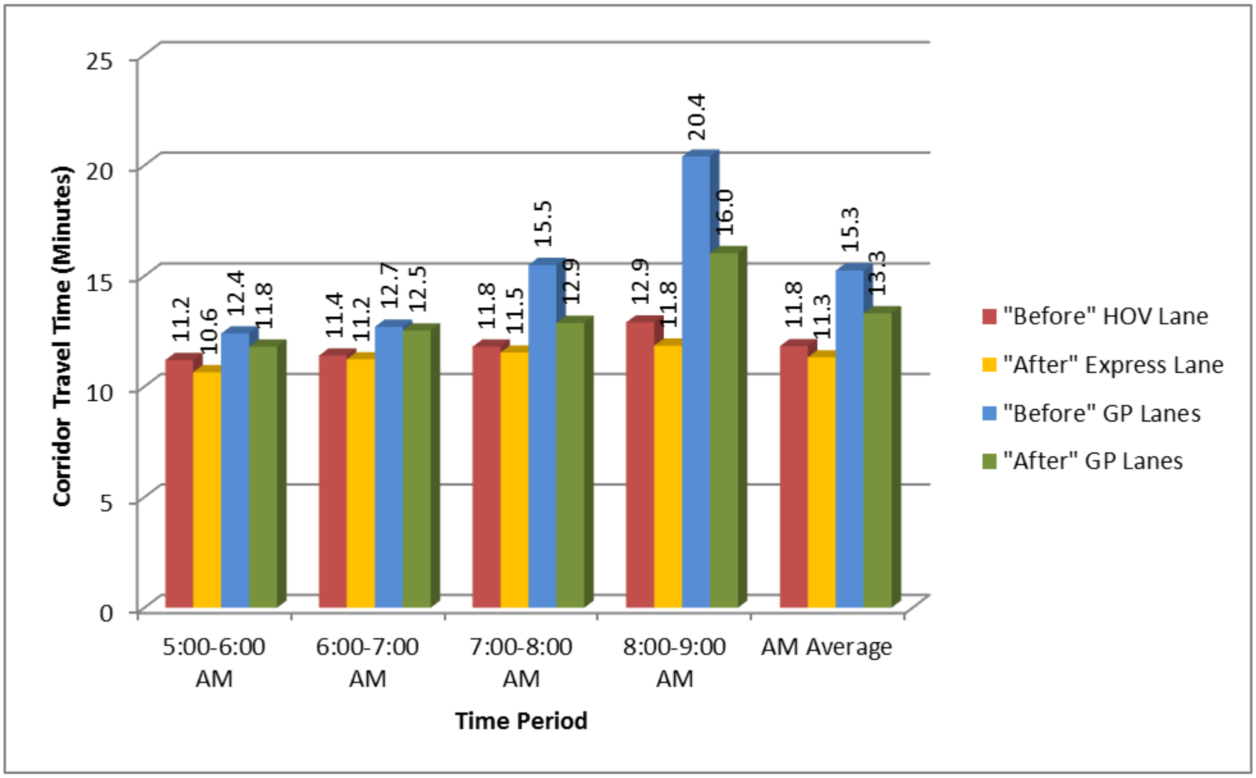
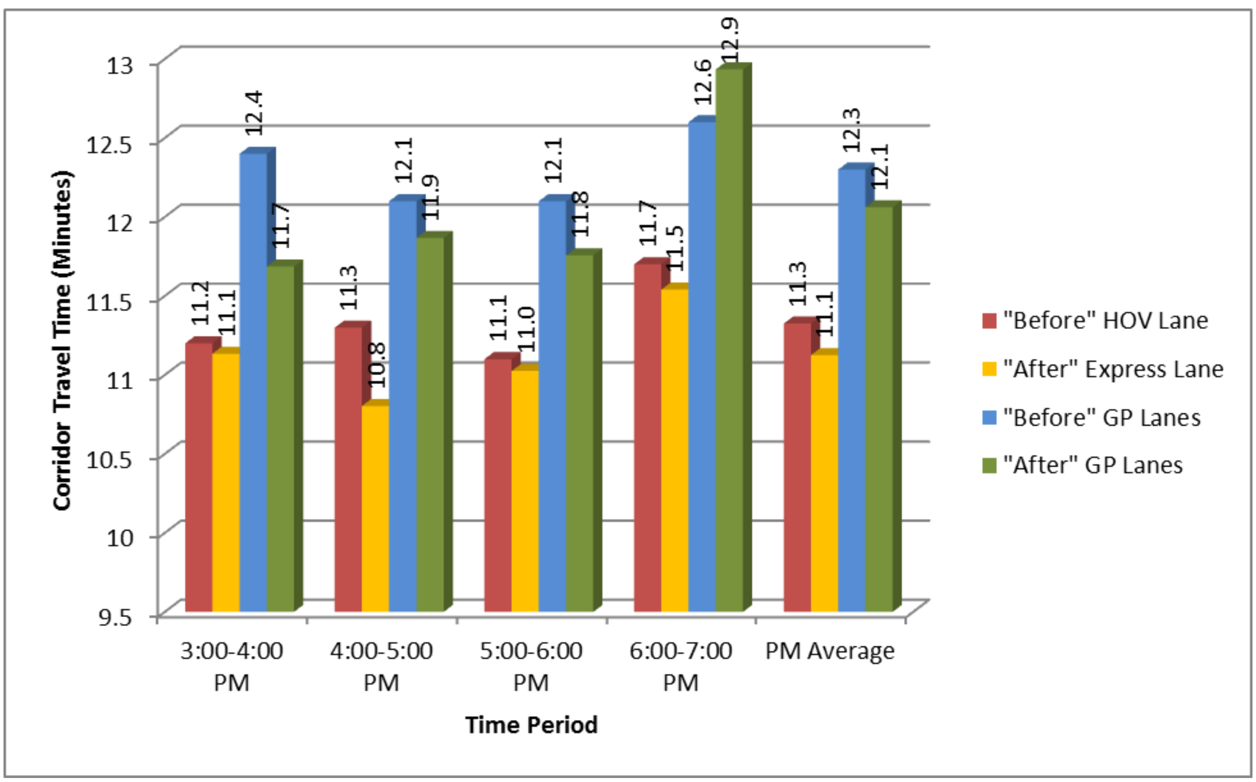


Figure 5: Southbound I-680 Study Corridor Travel Times, PM Peak Period



Study Corridor HOV/Express Lane Travel Time Savings

During the "Before" study, the maximum travel time savings for vehicles utilizing the HOV lane compared to the general purpose lanes was over 7 minutes during the AM peak period, and approximately 1 minute during the PM peak period. During the "After" study, the maximum travel time savings for vehicle using the Express Lane was over 4 minutes during the AM peak period, and approximately 1 minute during the PM peak period. The maximum Express Lane travel time savings in the "After" study were smaller than the "Before" study primarily due to improved travel times in the general purpose lanes. In general, the Express Lane provided about 1 minute of travel time savings during most time periods, and up to 4 minutes during the later portion of the AM peak period compared to using the general purpose lanes. These travel time comparisons are based on non-incident conditions.

Control Corridor Travel Time Comparison

Table 7 shows a comparison of the "Before" and "After" study average travel times in the HOV lane and general purpose lanes for the northbound I-680 control corridor, from Alcosta Boulevard to Livorna Road.

Table 7: Control Corridor Travel Time Comparison

TIME	"Before" Travel Time (minutes)			"After" Travel Time (minutes)			Change in Travel Time (minutes)	
	HOV Lane	General Purpose Lanes	HOV Savings	HOV Lane	General Purpose Lanes	HOV Lane Savings	HOV Lane	General Purpose Lanes
AM PEAK PERIOD								
6:00-7:00 AM	9.9	11.1	1.2	9.5	10.8	1.3	-0.4	-0.3
7:00-8:00 AM	10.7	15.2	4.5	9.8	11.8	2.0	-0.9	-3.4
8:00-9:00 AM	11.8	22.3	10.5	9.8	12.7	2.9	-2.0	-9.6
AM Average	10.8	16.2	5.4	9.7	11.8	2.1	-1.1 (-10.2%)	-4.4 (-27.2%)
PM PEAK PERIOD								
3:00-4:00 PM	10.5	12.6	2.1	10.0	12.3	2.3	-0.5	-0.3
4:00-5:00 PM	12.3	17.3	5.0	14.5	25.1	10.6	+2.2	+7.8
5:00-6:00 PM	13.6	18.7	5.1	15.1	35.1	20.0	+1.5	+16.4
PM Average	12.1	16.2	4.1	13.2	24.2	11.0	+1.1 (+9.1%)	+8.0 (+49.4%)

Control Corridor HOV Lane Travel Times

The travel times in the northbound I-680 control corridor HOV lane decreased during the AM peak period by an average of 1 minute (10 percent decrease) and increased during the PM peak period by an average of 1 minute (9 percent increase).

Control Corridor General Purpose Lane Travel Times

The travel times in the general purpose lanes of northbound I-680 decreased during the AM peak period by an average of 27 percent, and increased during the PM peak period by an average of 49 percent. The largest change in travel time occurred during the 5:00 to 6:00 PM hour, when travel times increased from 18.7 minutes to 35.1 minutes (88 percent increase).

Control Corridor HOV Lane Travel Time Savings

Travel time savings in the control corridor HOV lane were compared for the “Before” and “After” studies. During the “Before” study, the HOV lane saved up to 10.5 minutes during the AM peak period and up to 5 minutes during the PM peak period. In the “After” study, the maximum HOV time savings in the AM peak period had decreased to 3 minutes, but the HOV time savings in the PM peak period had increased to up to 20 minutes, likely due to the increased congestion experienced during the evening commute.

Statistical Analysis of Travel Times

There have been changes in travel times in both the HOV/Express Lane and the general purpose lanes between the “Before” and “After” conditions in both corridors. This section provides an analysis that determines if the changes are statistically significant. Details of the statistical analysis are included in Appendix 9.2.

There were no statistically significant increases in travel time on the study corridor Express Lane or general purpose lanes between the “Before” and “After” conditions.

The two primary questions of interest were:

- Was there a statistically significant increase in travel time on the Express Lane compared to the HOV-only lane due to the addition of toll-paying single-occupant vehicles in the Express Lane?
- Has the Express Lane had a statistically significant impact on travel times in the general purpose lanes due to increased diversion to the Express Lane?

Statistical hypothesis tests were formulated to investigate whether there are statistically significant differences in the observed travel time measurements in the “Before” and “After” conditions. The Student’s t-test was used to evaluate if there were significant differences in the mean travel times before and after the implementation of the Express Lane project.

Study Corridor Statistical Analysis

There were no statistically significant increases in mean travel time on the southbound I-680 study corridor Express Lane or general purpose lanes.

The AM peak period mean travel time on the general purpose lanes decreased by 12 percent, as described in the prior section. There was a high amount of variance in the AM peak period travel times in the “Before” study, due to several very long travel time runs that contributed to the higher mean time. The high variance in the “Before” times meant that standard statistical tests could not be used to determine the statistical significance of the decrease in mean travel times on the general purpose lanes due to the implementation of the Express Lane.

Control Corridor Statistical Analysis

Drivers in the control corridor HOV lanes did not experience a statistically significant increase in their mean travel time between the "Before" and "After" studies. There was a statistically significant increase in mean travel time on the control corridor general purpose lanes.

Travel Time Variability

Reliability of a freeway system is measured by the amount of variation of travel times. Travel time variability is often as large or a larger concern than average travel time. Freight traffic, especially where just-in-time inventories are being served, is especially sensitive to travel time variability. The following statistics for travel time were computed by time of day to measure travel time variability on the study and control corridors:

- Mean travel time by time of day
- Standard Deviation of travel time by time of day
- Coefficient of Variation of travel time by time of day

The mean travel time can be used as a measure of central tendency for the data. The standard deviation provides the information of the variability of the travel time on the study and control corridors. The Coefficient of Variation is the ratio of the standard deviation to the mean. The Coefficient of Variation is useful because it puts the standard deviation of data in context of the mean of the data. The Coefficient of Variation is a dimensionless number. This instead of the standard deviation can be used to compare the different mean travel times on the study and control corridors at different times of the day.

Detailed tables of travel time variability statistics are included in Appendix 9.3.

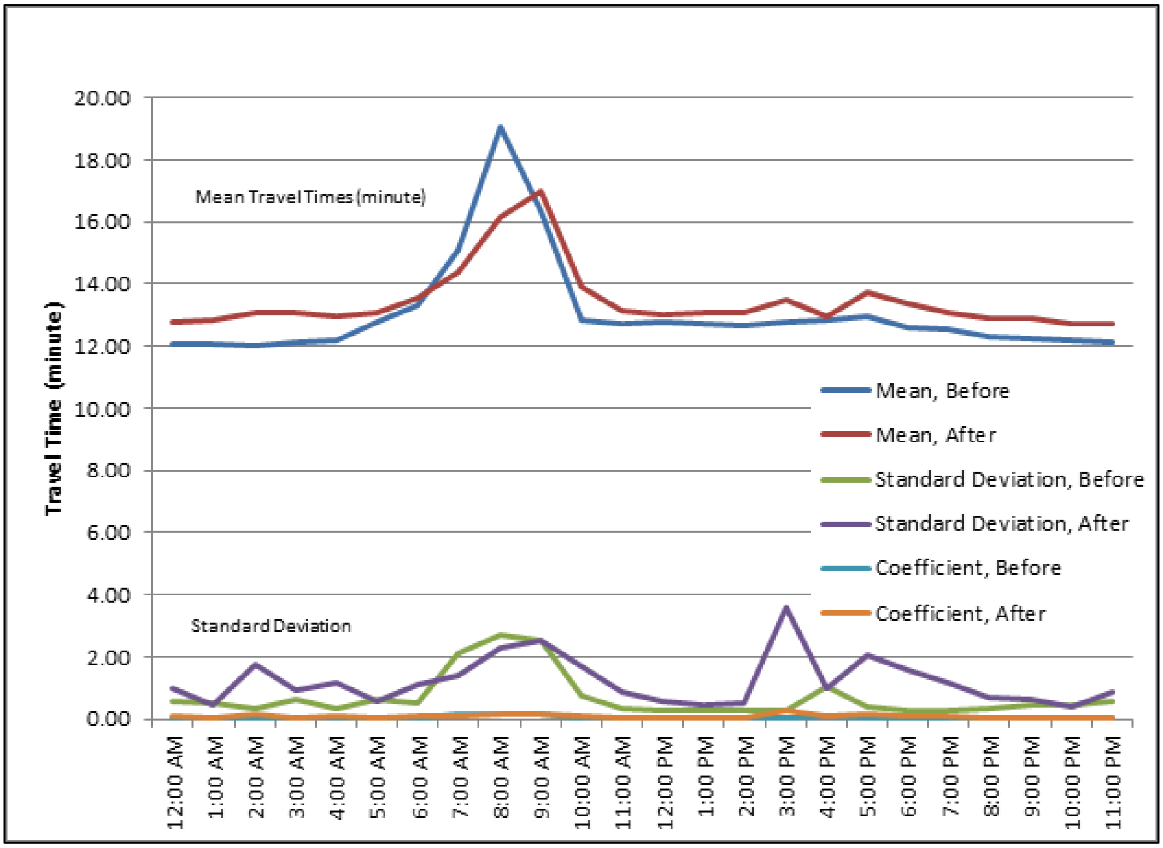
The Express Lane provided lower mean travel times and similar levels of travel time variability compared to "Before" conditions for the AM peak period, indicating that average corridor operations were improved but there was no change in the effects of incidents and temporary blockages.

Study Corridor Travel Time Variability

The mean travel times, standard deviation and coefficient of variation for the southbound I-680 travel times are compared in Figure 6. The mean travel time for all lanes combined was lower in the "After" conditions than in the "Before" conditions during the AM peak period. After the 9:00 AM end of the former HOV lane operation, the mean travel times in the "After" conditions tended to be higher than the "Before" condition. This indicates that the Express Lane is most effective at decreasing average corridor times during the peak AM commute period.

The travel time variability in the "After" condition, based on standard deviation, was similar to the "Before" conditions for the AM period, but more variable during the PM period. This indicates that the continuous access HOV lane in the "Before" condition may have allowed greater opportunities to maneuver past intermittent PM peak period congestion than the restricted-access Express Lane.

Figure 6: Study Corridor Travel Time Variability



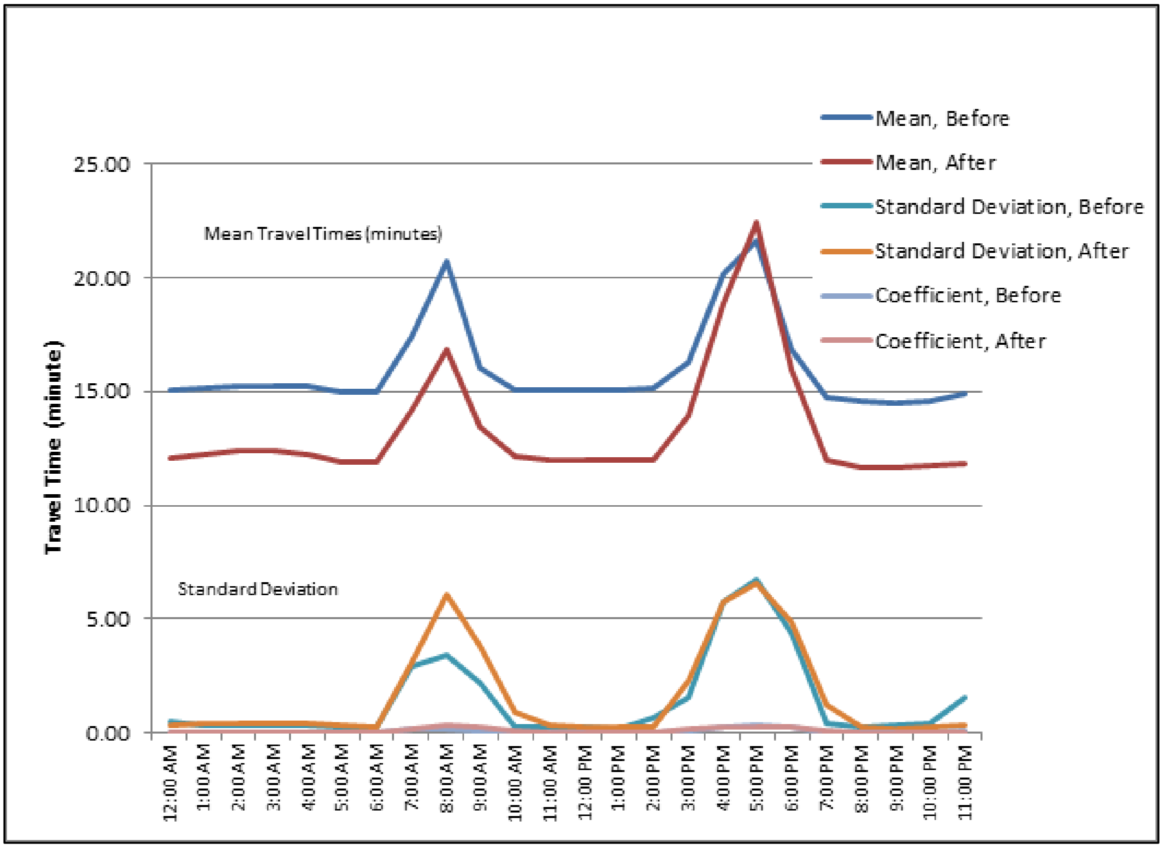
Control Corridor Travel Time Variability

The mean travel times, standard deviation and coefficient of variation for the northbound I-680 control corridor travel times are compared in Figure 7.

The travel time variability (measured by standard deviation) was similar for the "Before" and "After" conditions for hours after 10:00 AM. However, the travel times were more variable in the "After" conditions during the AM peak period from 7:00 to 10:00 AM. In this regard, the highest reported hourly increase in VMT throughput on the control corridor (12 percent) was observed during the 8:00 to 9:00 AM hour as discussed in the later sections of this chapter. This increase in travel demand may have contributed to the increase in travel time variability. The total increases in VMT throughput during the PM peak period were similar to the AM increases, but not as concentrated in a single peak hour.

The mean travel times from the 511.org data for the control corridor cannot be directly compared, due to inconsistencies in the lengths of segments reported for the "Before" and "After" conditions. The travel times for the "Before" condition were reported from I-580 to SR 24 (16 miles), but the travel times for the "After" conditions were reported for the shorter segment from Alcosta Boulevard to Livorna Road (11.3 miles). However, the variability measures can still be compared.

Figure 7: Control Corridor Travel Time Variability



Note: The distances of reported travel are different. "Before" was 16 miles and "After" was 11.3 miles.

5.2 TRAVEL SPEED EVALUATION

Travel speeds are evaluated for overall corridor-wide average and each individual segment of the corridor. The travel speeds are based on the same data as the travel time evaluation: floating car surveys, supplemented by detector information from the PeMS system.

Travel speeds during the AM peak period in the "After" study increased by up to 6 mph in the Express Lane and by up to 11 mph in the general purpose lanes compared to the "Before" study. Implementation of the Express Lane improved the travel speeds, particularly in the general purpose lanes, compared to the "Before" study. Travel speeds in the Express Lane are the same or faster than travel speeds in the prior HOV lane.The speed differential between the Express Lane and the general purpose lanes continues to be the highest at the most congested segment between Washington Boulevard and Auto Mall Parkway/Durham Road.

Study Corridor Travel Speed

The evaluation time periods for travel speeds on the study corridor are 5:00 to 9:00 AM and 3:00 to 7:00 PM. These evaluation hours include the majority of the busiest weekday commute hours in the morning and the afternoon and are consistent with the hours of operation of the HOV lane during the 2008 "Before" study.

Study Corridor Corridorwide Average Travel Speed

Table 8 shows a comparison of the "Before" and "After study average speeds in the HOV/Express Lane and general purpose lanes for each hour in the AM peak period for the study corridor.

Table 8: Study Corridor Travel Speed Comparison

Time	"Before" Study Speed (mph)		"After" Study Speed (mph)		Change in Speed (mph)	
	HOV	General Purpose Lanes	Express Lane	General Purpose Lanes	HOV/Express Lane	General Purpose Lanes
AM PEAK PERIOD						
5:00-6:00 AM[1]	70	63	73	66	+3	+3
6:00-7:00 AM[1]	68	61	69	62	+1	+1
7:00-8:00 AM	66	50	68	60	+2	+10
8:00-9:00 AM	60	38	66	49	+6	+11
AM Average	66	53	69	59	+3	+6
PM PEAK PERIOD						
3:00-4:00 PM	70	63	70	67	0	+4
4:00-5:00 PM	69	64	72	66	+3	+2
5:00-6:00 PM	70	64	71	66	+1	+2
6:00-7:00 PM[1]	67	62	68	60	+1	-2
PM Average	69	63	70	65	+1	+2

[1] *From PeMS data.*

The results show that the average travel speed was always higher in the HOV lane and in the Express Lane as compared to the travel speed in the general purpose lanes. The maximum speed differential during the "Before" study was 22 mph, during the 8:00 to 9:00 AM hour. The maximum speed differential during the "After" study was 17 mph during the same time period. The difference is smaller in the "After" study due to increased travel speeds in the general purpose lanes.

The "After" study average speeds in the Express Lane increased by 3 mph compared to the "Before" study average speeds in the HOV lane during the AM peak period, and by 1 mph during the PM peak period. The average speeds in the general purpose lanes were 2 mph higher in the "After" studies for the PM peak period, and 6 mph higher in the AM peak period. In particular, during the last two hours of the AM peak period, the average speeds in the "After" study were 10 to 11 miles per hour faster than the "Before" conditions.

Study Corridor Travel Speed by Segment

Average travel speeds for each freeway segment (between each pair of interchanges) were summarized by hour for the HOV/Express Lane and for the general purpose lanes. Segment speeds during the single peak hour are compared for the AM peak hour of 8:00 to 9:00 AM in Figure 8 and for the PM peak hour of 5:00 to 6:00 PM in Figure 9. The average speeds by segment are listed for each hour in the AM peak period in Table 9 and for each hour in the PM peak period in Table 10. Graphs showing comparative travel speeds for the individual hours are included in Appendix 9.1.

During the AM peak period in the "After" study, all Express Lane segments operated faster than 45 mph. The weave segment south of SR 84 to Andrade Road that serves the vehicles trying to access the entrance to the Express Lane operated at 46 mph between 8:00 and 9:00 AM. Other than the weave segment, which is prior to the Express Lane entrance, the speeds on the Express Lane were similar to or faster than the speeds on the HOV lane during the "Before" study.

The AM peak period speed results in the general purpose lanes in the "After" study were generally improved compared to the speed results in the "Before" study, with improvement in the majority of segments in the mid portion of the corridor. In particular, the "After" results had higher speeds in segments that reported speeds less than 45 mph in the 7:00 to 8:00 AM hour or speeds less than 40 mph from 8:00 to 9:00 AM during the "Before" study. The "After" study reported significantly slower speeds (21 mph compared to 37 mph) on one segment during the AM peak hour between 8:00 and 9:00 AM, between Washington Boulevard and Auto Mall Parkway/Durham Road. This location could be impacted by drivers attempting to weave across lanes from the Express Lane (exiting illegally from the Washington Boulevard Express Lane ingress) to the off-ramp at Auto Mall Parkway/Durham Road, since there is no legal egress from the Express Lane exists prior to this off-ramp.

During the PM peak period, the "After" study travel time surveys reported improved speeds of 64 mph or more in the Express Lane and speeds of 55 and 60 mph or better in the general purpose lanes for all hours. The only segment that showed reduced speeds was between Washington Boulevard and Auto Mall Parkway/Durham Road, with a decrease from approximately 66 mph to 55 mph. Decreased speeds were also reported on this segment during the AM peak period.

Figure 8: Study Corridor Segment Speeds - AM Peak Hour

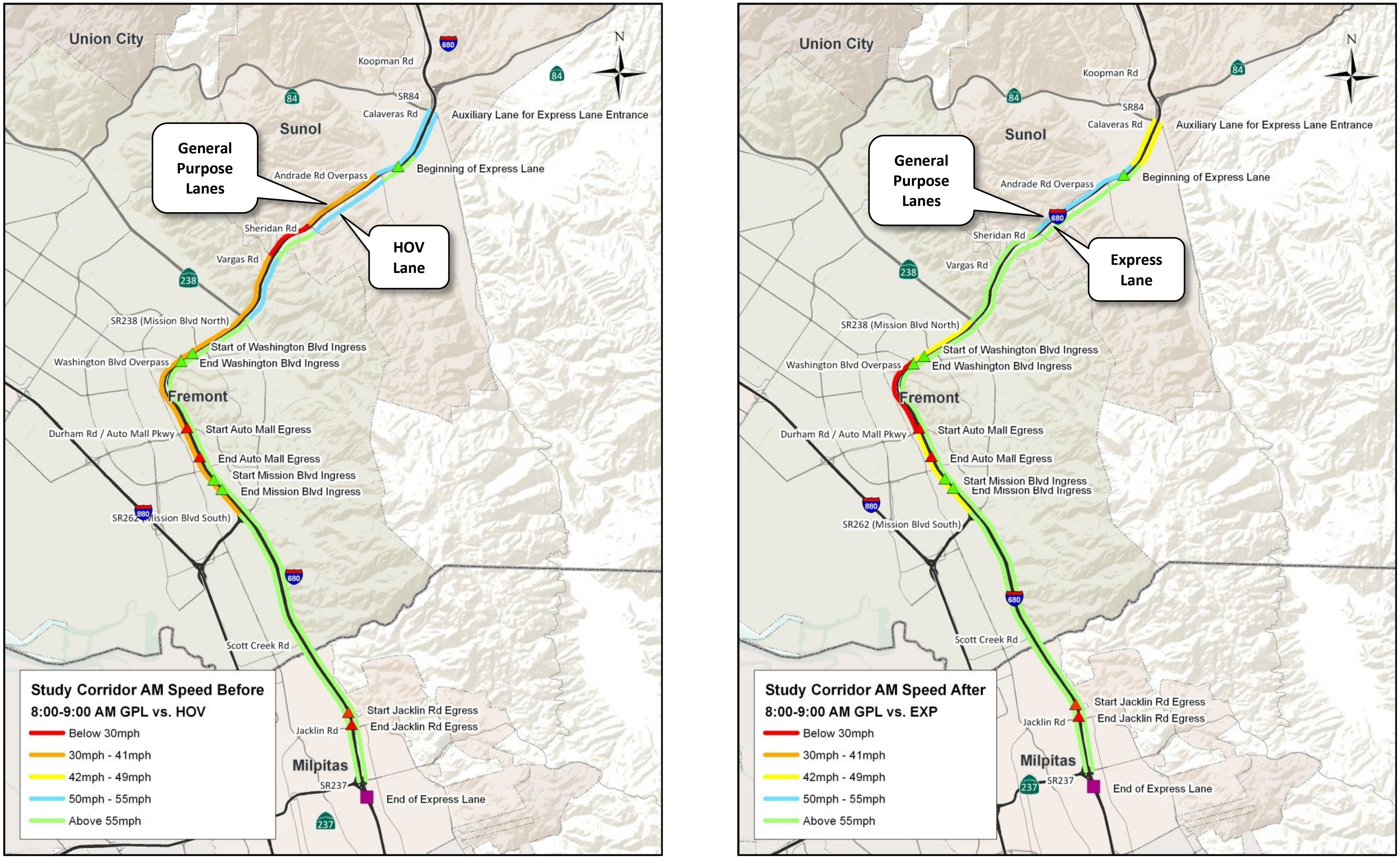


Figure 9: Study Corridor Segment Speeds - PM Peak Hour

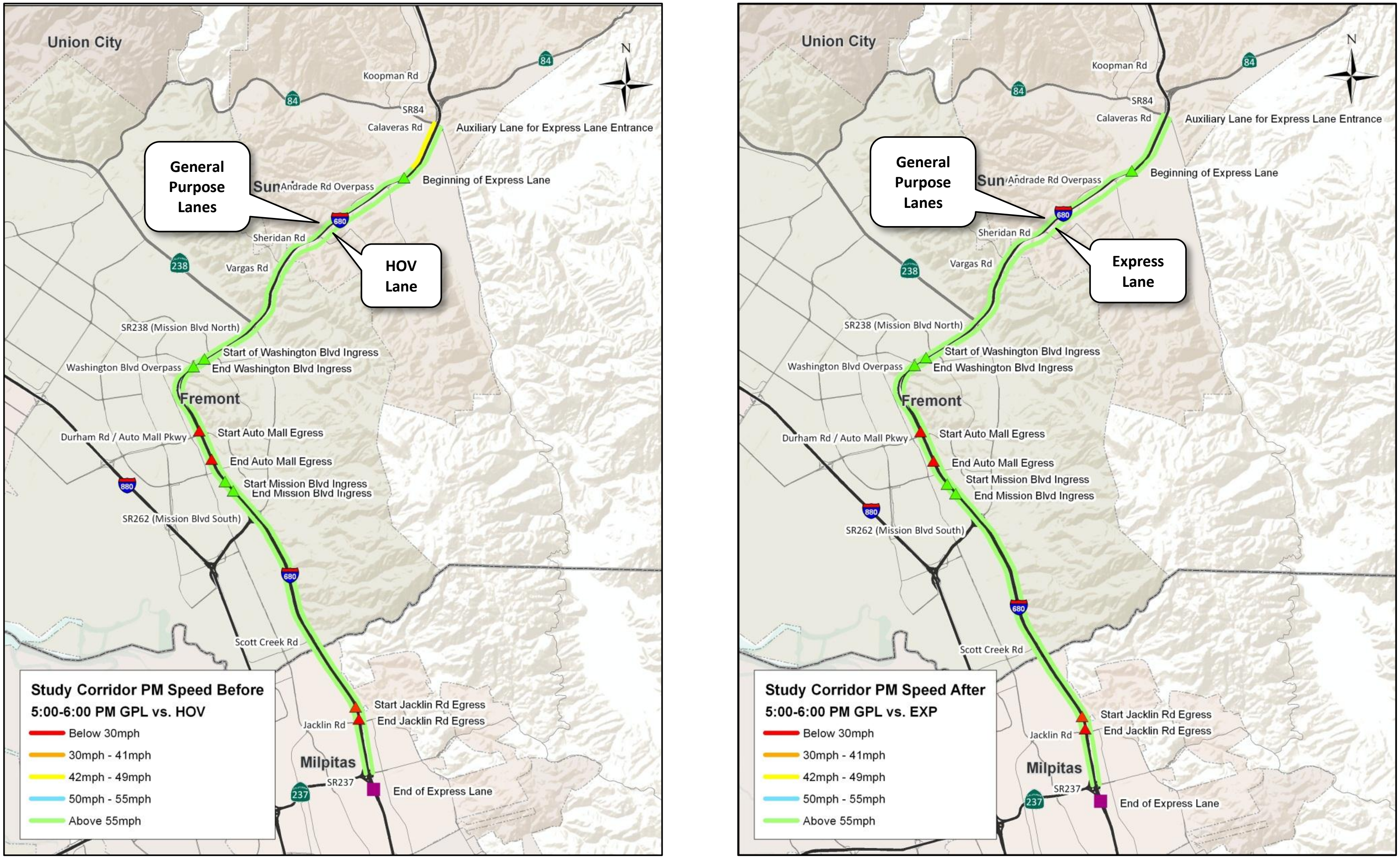


Table 9: Study Corridor Speed by Hour and Segment – AM Peak Period

Segment Limits		Length	HOV/Express Lane		General Purpose Lanes	
From	**To**	**(miles)**	**Before**	**After**	**Before**	**After**
5:00-6:00 AM[1]						
SR 84/Vallecitos	SR 237/Calaveras	- -	72	73	65	66
6:00-7:00 AM[1]						
SR 84/Vallecitos	SR 237/Calaveras	- -	70	69	63	62
7:00-8:00 AM						
Weave Lane SR 84/Vallecitos	*Begin Express Lane Calaveras Rd*	*0.3*	*55*	*60*	42	58
Calaveras Rd	Andrade Rd	1.34	63	65	52	50
Andrade Rd	Sheridan Rd	1.39	67	64	52	51
Sheridan Rd	Vargas Rd	0.82	71	68	60	58
Vargas Rd	SR 238/Mission	1.09	67	71	59	63
SR 238/Mission	Washington Blvd	1.14	66	70	45	61
Washington Blvd	Auto Mall/Durham	1.3	67	66	43	50
Auto Mall/Durham	SR 262/Mission	1.61	68	67	44	57
SR 262/Mission	Scott Creek Rd	2.17	69	69	61	67
Scott Creek Rd	Jacklin Rd	1.47	72	69	65	67
Jacklin Rd	SR 237/Calaveras	0.8	65	72	58	63
8:00-9:00 AM						
Weave Lane SR 84 (Vallecitos)	*Begin Express Lane Calaveras Rd*	*0.3*	*54*	46	50	44
Calaveras Rd	Andrade Rd	1.34	64	65	50	50
Andrade Rd	Sheridan Rd	1.39	55	66	38	53
Sheridan Rd	Vargas Rd	0.82	59	66	25	59
Vargas Rd	SR 238/Mission	1.09	55	72	33	57
SR 238/Mission	Washington Blvd	1.14	56	66	32	44
Washington Blvd	Auto Mall/Durham	1.3	64	59	37	21
Auto Mall/Durham	SR 262/Mission	1.61	68	63	36	41
SR 262/Mission	Scott Creek Rd	2.17	69	71	61	65
Scott Creek Rd	Jacklin Rd	1.47	71	73	66	67
Jacklin Rd	SR 237/Calaveras	0.8	58	72	59	66

[1] *Corridorwide average based on PeMS data*

Table 10: Study Corridor Speed by Hour and Segment – PM Peak Period

Segment Limits		Length	HOV/Express Lane		General Purpose Lanes	
From	To	(miles)	Before	After	Before	After
3:00-4:00 PM						
Weave Lane SR 84 (Vallecitos)	*Begin Express Lane Calaveras Rd*	*0.3*	*55*	64	45	62
Calaveras Rd	Andrade Rd	1.34	67	69	63	62
Andrade Rd	Sheridan Rd	1.39	69	70	62	61
Sheridan Rd	Vargas Rd	0.82	73	70	68	64
Vargas Rd	SR 238/Mission	1.09	74	73	67	64
SR 238/Mission	Washington Blvd	1.14	72	72	67	66
Washington Blvd	Auto Mall/Durham	1.3	72	70	66	55
Auto Mall/Durham	SR 262/Mission	1.61	74	71	65	65
SR 262/Mission	Scott Creek Rd	2.17	73	69	66	68
Scott Creek Rd	Jacklin Rd	1.47	72	69	64	67
Jacklin Rd	SR 237/Calaveras	0.8	65	70	59	66
4:00-5:00 PM						
Weave Lane SR 84 (Vallecitos)	*Begin Express Lane Calaveras Rd*	*0.3*	*57*	70	52	66
Calaveras Rd	Andrade Rd	1.34	66	73	65	62
Andrade Rd	Sheridan Rd	1.39	69	73	62	58
Sheridan Rd	Vargas Rd	0.82	71	69	67	62
Vargas Rd	SR 238/Mission	1.09	71	72	67	64
SR 238/Mission	Washington Blvd	1.14	70	73	68	67
Washington Blvd	Auto Mall/Durham	1.3	70	71	67	56
Auto Mall/Durham	SR 262/Mission	1.61	72	72	67	66
SR 262/Mission	Scott Creek Rd	2.17	72	73	66	66
Scott Creek Rd	Jacklin Rd	1.47	72	72	66	64
Jacklin Rd	SR 237/Calaveras	0.8	60	73	61	61
5:00-6:00 PM						
Weave Lane SR 84 (Vallecitos)	*Begin Express Lane Calaveras Rd*	*0.3*	*62*	68	48	63
Calaveras Rd	Andrade Rd	1.34	67	72	65	64
Andrade Rd	Sheridan Rd	1.39	70	72	62	62
Sheridan Rd	Vargas Rd	0.82	72	65	67	64
Vargas Rd	SR 238/Mission	1.09	71	71	68	65
SR 238/Mission	Washington Blvd	1.14	73	73	68	66
Washington Blvd	Auto Mall/Durham	1.3	71	72	67	55
Auto Mall/Durham	SR 262/Mission	1.61	71	73	67	66
SR 262/Mission	Scott Creek Rd	2.17	75	69	66	67
Scott Creek Rd	Jacklin Rd	1.47	74	69	66	63
Jacklin Rd	SR 237/Calaveras	0.8	67	70	61	63
6:00-7:00 PM[1]						
SR 84/Vallecitos	SR 237/Calaveras	- -	69	68	64	60

[1]*Corridorwide average based on PeMS data*

Control Corridor Travel Speed

The time periods for the control corridor travel speed evaluation are consistent with the HOV lane enforcement period and the evaluation for the “Before” study, from 6:00 to 9:00 AM and 3:00 to 6:00 PM.

Control Corridor Corridorwide Average Travel Speed

The northbound I-680 control corridor “Before” and “After” study average speeds in the HOV lane and general purpose lanes for each hour in the study period are shown in Table 11.

Table 11: Control Corridor Travel Speed Comparison

Time	“Before” Study Speed (mph)		“After” Study Speed (mph)		Change in Speed (mph)	
	HOV Lane	General Purpose Lanes	HOV Lane	General Purpose Lanes	HOV Lane	General Purpose Lanes
AM PEAK PERIOD						
6:00-7:00 AM	67	60	71	63	+4	+3
7:00-8:00 AM	62	44	69	57	+7	+13
8:00-9:00 AM	56	30	69	53	+13	+23
AM Average	62	45	70	58	+8	+13
PM PEAK PERIOD						
3:00-4:00 PM	63	53	67	55	+4	+2
4:00-5:00 PM	54	38	47	27	-7	-9
5:00-6:00 PM	49	36	45	19	-4	-17
PM Average	55	42	53	34	-2	-8

The average speeds in the Express Lane in the “After” study were 8 miles per hour (mph) higher than the average speeds in the HOV lane during the AM peak period, and 2 mph less during the PM peak period. The average speeds in the general purpose lanes were 13 mph higher in the “After” study for the AM peak period, and 8 mph higher in the PM peak period. The general purpose lanes slowed significantly to average speeds of 19 to 27 mph between 4:00 and 6:00 PM.

Control Corridor Travel Speed by Segment

Average travel speeds for each freeway segment (between each pair of interchanges) were summarized by hour for the HOV lane and for the general purpose lanes. Segment speeds during the one hour peak hour during the peak period are compared for the AM peak hour in Figure 10 and for the PM peak hour in Figure 11. The average speeds by segment and hour are listed in Table 12 for the AM peak period and Table 13 for the PM peak period. Graphs showing comparative travel speeds for the individual hours are included in Appendix 9.1.

Figure 10: Northbound I-680 Control Corridor Segment Speeds, AM Peak Hour

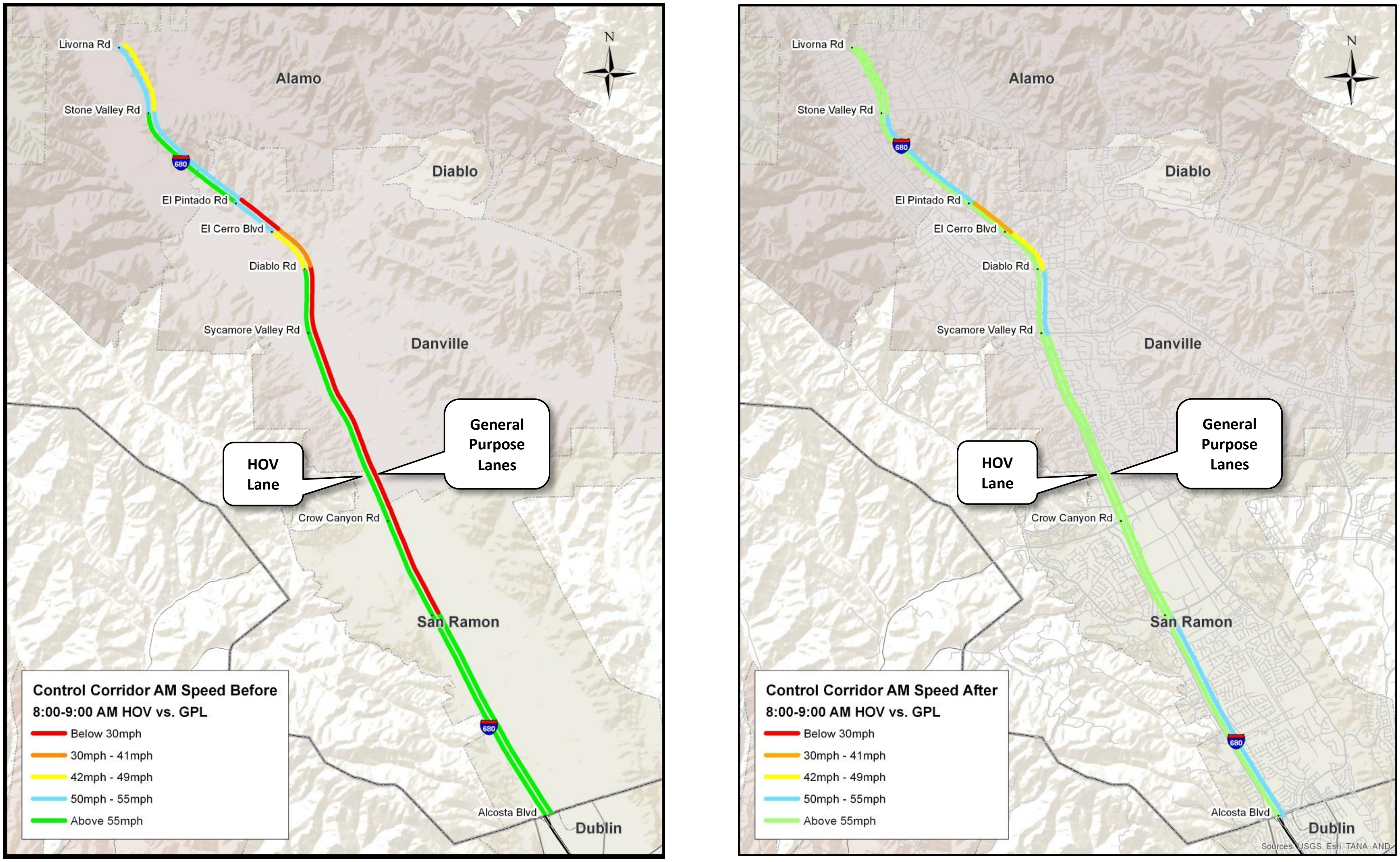


Figure 11: Northbound I-680 Control Corridor Segment Speeds, PM Peak Hour

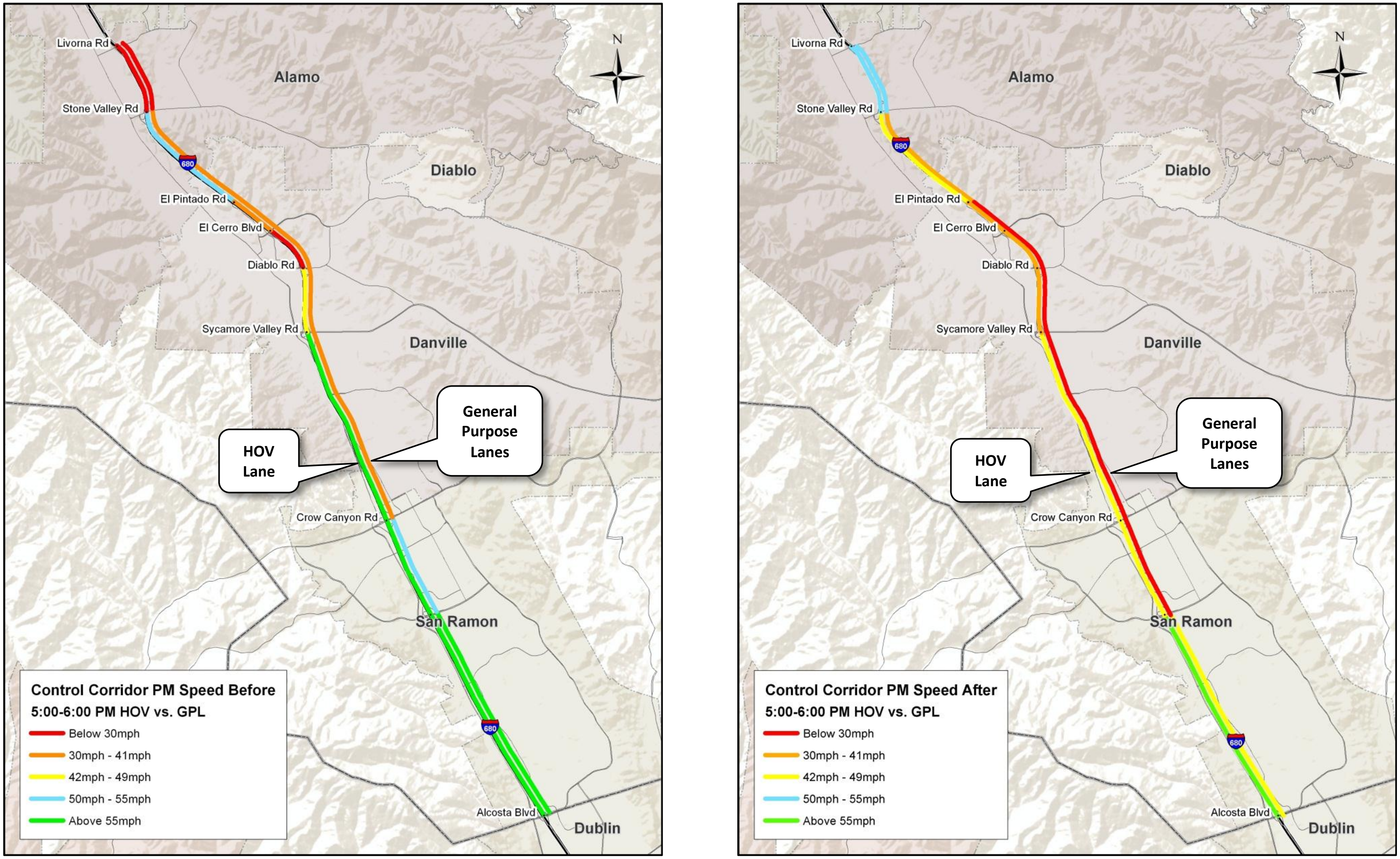


Table 12: Control Corridor Speed by Hour and Segment – AM Peak Period

Segment Limits			HOV Lane		General Purpose Lanes	
From	To	Length (miles)	Before	After	Before	After
6:00-7:00 AM						
Alcosta Blvd	Livorna Rd	- -	73	75	65	67
7:00-8:00 AM						
Alcosta Blvd	Bollinger Canyon Rd	2.83	61	70	59	61
Bollinger Canyon Rd	Crow Canyon Rd	1.28	72	71	65	68
Crow Canyon Rd	Sycamore Valley Rd	2.51	65	70	50	65
Sycamore Valley Rd	Diablo Rd	0.79	64	66	54	52
Diablo Rd	El Cerro Blvd	0.62	65	65	48	42
El Cerro Blvd	El Pintado Rd	0.57	62	67	43	47
El Pintado Rd	Stone Valley Rd	1.59	60	68	43	57
Stone Valley Rd	Livorna Rd	0.89	63	71	59	65
8:00-9:00 AM						
Alcosta Blvd	Bollinger Canyon Rd	2.83	60	70	62	55
Bollinger Canyon Rd	Crow Canyon Rd	1.28	60	72	17	63
Crow Canyon Rd	Sycamore Valley Rd	2.51	56	71	19	62
Sycamore Valley Rd	Diablo Rd	0.79	58	70	23	53
Diablo Rd	El Cerro Blvd	0.62	48	65	40	42
El Cerro Blvd	El Pintado Rd	0.57	53	63	28	30
El Pintado Rd	Stone Valley Rd	1.59	58	67	51	55
Stone Valley Rd	Livorna Rd	0.89	51	72	46	62

Speeds in the northbound I-680 control corridor HOV lane have improved between 2008 and 2012 for the AM peak period and declined for the PM peak period. During the “Before” study, speeds under 20 mph and under 30 mph were experienced in the mid-portion of the corridor approaching El Cerro Boulevard. During the “After” study, all HOV segments operated at speeds of 63 mph or higher during all AM peak hours.

Speeds also improved generally in the general purpose lanes during the AM peak period. During the “Before” study, there were speeds of 40 mph or less from Bollinger Canyon Road to El Pintado Road, a distance of nearly six miles, with particularly slow speeds of 23 mph or less for the 4.6 miles to Diablo Road. In the “After” study, speeds improved and there were speeds of 42 mph or less for only a little more than a mile, from Diablo Road to El Pintado Road while the rest of the corridor was showing higher speeds.

During the PM peak period, the northbound I-680 control corridor HOV lane had some locations with speeds less than 35 mph during the “Before” study, particularly at the end of the corridor near Livorna Road. In the “After” study, these speeds of below 30 mph no longer occurred, but there were several more segments with speeds of 35 mph or less in the center of the corridor approaching Stone Valley Road.

Table 13: Control Corridor Speed by Hour and Segment – PM Peak Period

Segment Limits			HOV Lane		General Purpose Lanes	
From	To	Length (miles)	Before	After	Before	After
3:00-4:00 PM						
Alcosta Blvd	Bollinger Canyon Rd	2.83	65	71	60	63
Bollinger Canyon Rd	Crow Canyon Rd	1.28	72	71	64	64
Crow Canyon Rd	Sycamore Valley Rd	2.51	69	71	61	62
Sycamore Valley Rd	Diablo Rd	0.79	62	67	50	55
Diablo Rd	El Cerro Blvd	0.62	52	63	42	49
El Cerro Blvd	El Pintado Rd	0.57	49	60	39	44
El Pintado Rd	Stone Valley Rd	1.59	63	65	51	53
Stone Valley Rd	Livorna Rd	0.89	58	62	55	52
4:00-5:00 PM						
Alcosta Blvd	Bollinger Canyon Rd	2.83	63	70	62	61
Bollinger Canyon Rd	Crow Canyon Rd	1.28	72	63	65	42
Crow Canyon Rd	Sycamore Valley Rd	2.51	66	53	45	33
Sycamore Valley Rd	Diablo Rd	0.79	56	48	36	23
Diablo Rd	El Cerro Blvd	0.62	61	41	32	18
El Cerro Blvd	El Pintado Rd	0.57	54	37	26	29
El Pintado Rd	Stone Valley Rd	1.59	49	44	34	29
Stone Valley Rd	Livorna Rd	0.89	28	53	29	49
5:00-6:00 PM						
Alcosta Blvd	Bollinger Canyon Rd	2.83	64	62	60	42
Bollinger Canyon Rd	Crow Canyon Rd	1.28	59	49	54	26
Crow Canyon Rd	Sycamore Valley Rd	2.51	55	46	35	16
Sycamore Valley Rd	Diablo Rd	0.79	44	39	32	21
Diablo Rd	El Cerro Blvd	0.62	26	38	35	23
El Cerro Blvd	El Pintado Rd	0.57	37	39	33	27
El Pintado Rd	Stone Valley Rd	1.59	49	45	35	36
Stone Valley Rd	Livorna Rd	0.89	23	53	24	54

The control corridor speeds in the general purpose lanes were generally slower in the “After” study than in the “Before” study, with several segments that operated generally between 30 and 40 mph in the “Before” study worsening to speeds generally between 20 and 30 mph in the “After” study. With northbound I-680 being the peak commute direction in the control corridor for the PM peak period, the peak commute congestion appears to have increased. This is a different finding than the speed and LOS results for the study corridor, where the speeds and LOS generally improved in the general purpose lanes.

5.3 VEHICLE AND PERSON THROUGHPUT

Vehicle throughput is a measurement of the total number of vehicles traveling on one or more segments of the corridor, while person throughput measures the total numbers of persons (accounting for vehicle occupancies) on the corridor. Person volumes were derived by multiplying vehicle counts by the appropriate average vehicle occupancies, from the occupancy surveys, for each lane type and time period.

Study Corridor Throughput

Study Corridor Vehicle Throughput

Overall vehicle throughput increased in the corridor in most locations. Comparing "Before" and "After" conditions, vehicle throughput showed modest to notable increases ranging between 0.6 percent and 11 percent at all 4 survey locations in the AM peak period. For the PM peak period and the 12-hour daytime period, improvements were observed at the three northern locations ranging between 1.4 percent and 38 percent for the PM peak period and 3.2 percent and 19.8 percent for the daytime period. The one location showing reductions during both the PM peak and daytime periods is at SR 237/Calaveras Boulevard.

The vehicle volumes at four survey locations were tabulated for "Before" and "After" conditions (Table 14). Additional detail by lane type (Express Lane, general purpose lanes) is listed in Appendix 9.4.

Table 14: Southbound I-680 Study Corridor Total Vehicle Throughput

Survey Location	Before Vehicle Volume	After Vehicle Volume	Difference	Percent Change
Andrade Road				
AM Peak 2 Hours (7-9 AM)	11,010	11,080	+70	+0.6%
PM Peak 4 Hours (3-7 PM)	11,910	14,240	+2,330	+19.6%
Daytime 12 Hours (7 AM-7 PM)	40,210	45,520	+5,310	+13.2%
Washington Boulevard				
AM Peak 2 Hours (7-9 AM)	12,320	12,720	+400	+3.3%
PM Peak 4 Hours (3-7 PM)	14,490	14,690	+200	+1.4%
Daytime 12 Hours (7 AM-7 PM)	49,170	50,920	+1,750	+3.5%
SR 262/Mission Boulevard				
AM Peak 2 Hours (7-9 AM)	10,660	10,720	+60	+0.6%
PM Peak 4 Hours (3-7 PM)	12,600	17,370	+4,770	+37.9%
Daytime 12 Hours (7 AM-7 PM)	40,850	48,930	+8,080	+19.8%
SR 237/Calaveras Boulevard				
AM Peak 2 Hours (7-9 AM)	7,000	7,760	+760	+10.8%
PM Peak 4 Hours (3-7 PM)	17,660	15,340	-2,320	-13.1%
Daytime 12 Hours (7 AM-7 PM)	41,850	39,440	-2,410	-5.8%

During the AM peak period, total vehicle volumes show modest increases at three of the survey locations and increased by 11 percent at the SR 237/Calaveras survey location. It is possible that the 0.6

percent change in vehicle throughput shown at the Andrade location is on the low end of a potential range of increases. The "After" vehicle volumes used for this analysis are based on data from vehicle detectors installed as part of the Express Lane project. However, two other traffic count sources that have data for one to three of the above locations, including Andrade Road, were Caltrans loop detectors and a Wavetronix traffic count conducted for this study. These sources indicated volumes to be generally higher than volumes reported in Table 14. In particular, the AM peak period volumes at the Andrade Road location were 22 percent to 26 percent higher than the 11,080 volume shown in Table 14. Therefore, this provides a conservative estimate of "After" conditions throughput.

Volumes at Washington Boulevard and particularly at SR 262/Mission Boulevard may be constrained during the 7:00-9:00 AM peak period by traffic bottlenecks, described in section 5.4.

The PM peak period and 12 daytime hour volumes increased significantly at 2 of the 4 locations, Andrade Road and SR 262/Mission Boulevard. This indicates that the Express Lane helped to accommodate an increase in demand after the AM peak period in the northern and central parts of the corridor. The decrease in volume at SR 237/Calaveras indicates a decrease in travel demand in the southern part of the study corridor. This decrease appears to be due to a combination of factors including the completion of improvements at the interchange of I-880 with SR 262/Mission Boulevard that would divert traffic away from I-680 to go to Santa Clara County, general employment changes and implementation of the Express Lane. The potential impact of I-880/SR 262/Mission Boulevard improvements on SB I-680 traffic is discussed in detail in Section 6.4.

Additional data on traffic volumes on the State Route 84 ramp to southbound I-680 are included in Appendix 9.4.

Study Corridor Person Throughput

Person throughput showed slight declines to modest increases (-1.0 percent to 2.4 percent) during the AM peak period, and increased by 19 percent to 38 percent at 2 locations during the PM peak and daytime periods. Similar to the vehicle throughput, person throughput showed notable decreases at the southern survey location, due to the same reasons.

The person throughput is based on vehicle volumes multiplied by observed average vehicle occupancies (Table 15). Additional detail by lane type (Express Lane, general purpose lanes) is listed in Appendix 9.4.

The AM peak period person throughput in the "After" study was similar (within 3 percent difference) to the "Before" conditions at all four survey locations. At the SR 237/Calaveras Road survey location, where vehicle throughput increased by 10.8 percent, the person throughput increased by only 2.4 percent. The differences between vehicle throughput and person throughput changes are due to lower average vehicle occupancies in the "After" study compared to the "Before" study, as described in Section 5.5.

Table 15: Southbound I-680 Study Corridor Total Person Throughput

Survey Location	Before Person Volume	After Person Volume	Difference	Percent Change
Andrade Road				
AM Peak 2 Hours (7-9 AM)	12,800	12,670	-130	-1.0%
PM Peak 4 Hours (3-7 PM)	14,860	17,720	+2,860	+19.3%
Daytime 12 Hours (7 AM-7 PM)	47,670	54,410	+6,740	+14.2%
Washington Boulevard				
AM Peak 2 Hours (7-9 AM)	14,210	13,960	-250	-1.8%
PM Peak 4 Hours (3-7 PM)	17.890	18,020	+130	+0.7%
Daytime 12 Hours (7 AM-7 PM)	59,240	59,550	+310	+0.5%
SR 262/Mission Boulevard				
AM Peak 2 Hours (7-9 AM)	12,130	11,940	-190	-1.5%
PM Peak 4 Hours (3-7 PM)	15,580	21,550	+5,970	+38.3%
Daytime 12 Hours (7 AM-7 PM)	48,640	58,510	+9,870	+20.3%
SR 237/Calaveras Boulevard				
AM Peak 2 Hours (7-9 AM)	8,280	8,480	+200	+2.4%
PM Peak 4 Hours (3-7 PM)	22,920	18,980	-3,940	-17.2%
Daytime 12 Hours (7 AM-7 PM)	52,910	46,740	-6,170	-11.7%

Control Corridor Throughput

Control Corridor Vehicle Throughput

The vehicle volumes at the two survey locations on the northbound I-680 control corridor were tabulated for "Before" and "After" conditions (Table 16). Additional detail by lane type (Express Lane, general purpose lanes) is listed in Appendix 9.4.

The control corridor experienced an average 12 percent increase in vehicle volumes at the south end at Alcosta Boulevard, and smaller increases of 5 percent or less at the north end of the corridor at Livorna Road. Increases in throughput at Livorna Road are likely to be smaller because demands are higher and there would be less capacity for volume increases.

Table 16: Northbound I-680 Control Corridor Total Vehicle Throughput

Survey Location	Before Vehicle Volume	After Vehicle Volume	Difference	Percent Change
Alcosta Boulevard				
AM Peak 2 Hours (7-9 AM)	10,390	11,860	+1,470	+14.1%
PM Peak 4 Hours (3-7 PM)	21,470	23,220	+1,750	+8.1%
Daytime 12 Hours (7 AM-7 PM)	55,410	62,180	+6,770	+12.2%
Livorna Road				
AM Peak 2 Hours (7-9 AM)	13,300	13,890	+590	+4.5%
PM Peak 4 Hours (3-7 PM)	26,020	26,220	+200	+0.8%
Daytime 12 Hours (7 AM-7 PM)	68,940	71,340	+2,400	+3.5%

Compared to the study corridor, the control corridor had somewhat larger increases in throughput during the AM peak period (which is the more constrained period in the study corridor). The control corridor did not have the same type of large increases in throughput that occurred at several locations on the study corridor during the PM peak and daytime periods.

Control Corridor Person Throughput

Person throughput on the northbound I-680 control corridor was based on vehicle volumes multiplied by observed average vehicle occupancies (Table 17).

The changes in person throughput follow the same general trends as the changes in vehicle throughput, with larger increases at Alcosta Boulevard than at Livorna Road.

Additional detail by lane type (HOV lane, general purpose lanes) is listed in Appendix 9.4.

Table 17: Northbound I-680 Control Corridor Total Person Throughput

Survey Location	Before Person Volume	After Person Volume	Difference	Percent Change
Alcosta Boulevard				
AM Peak 2 Hours (7-9 AM)	12,060	13,150	+1,090	+9.1%
PM Peak 4 Hours (3-7 PM)	26,620	27,160	+540	+2.0%
Daytime 12 Hours (7 AM-7 PM)	67,050	71,740	+4,690	+7.0%
Livorna Road				
AM Peak 2 Hours (7-9 AM)	16,020	16,930	+910	+5.7%
PM Peak 4 Hours (3-7 PM)	33,090	33,210	+120	+0.4%
Daytime 12 Hours (7 AM-7 PM)	83,560	88,430	+4,870	+5.8%

5.4 BOTTLENECK AND QUEUE EVALUATION

A bottleneck is a specific localized physical constriction of traffic flow. If traffic demand exceeds the capacity of a bottleneck, vehicle queues can form upstream from the bottleneck. The evaluation of bottlenecks and queues identifies the locations of bottlenecks and the length and approximate duration of queues.

The "After" conditions showed slow speeds and queuing for a shorter distance (7.4 vs. 2.9 miles) north of SR 262/Mission Boulevard compared to the "Before" conditions. Slow speeds north and south of the SR 84 on-ramp near the entry to the Express Lane were reported in the "After" conditions due to vehicles weaving to enter the Express Lane; these queues did not exist in the "Before" study. Existing queues from the bottlenecks at the southbound off-ramps at Auto Mall Parkway/Durham Road and SR 262/Mission Boulevard remain unchanged.

Bottleneck and Queue Locations

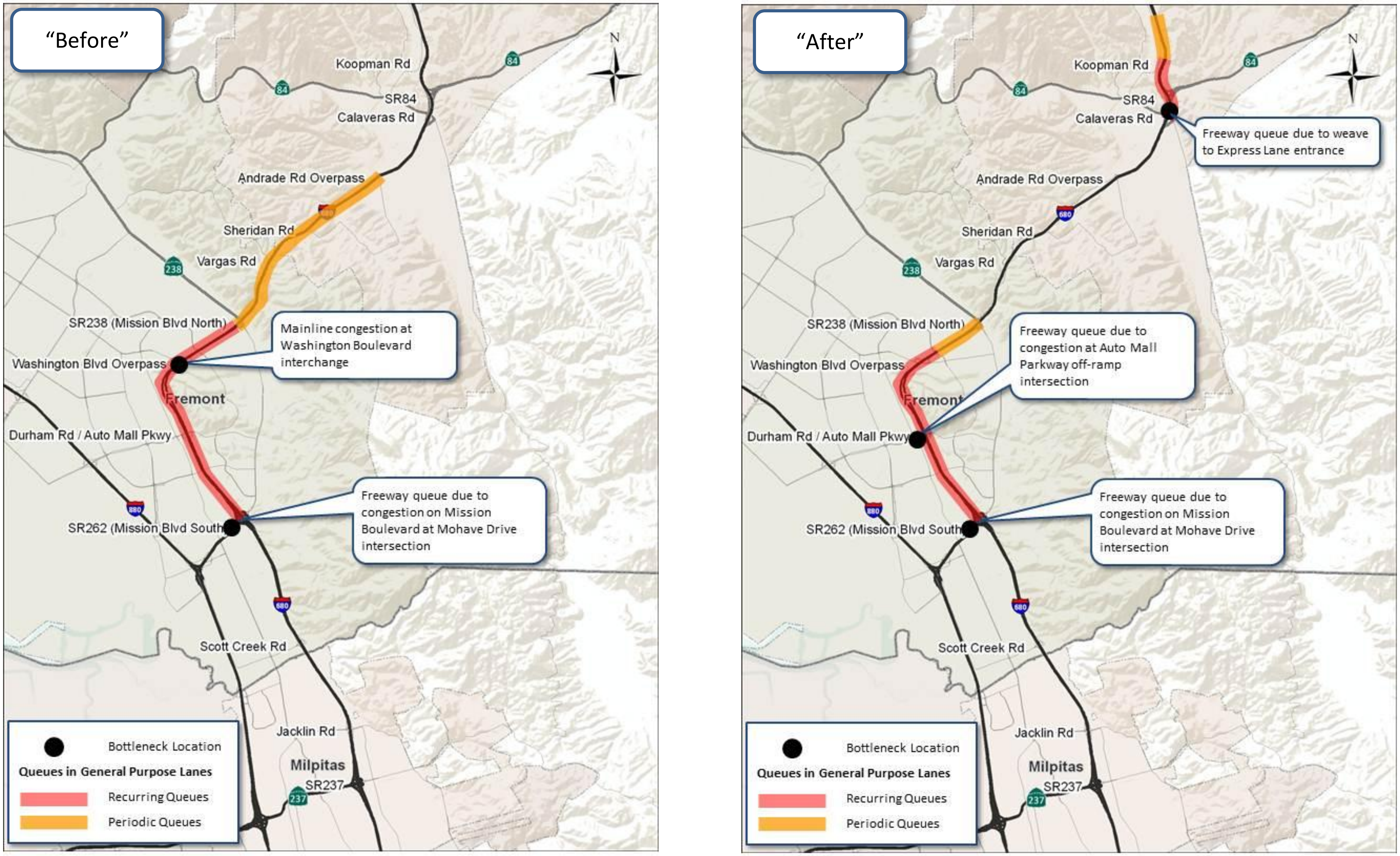
The bottlenecks and queues were identified using the floating car travel time surveys and aerial photographs taken at approximately 15 minute intervals. The results for the AM peak commute period "Before" and "After" conditions are summarized in Figure 12. Recurring queues are defined as segments where congestion was observed throughout most of the peak period (more than 30 minutes). Periodic queues are defined as segments where congestion was observed during a portion of the peak period, but for no more than 30 consecutive minutes.

The key bottlenecks in the "After" study were identified in three locations:

1. The merge with the SR 84 on-ramp.
2. Approaching the southbound off-ramp at Auto Mall Parkway/Durham Road, with queuing originating at the intersection of the southbound off-ramp with Auto Mall Parkway. The queue from this location extends back on to the southbound I-680 mainline up to Washington Boulevard.
3. Approaching the southbound off-ramp to SR 262/Mission Boulevard, with queues originating at the intersection of SR 262/Mission Boulevard with Mohave Drive, just west of the southbound off-ramp. The queue from this bottleneck extends back on to the southbound I-680 mainline up to Auto Mall Parkway/Durham Road.

The first location at SR 84 did not have queues in the "Before" study. The "Before" study did identify queues at the other two locations, approaching Auto Mall Parkway/Durham Road and SR 262/Mission Boulevard. The queues from these locations in the "Before" study were generally longer than the queues observed during the "After" study.

Figure 12: Study Corridor Bottlenecks and Queues in General Purpose Lanes, AM Peak Period



Bottlenecks and Queues Identified from Aerial Surveys

During the 2012 "After" surveys, congestion was observed on southbound I-680 north of the merge with SR 84 (Figure 13). The aerial photography did not extend north to this area during the 2008 "Before" study, so there is no direct comparison of queuing conditions in this particular location. Additional observations from survey vehicles confirmed that the congestion extended back to approximately Koopman Road during much of the AM peak period (recurring congestion) but beyond Koopman Road only during short portions of the AM peak period (periodic congestion).

Figure 13: I-680 at SR 84, AM Peak Period

Queuing from the Auto Mall Parkway/Durham Road interchange extended back nearly to Washington Boulevard (Figure 14). This is similar to conditions observed in the 2008 "Before" conditions.

Figure 14: I-680 at Washington Boulevard, AM Peak Period

Queuing at the SR 262/Mission Boulevard off-ramp started at the Mohave Drive intersection west of the interchange and continued back on the off-ramp and I-680 mainline to Auto Mall Parkway/Durham Road. The freeway mainline congestion (indicated by congested traffic on the photographs) to the north of the SR 262 off-ramp was much higher in the "After" conditions than in the "Before" conditions (Figure 15 through Figure 18).

Figure 15: I-680 South of Auto Mall Parkway/Durham Road, AM Peak Period, 2008 "Before" Conditions

Figure 16: I-680 at Auto Mall Parkway/Durham Road, AM Peak Period, 2012 "After" Conditions

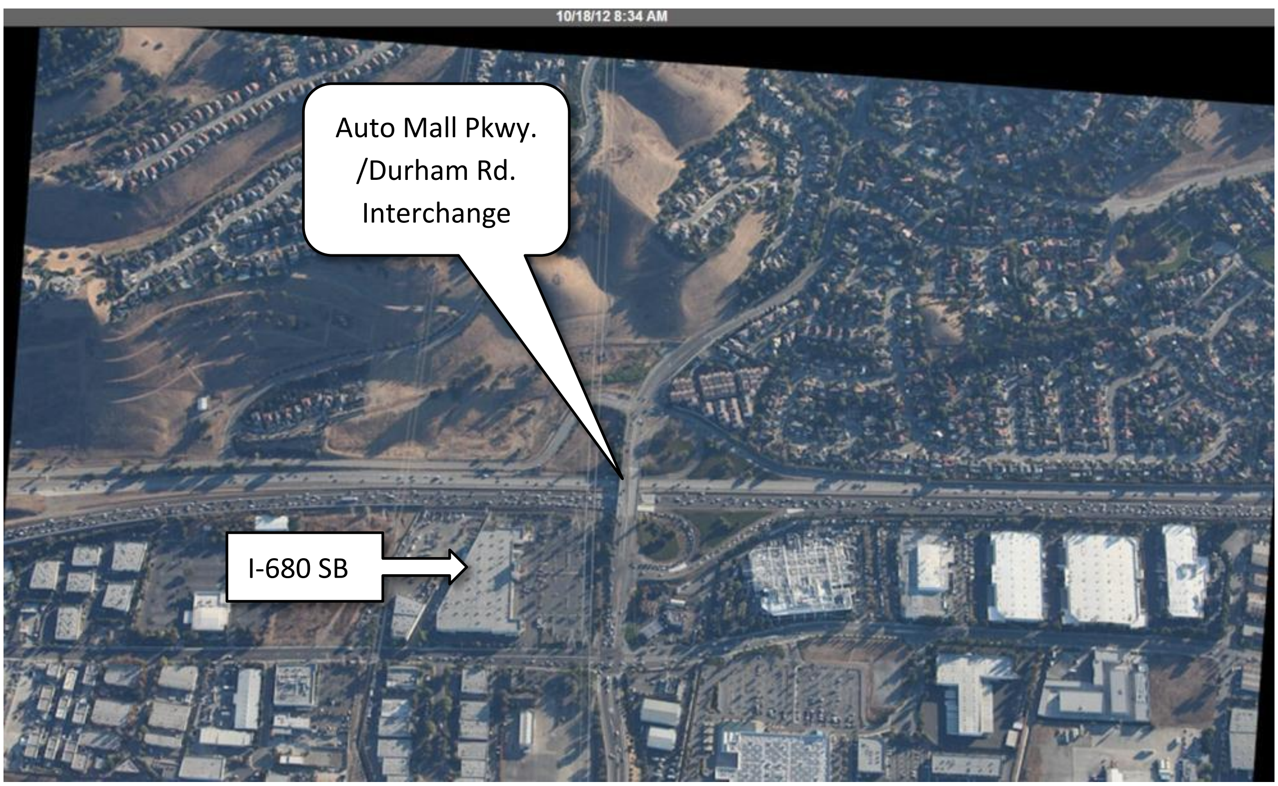
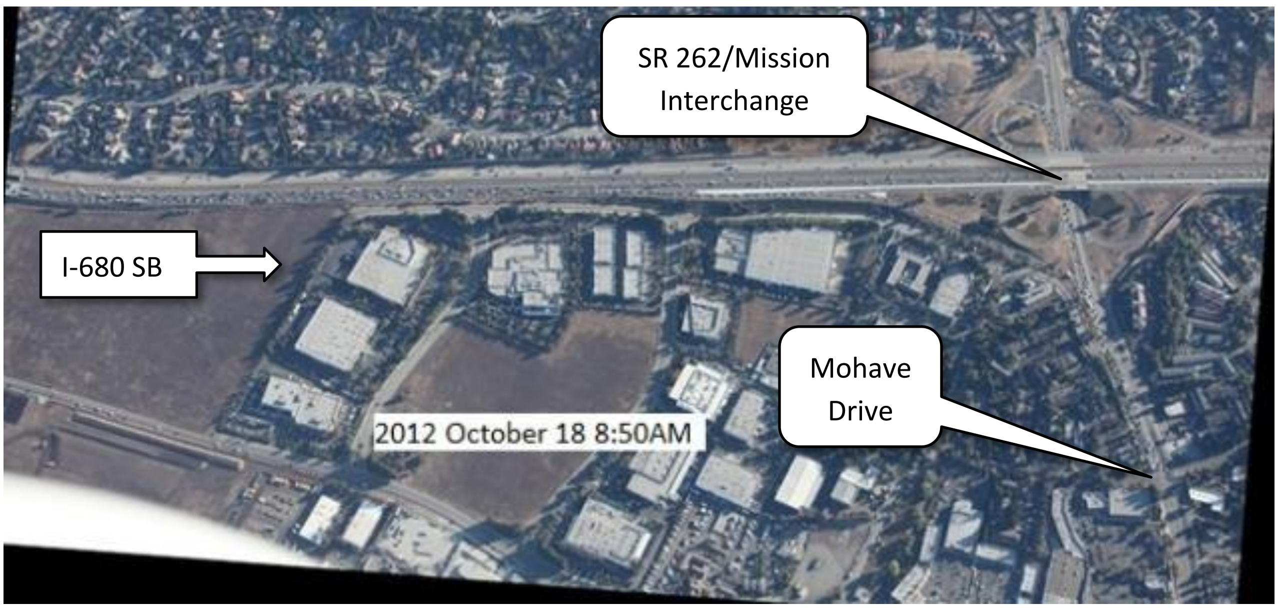


Figure 17: I-680 at SR 262 Mission South, AM Peak Period, 2008 "Before" Conditions

Figure 18: I-680 at SR 262 Mission South, AM Peak Period, 2012 "After" Conditions



Bottlenecks and Queues Identified from Floating Car Surveys

The "Before" study identified AM peak period congested speeds (speeds less than 30 mph) from Andrade Road to SR 262/Mission, but did not identify congested speeds for any hour during the AM peak period between SR 84 and Andrade Road.

On the first "After" floating car survey day, there was congestion (speeds less than 30 mph) at 7:00 AM only in the vicinity of Bernal Avenue and Sunol Boulevard, north of the study corridor. Towards 7:45 AM, slower speeds appeared between Koopman Road and SR 84 and before and after Calaveras Road, and a shorter period of periodic congestion north of Koopman Road between 7:45 and 8:15 AM. At 8:00 AM, the locations north and south of SR 84 were still slow, with significant congestion appearing between Washington Boulevard and the SR 262 Mission off-ramp. By 8:45 AM, the segments near SR 84 were near normal uncongested speeds, but slow speeds and congestion continued approaching Washington Boulevard, Auto Mall Parkway/Durham Road, and SR 262/Mission Boulevard.

On the second survey day, congestion north of SR 84 (from just south of Koopman Road) and south of SR 84 started by 7:00 AM and continued on and off throughout the AM peak period. Congestion approaching Auto Mall Parkway/Durham Road and SR 262/Mission Boulevard was mostly evident after 7:45 AM.

5.5 VEHICLE OCCUPANCY ANALYSIS

Vehicle occupancy includes measurements of the number of vehicles with one occupant (single occupant vehicles or SOVs) or two or more occupants (high occupancy vehicles or HOVs) on each type of freeway lane, HOV/Express Lane or general purpose lane. The vehicle occupancy analysis is based on the manual counts of vehicle classification and occupancy conducted at four locations on the study corridor and two locations on the control corridor. The surveys were conducted for each hour from 7:00 AM to 7:00 PM. Vehicle occupancy surveys could only be conducted for two hours during the four hour AM peak period, from 7:00 to 9:00 AM, due to reduced visibility prior to 7:00 AM that prevented surveyors from identifying the numbers of occupants in vehicles.

The total number of HOVs on the study corridor (Express Lane and general purpose lanes) decreased by an average of 32 percent in the AM peak period, 7 percent in the PM peak period and 11 percent for the 12-hour daytime period in the "After" study compared to the "Before" study conditions. **The *decrease may be attributable to an overall declining trend in carpool use, changes in employment in the subregion, and improved operating conditions in the general purpose lanes.***

Study Corridor Vehicle Occupancy

As described in the previous chapter, during the "Before" study, four data collection locations were selected for vehicle occupancy surveys: Washington Boulevard, Andrade Road, Mission Boulevard, and Calaveras Boulevard. During the "After" study period only one location, Washington Boulevard, remained the same as the "Before" study location. The other three locations were adjusted to collect data at Pico Road, Auto Mall Parkway/Durham Road, and Research Avenue based on changes in CHP policy for surveyor locations on the roadside due to safety concerns. The observations at the Research Avenue location were impeded during heavy traffic periods, so results from this location are not reported.

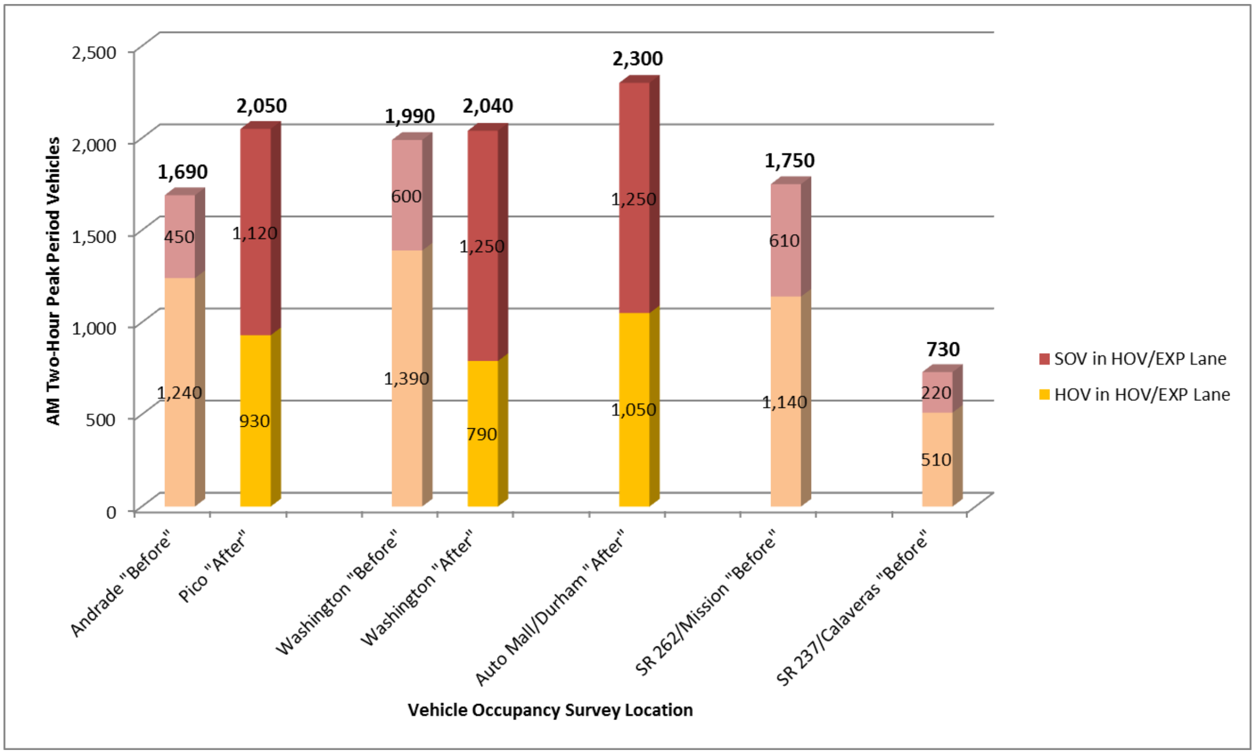
Study Corridor Vehicle Occupancy, HOV/Express Lane

Vehicle occupancy data collected in the southbound study corridor HOV lane during the "Before" study and Express Lane during the "After" study were analyzed and compared. The volumes in the HOV/Express Lane are summarized for the two hours of the AM peak period (7:00 to 9:00 AM) covered by the manual occupancy survey (Figure 19). All time periods were evaluated, however the AM peak period results are presented here as it is the primary commute direction with higher travel demand. Detailed tables of vehicle occupancy surveys in the HOV/Express Lane at the individual survey locations are included in Appendix 9.4.

Key findings of the HOV/Express Lane vehicle occupancy survey are as follows:

- The number of HOVs in the Express Lane decreased at the two common survey locations.
- The "Before" conditions resulted in 27 percent to 35 percent SOVs in the HOV lane. These single-occupant vehicles would either have had an eligible clean air vehicle sticker (hybrids such as Prius were still permitted at the time of the "Before" study) or were in violation of the HOV restrictions.
- The "After" conditions resulted in 54 percent to 61 percent SOVs in the Express Lane. These single-occupant vehicles include toll-paid vehicles, eligible clean air vehicles and potential violators of the Express Lane restrictions.

Figure 19: Study Corridor Vehicle Occupancy in HOV/Express Lane, AM Peak Period



Study Corridor Vehicle Occupancy, Total of All Lanes

This section describes the vehicle occupancy data aggregated for all travel lanes, including the HOV/Express Lane and the general purpose lanes. The vehicle counts for all lanes are shown in Figure 20.

The results of the vehicle occupancy surveys include:

- The average AM peak period HOV percentage in all lanes in the "Before" study ranged from 12 percent to 16 percent.
- In the "After" study, the average AM peak period HOV percentage in all lanes ranged from 9 percent to 12 percent.
- At the two common survey locations, the HOV percentage decreased by an average of 32 percent in the AM peak period, 7 percent in the PM peak period and 11 percent for the 12 daytime hours.

The decreases in HOV percentages should not be attributable to operating conditions in the Express Lane, as the "After" speeds and travel times in the Express Lane are similar to or improved compared to the speeds and travel times in the HOV lane during the "Before" study. Therefore, the decreases in HOV percentage could be attributable to a combination of factors including area-wide reductions in carpool usage (as documented in the next chapter), changes in employment, and the improvements in speed and travel time in the general purpose lanes, which could reduce the relative advantage of forming a carpool to use the HOV lane.

Figure 20: Study Corridor Vehicle Occupancy on All Lanes, AM Peak Period

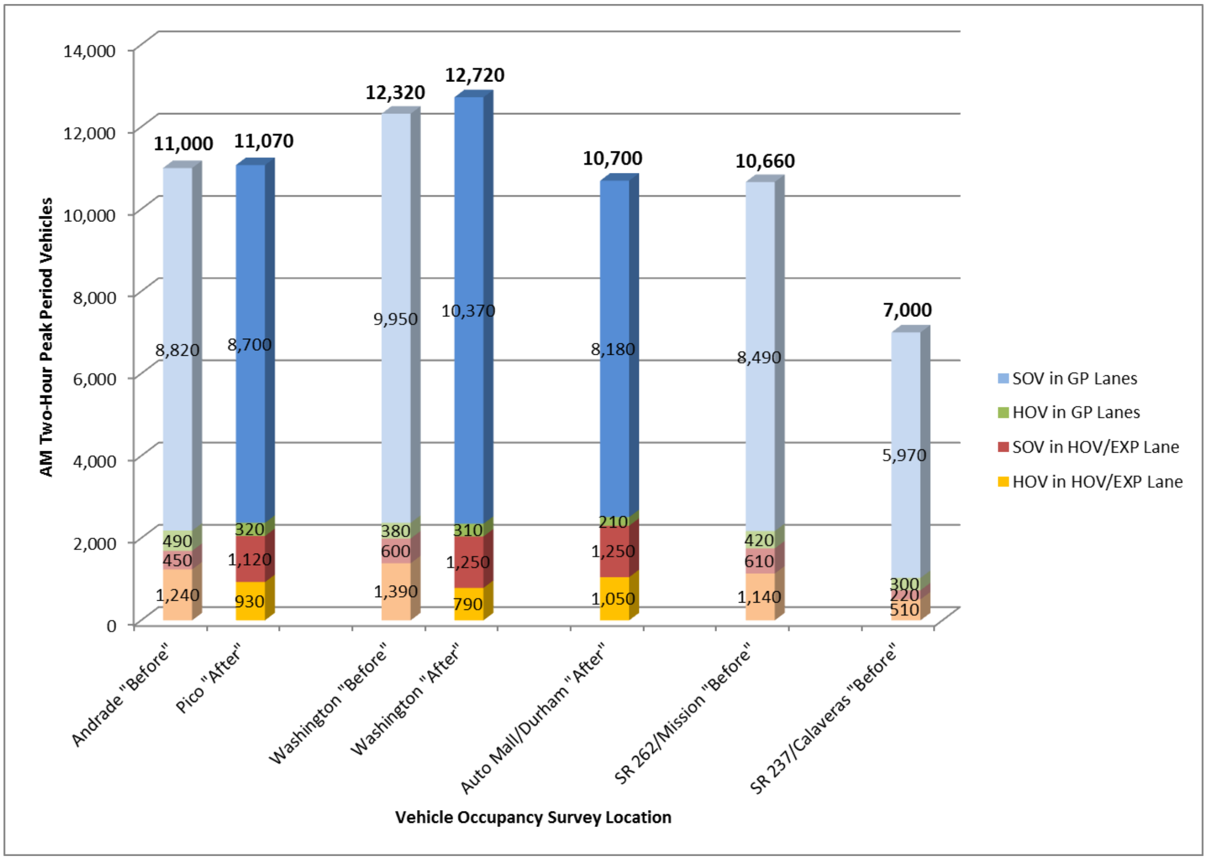
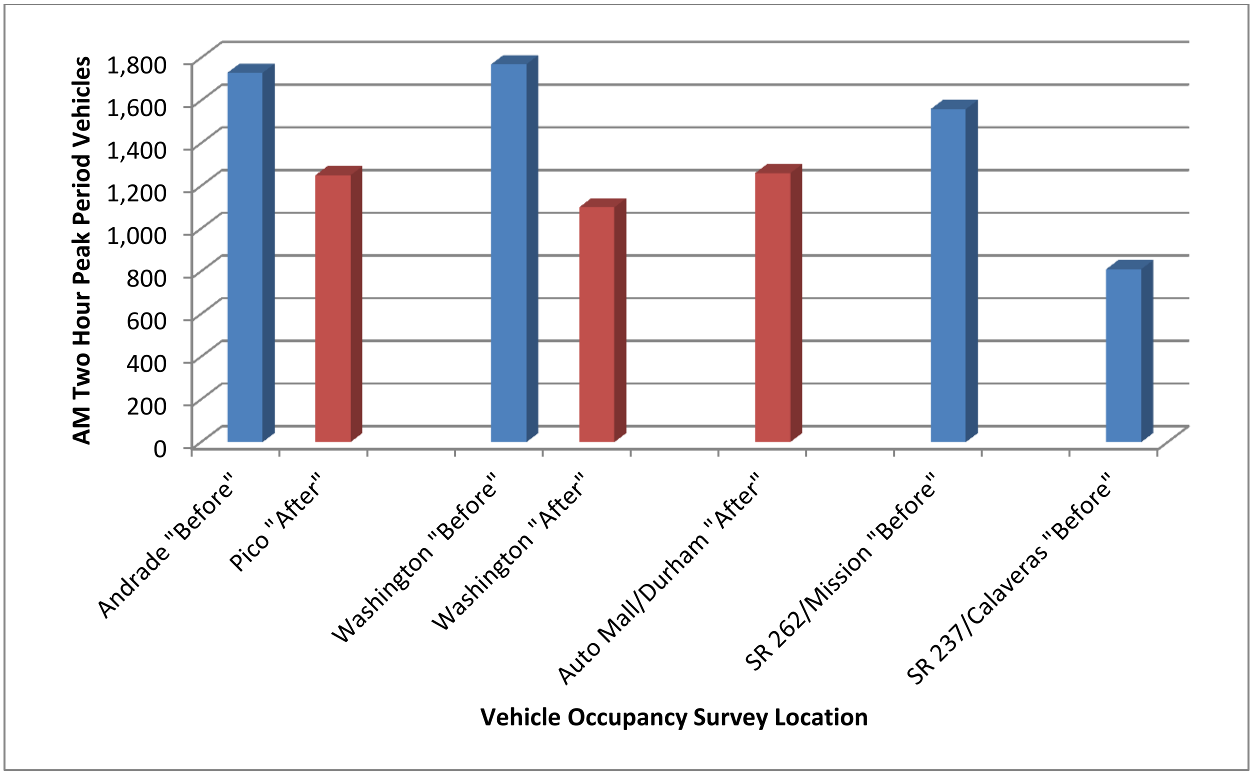


Figure 21 shows total AM peak period HOV volumes at each survey location, including HOVs in the HOV or Express Lane and HOVs in the general purpose lanes. The HOV volumes at the two common survey locations decreased by 28 percent to 38 percent between “Before” and “After” conditions.

Figure 21: Study Corridor HOV Volumes on All Lanes, AM Peak Period



Control Corridor Vehicle Occupancy

The number and percentage of SOVs and HOVs from the "After" study in the northbound control corridor were compared to the number and percentage of HOVs from the "Before" study. Vehicle occupancy data were collected at two survey locations. The south survey location at Alcosta Boulevard was identical for the "Before" and "After" study. The north survey location was revised for the "After" study based on changes in policy by the CHP for roadside surveyor locations due to safety concerns. Data were collected at Livorna Road for the "Before" study and at Fostoria Way during the "After" study. Therefore, the comparisons at the north survey location are not as directly comparable as comparisons at the Alcosta Boulevard survey location.

Detailed results for the individual survey locations are included in Appendix 9.4. The results of the vehicle occupancy survey are as follows:

- There were no changes in operating conditions on the control corridor between the "Before" and "After" conditions, including no changes in HOV lane operation and ramp metering.
- At the common survey location at Alcosta, between the "Before" and "After" studies the average HOV percentage decreased by 24 percent for the AM peak period, 20 percent for the PM peak period and by 19 percent for the 12-hour period between 7:00 AM and 7:00 PM.
- Total HOV volumes decreased by 22 percent to 29 percent at the Alcosta survey location.

The decreases in HOV percentage and volume on the control corridor were nearly as high as the changes on the study corridor (for example, 32 percent study corridor decrease versus 24 percent control corridor decrease for the AM peak period). This indicates that a significant portion of the change in HOV usage may be related to areawide reductions in carpool use and changes in employment.

5.6 LEVEL OF SERVICE AND RELATED MEASURES

A traffic operational analysis of the study and control corridors was prepared using the FREQ software. The FREQ analysis provides level of service (LOS) for each segment based on the 2000 *Highway Capacity Manual (HCM)*. The HCM bases level of service primarily on traffic density rather than speed, as described in Chapter 3, Methodology. Therefore LOS results based on the HCM are not directly comparable to speed-based LOS estimates such as those reported in the Alameda CTC's LOS Monitoring report. Details of the FREQ analysis results are included in Appendix 9.6.

In addition to LOS results, the FREQ analysis also reports additional measures such as vehicle miles of travel (VMT), vehicle hours of travel (VHT) and vehicle hours of delay (VHD). These results are also presented in this section.

Study Corridor Traffic Operations Analysis

The study corridor traffic operations analysis is summarized in terms of LOS on individual segments as well as overall corridor performance measures.

Study Corridor Level of Service

The level of service for each segment is summarized for the two peak hours of the AM peak period (7:00 to 9:00 AM) and the two peak hours of the PM peak period (4:00 to 6:00 PM).

The level of service (LOS) on the Express lane stayed at LOS A or B, above the required service level of LOS C.

The AM peak period LOS in the HOV/Express Lane was LOS A or B in all segments in both the "Before" and "After" studies (Table 18). There were small changes in LOS from LOS B to A in one segment between Washington Boulevard and Durham Road and from LOS A to B in the first segment from SR 84 to Calaveras Road.

Table 18: Study Corridor LOS on HOV/Express Lane, AM Peak Hours

Segment Limits		"Before" Study		"After" Study	
		HOV Lane		Express Lane	
From	To	Density	LOS	Density	LOS
7:00 AM - 8:00 AM					
SR 84/Vallecitos	Calaveras Rd	9.2	A	14.6	B
Calaveras Rd	Andrade Rd	11.5	B	15.3	B
Andrade Rd	Sheridan Rd	11.8	B	15.3	B
Sheridan Rd	Vargas Rd	11.9	B	15.3	B
Vargas Rd	SR 238/Mission	11.9	B	15.3	B
SR 238/Mission	Washington Blvd	12.3	B	15.3	B
Washington Blvd	Auto Mall/Durham	12.5	B	13.7	B
Auto Mall/Durham	SR 262/Mission	11.7	B	10.3	A
SR 262/Mission	Scott Creek Rd	10.4	A	10.3	A
Scott Creek Rd	Jacklin Rd	9.1	A	10.7	A
Jacklin Rd	SR 237/Calaveras	8.7	A	9.2	A
8:00 AM - 9:00 AM					
SR 84/Vallecitos	Calaveras Rd	11.5	B	12.5	B
Calaveras Rd	Andrade Rd	11.7	B	13.1	B
Andrade Rd	Sheridan Rd	12.0	B	13.1	B
Sheridan Rd	Vargas Rd	12.1	B	13.1	B
Vargas Rd	SR 238/Mission	12.1	B	13.1	B
SR 238/Mission	Washington Blvd	11.7	B	13.1	B
Washington Blvd	Auto Mall/Durham	12.8	B	11.5	B
Auto Mall/Durham	SR 262/Mission	12.2	B	8.8	A
SR 262/Mission	Scott Creek Rd	9.5	A	8.8	A
Scott Creek Rd	Jacklin Rd	10.0	A	9.2	A
Jacklin Rd	SR 237/Calaveras	9.3	A	7.7	A

The AM peak LOS in the general purpose lanes is shown in Table 19. The LOS has improved for segments in the mid-portion of the corridor in the "After" conditions, in particular between Vargas Road and Washington Boulevard. The LOS worsened in few segments, including SR 84 to Andrade Road and from Auto Mall Parkway/Durham Road to SR 262/Mission Boulevard, consistent with the performance results discussed in previous sections.

Table 19: Study Corridor LOS on General Purpose Lanes, AM Peak Hours

Segment Limits		"Before" General Purpose Lanes		"After" General Purpose Lanes	
From	To	Density	LOS	Density	LOS
7:00 AM - 8:00 AM					
SR 84/Vallecitos	Calaveras Rd	31.7	D	59.6	F[2]
Calaveras Rd	Andrade Rd	32.1	D	36.7	E
Andrade Rd	Sheridan Rd	30.5	D	35.4	E
Sheridan Rd	Vargas Rd	32.8	D	33.4	D
Vargas Rd	SR 238/Mission	34.6	F[1]	33.6	D
SR 238/Mission	Washington Blvd	68.9	F	35.7	E
Washington Blvd	Auto Mall/Durham	61.3	F	33.9	D
Auto Mall/Durham	SR 262/Mission	25.7	C	38.2	F[1]
SR 262/Mission	Scott Creek Rd	26.0	D	25.5	C
Scott Creek Rd	Jacklin Rd	21.5	C	23.3	C
Jacklin Rd	SR 237/Calaveras	20.5	C	25.6	C
8:00 AM - 9:00 AM					
SR 84/Vallecitos	Calaveras Rd	33.8	D	64.3	F[2]
Calaveras Rd	Andrade Rd	34.8	D	32.8	F[1,2]
Andrade Rd	Sheridan Rd	32.0	D	32.3	D
Sheridan Rd	Vargas Rd	56.2	F	31.2	D
Vargas Rd	SR 238/Mission	65.3	F	31.3	D
SR 238/Mission	Washington Blvd	100.9	F	31.9	D
Washington Blvd	Auto Mall/Durham	89.5	F	30.0	D
Auto Mall/Durham	SR 262/Mission	25.6	C	93.4	F
SR 262/Mission	Scott Creek Rd	30.2	D	25.5	C
Scott Creek Rd	Jacklin Rd	23.7	C	23.0	C
Jacklin Rd	SR 237/Calaveras	21.4	C	22.9	C

[1]*FREQ analysis reports LOS F sometimes for segments with density <45 if queues from downstream segments interfere with traffic flow.*

[2]*The LOS analysis is based on traffic counts that were collected at some locations on different days from the days of the floating car surveys that were used to determine travel times and speeds, therefore LOS results and speed results may not directly correlate for all segments due to daily fluctuations in volumes and congestion.*

Table 20 compares the LOS in the HOV/Express Lane during the PM peak period. The LOS for all segments improved from LOS B in the "Before" conditions with the HOV lane to LOS A in the "After" conditions with the Express Lane.

Table 20: Study Corridor LOS on HOV/Express Lane, PM Peak Hours

Segment Limits		"Before" HOV Lane		"After" Express Lane	
From	To	Density	LOS	Density	LOS
4:00 PM - 5:00 PM					
SR 84/Vallecitos	Calaveras Rd	11.5	B	5.7	A
Calaveras Rd	Andrade Rd	11.6	B	5.8	A
Andrade Rd	Sheridan Rd	11.8	B	5.8	A
Sheridan Rd	Vargas Rd	11.9	B	5.8	A
Vargas Rd	SR 238/Mission	11.9	B	5.8	A
SR 238/Mission	Washington Blvd	11.9	B	5.6	A
Washington Blvd	Auto Mall/Durham	11.9	B	5.2	A
Auto Mall/Durham	SR 262/Mission	12.6	B	4.2	A
SR 262/Mission	Scott Creek Rd	12.1	B	5.0	A
Scott Creek Rd	Jacklin Rd	13.2	B	4.3	A
Jacklin Rd	SR 237/Calaveras	12.7	B	6.8	A
5:00 PM - 6:00 PM					
SR 84/Vallecitos	Calaveras Rd	13.8	B	5.9	A
Calaveras Rd	Andrade Rd	13.9	B	6.0	A
Andrade Rd	Sheridan Rd	14.1	B	6.0	A
Sheridan Rd	Vargas Rd	14.2	B	6.0	A
Vargas Rd	SR 238/Mission	14.2	B	6.0	A
SR 238/Mission	Washington Blvd	13.6	B	6.4	A
Washington Blvd	Auto Mall/Durham	13.3	B	5.3	A
Auto Mall/Durham	SR 262/Mission	14.2	B	5.3	A
SR 262/Mission	Scott Creek Rd	13.5	B	4.2	A
Scott Creek Rd	Jacklin Rd	14.4	B	5.0	A
Jacklin Rd	SR 237/Calaveras	13.5	B	6.1	A

The PM peak LOS in the general purpose lanes is shown in Table 21. The PM peak LOS was LOS C or better on all segments in both the "Before" and "After" conditions. Seven segments changed from LOS B to LOS C during the 4:00 to 5:00 PM hour. There were more segments with increases in vehicle density than decreases between the "Before" and "After" conditions, indicating a higher overall utilization of the corridor during the PM peak period, while still operating at better flow conditions.

Table 21: Study Corridor LOS on General Purpose Lanes, PM Peak Hours

Segment Limits		"Before" General Purpose Lane		"After" General Purpose Lane	
From	To	Density	LOS	Density	LOS
4:00 PM - 5:00 PM					
SR 84/Vallecitos	Calaveras Rd	16.8	B	15.9	B
Calaveras Rd	Andrade Rd	17.1	B	20.1	C
Andrade Rd	Sheridan Rd	17.2	B	19.8	C
Sheridan Rd	Vargas Rd	17.2	B	20.1	C
Vargas Rd	SR 238/Mission	17.3	B	20.0	C
SR 238/Mission	Washington Blvd	17.4	B	20.2	C
Washington Blvd	Auto Mall/Durham	17.4	B	19.0	C
Auto Mall/Durham	SR 262/Mission	15.3	B	17.4	B
SR 262/Mission	Scott Creek Rd	17.7	B	17.0	B
Scott Creek Rd	Jacklin Rd	19.5	B	22.2	C
Jacklin Rd	SR 237/Calaveras	18.9	C	22.4	C
5:00 PM - 6:00 PM					
SR 84/Vallecitos	Calaveras Rd	20.3	C	17.0	B
Calaveras Rd	Andrade Rd	20.5	C	21.4	C
Andrade Rd	Sheridan Rd	15.4	C	21.1	C
Sheridan Rd	Vargas Rd	20.5	C	21.4	C
Vargas Rd	SR 238/Mission	20.5	C	21.4	C
SR 238/Mission	Washington Blvd	19.9	C	20.9	C
Washington Blvd	Auto Mall/Durham	19.5	C	19.2	C
Auto Mall/Durham	SR 262/Mission	16.5	B	17.9	C
SR 262/Mission	Scott Creek Rd	19.8	C	17.7	C
Scott Creek Rd	Jacklin Rd	21.4	C	20.5	C
Jacklin Rd	SR 237/Calaveras	20.0	C	21.8	C

Study Corridor Other Related Performance Measures

Other corridor performance measures were calculated from the FREQ analysis (Table 22). These measures include vehicle-miles of travel (VMT), vehicle-hours of travel (VHT), vehicle-hours of delay (VHD) and average corridor speed. These measures are described in Chapter 3, Methodology.

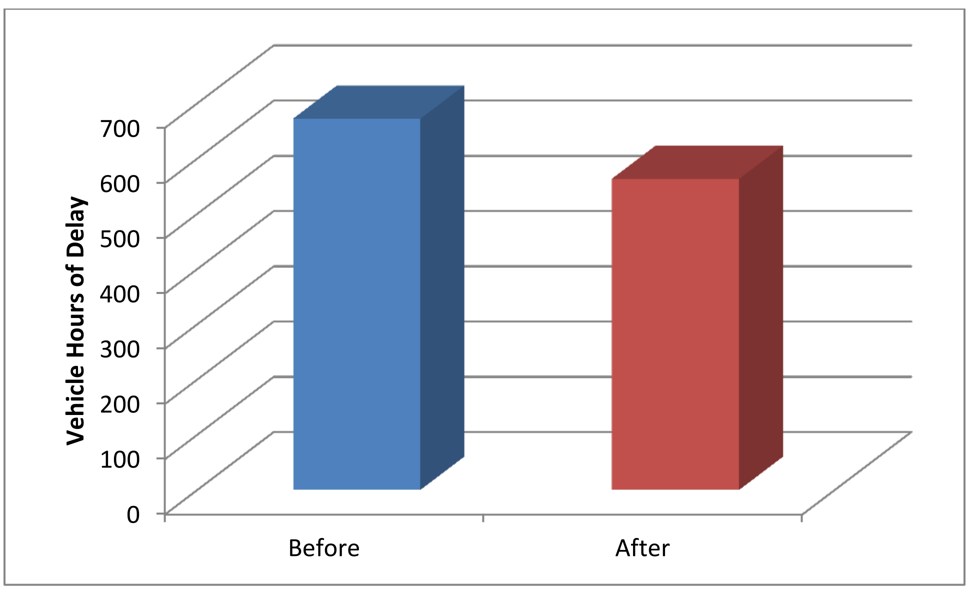
Vehicle Miles of Travel increased by 24% and Vehicle Hours of Delay reduced by a maximum of 16% for the AM peak period compared to the "Before" conditions.

Table 22: Study Corridor Other Performance Measures from FREQ Analysis

Performance Measure	"Before" Analysis	"After" Analysis	Percentage Change
AM PEAK 4-HOURS			
Vehicle Miles of Travel	246,800	306,300	+24%
Vehicle Hours of Travel	4,460	5,260	+18%
Vehicle Hours of Delay	672	563	-16%
Average Speed	55.4	58.2	+5%
PM PEAK 4-HOURS			
Vehicle Miles of Travel	211,600	201,100	-5%
Vehicle Hours of Travel	3,200	2,930	-8%
Vehicle Hours of Delay	0	0	-
Average Speed	66.1	68.6	+4%

In the AM peak four hour period, vehicle miles of travel (an indicator of total throughput) increased by 24 percent, while total vehicle hours of delay decreased by 16 percent (Figure 22) and average speed increased by 5 percent. The vehicle-hours of delay shown are for the study corridor from SR 84 to SR 237. Since some queuing does occur north of SR 84 during the AM peak period, the net reduction in vehicle-hours of delay may be less than 16 percent if the evaluation included the segment of I-680 immediately north of SR 84.

Figure 22: Study Corridor Vehicle Hours of Delay, AM Peak Period



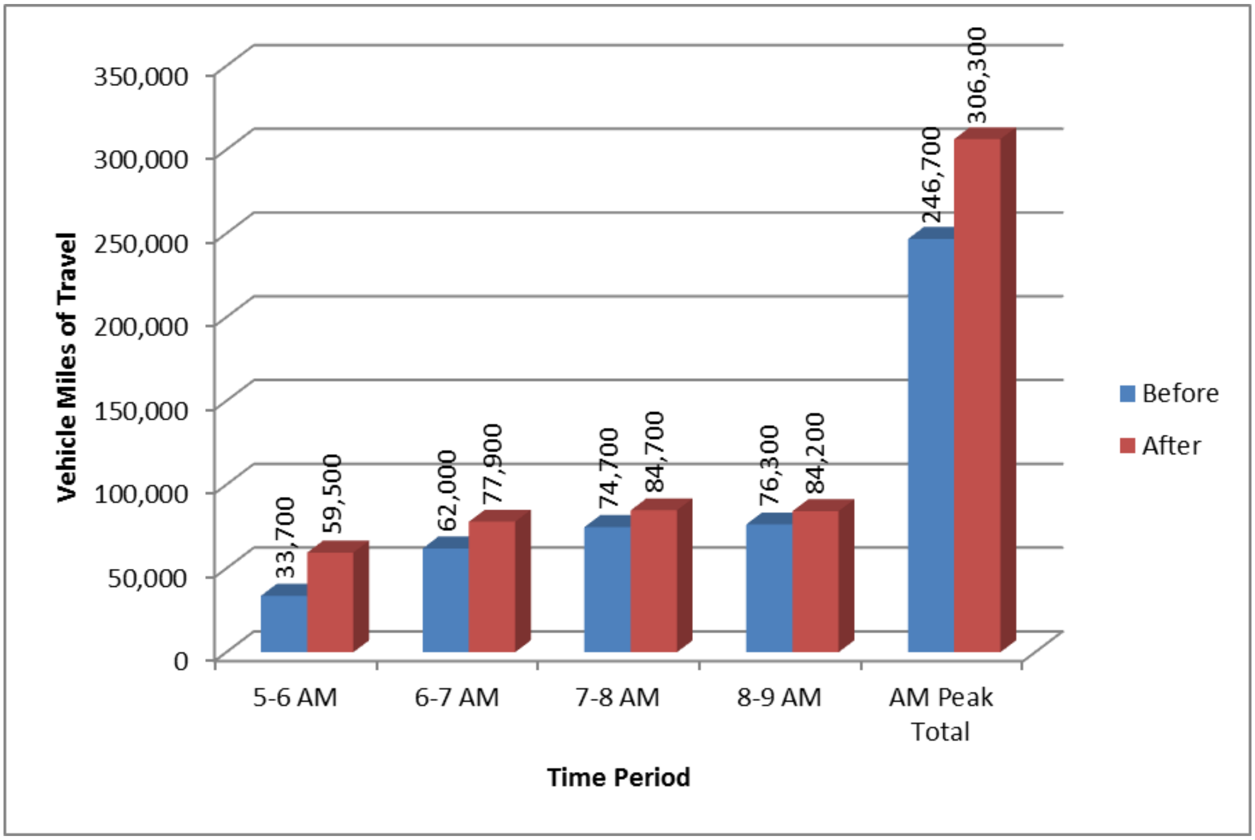
For the PM peak 4-hour period, VMT and vehicle-hours both decreased by 5 and 8 percent respectively, due to reductions in area travel demand, but there was also a small increase in average speed, indicating that corridor operations were improved compared to "Before" conditions.

The VMT on the study corridor was compared for each hour of the 4-hour AM and PM peak periods for the “Before” and “After” conditions (Table 23 and Figure 23). The VMT results indicate a 24 percent average increase in AM peak period vehicle throughput in 2012 compared to 2008. The PM peak period VMT decreased, particularly in the later hours of the PM peak period. This decrease would be due to decreases in general travel demand rather than implementation of the Express Lane. Overall peak period VMT (AM plus PM) increased by nearly 11 percent.

Table 23: Southbound I-680 Study Corridor Vehicle Miles of Travel

Hour	Before VMT	After VMT	Difference	Percent Change
AM PEAK PERIOD				
5-6 AM	33,700	59,500	25,800	+76.6%
6-7 AM	62,000	77,900	15,900	+25.6%
7-8 AM	74,700	84,700	10,000	+13.4%
8-9 AM	76,300	84,200	7,900	+10.4%
AM Peak Total	**246,700**	**306,300**	**59,600**	**+24.2%**
PM PEAK PERIOD				
3-4 PM	43,100	47,800	4,700	+10.9%
4-5 PM	54,700	55,200	500	+0.9%
5-6 PM	62,500	57,700	-4,800	-7.7%
6-7 PM	51,300	40,400	-10,900	-21.3%
PM Peak Total	**211,600**	**201,100**	**-10,500**	**-5.0%**
Peak Period Total (AM + PM 8 Hours)	**458,300**	**507,400**	**49,100**	**+10.7%**

Figure 23: Southbound I-680 Study Corridor Vehicle Miles of Travel, AM Peak Period



Control Corridor Traffic Operations Analysis

The control corridor traffic operations analysis is summarized in terms of LOS on individual segments as well as overall related corridor performance measures based on the FREQ analysis.

Control Corridor Level of Service

The LOS by segment for the control corridor HOV lane during the two peak hours during the AM peak period (7:00-9:00 AM) are listed in Table 24.

The HOV lane LOS was LOS B or better for every segment during every time period. There were slight changes in density and LOS between the "Before" and "After" conditions, with one segment changing from LOS A to B and two segments changing from LOS B to A during the 8:00 to 9:00 AM hour.

Table 24: Control Corridor LOS on HOV Lane, AM Peak Hours

Segment Limits		"Before" Study HOV Lane		"After" Study HOV Lane	
From	To	Density	LOS	Density	LOS
7:00 AM - 8:00 AM					
Alcosta Blvd	Bollinger Canyon Rd	12	B	11	B
Bollinger Canyon Rd	Crow Canyon Rd	10	A	10	A
Crow Canyon Rd	Sycamore Valley Rd	11	B	10	B
Sycamore Valley Rd	Diablo Rd	13	B	12	B
Diablo Rd	El Cerro Blvd	14	B	12	B
El Cerro Blvd	El Pintado Rd	14	B	12	B
El Pintado Rd	Stone Valley Rd	14	B	13	B
Stone Valley Rd	Livorna Rd	14	B	13	B
8:00 AM - 9:00 AM					
Alcosta Blvd	Bollinger Canyon Rd	12	B	12	B
Bollinger Canyon Rd	Crow Canyon Rd	9	A	12	B
Crow Canyon Rd	Sycamore Valley Rd	9	A	9	A
Sycamore Valley Rd	Diablo Rd	11	A	10	A
Diablo Rd	El Cerro Blvd	11	B	11	B
El Cerro Blvd	El Pintado Rd	12	B	11	A
El Pintado Rd	Stone Valley Rd	12	B	11	B
Stone Valley Rd	Livorna Rd	11	B	11	A

For the general purpose lanes in the AM peak hours (Table 25), LOS F conditions were reported from Crow Canyon Road to Livorna Road in both the "Before" and "After" studies. Some of the highest vehicle densities reported in the "Before" conditions, between Sycamore Valley Road and El Cerro Boulevard, were significantly reduced in the "After" conditions analysis, but the segments were still operating at LOS F.

Table 25: Control Corridor LOS on General Purpose Lanes, AM Peak Hours

Segment Limits		"Before" Study		"After" Study	
		General Purpose Lanes		General Purpose Lanes	
From	To	Density	LOS	Density	LOS
7:00 AM - 8:00 AM					
Alcosta Blvd	Bollinger Canyon Rd	29	D	33	D
Bollinger Canyon Rd	Crow Canyon Rd	18	C	23	C
Crow Canyon Rd	Sycamore Valley Rd	28	F[1]	31	F[1]
Sycamore Valley Rd	Diablo Rd	59	F	55	F
Diablo Rd	El Cerro Blvd	77	F	59	F
El Cerro Blvd	El Pintado Rd	54	F	66	F
El Pintado Rd	Stone Valley Rd	54	F	63	F
Stone Valley Rd	Livorna Rd	66	F	41	F[1]
8:00 AM - 9:00 AM					
Alcosta Blvd	Bollinger Canyon Rd	29	D	35	D
Bollinger Canyon Rd	Crow Canyon Rd	20	C	22	C
Crow Canyon Rd	Sycamore Valley Rd	53	F	54	F
Sycamore Valley Rd	Diablo Rd	102	F	51	F
Diablo Rd	El Cerro Blvd	111	F	75	F
El Cerro Blvd	El Pintado Rd	71	F	68	F
El Pintado Rd	Stone Valley Rd	68	F	64	F
Stone Valley Rd	Livorna Rd	74	F	73	F

[1] *FREQ analysis reports LOS F sometimes for segments with density <45 if queues from downstream segments interfere with traffic flow.*

Table 26 lists the LOS by segment for the control corridor HOV lane during the PM peak hours. The "Before" study reported LOS E or F conditions in the HOV lane for several segments approaching Stone Valley Road. All HOV lane segments operated at LOS B in the "After" conditions analysis.

Table 26: Control Corridor LOS on HOV Lane, PM Peak Hours

Segment Limits		"Before Study" HOV Lane		"After Study" HOV Lane	
From	To	Density	LOS	Density	LOS
4:00 PM - 5:00 PM					
Alcosta Blvd	Bollinger Canyon Rd	19	C	16	B
Bollinger Canyon Rd	Crow Canyon Rd	19	C	15	B
Crow Canyon Rd	Sycamore Valley Rd	21	F[1]	17	B
Sycamore Valley Rd	Diablo Rd	28	F[1]	18	B
Diablo Rd	El Cerro Blvd	41	F[1]	17	B
El Cerro Blvd	El Pintado Rd	37	F[1]	17	B
El Pintado Rd	Stone Valley Rd	22	E[1]	17	B
Stone Valley Rd	Livorna Rd	21	C	17	B
5:00 PM - 6:00 PM					
Alcosta Blvd	Bollinger Canyon Rd	20	C	16	B
Bollinger Canyon Rd	Crow Canyon Rd	19	C	14	B
Crow Canyon Rd	Sycamore Valley Rd	20	C	14	B
Sycamore Valley Rd	Diablo Rd	32	D	15	B
Diablo Rd	El Cerro Blvd	39	F[1]	15	B
El Cerro Blvd	El Pintado Rd	44	F[1]	15	B
El Pintado Rd	Stone Valley Rd	22	E[1]	15	B
Stone Valley Rd	Livorna Rd	21	C	15	B

[1]FREQ analysis reports LOS F sometimes for segments with density <45 if queues from downstream segments interfere with traffic flow.

For the general purpose lanes during the PM peak hours (Table 27), the "After" analysis showed general worsening of LOS conditions with LOS of F from Alcosta Boulevard to Stone Valley Road, but this congested condition was reported only from Crow Canyon Road to Stone Valley Road in the "Before" analysis. Vehicle densities were significantly increased in several segments, particularly from Bollinger Canyon Road to Sycamore Valley Road.

Table 27: Control Corridor LOS on General Purpose Lanes, PM Peak Hours

Segment Limits		"Before Study" General Purpose Lanes		"After Study" General Purpose Lanes	
From	To	Density	LOS	Density	LOS
4:00 PM - 5:00 PM					
Alcosta Blvd	Bollinger Canyon Rd	27	D	46	F
Bollinger Canyon Rd	Crow Canyon Rd	22	C	70	F
Crow Canyon Rd	Sycamore Valley Rd	34	F[1]	109	F
Sycamore Valley Rd	Diablo Rd	71	F	80	F
Diablo Rd	El Cerro Blvd	95	F	72	F
El Cerro Blvd	El Pintado Rd	66	F	60	F
El Pintado Rd	Stone Valley Rd	55	F	61	F
Stone Valley Rd	Livorna Rd	37	E	41	E
5:00 PM - 6:00 PM					
Alcosta Blvd	Bollinger Canyon Rd	31	D	45	F[1]
Bollinger Canyon Rd	Crow Canyon Rd	22	C	70	F
Crow Canyon Rd	Sycamore Valley Rd	44	F[1]	95	F
Sycamore Valley Rd	Diablo Rd	84	F	87	F
Diablo Rd	El Cerro Blvd	95	F	69	F
El Cerro Blvd	El Pintado Rd	67	F	77	F
El Pintado Rd	Stone Valley Rd	55	F	61	F
Stone Valley Rd	Livorna Rd	37	E	41	E

[1]FREQ analysis reports LOS F sometimes for segments with density <45 if queues from downstream segments interfere with traffic flow.

Control Corridor Performance Measures

The corridor performance measures on the control corridor were calculated from the FREQ analysis (Table 28). Vehicle hours of delay during the PM peak period have doubled since the 2008 "Before" conditions, with an 8 percent increase in VMT and an 18 percent decrease in average speed.

Table 28: Control Corridor Performance Measures from FREQ Analysis, PM Peak Four Hour Period

Performance Measure	"Before" Analysis	"After" Analysis	Percentage Change
Vehicle Miles of Travel	306,506	332,276	+8%
Vehicle Hours of Travel	6,249	8,215	+31%
Vehicle Hours of Delay	1,549	3,120	+101%
Average Speed	49.1	40.5	-18%

The VMT totals by hour on the northbound I-680 control corridor are presented in Table 29. The data are presented for three hours during each peak period rather than four hours, consistent with the hours of operation for the HOV lane on the control corridor.

Table 29: Northbound I-680 Control Corridor Vehicle Throughput in Vehicle Miles of Travel

Hour	Before VMT	After VMT	Difference	Percent Change
AM PEAK PERIOD				
6-7 AM	45,700	47,500	1,800	3.9%
7-8 AM	72,100	77,300	5,200	7.2%
8-9 AM	69,100	77,500	8,400	12.2%
AM Peak Total	**186,900**	**202,300**	**15,400**	**8.2%**
PM PEAK PERIOD				
3-4 PM	77,700	83,700	6,000	7.7%
4-5 PM	80,000	85,800	5,800	7.3%
5-6 PM	80,800	83,900	3,100	3.8%
PM Peak Total	**238,500**	**253,400**	**14,900**	**6.2%**
Peak Period Total (AM + PM 6 Hours)	**425,400**	**455,700**	**30,300**	**7.1%**

The VMT increased by an average of 7 percent from the 2008 "Before" data collection to the 2012 "After" data collection. This indicates an approximate 1.8 percent annual growth rate in corridor demand during the four year period. Since there were no geometric or operational changes on the control corridor, the changes in throughput should be entirely related to travel demand.

5.7 TRANSIT FREQUENCY AND RIDERSHIP

In order to determine whether the implementation of the Express Lane has had any effect on transit operations and ridership, information on transit operations in terms of frequency and ridership in the study and control corridors was compiled from the operators providing service on these corridors. These include the Santa Clara Valley Transit Authority (VTA), San Joaquin Regional Transit District (RTD), Livermore-Amador Valley Transit Authority (LAVTA/Wheels), and The County Connection (Central Contra Costa Transit Authority).

The average weekday transit ridership on routes operating in the study corridor decreased by 7 percent, similar to the 5 percent decrease on routes operating in the control corridor. The amount of transit service operating in the study corridor was significantly reduced between 2008 and 2012, and therefore, the ridership decreases experienced in both corridors were related to service reductions by the transit operators.

Average weekday ridership was identified as the common level of ridership data available from all four providers. Table 30 and Table 31 list the ridership information from all transit providers in the I-680 study and control corridors.

Table 30: I-680 Study Corridor Transit Ridership and Service Frequencies

Transit Provider and Route	Origin - Destination	Freeway Segment	"Before" Study Data: Average Weekday Ridership	"Before" Study Data: Peak Period Frequency (minutes) AM	"Before" Study Data: Peak Period Frequency (minutes) PM	"Before" Study Data: Off-Peak Frequency (minutes)	"After" Study Data: Average Weekday Ridership	"After" Study Data: Peak Period Frequency (minutes) AM	"After" Study Data: Peak Period Frequency (minutes) PM	"After" Study Data: Off-Peak Frequency (minutes)	Comments
San Joaquin Regional Transit District (RTD)											
162	Tracy - Lockheed Martin (Sunnyvale)	SR 84 to SR 237	32	1	1	--					not in operation in 2012
164	Manteca - Lockheed Martin (Sunnyvale)	SR 84 to SR 237	52	1	1	--	50	1	1	--	
166	Stockton - Lockheed Martin (Sunnyvale)	SR 84 to SR 237	47	1	1	--	60	1	1	--	
170	Stockton - San Jose Metro Drive Light Rail Station	SR 84 to SR 237	43	1	1	--					not in operation in 2012
172	Stockton - Lockheed Martin (Sunnyvale)	SR 84 to SR 237	37	1	1	--	71	1	1	--	
173	Stockton - Northrop Grumman (Sunnyvale)	SR 84 to SR 237	47	1	1	--	68	1	1	--	
174	Stockton - Mountain View/Palo Alto	SR 84 to SR 237	39	1	1	--					not in operation in 2012
175	Stockton - Santa Clara	SR 84 to SR 237	34	1	1	--					not in operation in 2012
Santa Clara Valley Transportation Authority (VTA)											
180	Fremont BART - Milpitas Main Transit Center/Great Mall	SR 238/North Mission to SR 237	1,858	15	15	15-60	2480	25-30	25	25-35	
181	Fremont BART - San Jose Diridon Transit Center	SR 238/North Mission to SR 237	797	15	15	--					Travel on I-880 in 2012
183	Fremont BART - Aborn and White	SR 238/North Mission to SR 237					59	60	60	-	New Route
TOTAL			**2,986**				**2,788 (-6.6%)**				

Table 31: I-680 Control Corridor Transit Ridership and Service Frequencies

Transit Provider and Route	Origin - Destination	Freeway Segment	"Before" Study Data				"After" Study Data				Comments
			Average Weekday Ridership	Peak Period Frequency (minutes) AM	Peak Period Frequency (minutes) PM	Off-Peak Frequency (minutes)	Average Weekday Ridership	Peak Period Frequency (minutes) AM	Peak Period Frequency (minutes) PM	Off-Peak Frequency (minutes)	
Central Contra Costa Transit Authority (CCCTA)											
92X	Mitchel Dr. Park & Ride - San Ramon Transit Center > Pleasanton Training Center	Livorna Rd to Crow Canyon Rd	273	60	60	--	201	60	60		Destination - Pleasanton Training Center
95X	Walnut Creek BART to San Ramon Transit Center	Livorna Rd to Crow Canyon Rd					194	40	40		
96X	Walnut Creek BART to Bishop Ranch	Livorna Rd to Crow Canyon Rd; Crow Canyon to Bollinger Canyon					581	15-20	15-20		
97X	San Ramon Transit Center to Dublin/Pleasanton BART	Bollinger Canyon Rd to Alcosta					123	30	30		
960B	Mitchel Dr. Park & Ride - Bishop Ranch	Bollinger Canyon Rd to Livorna Rd	467	15-30	15-40	--					not in operation in 2012
960C	Mitchel Dr. Park & Ride - Bishop Ranch	Bollinger Canyon Rd to Livorna Rd	261	30	30	--					not in operation in 2012
970B	Bishop Ranch - Dublin BART	Alcosta Rd to Bollinger Canyon Rd	58	30-45	30-75	--					not in operation in 2012
970C	Bishop Ranch - Dublin BART	Alcosta Rd to Bollinger Canyon Rd	59	30	30-60	--					not in operation in 2012
Livermore Amador Valley Transit Authority (LAVTA WHEELS)											
70X	Dublin BART - Pleasant Hill BART	Alcosta Rd to Livorna Rd	281	30	30	--	234	30	30		
TOTAL			**1,399**				**1,333 (-4.7%)**				

Total ridership by segment, as described in Table 32 and Table 33, was compiled based on the on- and off-ramps used by each route. The ridership aggregation calculation was the same as that was used in the “Before” study. Average daily ridership was reported for October 2012, with the exception of VTA, where a four-month average daily ridership was used. The 2012 “After” study segment ridership is displayed graphically in Figure 24 for the study corridor and Figure 25 for the control corridor.

Table 32: Average Daily Transit Ridership for the I-680 Study Corridor

Segment	“Before” (September 2008)	“After” (October 2012)	Change
SR 84 to SR 238	321	249	-22%
SR 238 to South SR 262	2,976	2,788	-6%
SR 262 to SR 237	2,179	2,729	+25%

Table 33: Average Daily Transit Ridership for the I-680 Control Corridor

Segment	“Before” (September 2008)	“After” (October 2012)	Change
Livorna Rd to Crow Canyon Rd	1,272	1,219	-4%
Crow Canyon Rd to Bollinger Canyon Rd	1,009	815	-19%
Bollinger Canyon Rd to Alcosta Blvd	661	357	-46%

Transit services were reduced in both study and control corridors compared to the “Before” conditions. In the study corridor, out of total 10 lines operated during the “Before” conditions, 5 lines were not operating and one new line was added in the “After” study. In the control corridor, out of 9 total lines operating during the “Before” study, 4 lines were eliminated by the time of the “After” study.

The average weekday transit ridership on bus routes using the study corridor decreased by 7 percent. At the same time, the average weekday transit ridership on bus routes using the control corridor decreased by 5 percent.

The ridership decreases experienced in both corridors were related to service reductions by the transit operators. It is likely that the ridership reduction is part of larger level trends and not related to Express Lane operations.

Figure 24: Average Weekday Transit Ridership in I-680 Study Corridor

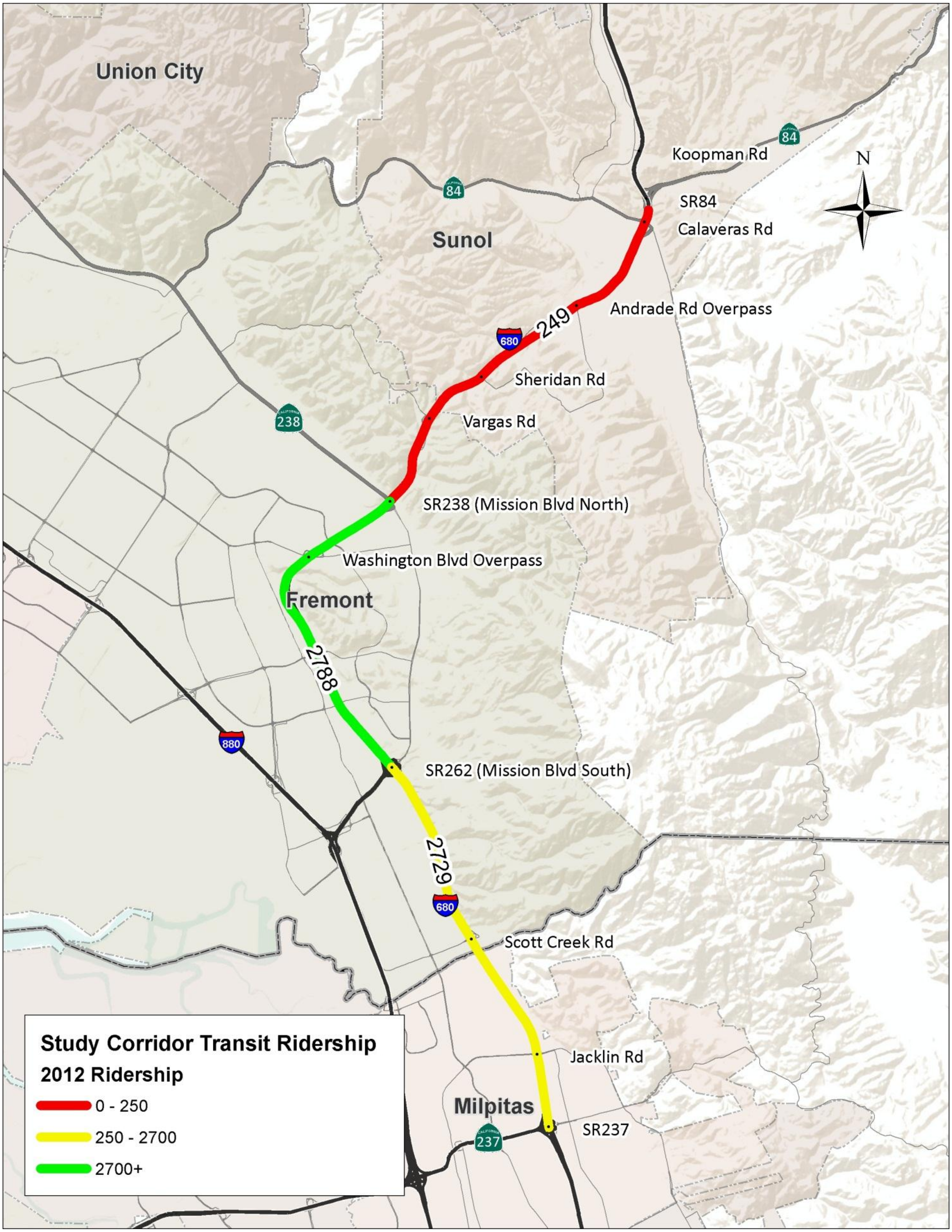
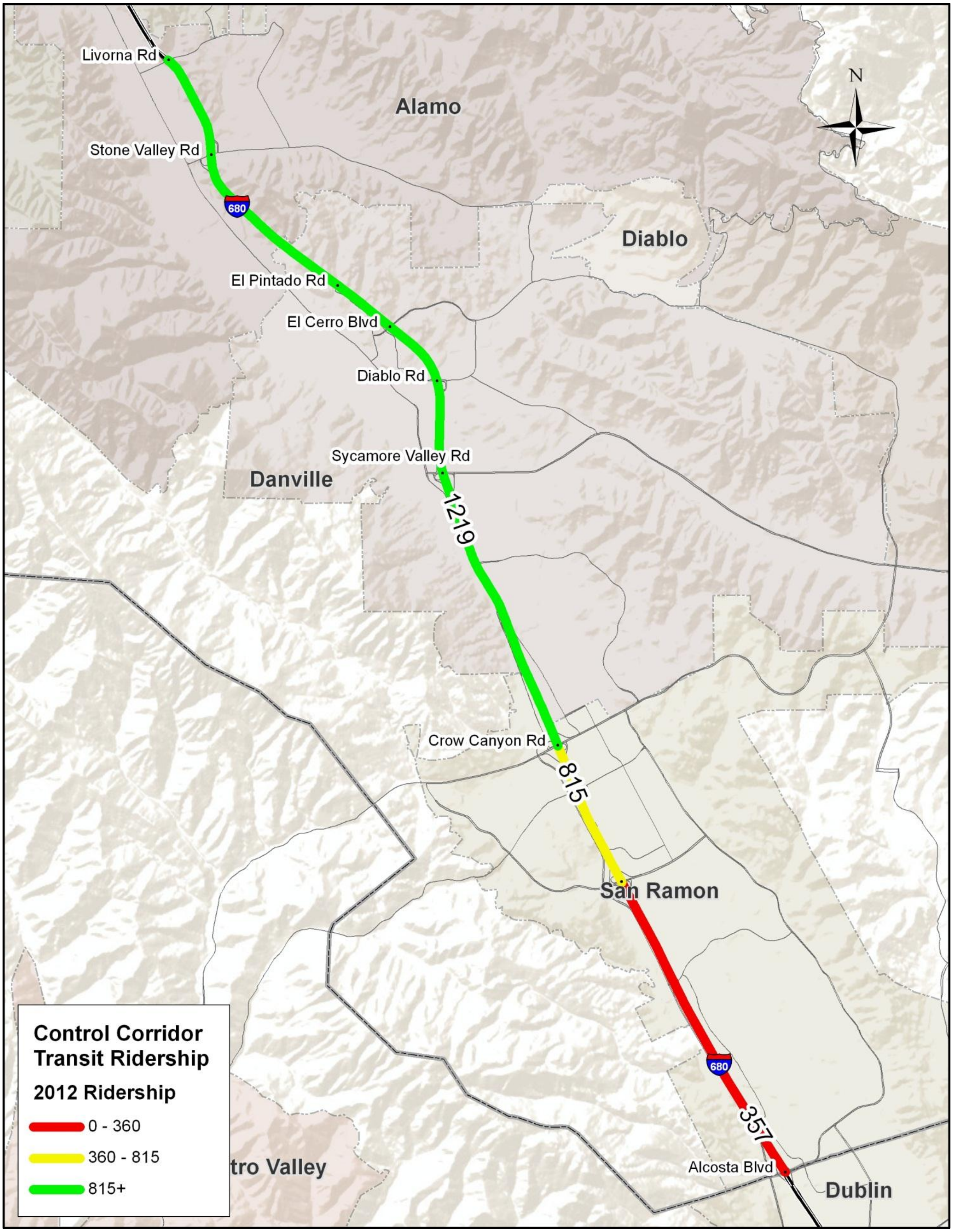


Figure 25: Average Weekday Transit Ridership in I-680 Control Corridor



5.8 SAFETY EVALUATION

The safety evaluation is based on the number of collisions reported on the corridors and the collision rates. Collision rates are calculated by dividing the number of collisions by the amount of vehicle travel.

The collision rates on the I-680 study and control corridors both dropped by approximately 50 percent.

Comparison of Collision Rates

The collision rates for the study and control corridors were compared for "Before" and "After" conditions (Figure 26 and Table 34). As described in the Methodology section 3.2, collision data from 2011 are the only full year data available to represent "After" conditions. The "Before" data are based on the single year of 2006 for comparability with the single year of 2011. Three-year data for the "Before" conditions (2005-2007) are also available in Appendix 9.7: Collision Detail.

Figure 26: Annual Collision Rates

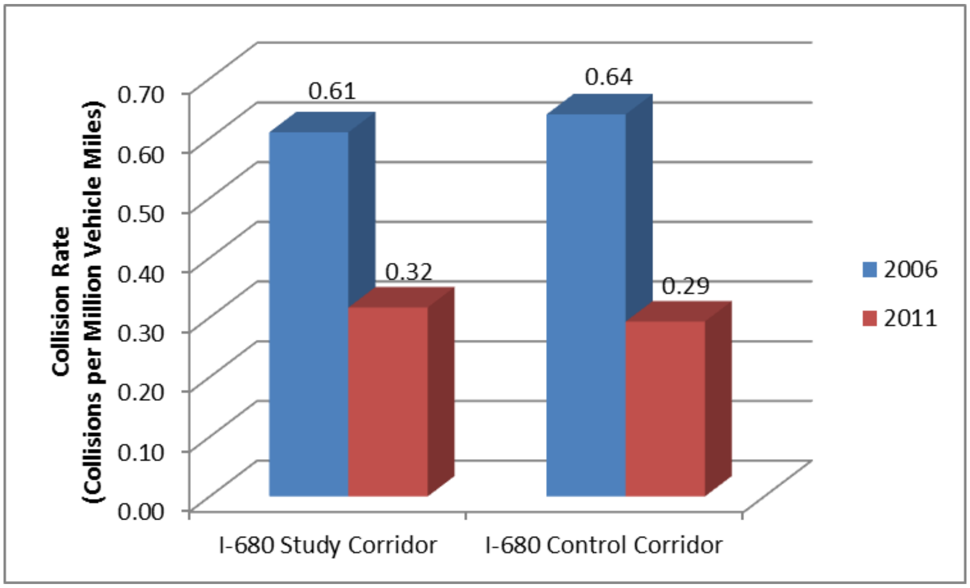


Table 34: Number of Collisions and Rates

Time Period	Road Miles	Million Vehicle Miles Traveled (MVM)	Collisions Total Number	Rate (MVM)
Study Corridor Annual Collisions				
2006	13.69	734	451	0.61
2011	13.69	645	215	0.32
Control Corridor Annual Collisions				
Time Period	**Road Miles**	**Million Vehicle Miles Traveled (MVM)**	**Collisions Total Number**	**Rate (MVM)**
2006	11.26	698	448	0.64
2011	11.26	661	197	0.29

Source: California Highway Patrol SWITRS data and Caltrans Traffic Volumes.

Between 2006 and 2011, the collision rates on the I-680 study and control corridors both dropped by approximately 50 percent, from 0.61 to 0.32 accidents per million vehicle miles on the study corridor and from 0.64 to 0.29 on the control corridor. Potential reasons for such significant changes could not be obtained at the time of writing this report.

Since the control corridor also experienced a decrease in collision rate, it cannot be inferred that the decrease in collision rate on the study corridor can be directly attributed to the Express Lane. However, it may be concluded that the Express Lane did not cause an increase in collision rates on the study corridor.

Accident information was also compiled by the severity of injuries, by primary factor and by collision type. The percentages of collisions involving fatalities remained at 0 to 1 per year. The percentages of collisions involving severe injuries increased in both the study corridor and control corridor from 1.5 to 2.4 percent and 1.0 to 3.4 percent respectively. Detailed tables of these collisions by type are included in Appendix 9.7: Collision Detail.

Figure 27: 2011 Total Collisions on Study Corridor

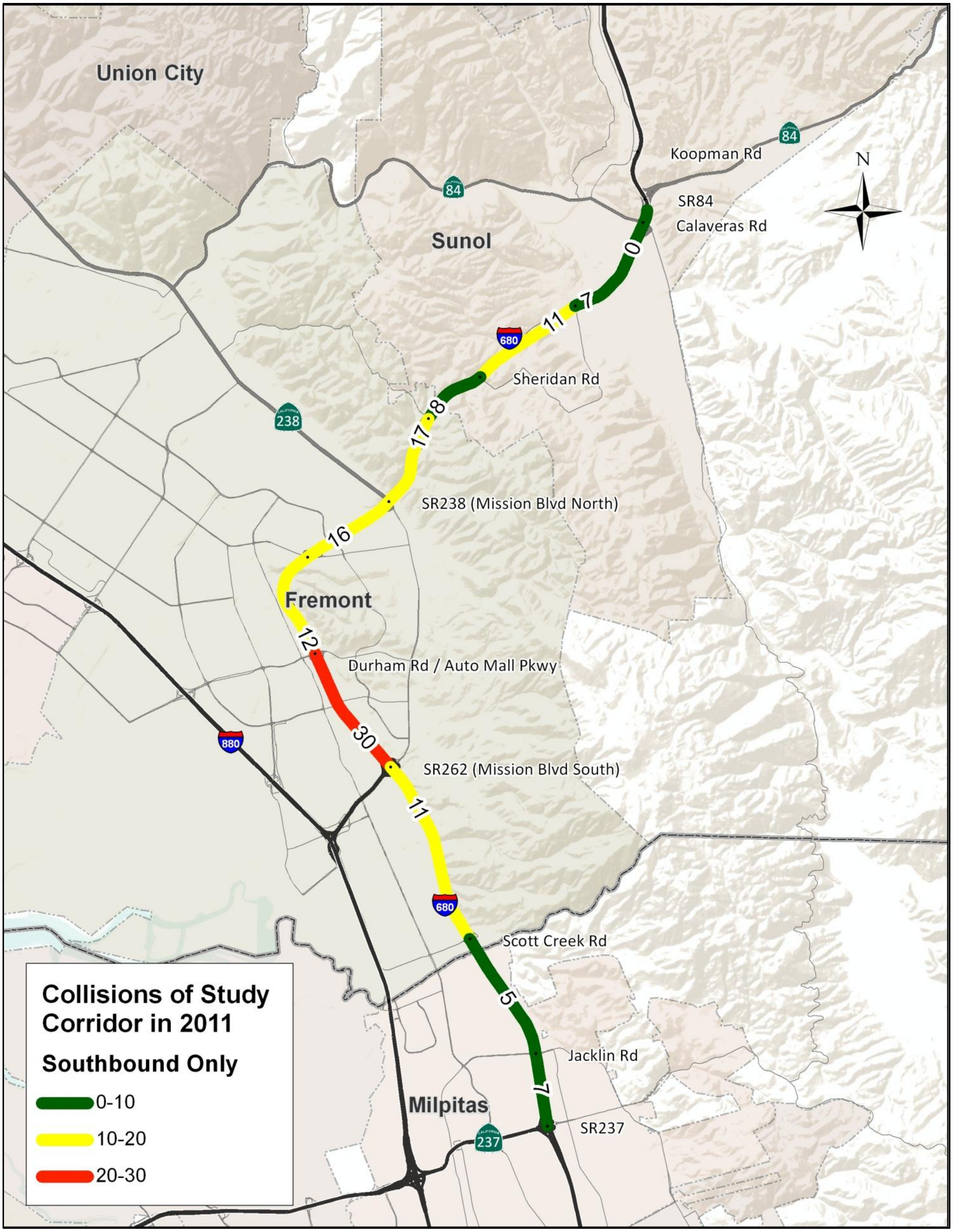
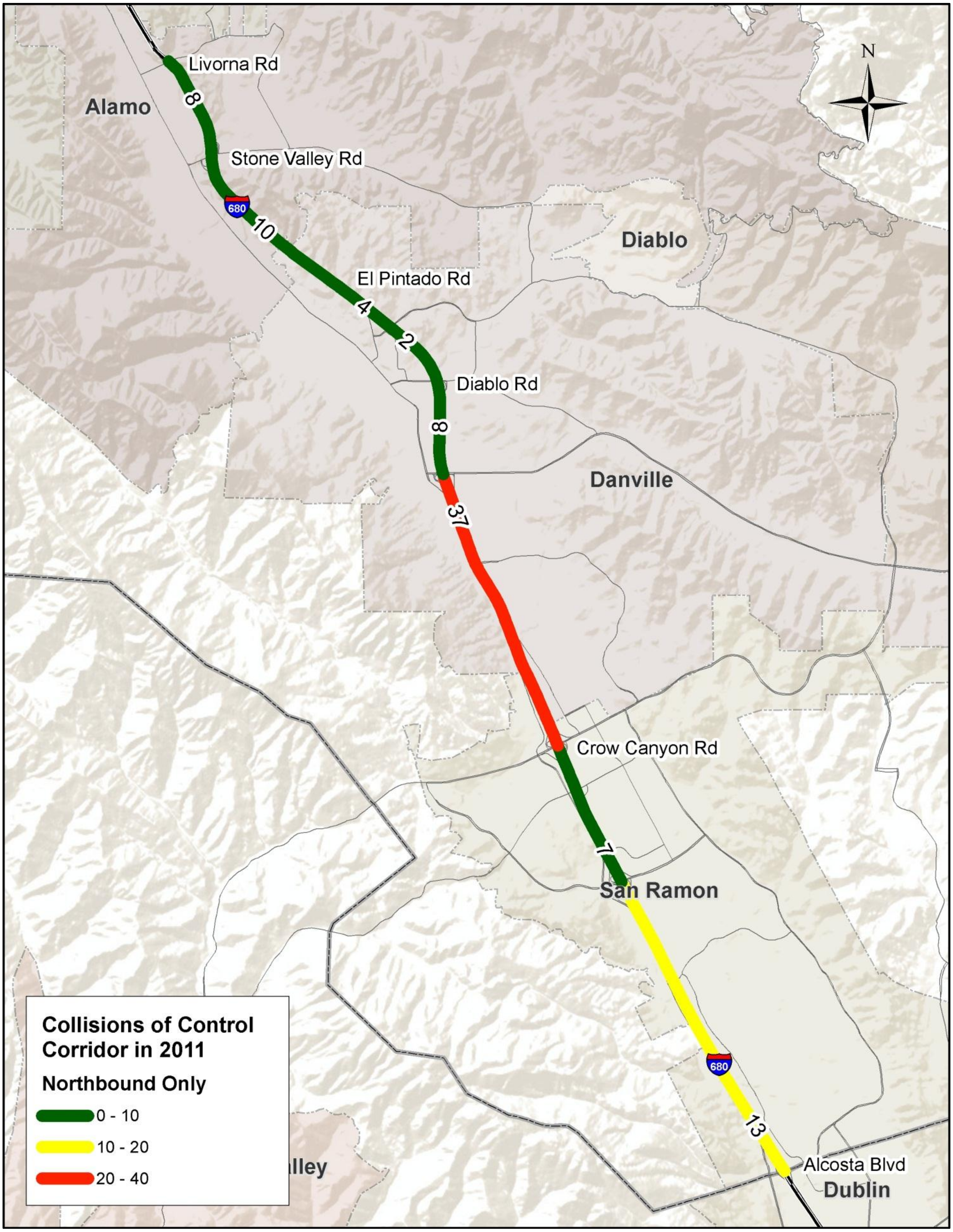


Figure 28: 2011 Total Collisions on Control Corridor



5.9 HOV/EXPRESS LANE VIOLATIONS AND ENFORCEMENT

Issues related to violations and enforcement are summarized based on:

- Violations observed on the Express Lane, including non-payment and illegal lane crossings; and
- Citations issued by the California Highway Patrol (CHP).

The maximum violation rate (single-occupant vehicles not paying a toll) observed on the Express Lane was 20 percent of single-occupant vehicles; and rates of less than 1 percent were observed for drivers illegally crossing the double white line throughout the Express Lane corridor. A violation rate of 6 percent was observed for vehicles using the Washington Boulevard Express Lane ingress as an egress

Express Lane Violations

Based on the data collected and discussions held with the stakeholders, three types of Express Lane violations were identified for the study corridor:

1. Single-occupant vehicles not paying tolls;
2. Illegal crossings of the solid double line into or out of the Express Lane; and
3. Illegal use of the Express Lane ingress as an egress at Washington Boulevard.

The following sections describe the data sources, analysis and results for each of these three types of violations.

Toll Violations

The estimated toll violation rate (single-occupant vehicles not paying a toll) observed on the Express Lane was 20% of single-occupant vehicles or 11% of all vehicles in the Express Lane.

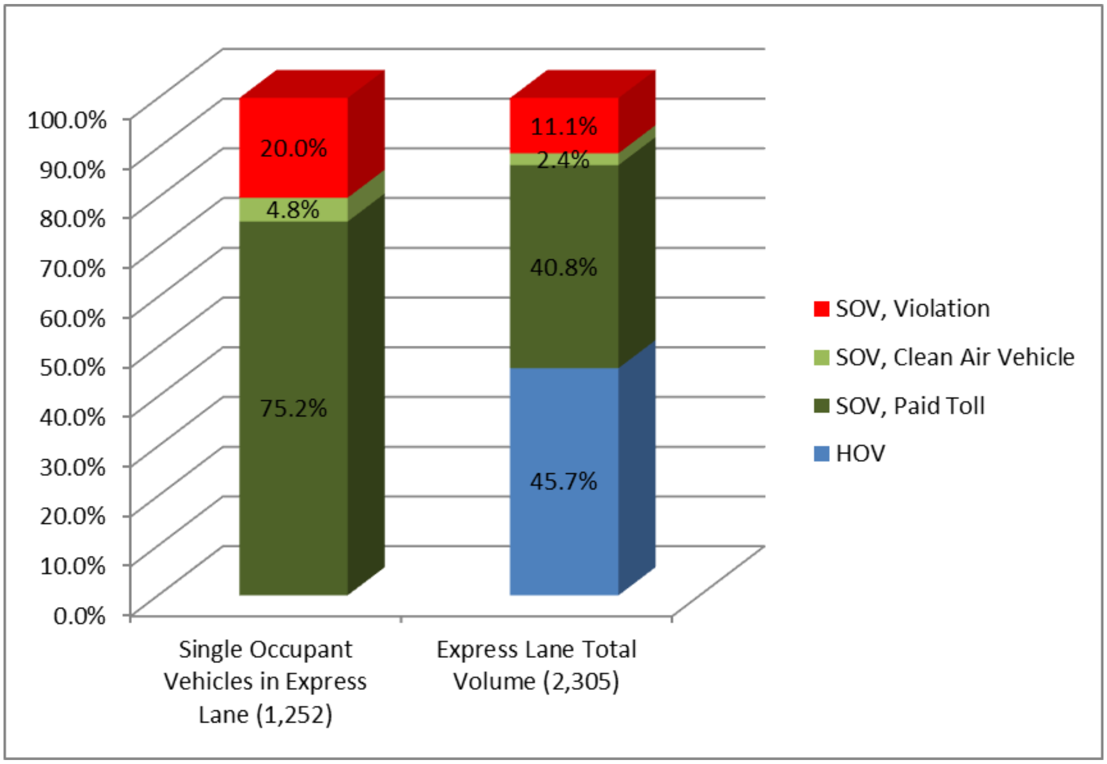
There are three types of vehicles that can legally travel in the Express Lane: High-occupancy vehicles (HOVs) with two or more occupants, eligible clean air vehicles, and single-occupant vehicles (SOVs) paying a toll. Toll violations occur when a single-occupant vehicle that should have normally paid the toll doesn’t pay, but uses the lane. Violations can also be recorded if the FasTrak transponder in a single-occupant vehicle is not functioning. Toll violations are estimated as the difference between the total number of single-occupant vehicles in the Express Lane and the number of vehicles paying tolls in the same segment of the Express Lane during the same period.

Toll violations were evaluated for the Express Lane segment between Washington Boulevard and north of Auto Mall Parkway/Durham Road, as this segment includes a toll reader and a manual vehicle occupancy count was conducted at this location. In addition, there is no legal Express Lane ingress or egress between the toll reader and the manual occupancy survey locations, therefore the volume differences for single-occupant vehicles can be estimated to show the toll violation. The analysis is based on data collected on October 25, 2012 from 7:00 to 9:00 AM, as all required data types were available for this period.

During the two-hour AM peak period, the total volume counted in the Express Lane was 2,305 vehicles. Out of this total, 1,252 vehicles were single-occupant vehicles and 1,053 vehicles were HOVs, buses or other qualifying vehicles. During the same peak period, 941 vehicles were reported as toll-paying vehicles. The maximum number of SOV toll violations would be 311 vehicles (1,252-941).

The actual number of violations would be lower, since some of the SOVs could be qualifying clean air vehicles which are not required to pay a toll. The percentage of clean air vehicles on the corridor was estimated at 2.4 percent of the total Express Lane volume, as described in Section 3.2. Other SOVs could have legal transponders that were not recorded at that particular toll reader. Therefore, the upper bound for the toll violation rate is estimated as 20 percent of single-occupant vehicles, or 11 percent of all Express Lane vehicles (Figure 29)

Figure 29: Express Lane Toll Violations, October 25, 2012 7:00 to 9:00 AM at Auto Mall Parkway/Durham Road



Illegal Lane Crossings

The southbound I-680 Express Lane is separated from the general purpose lanes by a double solid white line. It is illegal for drivers to cross the double white lane. Ingress and egress are permitted only at designated locations where the Express Lane is separated by a single dashed line. The “After” study included video recording surveys at four locations using eight cameras to identify the frequency of illegal crossings of the double white line. The video surveys cover eight specific camera views of the corridor, and do not represent a comprehensive inventory of all illegal crossing activity throughout the length of the corridor. The manual compilation of illegal crossing data was completed for the single survey date of October 11, 2012 and for two hours of the AM peak period, from 7:00 to 9:00 AM.

The illegal double-line crossing observations are summarized in Table 35. These observations do not include vehicles illegally using the designated ingress location at Washington Boulevard as an egress.

Table 35: Illegal Express Lane Ingress/Egress

Locations	Descriptions	7am – 8am	8am – 9am
Location 1: Between Andrade SB Off and On Ramps North-Facing Camera	Total GPL volume	5679	5646
	Total Express Lane volume	1143	1171
	Illegal crossings from GPL to Express Lane	1	0
	Illegal crossings from Express Lane to GPL	1	0
Location 1: Between Andrade SB Off and On Ramps South-Facing Camera	Total GPL volume	5656	5566
	Total Express Lane volume	1135	1164
	Illegal crossings from GPL to Express Lane	0	0
	Illegal crossings from Express Lane to GPL	1	0
Location 2: Between Vargas SB Off and On Ramps North-Facing Camera	Total GPL volume	5628	5743
	Total Express Lane volume	1131	1147
	Illegal crossings from GPL to Express Lane	1	0
	Illegal crossings from Express Lane to GPL	0	0
Location 2: Between Vargas SB Off and On Ramps South-Facing Camera	Total GPL volume	5677	5711
	Total Express Lane volume	1106	1146
	Illegal crossings from GPL to Express Lane	0	0
	Illegal crossings from Express Lane to GPL	1	0
Location 3: South of Washington Blvd SB On Ramp (on the curve) North-Facing Camera	Total GPL volume	5738	5698
	Total Express Lane volume	1107	1169
	Illegal crossings from GPL to Express Lane	1	3
	Illegal crossings from Express Lane to GPL	6	0
Location 3: South of Washington Blvd SB On Ramp (on the curve) South-Facing Camera	Total GPL volume	5817	5977
	Total Express Lane volume	1128	1193
	Illegal crossings from GPL to Express Lane	0	0
	Illegal crossings from Express Lane to GPL	0	0
Location 4: FasTrak checkpoint just north of Auto Mall Pkwy SB Off Ramp North-Facing Camera	Total GPL volume	5775	5708
	Total Express Lane volume	1121	1278
	Illegal crossings from GPL to Express Lane	0	1
	Illegal crossings from Express Lane to GPL	0	0
Location 4: FasTrak checkpoint just north of Auto Mall Pkwy SB Off Ramp South-Facing Camera	Total GPL volume	5769	5782
	Total Express Lane volume	1130	1266
	Illegal crossings from GPL to Express Lane	0	0
	Illegal crossings from Express Lane to GPL	0	0
Total Observed Violations		**12**	**4**
AVERAGE EXPRESS LANE VOLUME		1,160	
AVERAGE ILLEGAL CROSSINGS PER LOCATION		1.0	
Average Violation Rate		**0.1%**	

There were generally very few illegal double line crossing violations observed during the survey period. At the Washington Boulevard interchange between 7:00 and 8:00 AM, 6 cars were observed exiting the Express Lane to the general purpose lanes (0.6% of Express Lane vehicles), the maximum number recorded for any hour at any location. The location of this illegal movement is consistent with comments received from stakeholders including the CHP. The total number of illegal crossings observed during the two hours of the AM peak period (7:00 to 9:00 AM) at the eight survey camera locations was 16 illegal crossings, or an average of 1.0 violation per hour per location. The average hourly volume in the Express Lane at the eight locations was 1,160 vehicles. Therefore, the observed illegal crossings represent approximately 0.1 percent of observed Express Lane drivers.

These observations represent activity at 8 discrete locations on the corridor, representing approximately 30 percent of the corridor length (assuming one-half mile visibility from each camera location, then the observations represent 4 out of 14 total miles). Additional illegal crossings are likely to occur in other locations along the corridor. The percentage of vehicles conducting illegal crossings in other locations would be expected to be similar to the violation rate in the observed locations.

Illegal Use of Washington Boulevard Ingress as Egress

Vehicles have been observed exiting the Express Lane at the Washington Boulevard ingress location. At this location, there is a dashed line separating the Express Lane from the general purpose lanes, but no Express Lane exits are permitted at this location. To determine the number of vehicles illegally using the Washington Boulevard ingress location as an egress, traffic volumes north and south of the ingress were compared.

Express Lane traffic counts from the upstream SR 238/Mission interchange were compared with traffic counts at the downstream Washington Boulevard interchange (Table 36). There is no legal exit from the Express Lane between these two points, so the difference in volumes should provide an indication of illegal exits. There is a legal Express Lane ingress at Washington Boulevard, but the traffic count on the Express Lane used for this analysis occurs prior to the merge with the ingress traffic.

Table 36: Illegal Express Lane Exits at Washington Boulevard

Time Period	Express Lane Count at SR 238/Mission	Express Lane Count at Washington	Difference
5:00 to 6:00 AM	415	377	38 (9.2%)
6:00 to 7:00 AM	1023	935	88 (8.6%)
7:00 to 8:00 AM	1122	1,054	68 (6.1%)
8:00 to 9:00 AM	1187	1,142	45 (3.8%)
Total 4-Hour AM Peak Period	3,747	3,508	239 (6.4%)

The upstream traffic volume during the four-hour AM peak period exceeded the downstream traffic volume by 239 vehicles (6% of total Express Lane volume), indicating that at least that number of vehicles must have exited the Express Lane between the upstream and downstream interchanges.

The lane striping on the right side of the Express Lane adjacent to the ingress lane at Washington Boulevard switches from double solid white to single solid white. The single solid white line is similar to the demarcation used for many standard HOV lanes, where it is legal to cross between the HOV lane and the general purpose lanes. Therefore, some drivers may believe that it is legal to cross the single white solid line from the Express Lane to the general purpose lanes adjacent to the Washington Boulevard ingress.

Caltrans HOV Violation Report

Caltrans has historically conducted manual vehicle occupancy surveys on HOV lanes throughout the Bay Area, including I-680, to help identify HOV violation rates. However, they discontinued these surveys on the southbound I-680 Express Lane due to the inability to directly identify non-paying SOVs through manual observation. The available Caltrans HOV surveys are summarized in this section.

Caltrans District 4 reported data from the annual manual vehicle occupancy survey conducted on southbound I-680 between SR 84 and the Santa Clara County line (Table 37). Since the opening of the

Express Lane in late 2010, Caltrans could not identify whether an observed single-occupant vehicle was in violation and therefore discontinued calculation of a violation rate as of 2011.

The HOV violation rate reported by Caltrans during the AM peak period was 3 percent or more prior to 2008, and then dropped to less than 1 percent prior to the opening of the Express Lane. During the PM peak period, the HOV violation rate had increased to over 5 percent in 2009, and then dropped to 3.9 percent in the last year reported.

Table 37: Caltrans HOV Violation Rates on I-680 Study Corridor

Time	Date	Period	Total HOV Traffic Flow	Violation
		Monitored	Volume	Rate
AM PEAK	Wed Mar 30, 2011	6:00 - 9:00 AM	2560	N.A.
	Thu Apr 29, 2010	6:00 - 9:00 AM	2172	0.60%
	Thu Nov 12, 2009	6:00 - 9:00 AM	3143	0.30%
	Wed Oct 22, 2008	6:00 - 9:00 AM	2549	1.50%
	Wed Sep 19, 2007	6:00 - 9:00 AM	2454	3.30%
	Tue Jun 13, 2006	6:00 - 9:00 AM	2121	3.00%
	Tue Oct 4, 2005	6:00 - 9:00 AM	2133	3.60%
PM PEAK	Tue Sep 27, 2011	3:00 - 6:00 PM	516	N.A.
	Thu Apr 29, 2010	3:00 - 6:00 PM	1595	3.90%
	Tue May 12, 2009	3:00 - 6:00 PM	980	5.70%
	Tue Dec 9, 2008	3:00 - 6:00 PM	1052	2.60%
	Tue Jun 5, 2007	3:00 - 6:00 PM	1481	3.50%
	Tue Sep 19, 2006	3:00 - 6:00 PM	1669	1.10%
	Thu Nov 3, 2005	3:00 - 6:00 PM	1752	1.00%

Source: http://www.dot.ca.gov/dist4/reports.htm

The HOV violation rate reported by Caltrans for 2008 (1.5 percent to 2.6 percent) is much lower than the percentage of single-occupant vehicles reported in the "Before" study (27 percent to 35 percent). The difference is due to two differences in survey methodology. The Caltrans occupancy survey attempted to separate clean air vehicles from other SOVs, while the occupancy survey for the "Before" study included clean air vehicles based on their observed occupancy. Also, when additional occupants could not be easily identified by the surveyors, the "Before" study classified the vehicle as SOV, while the Caltrans occupancy survey may have assumed a legal HOV.

HOV/Express Lane Citations

The most specific information available on enforcement is the citation records from the California Highway Patrol (CHP). These data are summarized for the past four years, including years before and after the implementation of the Express Lane.

The number of CHP citations increased initially and reduced later, indicating that increased enforcement for the Express Lane likely is resulting in reduced citations.

The study corridor citations for “Before” and “After” conditions are summarized in Table 38. The number of citations increased significantly during 2011, the first full year of Express Lane operations, and then decreased significantly in 2012.

Table 39 summarizes HOV lane citations in the northbound I-680 control corridor. The number of HOV lane citations nearly doubled from 2009 to 2010, stayed relatively constant in 2011, and then increased by 62 percent from 2011 to 2012.

Table 38: California Highway Patrol HOV/Express Lane Citations - Study Corridor

Year	Dublin CHP Office	Dublin CHP Office	San Jose CHP Office	Total
	SR 84 -> N. Mission	N. Mission -> Santa Clara County line	Santa Clara County line -> CA 101	All Segments
2009	26	43	136	205
2010	18	33	349	400
2011	39	85	354	478
2012	5	33	185	223

Table 39: California Highway Patrol HOV Lane Citations - Control Corridor

Year	Dublin CHP Office	Dublin CHP Office	Contra Costa CHP Office	Total
	Stoneridge -> Bollinger Canyon	Bollinger Canyon -> Diablo Rd	Diablo Rd -> Olympic Blvd	All Segments
2009	75	46	209	330
2010	110	74	461	645
2011	95	70	440	605
2012	150	111	721	982

License plate readers and self-identification of carpools (using switchable toll tags or web-based applications) are being explored for use in the Bay Area region to improve enforcement and potentially reduce violations.

In addition, several new Intelligent Transportation Systems (ITS) technologies are being implemented to improve monitoring and enforcement of Express Lane operations around the country. Several of these emerging technologies are described in Appendix 9.8.

6 OTHER FACTORS POTENTIALLY INFLUENCING STUDY CORRIDOR TRAVEL

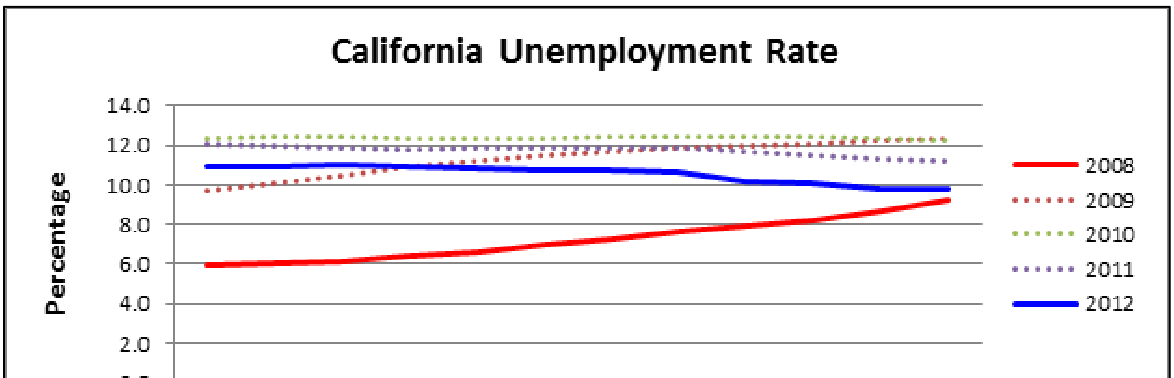
Corridor operations and the associated performance can be influenced by other factors in addition to the configuration and operation of the freeway corridor and Express Lane. Prevailing economic conditions, including employment and gasoline prices, can influence commute and travel behavior, and can impact corridor performance. Also, in addition to the conversion of the southbound I-680 HOV lane to an Express Lane in 2010, traffic conditions on the study corridor have also been affected by the implementation of ramp metering in 2011 and completion of the I-880/SR 262/Mission Boulevard improvements. This chapter describes these external factors and whether and how they could have impacted the Express Lane and the corridor performance.

6.1 ECONOMIC CONDITIONS

One economic indicator that can affect peak period traffic demand is the unemployment rate. At the time of the I-680 Express Lane “Before” study in Fall 2008, the California economy had started a period of recession and high unemployment. The California unemployment rate was around 6 percent at the beginning of 2008 and had risen to 8 percent at the time of the “Before” surveys in the fall (Figure 30). The unemployment rate remained at 11 to 12 percent from 2009 through the first part of 2012. By the time of the “After” survey in the fall of 2012, the unemployment rate had decreased to about 10 percent, still 2 percent higher than the unemployment rate during the “Before” study.[3]

The higher unemployment rate could correlate with lower travel demand during commute periods. However, as noted in the previous chapter, the vehicle counts and throughput during the “After” study were actually similar to or higher than vehicle counts during the “Before” study.

Figure 30: California Unemployment Rates

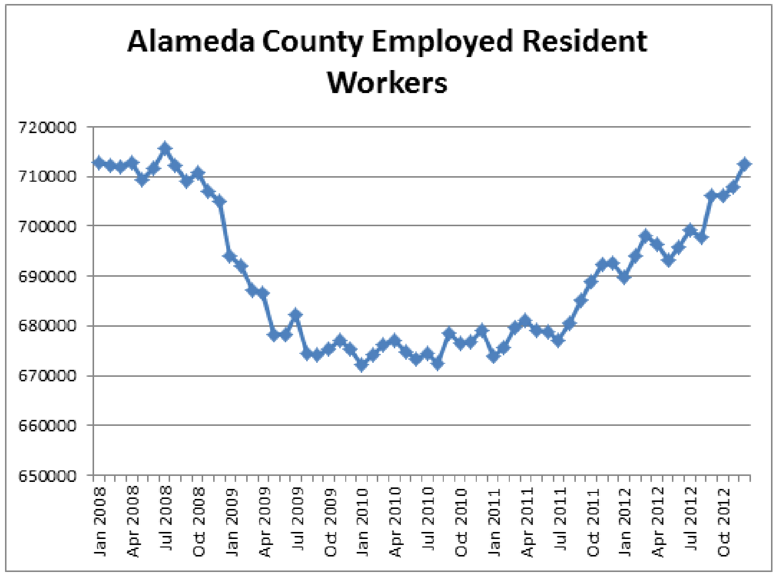


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008	5.9	6.0	6.1	6.4	6.6	7.0	7.3	7.6	7.9	8.2	8.7	9.2
2009	9.7	10.1	10.5	10.9	11.2	11.5	11.7	11.9	12.0	12.1	12.2	12.3
2010	12.3	12.4	12.4	12.3	12.3	12.3	12.4	12.4	12.4	12.4	12.3	12.2
2011	12.1	12.0	11.9	11.8	11.9	11.9	11.9	11.9	11.7	11.5	11.3	11.2
2012	10.9	10.9	11.0	10.9	10.8	10.7	10.7	10.6	10.2	10.1	9.8	9.8

[3] http://www.bls.gov/eag/eag.ca.htm

More specific employment data are available for the I-680 study area. The number of employed residents in Alameda County can affect the commute demand through the I-680 corridor. Employment statistics from the Bureau of Labor Statistics (BLS) indicate that the number of employed residents in Alameda County in the fall of 2012 was similar to or slightly higher than the number in the fall of 2008 (Figure 31) after a loss and gain of approximately 60,000 jobs in the meantime. Commute travel demand in the I-680 corridor can also be affected by employment rates in Contra Costa and San Joaquin counties.

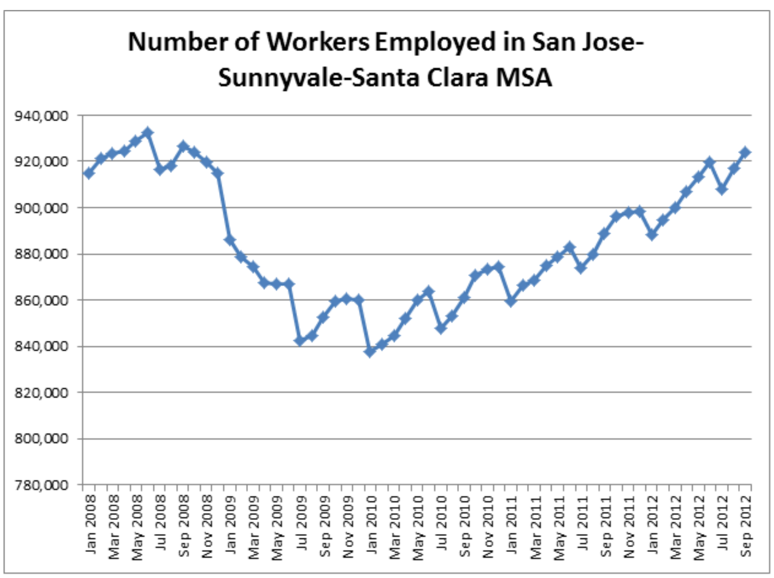
Figure 31: Alameda County Employed Resident Workers



Another important factor affecting demand in the study corridor would be jobs in Santa Clara County. The number of workers employed in Santa Clara County were compiled from the BLS labor statistics (Figure 32).

The number of workers in Santa Clara County in the fall of 2012 was very similar to the number in the fall of 2008 after a drop and gain of approximately 80,000 jobs in the meanwhile. Therefore, overall commute demand towards Santa Clara County during the "After" conditions should be very similar to the commute demand during the "Before" conditions.

Figure 32: Number of Workers Employed in Santa Clara County



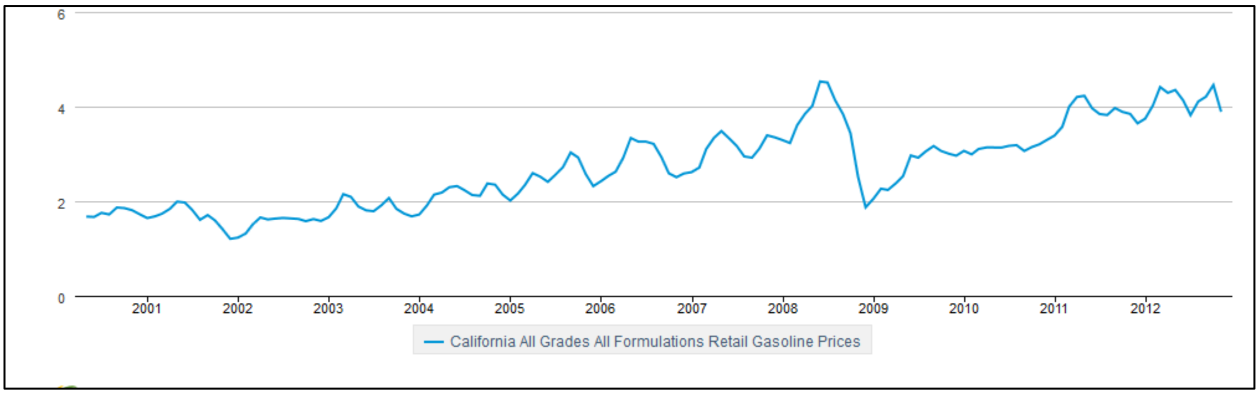
While the unemployment rate or employment levels are comparable between 2008 and 2012, the significant change in employment that occurred in the years in between due to the economic downturn has likely created some changes in the types of employment and number of workers by employment type, and therefore resulted in shifts in modal preferences.

6.2 GASOLINE PRICES

According to the Energy Information Administration[4], the average price for all grades of gasoline in California was $3.84 per gallon in September 2008 and $3.44 per gallon in October 2008, the period of the "Before" studies. The gas prices in California through the months of January 2008 to October 2008 were at historic highs.

Gas prices dropped in 2009 but since then have risen back to 2008 levels in 2012 (Figure 33). At the time of the "After" studies, the average price for all grades of gasoline in California was $4.45 per gallon in October 2012 and $3.89 per gallon in November 2012.

Figure 33: California Historical Retail Gas Prices: All Grades (Dollars per Gallon)



Source: US Energy Information Administration

Higher gas prices could have the impact of reducing discretionary travel or inducing additional travelers to use alternative modes such as ridesharing or transit.

Since gas prices at the time of the "After" studies were similar to gas prices at the time of the "Before" studies, it is unlikely that gas prices had an impact on the study findings or performance measures.

6.3 RAMP METERING EFFECTS

Ramp metering was implemented along the southbound I-680 corridor on July 25, 2011. The ramp metering along the corridor begins on the north end at the Stoneridge Drive interchange in Pleasanton and extends south to the SR 237/Calaveras Boulevard interchange in Milpitas, covering a total distance of approximately 22 miles. Ramp metering can impact vehicle throughput and congestion levels in the corridor, and can also improve traffic flow in the general purpose lanes, requiring associated adjustments in the pricing and operation of the Express Lane.

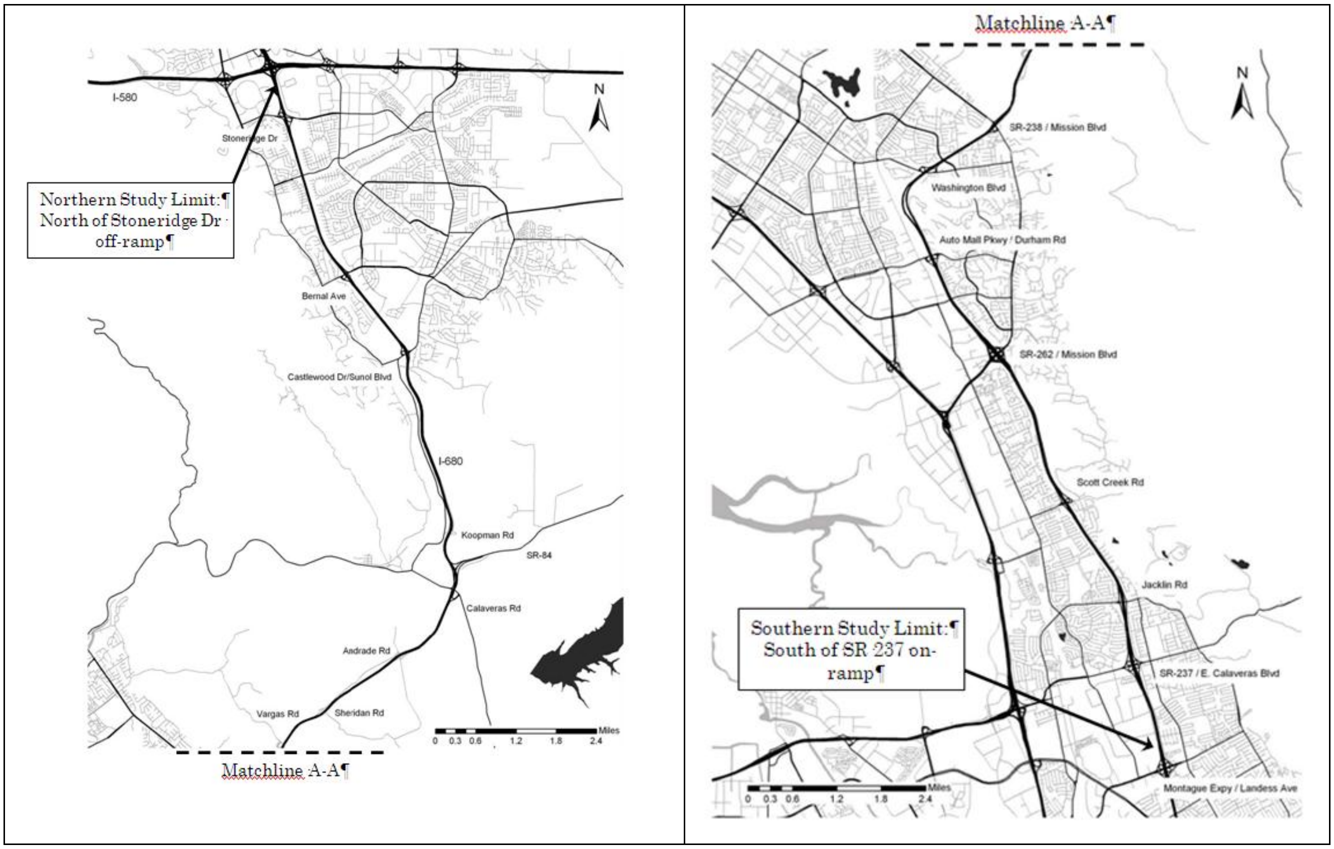
The implementation of ramp metering in the study corridor slightly increased traffic volumes and travel times in the Express Lane.

[4] Official Energy Statistics from the U.S. Government http://tonto.eia.doe.gov/dnav/pet/pet_pri_gnd_dcus_nus_m.htm

Ramp Metering "Before and After" Studies

The Metropolitan Transportation Commission (MTC) prepared the "I-680 Southbound Ramp Metering 'Before and After' Study." The ramp metering study limits are shown in Figure 34. The changes in performance on the I-680 study corridor that were attributed directly to the implementation of ramp metering are summarized in this section.

Figure 34: Study Limit of the I-680 Southbound Ramp Metering "Before and After" Study



The ramp metering "Before" data were collected May 10-12, 2011. These data included mainline and ramp traffic counts, and floating car travel time surveys. Ramp metering was implemented on southbound I-680 on July 25, 2011. An "Immediate After Study" was conducted on July 27-29, 2011. Based on initial observations, the ramp metering rates at the Bernal Avenue on-ramp were adjusted in October 2011. A comprehensive "After" study was conducted on May 8-10, 2012.

Traffic Volumes Before and After Ramp Metering

The total traffic volume entering the southbound I-680 corridor at the north end of the project (from Bernal to Calaveras) increased by 2 percent from May 2011 (before ramp metering) to May 2012 (after ramp metering). Average southbound traffic volumes along the freeway increased by approximately 4.7 percent from November 2010 to May 2011 (before ramp metering) and increased again by approximately 1.9 percent from May 2011 to May 2012 (after ramp metering).

Almost all of the increase in traffic volume measured on the freeway occurred in the Express Lane. Express Lane traffic volumes increased by 18 percent after the implementation of ramp metering.

The largest increase in traffic volumes between May 2011 and May 2012 occurred at the Calaveras Road on-ramp, where the average AM peak period traffic volume increased by 485 vehicles or around 85 percent. The largest decrease in vehicles was at the on-ramp from SR 84 to I-680, which saw a decline of 415 vehicles between May of 2011 and May of 2012, or about a 7 percent reduction. Traffic counts showed, and observations confirmed, that vehicles exited SR 84 to Calaveras Road, prior to the merge with southbound I-680, and then re-entered the freeway at the Calaveras Road on-ramp to avoid the queue approaching I-680 caused by the ramp metering. Vehicles using Calaveras Road to access I-680 rather than the direct connection from SR 84 to I-680 are not able to use the first ingress to the Express Lane.

Traffic volumes after the implementation of ramp metering peaked earlier in the morning than before ramp metering was implemented.

Travel Times Before and After Ramp Metering

The “Immediate After Study” conducted upon completion of ramp metering implementation in July 2011 showed that ramp metering initially reduced travel times by 2 percent over the four-hour period of ramp metering (6:00 to 10:00 AM) and by 8 percent over the two-hour peak period from 7:00 to 9:00 AM.

The results were different in the “After” study conducted in May 2012. The average peak corridor travel time in the general purpose lanes was about 27 minutes in 2011 before ramp metering and in May 2012 (after ramp metering) was about 30 minutes (+2.5 minutes). Compared to free-flow travel times, this indicated that congestion caused 8 to 11 minutes of delay on average along the corridor.

The I-680 Ramp Metering “Before and After” studies found that increases in traffic volume likely caused increased congestion and most of the increases in travel time measured between May 2011 and May 2012. Increases in travel time were attributable to causes other than traffic volume increases. Possible other causes identified in the study included:

- Ramp meter adjustments at Bernal Avenue;
- Travelers adjusting their travel patterns in response to the metering;
- Additional weaving from freeway entries to Express Lane entries; and
- Additional weaving from Express Lane exits to freeway exits at SR 262/Mission and SR 237/Calaveras.

Traffic Operations Before and After Ramp Metering

Before the implementation of ramp metering, bottlenecks occurred at the Sunol Boulevard and Vallecitos (SR 84) on-ramps due to on-ramp traffic merging with mainline freeway traffic. Congestion also occurred on the freeway at the Auto Mall Parkway/Durham Road and SR 262/Mission Boulevard off-ramps due to limited capacity on the arterial streets constraining vehicles from exiting the freeway.

Ramp metering reduced, but did not eliminate, the bottlenecks on the freeway at the on-ramps, located in the northern portion of the corridor. As expected, ramp metering had little or no effect on bottlenecks at the off-ramps, located in the southern portion of the corridor.

The implementation of ramp metering in the study corridor slightly increased traffic volumes and travel times in the Express Lane. Even with these increases, a comparison of the Express Lane "Before" and "After" studies travel times showed overall modest to notable improvements in both the general purpose lanes and Express Lane as discussed earlier.

6.4 ROADWAY IMPROVEMENTS

The implementation of the Express Lane and ramp metering represent major changes in the road system within the study corridor. Other major changes in the roadway system in the surrounding area can also affect travel patterns in the corridor.

After the completion of the "Before" study in 2009, the I-880 at SR 262/Mission Boulevard interchange improvement project was completed. Analysis of traffic volumes between 2008 and 2011 on both southbound I-680 and southbound I-880 at the Santa Clara County Line show that volumes using southbound I-680 from Fremont have decreased in conjunction with the overall volume increases on I-880 south of Fremont, indicating that traffic from Fremont has generally diverted away from I-680 and towards I-880 to travel to Santa Clara County.

In 2009, after the completion of the "Before" study, a major interchange improvement project was completed on I-880 at Mission Boulevard. The modifications significantly improved connections between I-608 and I-880 in southern Fremont. Further, the completion of major construction on I-880 also would have improved traffic conditions on the freeway corridor compared to the prior several years when construction was underway. It is expected that the completion of the I-880/Mission Boulevard interchange could have diverted some traffic that previously used I-680 to travel between Fremont and Santa Clara County, and could explain some of the decreases in traffic volume observed on I-680 on the southern part of the study corridor.

Traffic volumes on I-680 and I-880 at the Alameda/Santa Clara county line are presented in Table 40 and Figure 35. The total traffic volume at the county line decreased from 2006 to 2009, and then began increasing after 2009. Average daily traffic on I-680 continued to decrease even as total county line traffic began increasing. After 2009, when the I-880/Mission Boulevard interchange construction was completed, the traffic growth rate on I-880 increased from less than 1% per year to 5% per year. This indicates that total travel demand between Alameda and Santa Clara Counties increased between 2008 and 2011, but the interchange improvements on I-880 allowed I-880 to accommodate more of the growth, while overall traffic volumes decreased on I-680.

Traffic volumes were also compiled on I-880 on the north side of the City of Fremont, north of the Alvarado Boulevard/Fremont Boulevard interchange (Table 41). At this location, traffic volumes on I-880 steadily decreased from 2006 to 2010, and have only recently begun to rise again. This indicates that the volume increases on I-880 south of Fremont are not due to through traffic from the north, but are more related to increased use of I-880 by traffic to and from Fremont.

Table 40: Average Daily Traffic Volumes at Alameda/Santa Clara County Line

Year	I-680	I-880	Total
2005	143,000	173,000	316,000
2006	140,000	176,000	316,000
2007	135,000	176,000	311,000
2008	131,000	177,000	308,000
2009	122,000	178,000	300,000
2010	120,000	189,000	309,000
2011	119,000	197,000	316,000
2012	n/a	n/a	n/a
Change 2008-2011	**-9.2%**	**11.3%**	**2.6%**

Source: Caltrans Traffic Volumes

Figure 35: Average Daily Traffic Volumes at Alameda/Santa Clara County Line

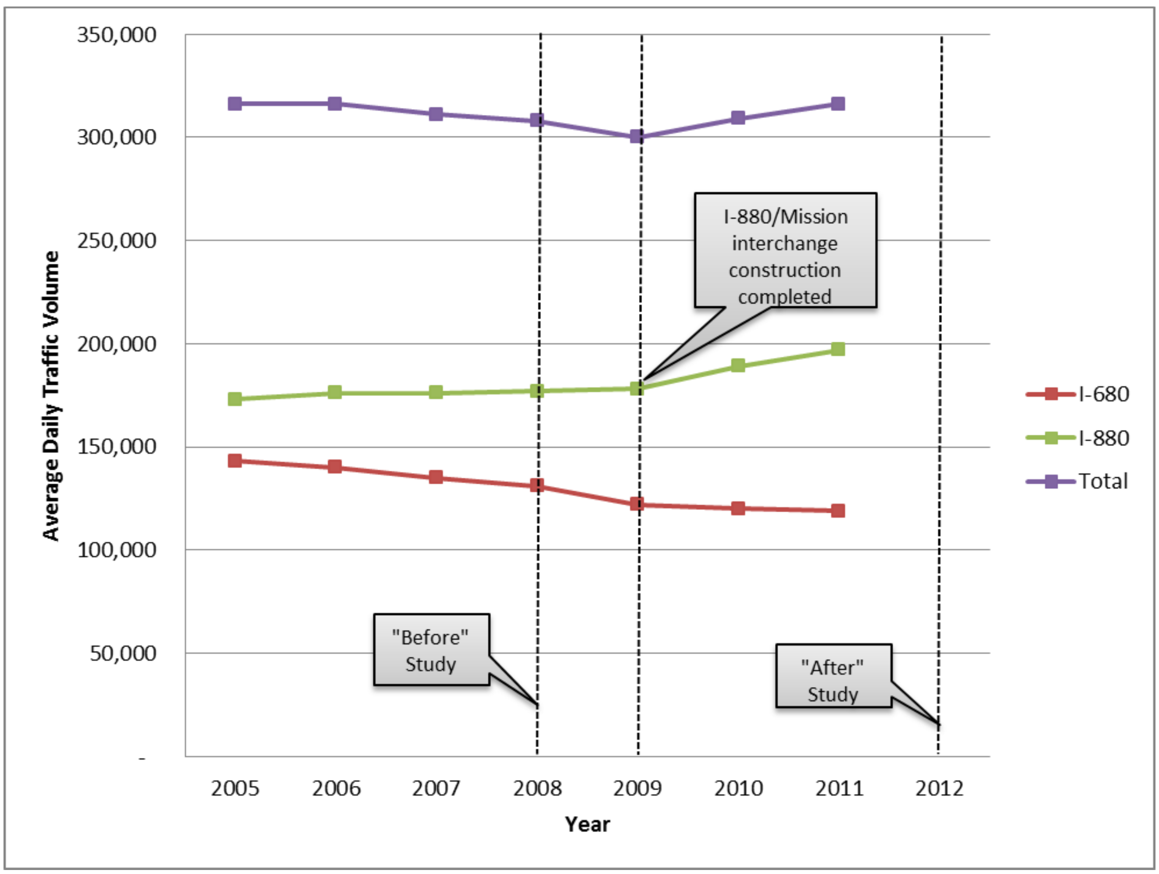


Table 41: Average Daily Traffic Volumes on I-880 North of Alvarado Blvd./Fremont Blvd.

Year	I-880
2005	206,000
2006	210,000
2007	200,000
2008	199,000
2009	197,000
2010	190,000
2011	194,000
2012	n/a
Change 2008-2011	**-2.5%**

Source: Caltrans Traffic Volumes

In addition, the freeway ramp volumes for the southbound I-680 ramps serving Fremont were compared between the 2008 "Before" and 2012 "After" conditions (Table 42). The volumes on the off-ramps serving Fremont have decreased by 9 percent in the AM peak period and by 4 percent for total daily traffic. The decreases in southbound on-ramp volumes were 17 percent for the AM peak period and 10 percent for total daily traffic. This confirms that volumes using southbound I-680 from Fremont have decreased in conjunction with the overall volume increases on I-880 south of Fremont, indicating that traffic from Fremont has generally diverted away from I-680 and towards I-880 to travel to Santa Clara County.

Table 42: Southbound I-680 Freeway Ramp Volumes in Fremont

	Off-Ramps				On-Ramps			
Interchange	2008	2012	Change	%	2008	2012	Change	%
AM Peak Period (7-9 AM)								
SR 238/Mission Blvd.	1,270	1,170	-100	-8%	1,680	1,400	-280	-17%
Washington Blvd.	790	770	-20	-3%	1,270	1,060	-210	-17%
Auto Mall Pkwy./Durham Rd.	2,170	1,820	-350	-16%	1,410	1,060	-350	-25%
SR 262/Mission Blvd.	2,280	2,400	120	5%	1,210	1,020	-190	-16%
Scott Creek Rd.	2,200	1,800	-400	-18%	660	610	-50	-8%
TOTAL	**8,710**	**7,960**	**-750**	**-9%**	**6,230**	**5,150**	**-1,080**	**-17%**
Daily								
SR 238/Mission Blvd.	6,990	6,970	-20	0%	7,780	6,900	-880	-11%
Washington Blvd.	4,950	4,950	0	0%	5,890	5,490	-400	-7%
Auto Mall Pkwy./Durham Rd.	10,820	10,410	-410	-4%	10,060	8,900	-1,160	-12%
SR 262/Mission Blvd.	22,600	21,600	-1,000	-4%	9,910	8,310	-1,600	-16%
Scott Creek Rd.	7,330	6,530	-800	-11%	6,190	6,120	-70	-1%
TOTAL	**52,690**	**50,460**	**-2,230**	**-4%**	**39,830**	**35,720**	**-4,110**	**-10%**

Sources: Automatic traffic counts conducted for I-680 Express Lane evaluation; Caltrans ramp metering detectors.

6.5 TRAVEL MODE TRENDS

Some changes in travel trends on the study corridor could potentially be explained by overall area trends in commuting and travel mode choice, rather than the characteristics of the corridor itself.

Survey data on total commuting and commute mode are available from the American Community Survey (ACS) administered by the United States Census. The ACS recruits a small sample of households each year throughout the United States to answer more extensive questions than those included in the decennial census. The ACS is intended to replace the former census “long form” that was discontinued after the 2000 census. The most recent year for available ACS data is 2011.

Data from the ACS on total workers and workers using the carpool show that the percentage of commuters using carpools declined 4 percent between 2000 and 2011 Alameda County from 14percent to 10 percent. This data were compiled for the three counties most likely to use the I-680 study corridor (Table 43) for 2008 to 2011. The total number of workers decreased by 5 percent from 2008 to 2011, consistent with the employment statistics described earlier. As noted in the earlier section, by fall of 2012 the employment in the study area was close to the employment levels in the fall of 2008. However, the share of workers using carpools decreased by 0.5 percent, resulting in a total 10 percent decrease in the overall number of carpools in the three counties. This trend helps to explain some of the overall decrease in HOV usage observed on the I-680 study corridor.

Table 43: Study Area Workers and Carpool Use from American Community Survey

	2008	2011	Change
TOTAL WORKERS			
Alameda County	715,600	667,700	-7%
Contra Costa County	487,800	471,400	-1%
San Joaquin County	273,100	256,700	-6%
Total	**1,476,500**	**1,395,800**	**-5%**
COMMUTERS USING CARPOOLS			
Alameda County	75,000	67,800	-10%
Contra Costa County	58,500	49,100	-16%
San Joaquin County	41,300	39,700	-4%
Total	**174,800**	**156,600**	**-10%**
CARPOOL PERCENT			
Alameda County	10.5%	10.2%	- 0.3%
Contra Costa County	12.0%	10.4%	- 1.6%
San Joaquin County	15.1%	15.5%	+0.4%
Total	**11.8%**	**11.2%**	**-0.5%**

7 EXPRESS LANE REVENUE

Toll revenues collected on the I-680 Southbound Express Lane have been fully utilized to pay for operations and maintenance of the Express Lane facility. In the current facility ramp up period, the revenues do not exceed operating costs. The operating cost has been subsidized by the unspent grant funds left in the Project. When the Express Lane becomes financially sustainable, i.e.) the toll revenues exceed the operations and maintenance costs, the Sunol Smart Carpool Lane JPA Board will determine how to reinvest these funds into the project corridor. An Expenditure Plan will be adopted biennially that may include funding for the construction of HOV facilities including the I-680 Northbound Sunol Smart Carpool Lane project and/or transit capital and operations that directly serve the Project corridor. Tables 44 and 45 present information on toll revenues and operating budget.

Table 44: Southbound I-680 Express Lane Revenue Summary

Time Period	Total Toll Paying Trips	Average Peak Period Toll Rate	Toll Revenue
Fiscal Year - 2011-12	521,315	$3.09	$ 1.1 million (Fiscal Year)
Month of March 2012	1881	$2.41	$4,525 (daily)
Month of March 2013	2330	$2.11	$4,925 (daily)

Source: I-680 Southbound Express Lane Annual Report FY 2011-12 and Express Lane Operations Update to SSCLJPA meeting on May 06, 2013

Table 45: Southbound I-680 Express Lane Revenues and Expenses, Fiscal Year 2012-2013

	FY 2012-13 Budget
Operating Revenues	$1,050,000
Operating Expenses	$1,581,000*

Source: SSCLJPA meeting agenda on May 06, 2013

*- Amount does not include operating expenses paid directly by project grant funds.

8 CONCLUSIONS AND RECOMMENDATIONS

This chapter describes how the objectives identified for the Express Lane described in Chapter 2 are met based on the analysis of various performance measures and other external factors that may have impacted the Express Lane corridor as presented in Chapters 5 and 6. It also takes the next step in identifying recommendations for improvement of the performance of the Express Lane corridor in terms of the performance measures that either did not perform well or performed with a mix of positive and negative results.

8.1 CONCLUSIONS

Both "Before" and "After" studies identified key objectives related to performance of the Express Lane in meeting the legislative mandate. Based on the results presented in Chapters 5 and 6 for various performance measures, the following summary describes how the objectives are met:

- ***Objective:*** Optimize the HOV lane usage to improve traffic throughput in the corridor

  Results: Overall vehicle and person throughput in the corridor increased, average travel times decreased by 2 minutes (13 percent) in the general purpose lanes and 1 minute (4%) in the Express Lane, and average speeds increased by 6 mph in the general purpose lanes and 3 mph in the Express Lane.

- ***Objective:*** Maintain LOS C or better for all Express Lane users

  Results: Express Lane LOS levels did not go below LOS B

- ***Objective:*** Use net revenue to improve highway and transit in the corridor

  Results: Currently all toll revenues are being used towards the Express Lane operations. When net revenue becomes available over and above covering the Express Lane operations, it will be used to improve highway and transit in the corridor

- ***Objective:*** Employ new intelligent transportation system (ITS) technologies

  Results: Dynamic pricing is currently being deployed to optimize the throughput. Working with the regional partners, technology options for other purposes are being explored including switchable toll tags and automated license plate reading for enforcement purposes.

8.2 RECOMMENDATIONS

Analysis of performance measures for the "Before" and "After" studies showed that some improvements can be implemented to further improve the corridor performance in both the Express Lane and general purpose lanes regarding the measures that either did not perform well or performed with a mix of positive and negative results. These performance measures include: vehicle occupancy (carpool use), level of service and related bottlenecks, transit ridership, and toll and access violations. Recommendations regarding these potential improvements are presented below:

- Increased HOV usage and transit ridership for trips within Alameda County could be achieved through focused implementation of a Transportation Demand Management program that includes tools to promote use of alternate modes.

- Toll violation rates could be reduced through implementation of new technologies such as automated license plate reading combined with the switchable toll tag capabilities that are currently being explored.
- To improve the new bottleneck at SR 84 and the two existing bottlenecks at the southern portion of the Express Lane at the Auto Mall Parkway/Durham Road and SR 262/Mission Boulevard interchanges, and to address the access issues experienced at the Washington Boulevard and Auto Mall Parkway/Durham Road interchanges, further studies could be performed to identify potential improvement options.

9 APPENDICES

9.1 TRAVEL SPEED SURVEY DETAIL

The travel speeds in each segment for each survey hour are compared graphically. The study corridor travel speeds on the HOV/Express lane and general purpose lanes are compared for the AM peak period (Figure 36 and Figure 37) and PM peak period (Figure 38 and Figure 39). Similarly, the control corridor travel speeds on the HOV lane and general purpose lanes are compared for the AM peak period (Figure 40 and Figure 41) and PM peak period (Figure 42 and Figure 43).

Figure 36: Study Corridor HOV/Express Lane Travel Speeds – AM Peak Period

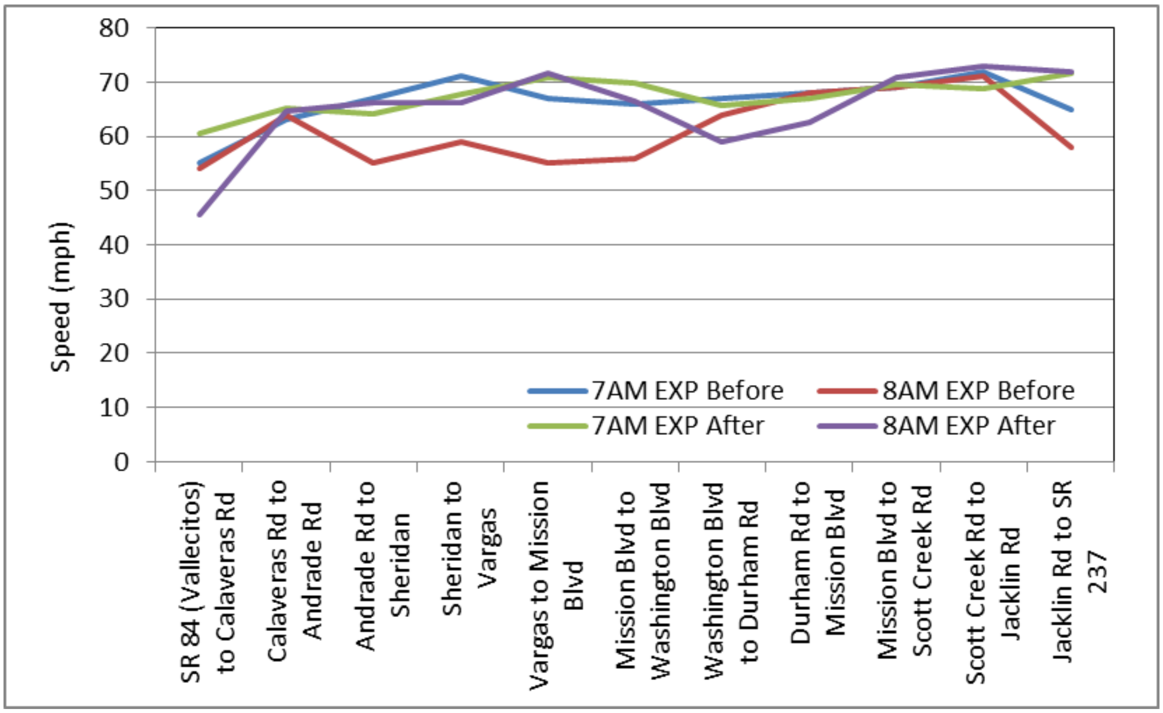


Figure 37: Study Corridor General Purpose Lanes Travel Speeds – AM Peak Period

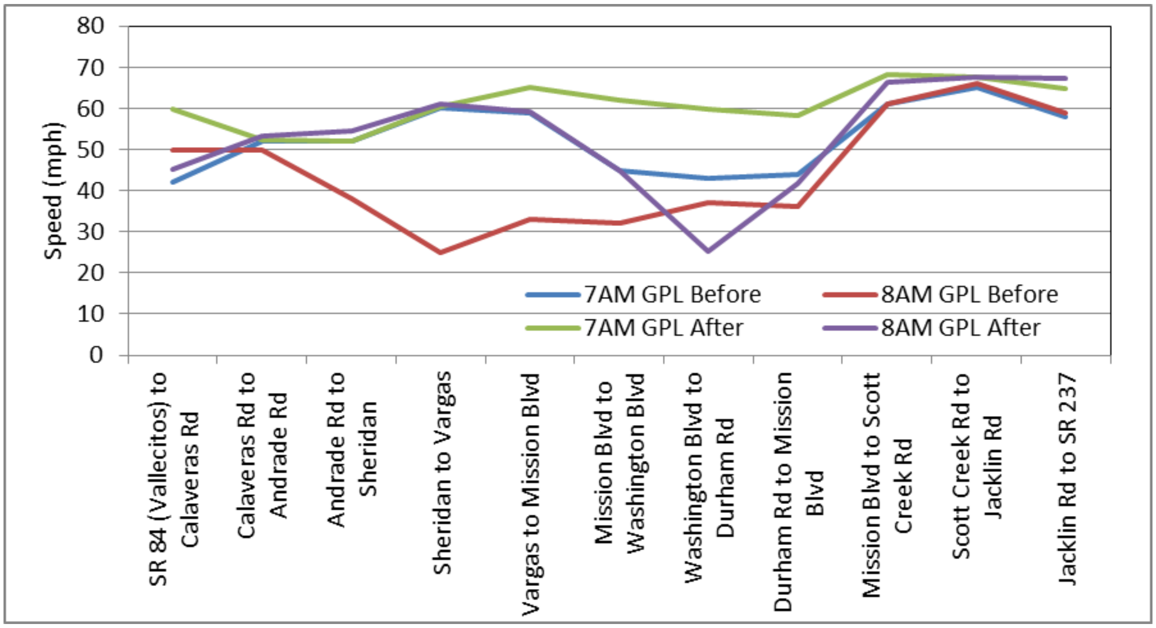


Figure 38: Study Corridor HOV/Express Lane Travel Speeds – PM Peak Period

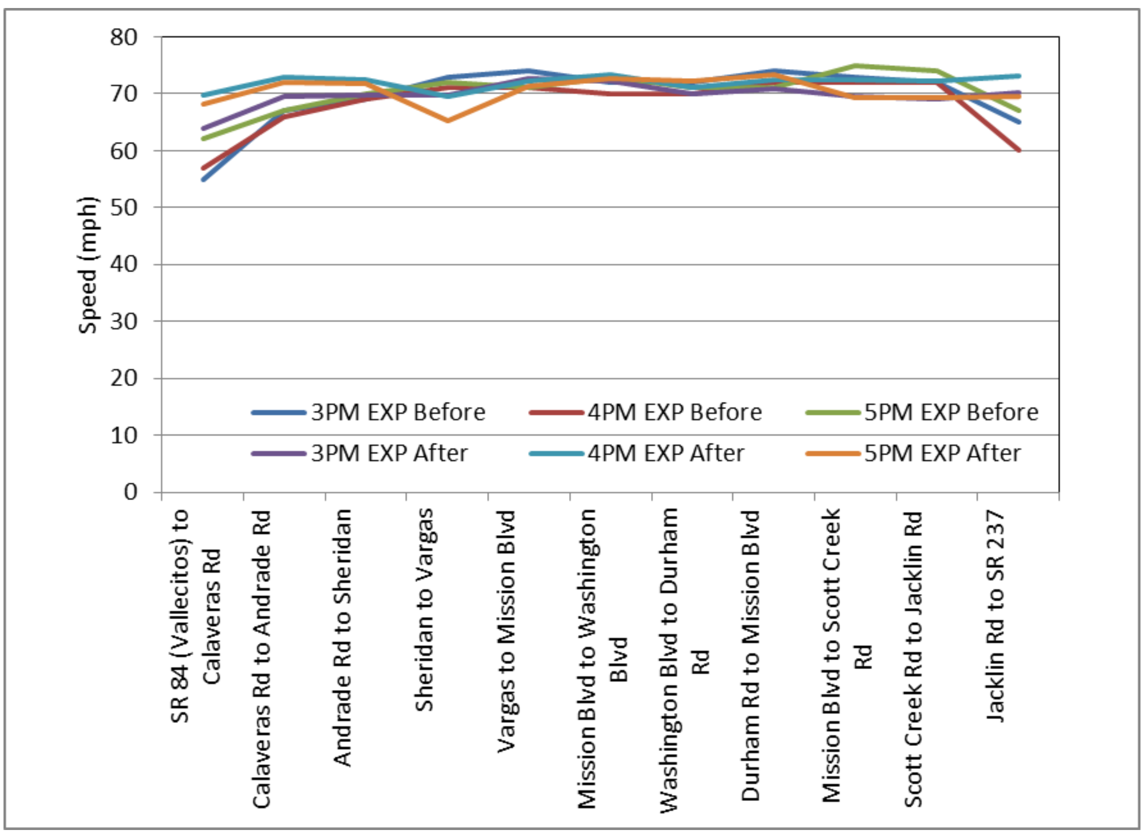


Figure 39: Study Corridor General Purpose Lanes Travel Speeds – PM Peak Period

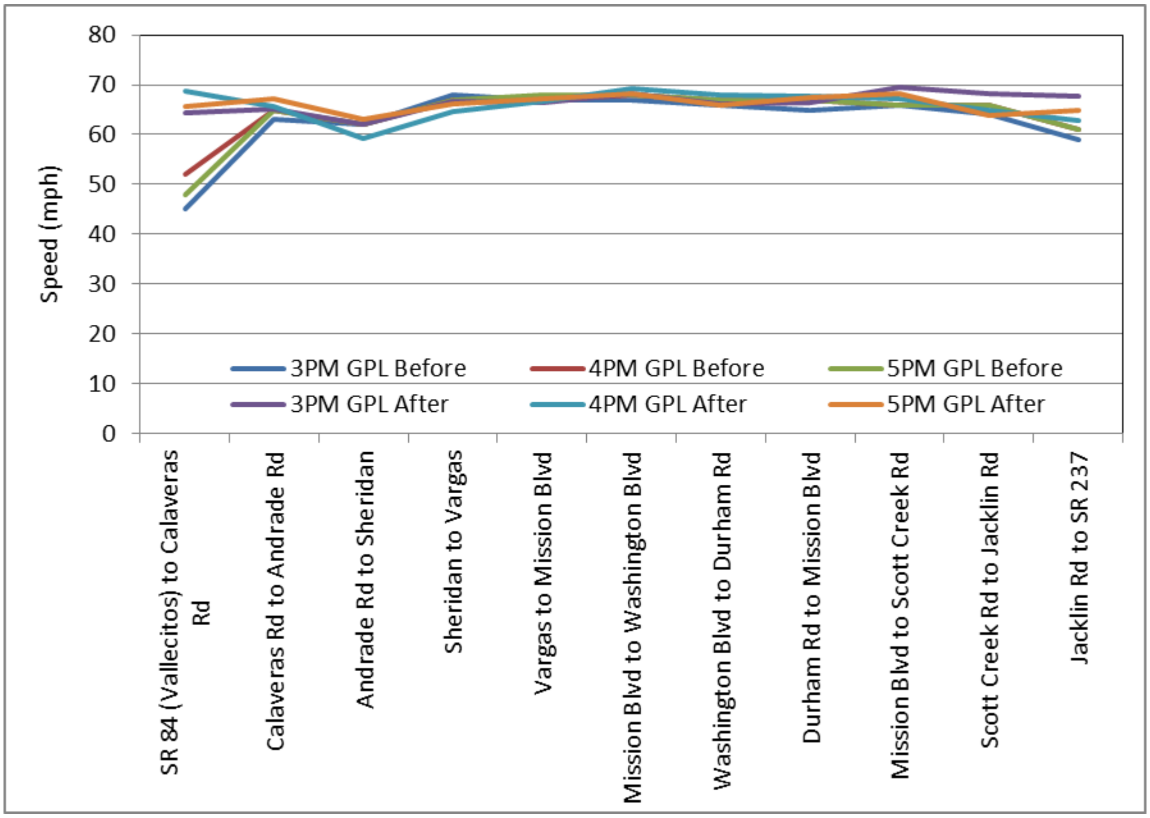


Figure 40: Control Corridor HOV Lane Travel Speed – AM Peak Period

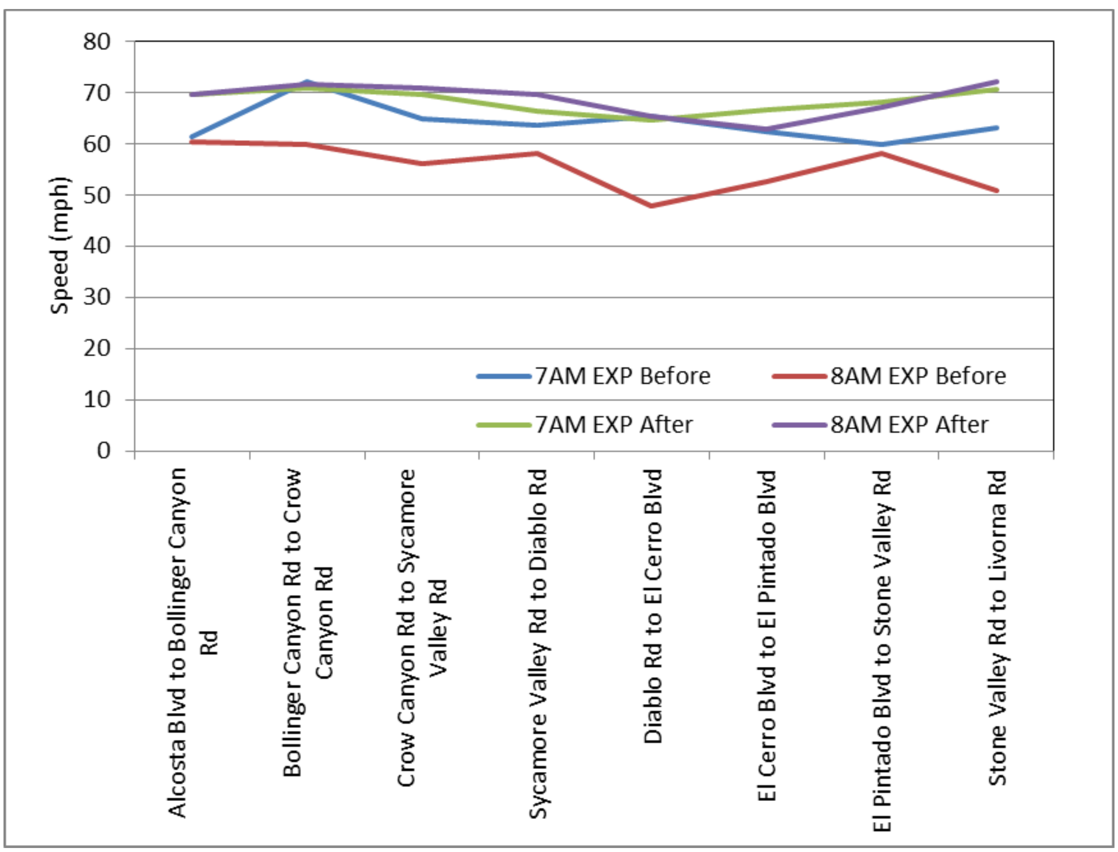


Figure 41: Control Corridor General Purpose Lanes Travel Speed – AM Peak Period

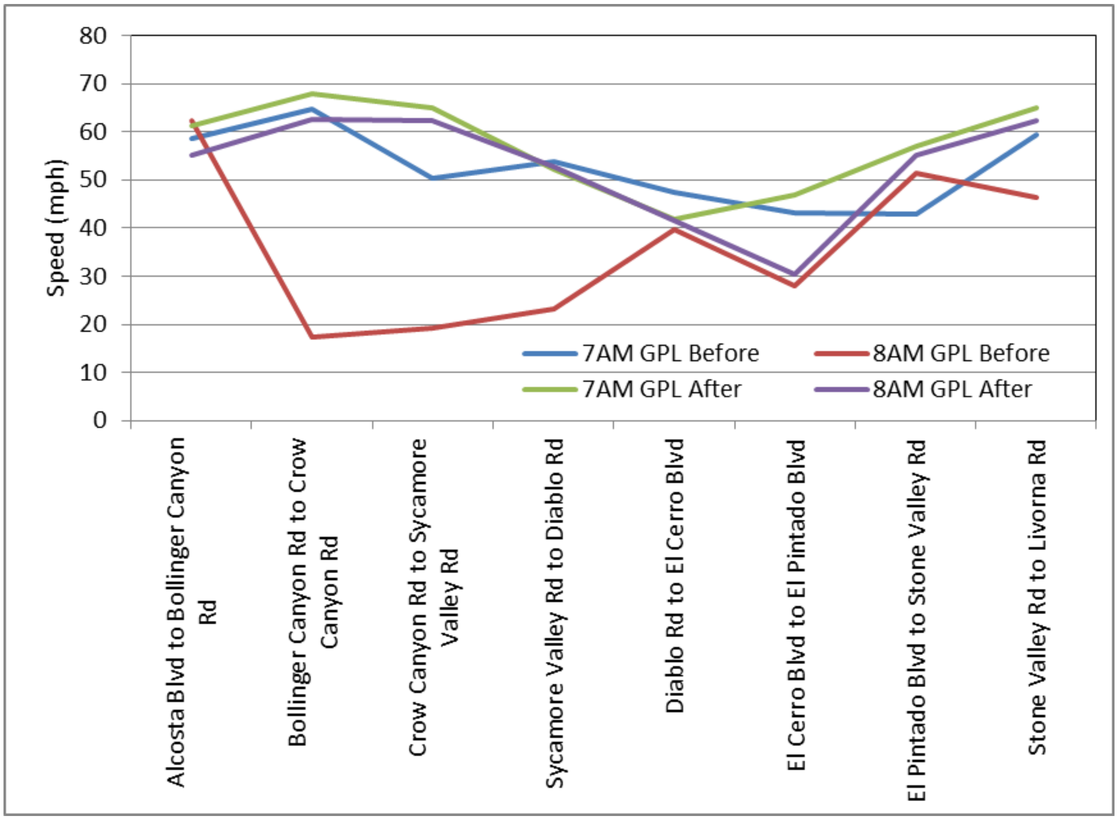


Figure 42: Control Corridor HOV Lane Travel Speed – PM Peak Period

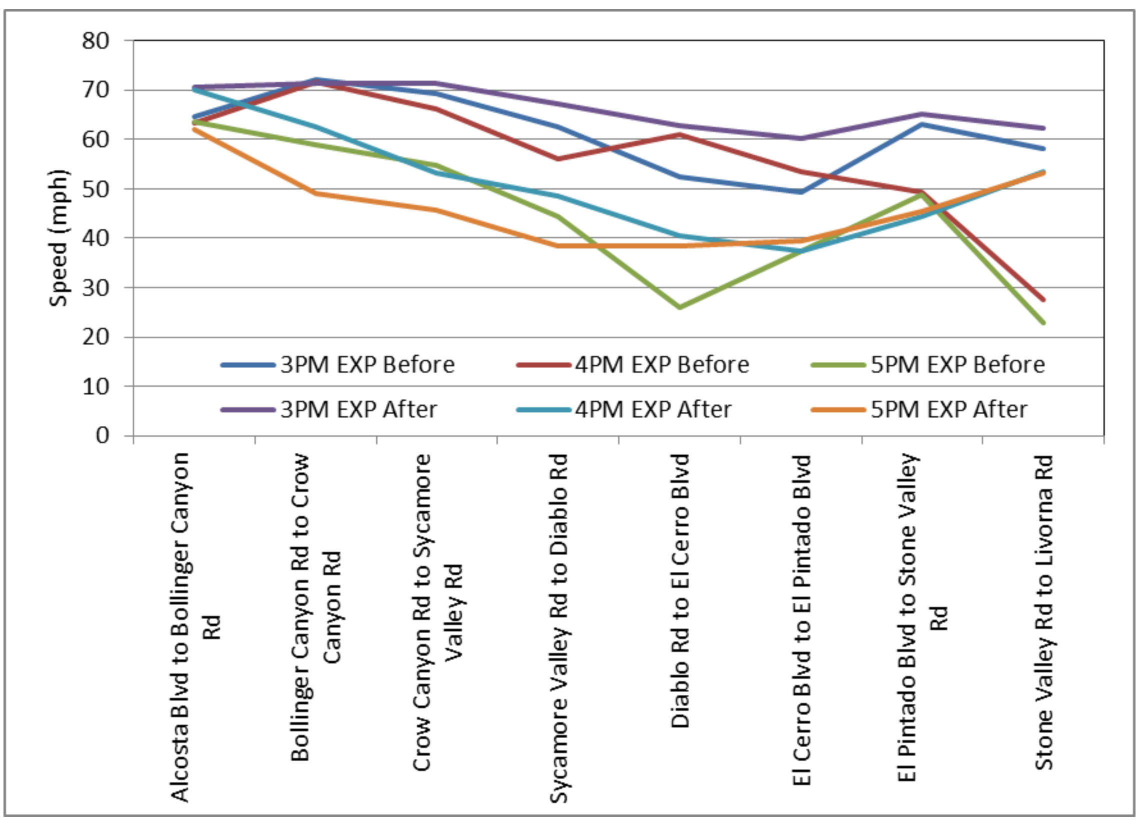
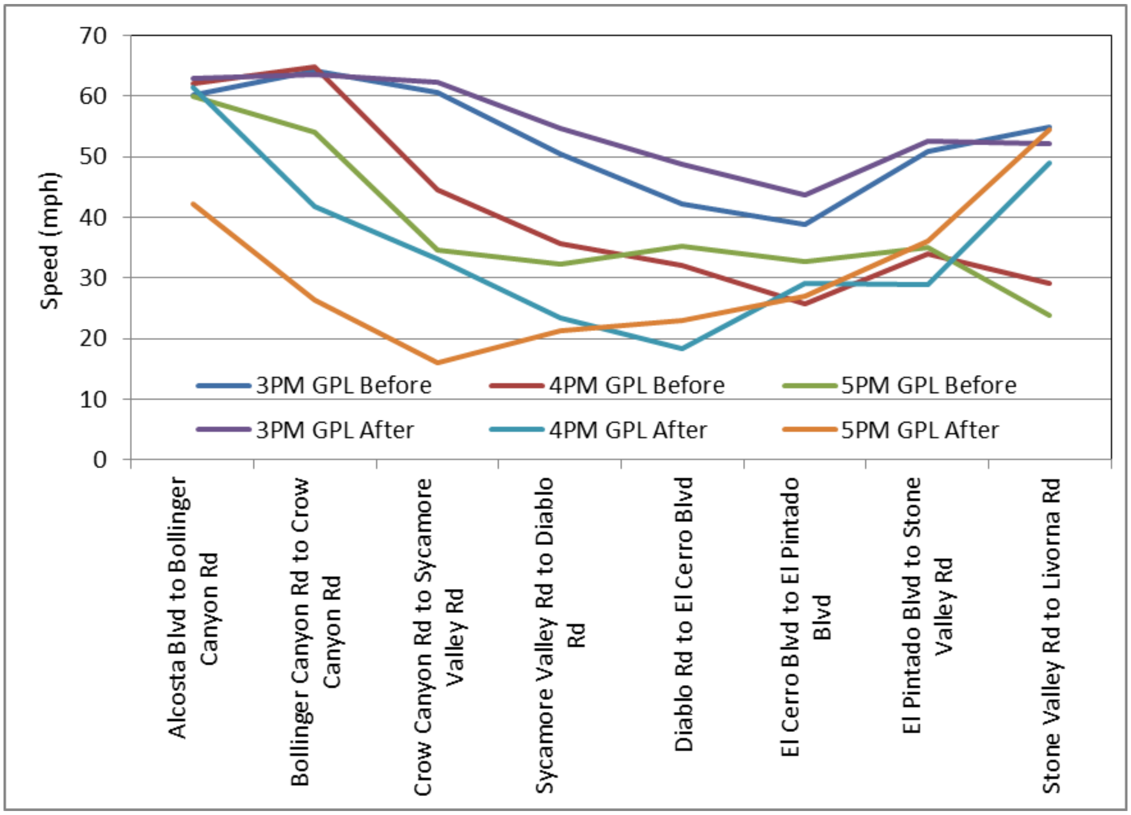


Figure 43: Control Corridor General Purpose Lanes Travel Speed – PM Peak Period



9.2 STATISTICAL ANALYSIS OF TRAVEL TIMES DETAIL

Study Corridor - Statistical Analysis and Hypothesis Testing

Statistical tests were conducted to compare the travel time data from the "After" study period against "Before" study data. The statistical test involved conducting the Student's t test (t-test) to evaluate if the mean travel times had significantly changed.

Two sets of tests were conducted. The first compared the travel times in the HOV ("Before") and Express Lane ("After"), while the second compared the travel times in the general purpose lanes before and after the implementation of the Express Lane.

Statistical Tests Conclusions

Table 46 presents a summary of the statistical tests. The summary indicates the following:

- Drivers in the southbound HOV/Express Lane and general purpose lanes did not experience a statistically significant increase in their mean travel times when the HOV lanes were converted to the Express Lane.
- Drivers in the control corridor HOV lanes also did not experience a statistically significant increase in their mean travel times during the same period.
- Drivers in the control corridor general purpose lanes saw an increase in their mean travel time while those on the study corridor general purpose lanes did not see an increase in their mean travel time.
- Travel time variance did not change in any of the lane groups (HOV/Express or GP lanes) in either the southbound study corridor or the northbound control corridor.

Based on the statistical tests, there was a net benefit in converting the HOV lanes to Express Lanes. The study corridor travel times either remained the same or decreased across both the Express Lane and general purpose lanes after the conversion. On the control corridor, mean travel time in the general purpose lanes increased while travels time in the HOV lane decreased or remained constant.

Table 46: Summary of Travel Time Statistic Test Results

Location	Lane Group	Test Hypothesis	Conclusion
Study Corridor	HOV/Express Lane	Null: Mean(Exp.)≤Mean(HOV) Alt. Mean(Exp.)>Mean(HOV)	Test accepted Null Hypothesis: HOV drivers did not experience an increase in average travel time despite addition of solo drivers into the Express Lane
		Null: Var(Exp.)=Var(HOV) Alt. Var(Exp.)≠Var(HOV)	Test accepted Null Hypothesis: HOV drivers in the HOV lane did not experience any change in travel time reliability due to conversion to Express Lane
	General Purpose Lanes	Null: Mean(GP_{After})≤Mean(GP_{Before}) Alt. Mean(GP_{After})>Mean(GP_{Before})	Test accepted Null Hypothesis: Travel times decreased or remained the same in the GP lanes after the opening of the Express Lane
		Null: Var(GP_{After})=Var(GP_{Before}) Alt. Var(GP_{After})≠Var(GP_{Before})	Test accepted Null Hypothesis: Drivers in the GP lanes did not experience any change in travel time reliability due to conversion of HOV to Express Lane
Control Corridor	HOV Lanes	Null: Mean(HOV_{After})≤Mean(HOV_{Before}) Alt. Mean(HOV_{After})>Mean(HOV_{Before})	Test accepted Null Hypothesis: HOV lane drivers on control corridor did not experience an increase in average travel time during the study period
		Null: Var(HOV_{Before})=Var(HOV_{After}) Alt.: Var(HOV_{Before})≠ Var(HOV_{After})	Test accepted Null Hypothesis: HOV lane drivers on control corridor did not experience any change in travel time reliability during the study period
	General Purpose Lanes	Null: Mean(GP_{Before})≤Mean(GP_{After}) Alt. Mean(GP_{Before})>Mean(GP_{After})	Test accepted Null Hypothesis: Average travel time on the control corridor GP lanes increased during the study period
		Null: Var(GP_{Before})=Var(GP_{After}) Alt.: Var(GP_{Before})≠Var(GP_{After})	Test accepted Null Hypothesis: Drivers on control corridor GP lanes did not experience any change in travel time reliability during the study period

Study Corridor - Statistical Evaluation of HOV/Express Lane Travel Times

The Student's t-test was used for the statistical analysis to compare the means of travel time distributions. The specific Student t-test to be used depends on whether the variances of the sample distributions are the same. For each analysis set, the F-test was conducted first, the results of which were used to select the appropriate form of the Student t-test. The travel time data used for the statistical analyses are shown in Table 47.

Table 47: Study Corridor Travel Times in Managed and General Purpose Lanes

Time Slice	"Before" Study Travel Time (minutes)		"After" Study Travel Time (minutes)		Change in Travel Time - "Before" - "After" (minutes)	
	HOV	GP Lane-Before	Express Lane	GP Lane-After	HOV/Express Lane	General Purpose Lane
5:00-6:00 AM*	11.2	12.4	10.6	11.8	0.6	0.6
6:00-7:00 AM*	11.4	12.7	11.2	12.5	0.2	0.2
7:00-8:00 AM	11.8	15.5	12.0	13.4	-0.2	2.1
8:00-9:00 AM	12.9	20.4	12.3	16.4	0.6	4.0
3:00-4:00 PM	11.2	12.4	11.6	12.2	-0.4	0.2
4:00-5:00 PM	11.3	12.1	11.3	12.4	0.0	-0.3
5:00-6:00 PM	11.1	12.1	11.5	12.3	-0.4	-0.2
6:00-7:00 PM*	11.7	12.6	11.5	12.9	0.2	-0.3
Mean	11.58	13.78	11.50	12.99		
Variance	0.35	8.40	0.26	2.13		
Std. Deviation	0.59	2.90	0.51	1.46		

Note *: The travel time data was obtained via PeMS

Table 48 is the result of the Student t-tests comparing the mean travel time in the HOV and Express Lanes. The null hypothesis was that the mean travel time in the Express Lane was less than the average travel time in the HOV lane (before it was converted to the Express Lane). The hypothesis is described as:

H_o: $\mu_{\text{Express Lane}} \leq \mu_{\text{HOV Lane}}$

H_1: $\mu_{\text{Express Lane}} > \mu_{\text{HOV Lane}}$

μ_{HOV} = mean of travel time in the HOV lane ("Before")

$\mu_{\text{Express Lane}}$ = mean travel time data in the Express Lane ("After")

The one-tail p-value test was applied. The p-value of 0.395 is greater than 0.05 implying that the null hypothesis cannot be rejected. Therefore, the null hypothesis is accepted. The test concludes that the average travel time in the Express Lanes is less than or equal to that in the HOV lane. Based on the test, there was no statistically significant increase in mean travel time due to the conversion of the Express Lane.

Table 48: T-test Comparing Mean Travel Times in HOV and Express Lanes

	HOV	Express Lane
Mean	11.575	11.5
Variance	0.347857143	0.262857143
Observations	8	8
Pooled Variance	0.305357143	
Hypothesized Mean Difference	0	
df	14	
t Stat	0.271448357	
P(T<=t) one-tail	0.39500393	
t Critical one-tail	1.761310136	
P(T<=t) two-tail	0.79000786	
t Critical two-tail	2.144786688	
t-Test: Two-Sample Assuming Equal Variances		

To ensure the Student t-test was applied statistically correctly, an F-test was conducted first to compare the variances of the HOV and Express Lane travel times. The null hypothesis of the F-test states that the variance of the travel time distribution for the HOV and Express Lanes are the same. The hypothesis is described as:

H_o: $\sigma_{HOV} = \sigma_{Express\ Lane}$

H_1: $\sigma_{HOV} \neq \sigma_{Express\ Lane}$

σ_{HOV} = variance of travel time data from the HOV lane ("Before")

$\sigma_{Express\ Lane}$ = variance of travel time data from the Express Lane ("After")

The p-value of 0.72 from the F-test results (shown in Table 49) is greater than 0.05. This value implies that the null hypothesis cannot be rejected. Thus, the variances are statistically equal. This was the basis for applying the "equal variances" form of the Student t-test in Table 48.

Table 49: F-test Comparing Variances of Mean Travel Times in HOV and Express Lanes

	HOV	Express Lane
Mean	11.575	11.5
Variance	0.347857143	0.262857143
Observations	8	8
df	7	7
F	1.323369565	
P(F<=f) one-tail	0.360499757	
F Critical one-tail	4.994909219	
P(F<=f) two-tail	0.72	
F-Test Two-Sample for Variances		

Study Corridor - Statistical Evaluation of General Purpose Lane Travel Times

Tests were also conducted to assess the impact of the Express Lane conversion on travelers in the general purpose (GP) lanes. The null hypothesis for this test was that the mean travel time in the GP lanes reduced or remained constant after the Express Lane was introduced. The hypothesis is described as:

H_o: $\mu_{\text{GP Lane (After)}} \leq \mu_{\text{GP Lane (Before)}}$

H_o: $\mu_{\text{GP Lane (After)}} > \mu_{\text{GP Lane (Before)}}$

$\mu_{\text{GP Lane (Before)}}$ = mean of travel time in General Purpose Lane before project implementation

$\mu_{\text{GP Lane (After)}}$ = mean of travel time in General Purpose Lane after project implementation

Table 50 shows the results of statistical Student t-test. The p-value of 0.251 (one-tail) is greater than 0.05, meaning the null hypothesis cannot be rejected. It can be concludes that the mean travel time in the GP lane remained the same or decreased after the conversion of the HOV lane to an Express Lane.

Table 50: T-test Comparing Mean Travel Times in General Purpose Lanes - Study Corridor

	GP Lane-Before	GP Lane-After
Mean	13.775	12.9875
Variance	8.399285714	2.129821429
Observations	8	8
Pooled Variance	5.264553571	
Hypothesized Mean Difference	0	
df	14	
t Stat	0.686435576	
P(T<=t) one-tail	0.251824829	
t Critical one-tail	1.761310136	
P(T<=t) two-tail	0.503649659	
t Critical two-tail	2.144786688	

t-Test: Two-Sample Assuming Equal Variances

The F-test results (Table 51) comparing the variances produced a p-value of 0.091 which is less than 0.05. Hence, the null hypothesis could not be rejected. Based on the test, it may be concluded that the variances are the same and hence the "equal variance" form of the t-test was used in Table 51.

In summary, the tests indicate that travelers in both the study corridor Express Lane and the GP lanes either experienced a decrease in their travel times or they remained the same.

Table 51: F-test Comparing Variances of Travel Times in General Purpose Lanes – Study Corridor

	GP Lane-Before	GP Lane-After
Mean	13.775	12.9875
Variance	8.399285714	2.129821429
Observations	8	8
df	7	7
F	3.943657248	
P(F<=f) one-tail	0.045349298	
F Critical one-tail	4.994909219	
P(F<=f) two-tail	0.091	
F-Test Two-Sample for Variances		

Control Corridor - Statistical Analysis and Hypothesis Testing

The control corridor (I-680 northbound) was evaluated to investigate whether there would be statistically significant impacts of regional changes between 2008 and 2012. The travel times on the control corridor are shown in Table 52.

Table 52: Control Corridor Travel Times in HOV and General Purpose Lanes

Time Slice	"Before" Study Travel Time (minutes)		"After" Study Travel Time (minutes)		Change in Travel Time - "Before" - "After" (minutes)	
	HOV-Before	GPL-Before	HOV-After	GPL-After	HOV	GPL
6:00-7:00 AM*	9.9	11.1	9.5	10.8	0.4	0.3
7:00-8:00 AM	10.7	15.2	9.8	11.8	0.8	3.4
8:00-9:00 AM	11.8	22.3	9.8	12.7	2.0	9.6
3:00-4:00 PM	10.5	12.6	10.0	12.3	0.5	0.3
4:00-5:00 PM	12.3	17.3	14.3	27.8	-2.0	-10.5
5:00-6:00 PM	13.6	18.7	14.7	26.9	-1.1	-8.2
Mean	11.46	16.21	11.37	17.05		
Variance	1.86	16.93	5.95	64.06		

Note *: The travel time data was obtained via PeMS

Control Corridor - Statistical Evaluation of HOV Travel Times

The control corridor HOV travel time was evaluated using the same approach as for the study corridor. First, F-tests were used to check if the "Before" and "After" variances were equal, and based on that the appropriate Student's t-test was selected. Table 53 shows the Student t-test results comparing the HOV lane mean travel times. The null hypothesis was that the mean travel time in HOV lane reduced over the study period. The hypothesis is described as:

H_0: $\mu_{\text{HOV Lane After}} \leq \mu_{\text{HOV Lane Before}}$

H_1: $\mu_{\text{HOV Lane After}} > \mu_{\text{HOV Lane Before}}$

$\mu_{\text{HOV Lane Before}}$ = mean of travel time in the HOV lane ("Before")

$\mu_{\text{HOV Lane After}}$ = mean travel time data in the Express Lane ("After")

Table 53: T-test Comparing Mean Travel Times in HOV Lanes - Control Corridor

	HOV-Before	HOV-After
Mean	11.45787037	11.37195833
Variance	1.860130916	5.95243386
Observations	6	6
Pooled Variance	3.906282388	
Hypothesized Mean Difference	0	
df	10	
t Stat	0.075289225	
P(T<=t) one-tail	0.470734742	
t Critical one-tail	1.812461123	
P(T<=t) two-tail	0.941469485	
t Critical two-tail	2.228138852	
t-Test: Two-Sample Assuming Equal Variances		

The Student t-test p-value of 0.471 (one-tail) is greater than 0.05. The test indicates that the null hypothesis cannot be rejected. The test indicates that the mean travel time decreased or remained equal over the course of the project. Based on the test result, the drivers in the control corridor HOV lanes did not experience a statistically significant increase in travel time change over the project period.

The results of an F-test of the HOV travel time variances are shown in Table 54.

Table 54: F-test Comparing Variances of Mean Travel Times in HOV Lanes - Control Corridor

	HOV-After	HOV-Before
Mean	11.37	11.46
Variance	5.95	1.86
Observations	6	6
df	5	5
F	3.20	
P(F<=f) one-tail	0.11	
F Critical one-tail	7.15	
P(F<=f) two-tail	0.23	

F-Test Two-Sample for Variances

The null hypothesis is described as:

H_o: $\sigma_{HOV\text{-}Before} = \sigma_{HOV\text{-}After}$

H_1: $\sigma_{HOV\text{-}Before} \neq \sigma_{HOV\text{-}After}$

$\sigma_{HOV\text{-}Before}$ = variance of travel time data from the HOV lane ("Before")

$\sigma_{HOV\text{-}After}$ = variance of travel time data from the HOV Lane ("After")

The p-value of 0.23 is greater than 0.05. The test indicates that the null hypothesis that the variances are equal cannot be rejected. This was the basis for applying the "equal variances" form of the Student t-test when testing the means.

Control Corridor - Statistical Evaluation of General Purpose Lane Travel Times

Table 55 shows the t-test results comparing the mean travel time in the GP lanes. The null hypothesis was that the mean travel times in the control corridor GP lanes during the "Before" study were less than the travel time during the "After" study. The hypothesis is described as:

$H_o: \mu_{GP\ Lane\ (Before)} \leq \mu_{GP\ Lane\ (After)}$

$H_1: \mu_{GP\ Lane\ (Before)} > \mu_{GP\ Lane\ (After)}$

$\mu_{GP\ Lane\ (Before)}$ = mean of travel time in General Purpose Lane before project implementation

$\mu_{GP\ Lane\ (After)}$ = mean of travel time in General Purpose Lane after project implementation

The p-value of 0.411 from the t-test is greater than 0.05. Hence, the null hypothesis cannot be rejected. The test indicates that the average travel time increases in the "After" conditions.

Table 55: T-test Comparing Mean Travel Times in General Purpose Lanes - Control Corridor

	GPL-After	GPL-Before
Mean	17.05393056	16.20509259
Variance	64.05750486	16.92825437
Observations	6	6
Pooled Variance	40.49287962	
Hypothesized Mean Difference	0	
df	10	
t Stat	0.231044743	
P(T<=t) one-tail	0.410969315	
t Critical one-tail	1.812461123	
P(T<=t) two-tail	0.821938629	
t Critical two-tail	2.228138852	
t-Test: Two-Sample Assuming Equal Variances		

The F-test of the travel time variances generated a p-value of 0.17 (Table 56). The p-value is greater than 0.05. The test indicates that the null hypothesis that the variances are equal cannot be rejected. Based on the test result, the "equal variances" form of the Student t-test was used.

In summary, the control corridor tests show the travel time either remained constant or decreased in the HOV lanes, while the travel time increased in the general purpose lanes.

Table 56: F-test Comparing Variances of Travel Times in General Purpose Lanes – Control Corridor

	GPL-After	GPL-Before
Mean	17.05393056	16.20509259
Variance	64.05750486	16.92825437
Observations	6	6
df	5	5
F	3.784058501	
P(F<=f) one-tail	0.085233674	
F Critical one-tail	7.146381829	
P(F<=f) two-tail	0.17	

F-Test Two-Sample for Variances

9.3 TRAVEL TIME VARIABILITY DETAILS

Table 57: Study Corridor Travel Times and Variability

Time	Mean, Before	Mean, After	90 % Confidence Interval		Standard Deviation, Before	Standard Deviation, After	Coefficient, Before	Coefficient, After
			After Lower Bound	After Upper Bound				
12:00 AM	12.05	12.77	12.02	12.07	0.56	1.019	0.05	0.08
1:00 AM	12.10	12.82	12.08	12.12	0.52	0.453	0.04	0.04
2:00 AM	12.03	13.06	12.02	12.04	0.33	1.772	0.03	0.14
3:00 AM	12.13	13.06	12.10	12.16	0.63	0.927	0.05	0.07
4:00 AM	12.18	12.93	12.16	12.19	0.36	1.182	0.03	0.09
5:00 AM	12.76	13.07	12.73	12.79	0.66	0.584	0.05	0.04
6:00 AM	13.32	13.57	13.30	13.34	0.54	1.120	0.04	0.08
7:00 AM	15.07	14.39	14.98	15.16	2.10	1.396	0.14	0.10
8:00 AM	19.03	16.18	18.92	19.15	2.69	2.289	0.14	0.14
9:00 AM	16.31	16.99	16.20	16.42	2.55	2.535	0.16	0.15
10:00 AM	12.83	13.89	12.80	12.86	0.75	1.721	0.06	0.12
11:00 AM	12.72	13.13	12.71	12.73	0.33	0.846	0.03	0.06
12:00 PM	12.77	13.03	12.76	12.78	0.30	0.563	0.02	0.04
1:00 PM	12.71	13.08	12.70	12.73	0.28	0.462	0.02	0.04
2:00 PM	12.67	13.06	12.66	12.68	0.26	0.530	0.02	0.04
3:00 PM	12.77	13.52	12.76	12.78	0.28	3.594	0.02	0.27
4:00 PM	12.87	12.96	12.82	12.91	1.04	0.996	0.08	0.08
5:00 PM	12.97	13.70	12.96	12.99	0.39	2.040	0.03	0.15
6:00 PM	12.60	13.35	12.59	12.62	0.26	1.584	0.02	0.12
7:00 PM	12.53	13.08	12.52	12.54	0.28	1.184	0.02	0.09
8:00 PM	12.31	12.92	12.29	12.32	0.32	0.669	0.03	0.05
9:00 PM	12.25	12.88	12.23	12.27	0.49	0.658	0.04	0.05
10:00 PM	12.17	12.75	12.15	12.19	0.47	0.390	0.04	0.03
11:00 PM	12.16	12.70	12.13	12.18	0.59	0.900	0.05	0.07

Note: Travel time is the average of all travel lanes based on FasTrak transponders and roadway sensors.

Table 58: Control Corridor Travel Times and Variability

Time	Mean, Before	Mean, After	90 % Confidence Interval		Standard Deviation, Before	Standard Deviation, After	Coefficient, Before	Coefficient, After
			After Lower Bound	After Upper Bound				
12:00 AM	15.06	12.07	12.05	12.08	0.54	0.33	0.04	0.03
1:00 AM	15.13	12.25	12.23	12.27	0.35	0.40	0.02	0.03
2:00 AM	15.19	12.39	12.37	12.41	0.38	0.43	0.03	0.03
3:00 AM	15.21	12.36	12.34	12.37	0.34	0.42	0.02	0.03
4:00 AM	15.21	12.21	12.20	12.23	0.35	0.43	0.02	0.03
5:00 AM	14.98	11.91	11.90	11.93	0.29	0.32	0.02	0.03
6:00 AM	14.97	11.90	11.88	11.91	0.26	0.28	0.02	0.02
7:00 AM	17.42	14.14	14.00	14.27	2.96	3.13	0.17	0.22
8:00 AM	20.68	16.81	16.55	17.07	3.45	6.05	0.17	0.36
9:00 AM	16.07	13.46	13.29	13.62	2.20	3.79	0.14	0.28
10:00 AM	15.06	12.17	12.13	12.21	0.26	0.91	0.02	0.08
11:00 AM	15.09	12.02	12.01	12.04	0.25	0.36	0.02	0.03
12:00 PM	15.05	12.00	11.99	12.01	0.23	0.25	0.02	0.02
1:00 PM	15.04	11.95	11.94	11.97	0.21	0.24	0.01	0.02
2:00 PM	15.13	11.98	11.97	11.99	0.64	0.27	0.04	0.02
3:00 PM	16.31	13.91	13.81	14.01	1.58	2.32	0.10	0.17
4:00 PM	20.15	18.83	18.58	19.08	5.74	5.80	0.29	0.31
5:00 PM	21.57	22.40	22.12	22.69	6.76	6.60	0.31	0.29
6:00 PM	16.86	15.99	15.77	16.20	4.43	4.91	0.26	0.31
7:00 PM	14.70	12.00	11.95	12.05	0.43	1.21	0.03	0.10
8:00 PM	14.55	11.69	11.68	11.70	0.31	0.24	0.02	0.02
9:00 PM	14.53	11.68	11.67	11.69	0.37	0.22	0.03	0.02
10:00 PM	14.58	11.73	11.72	11.74	0.40	0.28	0.03	0.02
11:00 PM	14.93	11.86	11.84	11.87	1.55	0.31	0.10	0.03

Note: The distances of travel are different. “Before” was 16 miles and “After” was 11.3 miles.

9.4 VEHICLE THROUGHPUT FROM SR 84

Average hourly vehicle counts at the beginning of the study corridor on the connecting ramp from SR 84 are presented in Table 59. The traffic volumes at the beginning of the study corridor had increased during every hour, and had increased about 900 cars (20%) during the entire four-hour AM peak period.

Table 59: Westbound SR 84 Vehicle Throughput at Southbound I-680 Connector

Hour	Before Conditions	After Conditions	Volume Difference	Percent Change
AM PEAK PERIOD				
5-6 AM	991	1,313	322	32%
6-7 AM	1,174	1,494	320	27%
7-8 AM	1,192	1,311	119	10%
8-9 AM	1,199	1,330	131	11%
AM Peak Total	4,556	5,448	892	20%
PM PEAK PERIOD				
3-4 PM	437	544	107	24%
4-5 PM	524	662	138	26%
5-6 PM	519	692	173	33%
6-7 PM	378	573	195	52%
PM Peak Total	1,858	2,471	613	33%
Peak Period Total (AM + PM 8 Hours)	6,414	7,919	1,505	23%

This increased traffic volume from SR 84 could be one of the factors contributing to the increased weaving at the northern portion of the Express Lane corridor trying to get to the Express Lane entrance creating new congestion.

9.5 VEHICLE OCCUPANCY SURVEY DETAILS

Study Corridor Vehicle Occupancy

Table 60: Study Corridor Vehicle Occupancy at Andrade Rd./Pico Rd. "Before" and "After", HOV/Express Lane

" Before" Occupancy Survey, Andrade Road								
Time	**SOV**	**HOV2**	**HOV3+**	**Bus**	**Vanpool**	**Motorcycle**	**Trucks**	**Total**
Counts								
7:00 AM - 9:00 AM	453	1,042	32	5	3	104	57	1,696
3:00 PM - 7:00 PM	184	722	166	4	4	43	47	1,170
7:00 AM - 7:00 PM	3,295	2,509	238	10	8	224	412	6,696
Percentage								
Morning: 7-9 AM	26.7%	61.4%	1.9%	0.3%	0.2%	6.1%	3.4%	100.0%
Afternoon: 3-7 PM	15.7%	61.7%	14.2%	0.3%	0.3%	3.7%	4.0%	100.0%
7:00 AM - 7:00 PM	49.2%	37.5%	3.6%	0.1%	0.1%	3.3%	6.2%	100.0%
" After" Occupancy Survey, Pico Road								
Time	**SOV**	**HOV2**	**HOV3+**	**Bus**	**Vanpool**	**Motorcycle**	**Trucks**	**Total**
Counts								
7:00 AM - 9:00 AM	1,240	765	97	14	50	76	27	2,269
3:00 PM - 7:00 PM	253	429	97	5	10	26	8	828
7:00 AM - 7:00 PM	2,338	1,847	288	25	79	157	47	4,781
Percentage*								
Morning: 7-9 AM	54.6%	33.7%	4.3%	0.6%	2.2%	3.3%	1.2%	100.0%
Afternoon: 3-7 PM	30.6%	51.9%	11.7%	0.5%	1.2%	3.2%	0.9%	100.0%
7:00 AM - 7:00 PM	48.9%	38.6%	6.0%	0.5%	1.6%	3.3%	1.0%	100.0%

Table 61: Study Corridor Vehicle Occupancy at Washington Blvd., "Before" and "After", HOV/Express Lane

" Before" Occupancy Survey, Washington Blvd.								
Time	**SOV**	**HOV2**	**HOV3+**	**Bus**	**Vanpool**	**Motorcycle**	**Trucks**	**Total**
Counts								
7:00 AM - 9:00 AM	597	1,145	46	15	5	117	66	1,991
3:00 PM - 7:00 PM	264	877	18	5	2	48	49	1,262
7:00 AM - 7:00 PM	4,156	2,855	95	25	8	239	417	7,795
Percentage								
Morning: 7-9 AM	30.0%	57.5%	2.3%	0.8%	0.3%	5.9%	3.3%	100.0%
Afternoon: 3-7 PM	20.9%	69.5%	1.4%	0.4%	0.2%	3.8%	3.9%	100.0%
7:00 AM - 7:00 PM	53.3%	36.6%	1.2%	0.3%	0.1%	3.1%	5.3%	100.0%
" After" Occupancy Survey , Washington Blvd.								
Time	**SOV**	**HOV2**	**HOV3+**	**Bus**	**Vanpool**	**Motorcycle**	**Trucks**	**Total**
Counts								
7:00 AM - 9:00 AM	1,334	674	33	19	5	76	41	2,183
3:00 PM - 7:00 PM	367	493	35	12	3	27	7	943
7:00 AM - 7:00 PM	2,753	1,870	95	46	8	164	53	4,990
Percentage*								
Morning: 7-9 AM	61.1%	30.9%	1.5%	0.9%	0.2%	3.5%	1.9%	100.0%
Afternoon: 3-7 PM	38.9%	52.3%	3.7%	1.2%	0.3%	2.9%	0.7%	100.0%
7:00 AM - 7:00 PM	55.2%	37.5%	1.9%	0.9%	0.2%	3.3%	1.1%	100.0%

Table 62: Study Corridor Vehicle Occupancy at Auto Mall/Durham, "After" Only, Express Lane

"After" Occupancy Survey, Auto Mall Parkway/Durham Road								
Time	**SOV**	**HOV2**	**HOV3+**	**Bus**	**Vanpool**	**Motorcycle**	**Trucks**	**Total**
Counts								
7:00 AM - 9:00 AM	1,251	819	71	24	25	64	53	2,305
3:00 PM - 7:00 PM	340	618	55	14	0	18	2	1,047
7:00 AM - 7:00 PM	2,845	2,356	424	59	34	130	83	5,931
Percentage*								
Morning: 7-9 AM	54.3%	35.5%	3.1%	1.0%	1.1%	2.8%	2.3%	100.0%
Afternoon: 3-7 PM	32.5%	59.0%	5.2%	1.4%	0.0%	1.7%	0.2%	100.0%
7:00 AM - 7:00 PM	48.0%	39.7%	7.2%	1.0%	0.6%	2.2%	1.4%	100.0%

Table 63: Study Corridor Vehicle Occupancy at SR 262/Mission, "Before" Only, HOV Lane

"Before" Occupancy Survey, Mission Blvd.								
Time	**SOV**	**HOV2**	**HOV3+**	**Bus**	**Vanpool**	**Motorcycle**	**Trucks**	**Total**
Counts								
7:00 AM - 9:00 AM	607	909	84	14	3	65	67	1,749
3:00 PM - 7:00 PM	212	750	169	5	6	45	51	1,238
7:00 AM - 7:00 PM	3,358	2,430	334	23	13	148	436	6,742
Percentage								
Morning: 7-9 AM	34.7%	52.0%	4.8%	0.8%	0.2%	3.7%	3.8%	100.0%
Afternoon: 3-7 PM	17.1%	60.6%	13.7%	0.4%	0.5%	3.6%	4.1%	100.0%
7:00 AM - 7:00 PM	49.8%	36.0%	5.0%	0.3%	0.2%	2.2%	6.5%	100.0%

Table 64: Study Corridor Vehicle Occupancy at SR 237/Calaveras, "Before" Only, HOV Lane

"Before" Occupancy Survey, Calaveras Blvd (SR 237)								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	219	424	35	3	2	18	26	725
3:00 PM - 7:00 PM	971	1,354	106	3	9	61	40	2,543
7:00 AM - 7:00 PM	2,809	2,281	172	9	13	101	191	5,574
Percentage								
Morning: 7-9 AM	30.2%	58.4%	4.8%	0.4%	0.2%	2.5%	3.5%	100.0%
Afternoon: 3-7 PM	38.2%	53.3%	4.2%	0.1%	0.4%	2.4%	1.6%	100.0%
7:00 AM - 7:00 PM	50.4%	40.9%	3.1%	0.2%	0.2%	1.8%	3.4%	100.0%

Table 65: Study Corridor Vehicle Occupancy at Andrade Rd./Pico Rd. "Before" and "After", General Purpose Lanes

" Before" Occupancy Survey, Andrade Road								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	8,500	417	54	5	3	7	327	9,313
3:00 PM - 7:00 PM	8,878	1,170	175	16	2	33	465	10,739
7:00 AM - 7:00 PM	28,238	2,781	393	44	17	101	1,943	33,517
Percentage								
Morning: 7-9 AM	91.3%	4.5%	0.6%	0.1%	0.0%	0.1%	3.5%	100.0%
Afternoon: 3-7 PM	82.7%	10.9%	1.6%	0.1%	0.0%	0.3%	4.3%	100.0%
7:00 AM - 7:00 PM	84.2%	8.3%	1.2%	0.1%	0.1%	0.3%	5.8%	100.0%
" After" Occupancy Survey, Pico Road								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	9,610	327	35	4	0	5	528	10,509
3:00 PM - 7:00 PM	11,370	1,908	261	17	11	31	609	14,207
7:00 AM - 7:00 PM	37,063	4,389	502	41	18	84	2,929	45,028
Percentage*								
Morning: 7-9 AM	91.4%	3.1%	0.3%	0.0%	0.0%	0.1%	5.0%	100.0%
Afternoon: 3-7 PM	80.0%	13.4%	1.8%	0.1%	0.1%	0.2%	4.3%	100.0%
7:00 AM - 7:00 PM	82.3%	9.7%	1.1%	0.1%	0.0%	0.2%	6.5%	100.0%

Table 66: Study Corridor Vehicle Occupancy at Washington Blvd., "Before" and "After", General Purpose Lanes

" Before" Occupancy Survey, Washington Blvd.								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	9,586	318	21	7	11	19	366	10,327
3:00 PM - 7:00 PM	10,520	2,004	106	13	12	61	510	13,224
7:00 AM - 7:00 PM	33,651	4,703	569	51	36	221	2,150	41,378
Percentage								
Morning: 7-9 AM	92.8%	3.1%	0.2%	0.1%	0.1%	0.2%	3.5%	100.0%
Afternoon: 3-7 PM	79.6%	15.2%	0.8%	0.1%	0.1%	0.5%	3.9%	100.0%
7:00 AM - 7:00 PM	81.3%	11.4%	1.4%	0.1%	0.1%	0.5%	5.2%	100.0%
" After" Occupancy Survey , Washington Blvd.								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	9,095	267	7	5	2	11	549	9,935
3:00 PM - 7:00 PM	9,945	2,105	71	13	3	27	670	12,835
7:00 AM - 7:00 PM	34,369	4,606	154	37	10	86	3,033	42,296
Percentage*								
Morning: 7-9 AM	91.5%	2.7%	0.1%	0.0%	0.0%	0.1%	5.5%	100.0%
Afternoon: 3-7 PM	77.5%	16.4%	0.6%	0.1%	0.0%	0.2%	5.2%	100.0%
7:00 AM - 7:00 PM	81.3%	10.9%	0.4%	0.1%	0.0%	0.2%	7.2%	100.0%

Table 67: Study Corridor Vehicle Occupancy at Auto Mall/Durham, "After" Only, General Purpose Lanes

"After" Occupancy Survey, Auto Mall Parkway/Durham Road								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	7,683	129	70	0	0	8	497	8,388
3:00 PM - 7:00 PM	9,898	2,026	209	9	1	17	699	12,858
7:00 AM - 7:00 PM	32,426	4,671	441	20	19	60	3,029	40,665
Percentage*								
Morning: 7-9 AM	91.6%	1.5%	0.8%	0.0%	0.0%	0.1%	5.9%	100.0%
Afternoon: 3-7 PM	77.0%	15.8%	1.6%	0.1%	0.0%	0.1%	5.4%	100.0%
7:00 AM - 7:00 PM	79.7%	11.5%	1.1%	0.0%	0.0%	0.1%	7.4%	100.0%

Table 68: Study Corridor Vehicle Occupancy at SR 262/Mission, "Before" Only, General Purpose Lanes

"Before" Occupancy Survey, Mission Blvd.								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	8,421	105	24	5	1	2	351	8,909
3:00 PM - 7:00 PM	9,501	1,136	152	22	8	34	504	11,357
7:00 AM - 7:00 PM	28,582	2,823	358	53	16	82	2,197	34,111
Percentage								
Morning: 7-9 AM	94.5%	1.2%	0.3%	0.1%	0.0%	0.0%	3.9%	100.0%
Afternoon: 3-7 PM	83.7%	10.0%	1.3%	0.2%	0.1%	0.3%	4.4%	100.0%
7:00 AM - 7:00 PM	83.8%	8.3%	1.0%	0.2%	0.0%	0.2%	6.4%	100.0%

Table 69: Study Corridor Vehicle Occupancy at SR 237/Calaveras, "Before" Only, General Purpose Lanes

"Before" Occupancy Survey, Calaveras Blvd (SR 237)								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	5,757	165	50	24	58	8	214	6,275
3:00 PM - 7:00 PM	12,317	2,077	220	33	166	38	264	15,113
7:00 AM - 7:00 PM	29,680	4,232	416	117	473	90	1,269	36,276
Percentage								
Morning: 7-9 AM	91.7%	2.6%	0.8%	0.4%	0.9%	0.1%	3.4%	100.0%
Afternoon: 3-7 PM	81.5%	13.7%	1.5%	0.2%	1.1%	0.2%	1.7%	100.0%
7:00 AM - 7:00 PM	81.8%	11.7%	1.1%	0.3%	1.3%	0.2%	3.5%	100.0%

Table 70: Study Corridor Vehicle Occupancy at Andrade Rd./Pico Rd. "Before" and "After", All Lanes

" Before" Occupancy Survey, Andrade Road								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	8,953	1,459	86	10	6	111	384	11,009
3:00 PM - 7:00 PM	9,062	1,892	341	20	6	76	512	11,909
7:00 AM - 7:00 PM	31,533	5,290	631	54	25	325	2,355	40,213
Percentage								
Morning: 7-9 AM	81.3%	13.3%	0.8%	0.1%	0.1%	1.0%	3.5%	100.0%
Afternoon: 3-7 PM	76.1%	15.9%	2.9%	0.2%	0.1%	0.6%	4.3%	100.0%
7:00 AM - 7:00 PM	78.4%	13.2%	1.6%	0.1%	0.1%	0.8%	5.9%	100.0%
" After" Occupancy Survey, Pico Road								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	10,850	1,092	133	18	50	81	555	12,779
3:00 PM - 7:00 PM	11,623	2,337	357	22	21	58	617	15,035
7:00 AM - 7:00 PM	39,401	6,236	790	67	96	242	2,976	49,808
Percentage*								
Morning: 7-9 AM	84.9%	8.5%	1.0%	0.1%	0.4%	0.6%	4.3%	100.0%
Afternoon: 3-7 PM	77.3%	15.5%	2.4%	0.1%	0.1%	0.4%	4.1%	100.0%
7:00 AM - 7:00 PM	79.1%	12.5%	1.6%	0.1%	0.2%	0.5%	6.0%	100.0%

Table 71: Study Corridor Vehicle Occupancy at Washington Blvd., "Before" and "After", All Lanes

" Before" Occupancy Survey, Washington Blvd.								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	10,183	1,463	67	22	16	136	431	12,317
3:00 PM - 7:00 PM	10,784	2,881	124	18	14	108	559	14,486
7:00 AM - 7:00 PM	37,806	7,558	664	76	44	460	2,567	49,173
Percentage								
Morning: 7-9 AM	82.7%	11.9%	0.5%	0.2%	0.1%	1.1%	3.5%	100.0%
Afternoon: 3-7 PM	74.4%	19.9%	0.9%	0.1%	0.1%	0.7%	3.9%	100.0%
7:00 AM - 7:00 PM	76.9%	15.4%	1.3%	0.2%	0.1%	0.9%	5.2%	100.0%
" After" Occupancy Survey , Washington Blvd.								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	10,430	941	40	23	7	87	590	12,118
3:00 PM - 7:00 PM	10,312	2,598	106	25	5	54	677	13,777
7:00 AM - 7:00 PM	37,122	6,476	249	84	18	250	3,087	47,286
Percentage*								
Morning: 7-9 AM	86.1%	7.8%	0.3%	0.2%	0.1%	0.7%	4.9%	100.0%
Afternoon: 3-7 PM	74.8%	18.9%	0.8%	0.2%	0.0%	0.4%	4.9%	100.0%
7:00 AM - 7:00 PM	78.5%	13.7%	0.5%	0.2%	0.0%	0.5%	6.5%	100.0%

Table 72: Study Corridor Vehicle Occupancy at Auto Mall/Durham, "After" Only, All Lanes

"After" Occupancy Survey, Auto Mall Parkway/Durham Road								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	8,934	948	141	20	5	72	550	10,670
3:00 PM - 7:00 PM	10,238	2,644	263	24	1	34	701	13,905
7:00 AM - 7:00 PM	35,271	7,026	865	79	52	190	3,112	46,596
Percentage*								
Morning: 7-9 AM	83.7%	8.9%	1.3%	0.2%	0.0%	0.7%	5.2%	100.0%
Afternoon: 3-7 PM	73.6%	19.0%	1.9%	0.2%	0.0%	0.2%	5.0%	100.0%
7:00 AM - 7:00 PM	75.7%	15.1%	1.9%	0.2%	0.1%	0.4%	6.7%	100.0%

Table 73: Study Corridor Vehicle Occupancy at SR 262/Mission, "Before" Only, All Lanes

"Before" Occupancy Survey, Mission Blvd.								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	9,028	1,014	108	19	4	67	418	10,658
3:00 PM - 7:00 PM	9,713	1,886	321	27	14	79	555	12,595
7:00 AM - 7:00 PM	31,940	5,253	692	76	29	230	2,633	40,853
Percentage								
Morning: 7-9 AM	84.7%	9.5%	1.0%	0.2%	0.0%	0.6%	3.9%	100.0%
Afternoon: 3-7 PM	77.1%	15.0%	2.5%	0.2%	0.1%	0.6%	4.4%	100.0%
7:00 AM - 7:00 PM	78.2%	12.9%	1.7%	0.2%	0.1%	0.6%	6.4%	100.0%

Table 74: Study Corridor Vehicle Occupancy at SR 237/Calaveras, "Before" Only, All Lanes

"Before" Occupancy Survey, Calaveras Blvd (SR 237)								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	5,976	589	84	27	60	26	240	7,000
3:00 PM - 7:00 PM	13,287	3,431	326	36	175	99	303	17,656
7:00 AM - 7:00 PM	32,488	6,513	588	126	486	191	1,460	41,850
Percentage								
Morning: 7-9 AM	85.4%	8.4%	1.2%	0.4%	0.9%	0.4%	3.4%	100.0%
Afternoon: 3-7 PM	75.3%	19.4%	1.8%	0.2%	1.0%	0.6%	1.7%	100.0%
7:00 AM - 7:00 PM	77.6%	15.6%	1.4%	0.3%	1.2%	0.5%	3.5%	100.0%

Control Corridor Vehicle Occupancy

Table 75: Control Corridor Vehicle Occupancy at Alcosta Boulevard, "Before" and "After", HOV Lane

" Before" Occupancy Survey, Alcosta Boulevard								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
3:00 PM - 7:00 PM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7:00 AM - 7:00 PM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Percentage								
Morning: 7-9 AM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Afternoon: 3-7 PM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7:00 AM - 7:00 PM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
" After" Occupancy Survey, Alcosta Boulevard								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	294	486	3	11	18	15	3	828
3:00 PM - 7:00 PM	726	1,529	37	18	58	50	20	2,436
7:00 AM - 7:00 PM	2,690	2,636	50	34	87	75	34	5,605
Percentage*								
Morning: 7-9 AM	35.5%	58.6%	0.3%	1.3%	2.2%	1.8%	0.3%	100.0%
Afternoon: 3-7 PM	29.8%	62.8%	1.5%	0.7%	2.4%	2.0%	0.8%	100.0%
7:00 AM - 7:00 PM	48.0%	47.0%	0.9%	0.6%	1.5%	1.3%	0.6%	100.0%

Table 76: Control Corridor Vehicle Occupancy at Crow Canyon Road, "After" Only, HOV Lane

"After" Occupany Survey, Crow Canyon Road								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	267	599	28	16	21	24	27	983
3:00 PM - 7:00 PM	500	2,274	288	29	28	86	18	3,222
7:00 AM - 7:00 PM	3,744	3,752	353	47	71	137	67	8,171
Percentage*								
Morning: 7-9 AM	27.2%	61.0%	2.8%	1.6%	2.1%	2.4%	2.8%	100.0%
Afternoon: 3-7 PM	15.5%	70.6%	8.9%	0.9%	0.9%	2.7%	0.5%	100.0%
7:00 AM - 7:00 PM	45.8%	45.9%	4.3%	0.6%	0.9%	1.7%	0.8%	100.0%

Table 77: Control Corridor Vehicle Occupancy at Livorna Road, "Before" Only, HOV Lane

"Before" Occupancy Survey, Livorna Road								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	761	1,143	18	18	21	82	0	2,043
3:00 PM - 7:00 PM	2,241	2,923	194	30	80	145	1	5,614
7:00 AM - 7:00 PM	9,453	5,183	265	50	135	376	1	15,463
Percentage								
Morning: 7-9 AM	37.2%	55.9%	0.9%	0.9%	1.0%	4.0%	0.0%	100.0%
Afternoon: 3-7 PM	39.9%	52.1%	3.5%	0.5%	1.4%	2.6%	0.0%	100.0%
7:00 AM - 7:00 PM	61.1%	33.5%	1.7%	0.3%	0.9%	2.4%	0.0%	100.0%

Table 78: Control Corridor Vehicle Occupancy at Alcosta Boulevard, "Before" and "After", General Purpose Lanes

" Before" Occupancy Survey, Alcosta Boulevard								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
3:00 PM - 7:00 PM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7:00 AM - 7:00 PM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Percentage								
Morning: 7-9 AM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Afternoon: 3-7 PM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7:00 AM - 7:00 PM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
" After" Occupancy Survey, Alcosta Boulevard								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	7,936	347	3	8	0	20	600	8,914
3:00 PM - 7:00 PM	16,157	1,434	39	12	0	64	520	18,224
7:00 AM - 7:00 PM	40,387	4,310	84	27	0	125	2,920	47,854
Percentage*								
Morning: 7-9 AM	89.0%	3.9%	0.0%	0.1%	0.0%	0.2%	6.7%	100.0%
Afternoon: 3-7 PM	88.7%	7.9%	0.2%	0.1%	0.0%	0.3%	2.9%	100.0%
7:00 AM - 7:00 PM	84.4%	9.0%	0.2%	0.1%	0.0%	0.3%	6.1%	100.0%

Table 79: Control Corridor Vehicle Occupancy at Crow Canyon Road, "After" Only, General Purpose Lanes

"After" Occupany Survey, Crow Canyon Road								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	6,233	410	96	9	1	4	480	7,232
3:00 PM - 7:00 PM	12,672	768	33	18	0	4	436	13,931
7:00 AM - 7:00 PM	30,542	3,246	489	44	6	22	2,576	36,926
Percentage*								
Morning: 7-9 AM	86.2%	5.7%	1.3%	0.1%	0.0%	0.1%	6.6%	100.0%
Afternoon: 3-7 PM	91.0%	5.5%	0.2%	0.1%	0.0%	0.0%	3.1%	100.0%
7:00 AM - 7:00 PM	82.7%	8.8%	1.3%	0.1%	0.0%	0.1%	7.0%	100.0%

Table 80: Control Corridor Vehicle Occupancy at Livorna Road, "Before" Only, General Purpose Lanes

"Before" Occupancy Survey, Livorna Road								
Time	SOV	HOV2	HOV3+	Bus	Vanpool	Motorcycle	Trucks	Total
Counts								
7:00 AM - 9:00 AM	10,123	363	11	33	50	5	443	11,028
3:00 PM - 7:00 PM	17,177	1,711	111	55	75	29	348	19,506
7:00 AM - 7:00 PM	44,553	4,808	230	149	217	99	2,362	52,418
Percentage								
Morning: 7-9 AM	91.8%	3.3%	0.1%	0.3%	0.5%	0.0%	4.0%	100.0%
Afternoon: 3-7 PM	88.1%	8.8%	0.6%	0.3%	0.4%	0.1%	1.8%	100.0%
7:00 AM - 7:00 PM	85.0%	9.2%	0.4%	0.3%	0.4%	0.2%	4.5%	100.0%

Table 81: Control Corridor Vehicle Occupancy at Alcosta Boulevard, “Before” and “After”, All Lanes

“ Before” Occupancy Survey, Alcosta Boulevard								
Time	**SOV**	**HOV2**	**HOV3+**	**Bus**	**Vanpool**	**Motorcycle**	**Trucks**	**Total**
Counts								
7:00 AM - 9:00 AM	8,690	1,108	70	21	38	50	406	10,382
3:00 PM - 7:00 PM	16,789	3,612	329	35	106	142	428	21,439
7:00 AM - 7:00 PM	43,621	8,268	577	94	256	338	2,173	55,326
Percentage								
Morning: 7-9 AM	83.7%	10.7%	0.7%	0.2%	0.4%	0.5%	3.9%	100.0%
Afternoon: 3-7 PM	78.3%	16.8%	1.5%	0.2%	0.5%	0.7%	2.0%	100.0%
7:00 AM - 7:00 PM	78.8%	14.9%	1.0%	0.2%	0.5%	0.6%	3.9%	100.0%
“ After” Occupancy Survey, Alcosta Boulevard								
Time	**SOV**	**HOV2**	**HOV3+**	**Bus**	**Vanpool**	**Motorcycle**	**Trucks**	**Total**
Counts								
7:00 AM - 9:00 AM	8,230	832	6	18	4	35	603	9,727
3:00 PM - 7:00 PM	16,883	2,963	76	29	11	113	540	20,614
7:00 AM - 7:00 PM	43,077	6,946	134	61	20	200	2,954	53,392
Percentage*								
Morning: 7-9 AM	84.6%	8.6%	0.1%	0.2%	0.0%	0.4%	6.2%	100.0%
Afternoon: 3-7 PM	81.9%	14.4%	0.4%	0.1%	0.1%	0.5%	2.6%	100.0%
7:00 AM - 7:00 PM	80.7%	13.0%	0.3%	0.1%	0.0%	0.4%	5.5%	100.0%

Table 82: Control Corridor Vehicle Occupancy at Crow Canyon Road, “After” Only, All Lanes

“After” Occupany Survey, Crow Canyon Road								
Time	**SOV**	**HOV2**	**HOV3+**	**Bus**	**Vanpool**	**Motorcycle**	**Trucks**	**Total**
Counts								
7:00 AM - 9:00 AM	6,500	1,009	124	25	23	28	507	8,215
3:00 PM - 7:00 PM	13,171	3,042	321	47	28	90	454	17,153
7:00 AM - 7:00 PM	34,285	6,998	842	91	77	159	2,643	45,096
Percentage*								
Morning: 7-9 AM	79.1%	12.3%	1.5%	0.3%	0.3%	0.3%	6.2%	100.0%
Afternoon: 3-7 PM	76.8%	17.7%	1.9%	0.3%	0.2%	0.5%	2.6%	100.0%
7:00 AM - 7:00 PM	76.0%	15.5%	1.9%	0.2%	0.2%	0.4%	5.9%	100.0%

Table 83: Control Corridor Vehicle Occupancy at Livorna Road, “Before” Only, All Lanes

“Before” Occupancy Survey, Livorna Road								
Time	**SOV**	**HOV2**	**HOV3+**	**Bus**	**Vanpool**	**Motorcycle**	**Trucks**	**Total**
Counts								
7:00 AM - 9:00 AM	10,884	1,506	29	51	71	87	443	13,071
3:00 PM - 7:00 PM	19,418	4,634	305	85	155	174	349	25,120
7:00 AM - 7:00 PM	54,006	9,991	495	199	352	475	2,363	67,881
Percentage								
Morning: 7-9 AM	83.3%	11.5%	0.2%	0.4%	0.5%	0.7%	3.4%	100.0%
Afternoon: 3-7 PM	77.3%	18.4%	1.2%	0.3%	0.6%	0.7%	1.4%	100.0%
7:00 AM - 7:00 PM	79.6%	14.7%	0.7%	0.3%	0.5%	0.7%	3.5%	100.0%

9.6 FREQ ANALYSIS

FREQ Capacity Adjustments

The freeway mainline and ramp volumes for the Express Lane "After" conditions were input into the FREQ model that was developed and calibrated for the I-680 ramp metering studies.

Input capacities for all freeway subsections were kept the same as the settings in the I-680 ramp metering study. The only adjustment occurred at Subsection #30 (just upstream of the SR 262/Mission off-ramp) based on the auxiliary lane capacity calculation procedure recommended by MTC for all freeway related operation studies.

The procedure for auxiliary lane capacity calculation is to use the minimum between the maximum hourly volume for the adjacent on-ramp or the maximum hourly volume for the adjacent off-ramp. The maximum hourly volume of the adjacent ramps occurred between 8:00 AM and 9:00 AM on the on-ramp from Auto Mall Parkway. The same auxiliary lane capacity was applied for both the AM and PM peak periods. The capacity on Subsection #30 was adjusted from 6,200 to 6,125 (reduced by 75). The adjustment was calculated based on the observed volume, 5,550 plus the auxiliary lane capacity of 575.

FREQ Results

The following tables list the detailed FREQ density and LOS results for each segment and for each hourly time period.

Table 84: Study Corridor FREQ Analysis, "Before" Conditions, HOV Lane, AM Peak Period

Seg. No.	From	To	5:00 - 6:00		6:00 - 7:00		7:00 - 8:00		8:00 - 9:00	
			Density	LOS	Density	LOS	Density	LOS	Density	LOS
1	I-680 SB north of SR 84 on-ramp	HOV Begin	--	--	--	--	--	--	--	--
2	HOV Begin	SR 84 On-ramp	4.7	A	7.8	A	9.2	A	9.2	A
3	SR 84 On-ramp	Paloma Rd on-ramp	6.5	A	10.0	A	11.3	B	11.5	B
4	Paloma Rd on-ramp	Andrade Rd off-ramp	6.6	A	10.1	A	11.5	B	11.7	B
5	Andrade Rd off-ramp	Andrade Rd on-ramp	6.6	A	10.1	A	11.5	B	11.7	B
6	Andrade Rd on-ramp	Sheridan Rd on-ramp	6.6	A	10.3	A	11.8	B	12.0	B
7	Sheridan Rd on-ramp	Lane Drop	6.6	A	10.3	A	11.9	B	12.1	B
8	Lane Drop	Vargas Rd off-ramp	6.6	A	10.3	A	11.9	B	12.1	B
9	Vargas Rd off-ramp	Vargas Rd on-ramp	6.6	A	10.3	A	11.9	B	12.1	B
10	Vargas Rd on-ramp	SR 238 off-ramp	6.6	A	10.3	A	11.9	B	12.1	B
11	SR 238 off-ramp	SR 238 on-ramp	6.3	A	9.8	A	10.9	A	10.8	A
12	SR 238 on-ramp	Washington Blvd off-ramp	6.7	A	10.7	A	12.3	B	12.3	B
13	Washington Blvd off-ramp	Washington Blvd on-ramp	6.4	A	10.2	A	11.6	B	11.7	B
14	Washington Blvd on-ramp	Lane Add	6.5	A	10.6	A	12.5	B	12.8	B
15	Lane Add	Automall Pkwy off-ramp	6.5	A	10.6	A	12.5	B	12.8	B
16	Automall Pkwy off-ramp	Automall Pkwy on-ramp	5.0	A	9.2	A	10.6	A	11.0	A
17	Automall Pkwy on-ramp	SR 262 off-ramp	5.2	A	9.6	A	11.7	B	12.2	B
18	SR 262 off-ramp	SR 262 on-ramp	2.2	A	6.9	A	9.7	A	10.3	A
19	SR 262 on-ramp	Scott Creek Rd off-ramp	2.4	A	7.4	A	10.4	A	11.5	B
20	Scott Creek Rd off-ramp	Scott Creek Rd on-ramp	2.0	A	6.4	A	8.6	A	9.5	A
21	Scott Creek Rd on-ramp	Jacklin Rd off-ramp	2.1	A	6.6	A	9.1	A	10.0	A
22	Jacklin Rd off-ramp	Jacklin Rd on-ramp	2.0	A	6.4	A	8.7	A	9.3	A
23	Jacklin Rd on-ramp	SR-237 off-ramp	2.0	A	6.4	A	8.7	A	9.3	A
24	SR-237 off-ramp	South of SR-237 off-ramp	1.4	A	5.2	A	7.1	A	7.3	A
25		Second Half of Split	--	--	--	--	--	--	--	--

Table 85: Study Corridor FREQ Analysis, "Before" Conditions, HOV Lane, PM Peak Period

Seg. No.	From	To	3:00 - 4:00		4:00 - 5:00		5:00 - 6:00		6:00 - 7:00	
			Density	LOS	Density	LOS	Density	LOS	Density	LOS
1	I-680 SB north of SR 84 on-ramp	HOV Begin	--	--	--	--	--	--	--	--
2	HOV Begin	SR 84 On-ramp	7.8	A	10.0	A	12.4	B	10.2	A
3	SR 84 On-ramp	Paloma Rd on-ramp	9.0	A	11.5	B	13.8	B	11.3	B
4	Paloma Rd on-ramp	Andrade Rd off-ramp	9.2	A	11.6	B	13.9	B	11.3	B
5	Andrade Rd off-ramp	Andrade Rd on-ramp	9.2	A	11.6	B	13.9	B	11.3	B
6	Andrade Rd on-ramp	Sheridan Rd on-ramp	9.5	A	11.8	B	14.1	B	11.5	B
7	Sheridan Rd on-ramp	Lane Drop	9.6	A	11.9	B	14.2	B	11.5	B
8	Lane Drop	Vargas Rd off-ramp	9.6	A	11.9	B	14.2	B	11.5	B
9	Vargas Rd off-ramp	Vargas Rd on-ramp	9.6	A	11.9	B	14.1	B	11.5	B
10	Vargas Rd on-ramp	SR 238 off-ramp	9.6	A	11.9	B	14.2	B	11.5	B
11	SR 238 off-ramp	SR 238 on-ramp	8.5	A	10.7	A	12.4	B	10.0	A
12	SR 238 on-ramp	Washington Blvd off-ramp	9.7	A	11.9	B	13.6	B	11.2	B
13	Washington Blvd off-ramp	Washington Blvd on-ramp	9.0	A	11.0	B	12.2	B	10.3	A
14	Washington Blvd on-ramp	Lane Add	9.8	A	11.9	B	13.3	B	11.2	B
15	Lane Add	Automall Pkwy off-ramp	9.8	A	11.9	B	13.3	B	11.2	B
16	Automall Pkwy off-ramp	Automall Pkwy on-ramp	8.1	A	10.6	A	11.9	B	10.0	A
17	Automall Pkwy on-ramp	SR 262 off-ramp	9.7	A	12.6	B	14.2	B	11.7	B
18	SR 262 off-ramp	SR 262 on-ramp	6.9	A	9.8	A	11.1	B	9.1	A
19	SR 262 on-ramp	Scott Creek Rd off-ramp	9.0	A	12.1	B	13.5	B	11.2	B
20	Scott Creek Rd off-ramp	Scott Creek Rd on-ramp	8.4	A	11.6	B	12.9	B	10.6	A
21	Scott Creek Rd on-ramp	Jacklin Rd off-ramp	10.1	A	13.2	B	14.4	B	11.7	B
22	Jacklin Rd off-ramp	Jacklin Rd on-ramp	9.6	A	12.7	B	13.5	B	10.9	A
23	Jacklin Rd on-ramp	SR-237 off-ramp	9.6	A	12.7	B	13.5	B	10.9	A
24	SR-237 off-ramp	South of SR-237 off-ramp	8.6	A	11.6	B	12.2	B	9.6	A
25		Second Half of Split	--	--	--	--	--	--	--	--

Table 86: Study Corridor FREQ Analysis, "After" Conditions, HOV Lane, AM Peak Period

FREQ SS	LOCATION	Time Slice 1 5-6AM		Time Slice 2 6-7AM		Time Slice 3 7-8AM		Time Slice 4 8-9AM	
		Density (vphpl)	LOS	Density (vphpl)	LOS	Density (vphpl)	LOS	Density (vphpl)	LOS
14	ExpIngress/Andrade Off	12	B	15	B	15.3	B	13.1	B
15	Andrade Off/On	12	B	15	B	15.3	B	13.1	B
16	Andrade On/Sheridan On	12	B	15	B	15.3	B	13.1	B
17	Sheridan On/Lane Drop	12	B	15	B	15.3	B	13.1	B
18	Lane Drop/Vargas Off	12	B	15	B	15.3	B	13.1	B
19	Vargas Off/On	12	B	15	B	15.3	B	13.1	B
20	Vargas On/Mission Off	12	B	15	B	15.3	B	13.1	B
21	Mission(238) Off/On	12	B	15	B	15.3	B	13.1	B
22	Mission on/Washington Of	12	B	15.3	B	15.7	B	13.5	B
25	Washington Off/DummyEgrs	10.2	A	12.9	B	13.6	B	11.3	B
26	DummyEgress-WashIngress	10.2	A	12.9	B	13.6	B	11.3	B
27	ExpIngres/Washington On	10.2	A	12.9	B	13.6	B	11.3	B
28	Washington On/Durham Off	10.2	A	12.9	B	13.6	B	11.3	B
29	Durham Off/ExpEgress	10.2	A	12.9	B	13.6	B	11.3	B
30	ExpEgress/Durham On	10.2	A	12.9	B	13.6	B	11.3	B
31	Durham On/ExpIngress	10.4	A	13.1	B	14.1	B	11.9	B
34	ExpIng/Mission (262) Off	6	A	8.8	A	10.4	A	8.7	A
35	Mission (262) Off/On	6	A	8.8	A	10.4	A	8.7	A
36	Mission On/Scott Crk Off	6	A	8.8	A	10.4	A	8.7	A
37	Scott Creek Off/On	6	A	8.8	A	10.4	A	8.7	A
38	Scott Crk On/Jacklin Off	6	A	8.8	A	10.4	A	8.7	A
39	Jacklin Off/ExpEgress	6	A	8.8	A	10.4	A	8.7	A
41	ExpEgress/Jacklin On	4.9	A	6.8	A	8.5	A	6.7	A
43	Jacklin On/Rte 237 Off	5.1	A	7.4	A	9.2	A	7.7	A
44	Rte 237 Off/End HOV	5.1	A	7.4	A	9.2	A	7.7	A

Table 87: Study Corridor FREQ Analysis, "After" Conditions, HOV Lane, PM Peak Period

FREQ SS	LOCATION	Time Slice 1 3-4PM		Time Slice 2 4-5PM		Time Slice 3 5-6PM		Time Slice 4 6-7PM	
		Density (vphpl)	LOS	Density (vphpl)	LOS	Density (vphpl)	LOS	Density (vphpl)	LOS
14	ExpIngress/Andrade Off	5.1	A	5.8	A	6	A	4.2	A
15	Andrade Off/On	5.1	A	5.8	A	6	A	4.2	A
16	Andrade On/Sheridan On	5.1	A	5.8	A	6	A	4.2	A
17	Sheridan On/Lane Drop	5.1	A	5.8	A	6	A	4.2	A
18	Lane Drop/Vargas Off	5.1	A	5.8	A	6	A	4.2	A
19	Vargas Off/On	5.1	A	5.8	A	6	A	4.2	A
20	Vargas On/Mission Off	5.1	A	5.8	A	6	A	4.2	A
21	Mission(238) Off/On	5.1	A	5.8	A	6	A	4.2	A
22	Mission on/Washington Of	5.4	A	6.2	A	6.4	A	4.5	A
23	Washington Off/DummyEgrs	4.6	A	5.2	A	5.3	A	3.6	A
24	DummyEgress-WashIngress	4.6	A	5.2	A	5.3	A	3.6	A
25	ExpIngres/Washington On	4.6	A	5.2	A	5.3	A	3.6	A
26	Washington On/Durham Off	4.6	A	5.2	A	5.3	A	3.6	A
27	Durham Off/ExpEgress	4.6	A	5.2	A	5.3	A	3.6	A
28	ExpEgress/Durham On	4.6	A	5.2	A	5.3	A	3.6	A
29	Durham On/ExpIngress	5.5	A	6.2	A	6.4	A	4.2	A
30	ExpIng/Mission (262) Off	4.1	A	5	A	5	A	2.9	A
31	Mission (262) Off/On	4.1	A	5	A	5	A	2.9	A
32	Mission On/Scott Crk Off	4.1	A	5	A	5	A	2.9	A
33	Scott Creek Off/On	4.1	A	5	A	5	A	2.9	A
34	Scott Crk On/Jacklin Off	4.1	A	5	A	5	A	2.9	A
35	Jacklin Off/ExpEgress	4.1	A	5	A	5	A	2.9	A
36	ExpEgress/Jacklin On	3.7	A	4.6	A	4.3	A	2.5	A
37	Jacklin On/Rte 237 Off	5.2	A	6.5	A	6.1	A	3.8	A
38	Rte 237 Off/End HOV	5.2	A	6.5	A	6.1	A	3.8	A

Table 88: Study Corridor FREQ Analysis, "Before" Conditions, General Purpose Lanes, AM Peak Period

Seg. No.	From	To	5:00 - 6:00		6:00 - 7:00		7:00 - 8:00		8:00 - 9:00	
			Density	LOS	Density	LOS	Density	LOS	Density	LOS
1	I-680 SB north of SR 84 on-ramp	HOV Begin	13.1	B	21.4	C	26.8	D	27.5	D
2	HOV Begin	SR 84 On-ramp	11.5	B	18.8	C	22.3	C	23.0	C
3	SR 84 On-ramp	Paloma Rd on-ramp	16.1	B	25.2	C	31.7	D	33.8	D
4	Paloma Rd on-ramp	Andrade Rd off-ramp	16.2	B	25.4	C	32.1	D	34.8	D
5	Andrade Rd off-ramp	Andrade Rd on-ramp	15.6	B	24.8	C	30.5	D	32.0	D
6	Andrade Rd on-ramp	Sheridan Rd on-ramp	11.8	B	18.3	C	21.1	C	21.3	C
7	Sheridan Rd on-ramp	Lane Drop	11.8	B	18.4	C	21.2	C	43.3	F
8	Lane Drop	Vargas Rd off-ramp	15.8	B	25.6	C	32.9	D	56.2	F
9	Vargas Rd off-ramp	Vargas Rd on-ramp	15.8	B	25.5	C	32.8	D	61.2	F
10	Vargas Rd on-ramp	SR 238 off-ramp	15.8	B	25.7	C	34.6	F	65.3	F
11	SR 238 off-ramp	SR 238 on-ramp	15.1	B	23.7	C	68.9	F	100.9	F
12	SR 238 on-ramp	Washington Blvd off-ramp	15.9	B	27.4	D	35.9	F	66.1	F
13	Washington Blvd off-ramp	Washington Blvd on-ramp	15.2	B	25.2	C	61.3	F	89.5	F
14	Washington Blvd on-ramp	Lane Add	15.6	B	26.9	D	36.5	E	36.4	E
15	Lane Add	Automall Pkwy off-ramp	11.7	B	19.0	C	22.0	C	21.9	C
16	Automall Pkwy off-ramp	Automall Pkwy on-ramp	11.9	B	21.9	C	25.7	C	25.6	C
17	Automall Pkwy on-ramp	SR 262 off-ramp	9.7	A	17.6	B	20.7	C	21.0	C
18	SR 262 off-ramp	SR 262 on-ramp	5.3	A	16.5	B	22.7	C	23.8	C
19	SR 262 on-ramp	Scott Creek Rd off-ramp	6.0	A	17.9	B	26.0	D	30.2	D
20	Scott Creek Rd off-ramp	Scott Creek Rd on-ramp	4.8	A	15.2	B	20.0	C	21.6	C
21	Scott Creek Rd on-ramp	Jacklin Rd off-ramp	5.1	A	16.0	B	21.5	C	23.7	C
22	Jacklin Rd off-ramp	Jacklin Rd on-ramp	4.7	A	15.3	B	20.5	C	21.4	C
23	Jacklin Rd on-ramp	SR-237 off-ramp	4.0	A	12.5	B	17.9	B	18.5	C
24	SR-237 off-ramp	South of SR-237 off-ramp	3.8	A	13.5	B	19.2	C	19.1	C
25		Second Half of Split	4.3	A	15.2	B	21.5	C	21.5	C

Table 89: Study Corridor FREQ Analysis, "Before" Conditions, General Purpose Lanes, PM Peak Period

Seg. No.	From	To	3:00 - 4:00		4:00 - 5:00		5:00 - 6:00		6:00 - 7:00	
			Density	LOS	Density	LOS	Density	LOS	Density	LOS
1	I-680 SB north of SR 84 on-ramp	HOV Begin	14.5	B	18.3	C	23.0	C	18.7	C
2	HOV Begin	SR 84 On-ramp	11.7	B	14.7	B	18.3	C	15.0	B
3	SR 84 On-ramp	Paloma Rd on-ramp	13.5	B	16.8	B	20.3	C	16.5	B
4	Paloma Rd on-ramp	Andrade Rd off-ramp	13.8	B	17.1	B	20.5	C	16.6	B
5	Andrade Rd off-ramp	Andrade Rd on-ramp	13.3	B	16.8	B	20.1	C	16.4	B
6	Andrade Rd on-ramp	Sheridan Rd on-ramp	10.3	A	12.8	B	15.3	B	12.4	B
7	Sheridan Rd on-ramp	Lane Drop	10.4	A	12.9	B	15.4	B	12.5	B
8	Lane Drop	Vargas Rd off-ramp	13.9	B	17.2	B	20.5	C	16.7	B
9	Vargas Rd off-ramp	Vargas Rd on-ramp	13.9	B	17.2	B	20.4	C	16.7	B
10	Vargas Rd on-ramp	SR 238 off-ramp	14.0	B	17.3	B	20.5	C	16.7	B
11	SR 238 off-ramp	SR 238 on-ramp	12.3	B	15.5	B	17.9	B	14.5	B
12	SR 238 on-ramp	Washington Blvd off-ramp	14.3	B	17.4	B	19.9	C	16.3	B
13	Washington Blvd off-ramp	Washington Blvd on-ramp	13.0	B	15.9	B	17.7	B	14.9	B
14	Washington Blvd on-ramp	Lane Add	14.5	B	17.4	B	19.5	C	16.4	B
15	Lane Add	Automall Pkwy off-ramp	10.9	A	13.1	B	14.7	B	12.3	B
16	Automall Pkwy off-ramp	Automall Pkwy on-ramp	11.7	B	15.3	B	17.2	B	14.5	B
17	Automall Pkwy on-ramp	SR 262 off-ramp	11.7	B	14.7	B	16.5	B	13.4	B
18	SR 262 off-ramp	SR 262 on-ramp	10.0	A	14.1	B	16.0	B	13.2	B
19	SR 262 on-ramp	Scott Creek Rd off-ramp	13.3	B	17.7	B	19.8	C	16.5	B
20	Scott Creek Rd off-ramp	Scott Creek Rd on-ramp	12.2	B	16.8	B	18.6	C	15.3	B
21	Scott Creek Rd on-ramp	Jacklin Rd off-ramp	15.1	B	19.5	C	21.4	C	17.4	B
22	Jacklin Rd off-ramp	Jacklin Rd on-ramp	14.2	B	18.6	C	19.8	C	16.1	B
23	Jacklin Rd on-ramp	SR-237 off-ramp	12.6	B	15.8	B	16.9	B	14.4	B
24	SR-237 off-ramp	South of SR-237 off-ramp	14.8	B	18.9	C	20.0	C	16.5	B
25		Second Half of Split	17.9	B	23.4	C	25.1	C	20.0	C

Table 90: Study Corridor FREQ Analysis, “After” Conditions, General Purpose Lanes, AM Peak Period

FREQ SS	LOCATION	Time Slice 1 5-6AM		Time Slice 2 6-7AM		Time Slice 3 7-8AM		Time Slice 4 8-9AM	
		Density (vphpl)	LOS	Density (vphpl)	LOS	Density (vphpl)	LOS	Density (vphpl)	LOS
10	Rte 84 Off/HOV Begin	20.1	C	31.4	D	42.5	F	72.9	F
11	HOVBegin/Rte 84 On	15.1	B	20.4	C	67.3	F	99.8	F
12	Rte 84 On/Calavares On	21	C	31	D	59.6	F	64.3	F
13	Calavares On/ExpIngress	21.1	C	36.7	F	32.8	E	32.8	E
14	ExpIngress/Andrade Off	27.8	D	37.2	E	36.7	E	33.8	D
15	Andrade Off/On	27.3	D	35.9	E	35.4	E	32.3	D
16	Andrade On/Sheridan On	19.4	C	26.8	D	26.7	D	21.5	C
17	Sheridan On/Lane Drop	19.5	C	26.9	D	26.9	D	21.6	C
18	Lane Drop/Vargas Off	26.7	D	33.3	D	33.4	D	31.2	D
19	Vargas Off/On	26.6	D	33.2	D	33.3	D	31.1	D
20	Vargas On/Mission Off	26.6	D	33.3	D	33.6	D	31.3	D
21	Mission(238) Off/On	25.8	C	30.3	D	29.1	D	25.7	C
22	Mission on/Washington Of	26.4	D	34	D	35.7	E	31.9	D
23	Washington Off/DummyEgrs	25.8	C	31.7	D	32	D	28	D
24	DummyEgress-WashIngress	26.2	D	33.3	D	33.9	D	30	D
25	ExpIngres/Washington On	26.1	D	32.6	D	32.7	D	28.3	D
26	Washington On/Durham Off	19.3	C	25.6	C	29.2	F	26.8	D
27	Durham Off/ExpEgress	21.7	C	26.1	D	72.3	F	74.3	F
28	ExpEgress/Durham On	22.9	C	29.8	D	84.8	F	93.4	F
29	Durham On/ExpIngress	17.8	B	21.9	C	38.2	F	37.7	E
30	ExpIng/Mission (262) Off	17.7	B	21.6	C	29.3	E	28	D
31	Mission (262) Off/On	14.9	B	20.9	C	25.5	C	25.5	C
32	Mission On/Scott Crk Off	11.6	B	16.8	B	20.4	C	21.1	C
33	Scott Creek Off/On	13.8	B	19.4	C	23.3	C	23	C
34	Scott Crk On/Jacklin Off	10.5	A	15.1	B	18.5	C	18.5	C
35	Jacklin Off/ExpEgress	13.8	B	19.7	C	24.1	C	22.9	C
36	ExpEgress/Jacklin On	14.3	B	20.8	C	25.6	C	24.5	C
37	Jacklin On/Rte 237 Off	11.1	B	16.5	B	21	C	20.2	C
38	Rte 237 Off/End HOV	12	B	16.7	B	22	C	19.7	C
39	End Exp/Rte 237 On	9.3	A	13.7	B	18.1	C	16.8	B
40	Rte 237 On/south of 237	9.9	A	15.1	B	20.4	C	19.4	C

Table 91: Study Corridor FREQ Analysis, "After" Conditions, General Purpose Lanes, PM Peak Period

FREQ SS	LOCATION	Time Slice 1 3-4PM		Time Slice 2 4-5PM		Time Slice 3 5-6PM		Time Slice 4 6-7PM	
		Density (vphpl)	LOS	Density (vphpl)	LOS	Density (vphpl)	LOS	Density (vphpl)	LOS
10	Rte 84 Off/HOV Begin	15.6	B	17.7	B	19.1	C	14	B
11	HOVBegin/Rte 84 On	11.7	B	13.3	B	14.3	B	10.5	A
12	Rte 84 On/Calavares On	13.9	B	15.9	B	17	B	12.4	B
13	Calavares On/ExpIngress	14.2	B	16.1	B	17.2	B	12.5	B
14	ExpIngress/Andrade Off	18.2	C	20.1	C	21.4	C	16	B
15	Andrade Off/On	17.9	B	19.8	C	21.1	C	15.8	B
16	Andrade On/Sheridan On	13.6	B	15.1	B	16	B	12.1	B
17	Sheridan On/Lane Drop	13.6	B	15.1	B	16	B	12.1	B
18	Lane Drop/Vargas Off	18.2	C	20.1	C	21.4	C	16.1	B
19	Vargas Off/On	18.2	C	20	C	21.3	C	16.1	B
20	Vargas On/Mission Off	18.2	C	20	C	21.4	C	16.1	B
21	Mission(238) Off/On	16.3	B	17.8	B	18.5	C	13.4	B
22	Mission on/Washington Of	18.3	C	20.2	C	20.9	C	15.5	B
23	Washington Off/DummyEgrs	16.8	B	18.6	C	18.7	C	13.7	B
24	DummyEgress-WashIngress	17	B	19	C	19.2	C	14	B
25	ExpIngres/Washington On	16.8	B	18.7	C	18.8	C	13.7	B
26	Washington On/Durham Off	13.2	B	14.8	B	14.9	B	11.1	B
27	Durham Off/ExpEgress	15.6	B	17.2	B	17.6	B	12.8	B
28	ExpEgress/Durham On	15.8	B	17.4	B	18	B	12.9	B
29	Durham On/ExpIngress	15.2	B	16.8	B	17.9	B	12.3	B
30	ExpIng/Mission (262) Off	15.1	B	16.6	B	17.5	B	12.2	B
31	Mission (262) Off/On	14.5	B	17	B	17.7	B	11	B
32	Mission On/Scott Crk Off	13.1	B	15.8	B	16.6	B	11	A
33	Scott Creek Off/On	16.3	B	20	C	20.5	C	13.3	B
34	Scott Crk On/Jacklin Off	14.7	B	17.7	B	17.7	B	11.8	B
35	Jacklin Off/ExpEgress	18.5	C	22.2	C	21.7	C	14.1	B
36	ExpEgress/Jacklin On	18.6	C	22.4	C	21.8	C	14.1	B
37	Jacklin On/Rte 237 Off	16	B	18.5	C	18.4	C	12.5	B
38	Rte 237 Off/End HOV	18.8	C	22.2	C	20.8	C	13.8	B
39	End Exp/Rte 237 On	14.6	B	17.6	B	16.8	B	10.9	A
40	Rte 237 On/south of 237	19.2	C	22.4	C	21	C	15.5	B

Table 92: Control Corridor FREQ Analysis, "Before" Conditions, HOV Lane, AM Peak Period

			6:00 - 7:00		7:00 - 8:00		8:00 - 9:00	
Seg. No.	From	To	Density	LOS	Density	LOS	Density	LOS
2	I-680 NB south of Alcosta	Alcosta Blvd off-ramp	6.1	A	10.1	A	10.0	A
3	Alcosta Blvd off-ramp	Alcosta Blvd on-ramp	6.1	A	10.1	A	10.0	A
4	Alcosta Blvd on-ramp	Bollinger Canyon off-ramp decel lane	6.8	A	11.5	B	11.5	B
5	Bollinger Canyon off-ramp decel lane	Bollinger Canyon Rd off-ramp	6.8	A	11.5	B	11.5	B
6	Bollinger Canyon Rd off-ramp	Bollinger Canyon Rd EB on-ramp	5.1	A	8.1	A	7.8	A
7	Bollinger Canyon Rd EB on-ramp	Bollinger Canyon Rd WB on-ramp	5.5	A	8.7	A	8.2	A
8	Bollinger Canyon Rd WB on-ramp	Crow Canyon Rd off-ramp	6.0	A	10.0	A	9.1	A
9	Crow Canyon Rd off-ramp	Crow Canyon Rd EB on-ramp	5.5	A	8.8	A	6.9	A
10	Crow Canyon Rd EB on-ramp	Crow Canyon Rd WB on-ramp	6.0	A	9.9	A	8.0	A
11	Crow Canyon Rd WB on-ramp	Sycamore Valley Rd off-ramp	6.6	A	11.1	B	9.2	A
12	Sycamore Valley Rd off-ramp	Sycamore Valley Rd on-ramp	6.3	A	10.6	A	8.5	A
13	Sycamore Valley Rd on-ramp	Diablo Rd off-ramp	7.7	A	13.1	B	10.9	A
14	Diablo Rd off-ramp	Diablo Rd EB on-ramp	7.5	A	12.6	B	10.1	A
15	Diablo Rd EB on-ramp	Diablo Rd WB on-ramp	7.6	A	12.8	B	10.5	A
16	Diablo Rd WB on-ramp	El Cerro Blvd off-ramp	7.8	A	13.5	B	11.0	B
17	El Cerro Blvd off-ramp	El Cerro Blvd on-ramp	7.7	A	13.0	B	10.6	A
18	El Cerro Blvd on-ramp	El Pintado Rd on-ramp	8.2	A	14.1	B	11.6	B
19	El Pintado Rd on-ramp	Stone Valley Rd EB off-ramp	8.2	A	14.3	B	11.8	B
20	Stone Valley Rd EB off-ramp	Stone Valley Rd WB off-ramp	8.1	A	14.0	B	11.6	B
21	Stone Valley Rd WB off-ramp	Stone Valley Rd on-ramp	8.0	A	13.8	B	11.4	B
22	Stone Valley Rd on-ramp	Livorna Rd off-ramp	8.0	A	13.8	B	11.4	B
23	Livorna Rd off-ramp	End of HOV lane	7.9	A	13.6	B	11.1	B
24	End of HOV lane	Livorna Rd on-ramp	7.9	A	13.6	B	11.1	B
25	Livorna Rd on-ramp	I-680 NB north of Livorna						

Table 93: Control Corridor FREQ Analysis, "Before" Conditions, HOV Lane, PM Peak Period

			3:00 - 4:00		4:00 - 5:00		5:00 - 6:00	
Seg. No.	From	To	Density	LOS	Density	LOS	Density	LOS
2	I-680 NB south of Alcosta	Alcosta Blvd off-ramp	16.2	B	17.7	B	18.8	C
3	Alcosta Blvd off-ramp	Alcosta Blvd on-ramp	16.2	B	17.7	B	18.8	C
4	Alcosta Blvd on-ramp	Bollinger Canyon off-ramp decel lane	18.0	B	19.1	C	20.4	C
5	Bollinger Canyon off-ramp decel lane	Bollinger Canyon Rd off-ramp	18.0	B	19.1	C	20.4	C
6	Bollinger Canyon Rd off-ramp	Bollinger Canyon Rd EB on-ramp	15.0	B	15.6	B	15.8	B
7	Bollinger Canyon Rd EB on-ramp	Bollinger Canyon Rd WB on-ramp	15.5	B	16.1	B	16.3	B
8	Bollinger Canyon Rd WB on-ramp	Crow Canyon Rd off-ramp	17.7	B	18.7	C	18.5	C
9	Crow Canyon Rd off-ramp	Crow Canyon Rd EB on-ramp	15.3	B	16.2	B	15.1	B
10	Crow Canyon Rd EB on-ramp	Crow Canyon Rd WB on-ramp	17.4	B	18.4	C	17.3	B
11	Crow Canyon Rd WB on-ramp	Sycamore Valley Rd off-ramp	20.0	C	20.5	F	19.9	C
12	Sycamore Valley Rd off-ramp	Sycamore Valley Rd on-ramp	18.5	C	28.5	F	28.2	D
13	Sycamore Valley Rd on-ramp	Diablo Rd off-ramp	21.4	C	27.7	F	31.7	D
14	Diablo Rd off-ramp	Diablo Rd EB on-ramp	19.9	C	38.0	F	41.8	E
15	Diablo Rd EB on-ramp	Diablo Rd WB on-ramp	21.0	F	40.9	F	42.1	F
16	Diablo Rd WB on-ramp	El Cerro Blvd off-ramp	24.7	F	38.1	F	39.1	F
17	El Cerro Blvd off-ramp	El Cerro Blvd on-ramp	32.5	F	42.9	F	44.0	F
18	El Cerro Blvd on-ramp	El Pintado Rd on-ramp	35.0	F	37.0	F	36.9	F
19	El Pintado Rd on-ramp	Stone Valley Rd EB off-ramp	21.9	E	21.9	E	21.9	E
20	Stone Valley Rd EB off-ramp	Stone Valley Rd WB off-ramp	21.4	C	21.4	C	21.4	C
21	Stone Valley Rd WB off-ramp	Stone Valley Rd on-ramp	20.7	C	20.7	C	20.9	C
22	Stone Valley Rd on-ramp	Livorna Rd off-ramp	20.7	C	20.7	C	20.9	C
23	Livorna Rd off-ramp	End of HOV lane	20.2	C	20.2	C	20.3	C
24	End of HOV lane	Livorna Rd on-ramp	20.2	C	20.2	C	20.3	C
25	Livorna Rd on-ramp	I-680 NB north of Livorna						

Table 94: Control Corridor FREQ Analysis, "After" Conditions, HOV Lane, AM Peak Period

FREQ SS	LOCATION	Time Slice 1 5-6AM		Time Slice 2 6-7AM		Time Slice 3 7-8AM		Time Slice 4 8-9AM	
		Density (vphpl)	LOS	Density (vphpl)	LOS	Density (vphpl)	LOS	Density (vphpl)	LOS
1	680 NB S/O Alcosta (HOV)	0	0	0	0	0	0	0	0
2	HOV Begin	0	0	0	0	0	0	0	0
3	NB Alcosta betwn off-on	2.9	A	5.7	A	9.7	A	10.2	A
4	NB Alcosta to Bollinger1	2.9	A	5.7	A	9.7	A	10.2	A
5	NB Alcosta to Bollinger2	3.1	A	6.4	A	11.2	B	11.5	B
6	NB Bollinger off-loop on	3.1	A	6.4	A	11.2	B	11.5	B
7	NB Bollinger loop-diag	2.4	A	4.8	A	7.8	A	7.5	A
8	NB Bollinger-Crow Canyon	2.5	A	5.2	A	8.4	A	8.1	A
9	NB Crow Canyon off-loop	2.7	A	5.6	A	9.5	A	9.2	A
10	NB Crow Canyon loop-diag	2.3	A	4.9	A	8.2	A	7.5	A
11	NB Crow Canyon-Sycamore	2.6	A	5.7	A	9.5	A	8.7	A
12	NB Sycamore off-on	2.7	A	6	A	10.3	A	9.6	A
13	NB Sycamore-Diablo	2.6	A	5.8	A	9.8	A	8.9	A
14	NB Diablo off-loop on	3.1	A	7	A	12.3	B	11.1	B
15	NB Diablo loop-diag on	3.1	A	6.8	A	11.6	B	10.2	A
16	NB Diablo-El Cerro	3.1	A	6.9	A	11.9	B	10.5	A
17	NB El Cerro off-on-ramp	3.1	A	7	A	12.1	B	10.8	A
18	NB El Cerro-El Pintado	3.1	A	6.9	A	11.7	B	10.2	A
19	NB El Pint-Stone Valley	3.3	A	7.3	A	12.7	B	11.2	B
20	NB Stone Vall off1-off2	3.3	A	7.4	A	12.9	B	11.4	B
21	NB Stone Valley off-on	3.3	A	7.3	A	12.7	B	11.1	B
22	NB Stone Valley-Livorna	3.2	A	7.2	A	12.5	B	10.9	A
23	NB Livorna off-on (HOV)	3.2	A	7.2	A	12.5	B	10.9	A
24	NB Livorna off-on	3.2	A	7.2	A	12.3	B	10.7	A

Table 95: Control Corridor FREQ Analysis, "After" Conditions, HOV Lane, PM Peak Period

FREQ SS	LOCATION	Time Slice 1 3-4PM		Time Slice 2 4-5PM		Time Slice 3 5-6PM		Time Slice 4 6-7PM	
		Density (vphpl)	LOS	Density (vphpl)	LOS	Density (vphpl)	LOS	Density (vphpl)	LOS
1	680 NB S/O Alcosta (HOV)	0	0	0	0	0	0	0	0
2	HOV Begin	13.7	B	14.7	B	14.3	B	13.2	B
3	NB Alcosta betwn off-on	13.7	B	14.7	B	14.3	B	13.2	B
4	NB Alcosta to Bollinger1	15.1	B	15.9	B	15.5	B	14.2	B
5	NB Alcosta to Bollinger2	15.1	B	15.9	B	15.5	B	14.2	B
6	NB Bollinger off-loop on	12.5	B	13	B	11.9	B	10.7	A
7	NB Bollinger loop-diag	13.2	B	13.4	B	12.2	B	11	A
8	NB Bollinger-Crow Canyon	15	B	15.3	B	13.8	B	12.6	B
9	NB Crow Canyon off-loop	12.7	B	12.6	B	10.7	A	10.1	A
10	NB Crow Canyon loop-diag	14.5	B	14.2	B	12.2	B	11.6	B
11	NB Crow Canyon-Sycamore	16.6	B	16.5	B	14.1	B	13.4	B
12	NB Sycamore off-on	15.3	B	15.4	B	12.9	B	12.2	B
13	NB Sycamore-Diablo	17.7	B	17.6	B	15.2	B	14.6	B
14	NB Diablo off-loop on	16.3	B	16.2	B	13.8	B	13.1	B
15	NB Diablo loop-diag on	17	B	16.7	B	14.4	B	13.7	B
16	NB Diablo-El Cerro	17.3	B	16.9	B	14.7	B	13.9	B
17	NB El Cerro off-on-ramp	16.5	B	16	B	13.9	B	13.1	B
18	NB El Cerro-El Pintado	17.9	B	17.1	B	15.1	B	14	B
19	NB El Pint-Stone Valley	18.1	C	17.3	B	15.3	B	14.2	B
20	NB Stone Vall off1-off2	17.7	B	17	B	15	B	13.8	B
21	NB Stone Valley off-on	17.1	B	16.5	B	14.7	B	13.4	B
22	NB Stone Valley-Livorna	17.1	B	16.5	B	14.7	B	13.4	B
23	NB Livorna off-on (HOV)	16.6	B	16.1	B	14.3	B	13	B
24	NB Livorna off-on	16.6	B	16.1	B	14.3	B	13	B

Table 96: Control Corridor FREQ Analysis, "Before" Conditions, General Purpose Lanes, AM Peak Period

Seg. No.	From	To	5:00 - 6:00		6:00 - 7:00		7:00 - 8:00		8:00 - 9:00	
			Density	LOS	Density	LOS	Density	LOS	Density	LOS
2	I-680 NB south of Alcosta	Alcosta Blvd off-ramp	4.8	A	11.5	B	19.5	C	19.4	C
3	Alcosta Blvd off-ramp	Alcosta Blvd on-ramp	5.6	A	14.4	B	24.1	C	23.9	C
4	Alcosta Blvd on-ramp	Bollinger Canyon off-ramp decel lane	6.1	A	16.0	B	28.9	D	28.9	D
5	Bollinger Canyon off-ramp decel lane	Bollinger Canyon Rd off-ramp	4.9	A	12.0	B	20.4	C	20.3	C
6	Bollinger Canyon Rd off-ramp	Bollinger Canyon Rd EB on-ramp	4.6	A	12.0	B	19.2	C	18.3	C
7	Bollinger Canyon Rd EB on-ramp	Bollinger Canyon Rd WB on-ramp	4.8	A	13.0	B	20.8	C	19.7	C
8	Bollinger Canyon Rd WB on-ramp	Crow Canyon Rd off-ramp	4.3	A	10.9	A	18.2	C	17.1	B
9	Crow Canyon Rd off-ramp	Crow Canyon Rd EB on-ramp	4.8	A	12.9	B	20.7	C	16.3	B
10	Crow Canyon Rd EB on-ramp	Crow Canyon Rd WB on-ramp	5.1	A	14.1	B	23.6	C	18.9	C
11	Crow Canyon Rd WB on-ramp	Sycamore Valley Rd off-ramp	5.6	A	15.6	B	27.7	F	53.4	F
12	Sycamore Valley Rd off-ramp	Sycamore Valley Rd on-ramp	5.3	A	14.9	B	48.6	F	110.1	F
13	Sycamore Valley Rd on-ramp	Diablo Rd off-ramp	5.1	A	13.6	B	59.4	F	101.8	F
14	Diablo Rd off-ramp	Diablo Rd EB on-ramp	6.2	A	17.8	B	58.2	F	87.4	F
15	Diablo Rd EB on-ramp	Diablo Rd WB on-ramp	6.3	A	18.0	C	58.9	F	82.4	F
16	Diablo Rd WB on-ramp	El Cerro Blvd off-ramp	5.2	A	13.8	B	76.8	F	111.1	F
17	El Cerro Blvd off-ramp	El Cerro Blvd on-ramp	6.4	A	18.1	C	65.9	F	84.2	F
18	El Cerro Blvd on-ramp	El Pintado Rd on-ramp	6.8	A	19.3	C	53.9	F	70.7	F
19	El Pintado Rd on-ramp	Stone Valley Rd EB off-ramp	6.9	A	19.5	C	54.3	F	67.6	F
20	Stone Valley Rd EB off-ramp	Stone Valley Rd WB off-ramp	6.8	A	19.0	C	61.6	F	71.1	F
21	Stone Valley Rd WB off-ramp	Stone Valley Rd on-ramp	6.8	A	18.8	C	65.9	F	74.3	F
22	Stone Valley Rd on-ramp	Livorna Rd off-ramp	7.1	A	20.1	C	39.3	E	39.3	E
23	Livorna Rd off-ramp	End of HOV lane	7.1	A	20.0	C	38.2	E	37.0	E
24	End of HOV lane	Livorna Rd on-ramp	7.1	A	17.0	B	28.3	D	26.9	D
25	Livorna Rd on-ramp	I-680 NB north of Livorna	7.4	A	17.7	B	31.5	D	30.2	D

Table 97: Control Corridor FREQ Analysis, "Before" Conditions, General Purpose Lanes, PM Peak Period

Seg. No.	From	To	3:00 - 4:00		4:00 - 5:00		5:00 - 6:00		6:00 - 7:00	
			Density	LOS	Density	LOS	Density	LOS	Density	LOS
2	I-680 NB south of Alcosta	Alcosta Blvd off-ramp	19.3	C	21.9	C	25.3	C	19.9	C
3	Alcosta Blvd off-ramp	Alcosta Blvd on-ramp	21.7	C	24.4	C	26.6	D	20.4	C
4	Alcosta Blvd on-ramp	Bollinger Canyon off-ramp decel lane	24.9	C	27.2	D	30.5	D	22.4	C
5	Bollinger Canyon off-ramp decel lane	Bollinger Canyon Rd off-ramp	18.1	C	19.2	C	20.6	C	17.9	B
6	Bollinger Canyon Rd off-ramp	Bollinger Canyon Rd EB on-ramp	20.1	C	21.0	C	21.2	C	17.2	B
7	Bollinger Canyon Rd EB on-ramp	Bollinger Canyon Rd WB on-ramp	21.0	C	21.8	C	22.1	C	18.0	B
8	Bollinger Canyon Rd WB on-ramp	Crow Canyon Rd off-ramp	18.5	C	19.6	C	19.5	C	16.9	B
9	Crow Canyon Rd off-ramp	Crow Canyon Rd EB on-ramp	20.5	C	21.8	C	20.2	C	16.4	B
10	Crow Canyon Rd EB on-ramp	Crow Canyon Rd WB on-ramp	23.9	C	25.7	C	23.6	C	19.0	C
11	Crow Canyon Rd WB on-ramp	Sycamore Valley Rd off-ramp	30.2	D	33.6	F	43.5	F	21.6	C
12	Sycamore Valley Rd off-ramp	Sycamore Valley Rd on-ramp	25.9	C	48.9	F	76.9	F	18.8	C
13	Sycamore Valley Rd on-ramp	Diablo Rd off-ramp	22.1	C	71.0	F	83.6	F	17.8	B
14	Diablo Rd off-ramp	Diablo Rd EB on-ramp	28.4	F	66.3	F	68.8	F	19.7	C
15	Diablo Rd EB on-ramp	Diablo Rd WB on-ramp	33.3	F	61.5	F	62.3	F	20.5	C
16	Diablo Rd WB on-ramp	El Cerro Blvd off-ramp	38.1	F	94.7	F	95.4	F	16.9	B
17	El Cerro Blvd off-ramp	El Cerro Blvd on-ramp	46.5	F	65.5	F	66.9	F	19.5	C
18	El Cerro Blvd on-ramp	El Pintado Rd on-ramp	48.3	F	57.0	F	56.6	F	20.8	C
19	El Pintado Rd on-ramp	Stone Valley Rd EB off-ramp	50.8	F	54.9	F	54.8	F	21.0	C
20	Stone Valley Rd EB off-ramp	Stone Valley Rd WB off-ramp	57.2	F	58.7	F	58.6	F	20.5	C
21	Stone Valley Rd WB off-ramp	Stone Valley Rd on-ramp	64.3	F	64.1	F	62.5	F	19.8	C
22	Stone Valley Rd on-ramp	Livorna Rd off-ramp	37.3	E	37.3	E	37.3	E	21.3	C
23	Livorna Rd off-ramp	End of HOV lane	34.8	D	34.9	D	34.6	D	20.4	C
24	End of HOV lane	Livorna Rd on-ramp	29.7	D	29.7	D	29.2	D	20.4	C
25	Livorna Rd on-ramp	I-680 NB north of Livorna	32.8	D	31.8	D	31.2	D	21.4	C

Table 98: Control Corridor FREQ Analysis, "After" Conditions, General Purpose Lanes, AM Peak Period

FREQ SS	LOCATION	Time Slice 1 5-6AM		Time Slice 2 6-7AM		Time Slice 3 7-8AM		Time Slice 4 8-9AM	
		Density (vphpl)	LOS	Density (vphpl)	LOS	Density (vphpl)	LOS	Density (vphpl)	LOS
1	680 NB S/O Alcosta (HOV)	6.1	A	12.2	B	21.1	C	22.6	C
2	HOV Begin	6.1	A	12.2	B	21.1	C	22.6	C
3	NB Alcosta betwn off-on	7.7	A	15.4	B	26.7	D	28.8	D
4	NB Alcosta to Bollinger1	8.3	A	17.1	B	33.1	D	35	D
5	NB Alcosta to Bollinger2	6.3	A	12.8	B	22.5	C	23.2	C
6	NB Bollinger off-loop on	6.5	A	13	B	20.9	C	20.2	C
7	NB Bollinger loop-diag	6.9	A	14.1	B	23.1	C	22.3	C
8	NB Bollinger-Crow Canyon	5.5	A	11.6	B	19.9	C	19.7	C
9	NB Crow Canyon off-loop	6.3	A	13.1	B	22	C	20.1	C
10	NB Crow Canyon loop-diag	6.9	A	15.2	B	26	C	23.4	C
11	NB Crow Canyon-Sycamore	7.3	A	16.2	B	30.5	F	53.5	F
12	NB Sycamore off-on	7.1	A	15.5	B	54.6	F	102	F
13	NB Sycamore-Diablo	6.3	A	14.2	B	42.8	F	51.1	F
14	NB Diablo off-loop on	8.2	A	18.3	C	58.6	F	80.2	F
15	NB Diablo loop-diag on	8.4	A	18.6	C	59	F	75.1	F
16	NB Diablo-El Cerro	6.3	A	14.2	B	46.3	F	57.8	F
17	NB El Cerro off-on-ramp	8.4	A	18.4	C	65.8	F	82.4	F
18	NB El Cerro-El Pintado	8.9	A	19.8	C	55.4	F	67.7	F
19	NB El Pint-Stone Valley	8.9	A	19.9	C	56.4	F	64.1	F
20	NB Stone Vall off1-off2	8.9	A	19.7	C	62.7	F	68.8	F
21	NB Stone Valley off-on	8.7	A	19.5	C	67.5	F	73.1	F
22	NB Stone Valley-Livorna	9.2	A	20.8	C	41.2	E	41.2	E
23	NB Livorna off-on (HOV)	9.2	A	20.8	C	40.2	E	39.1	E
24	NB Livorna off-on	6.9	A	15.6	B	24.8	C	24.5	C
25	HOV End	6.9	A	15.6	B	24.8	C	24.5	C
26	680 NB N/O Livorna on	7.2	A	16.4	B	27.1	D	26.6	D

Table 99: Control Corridor FREQ Analysis, "After" Conditions, General Purpose Lanes, PM Peak Period

FREQ SS	LOCATION	Time Slice 1 3-4PM		Time Slice 2 4-5PM		Time Slice 3 5-6PM		Time Slice 4 6-7PM	
		Density (vphpl)	LOS	Density (vphpl)	LOS	Density (vphpl)	LOS	Density (vphpl)	LOS
1	680 NB S/O Alcosta (HOV)	23.5	C	26	D	26.5	D	24.9	C
2	HOV Begin	23.5	C	26	D	26.5	D	24.9	C
3	NB Alcosta betwn off-on	27.9	D	30.9	D	29.6	D	26.3	D
4	NB Alcosta to Bollinger1	32.3	D	34.5	F	34.5	D	29.3	D
5	NB Alcosta to Bollinger2	22.2	C	46.3	F	45.1	F	20.9	C
6	NB Bollinger off-loop on	24.9	C	60.8	F	60.7	F	20.9	C
7	NB Bollinger loop-diag	26.7	D	69.6	F	70.4	F	21.7	C
8	NB Bollinger-Crow Canyon	21.3	F	66.8	F	67.2	F	22.4	C
9	NB Crow Canyon off-loop	31.1	F	109.1	F	110	F	38.9	E
10	NB Crow Canyon loop-diag	39.2	F	92.4	F	94.9	F	43	E
11	NB Crow Canyon-Sycamore	49.1	F	65.4	F	73	F	47.4	F
12	NB Sycamore off-on	61.7	F	80	F	87.2	F	65.3	F
13	NB Sycamore-Diablo	39.2	F	43.7	F	47.8	F	42.1	E
14	NB Diablo off-loop on	55.1	F	69.4	F	76.1	F	33.7	D
15	NB Diablo loop-diag on	54.6	F	63.5	F	69	F	37.3	E
16	NB Diablo-El Cerro	42.9	F	49.1	F	52.5	F	29.5	D
17	NB El Cerro off-on-ramp	61.8	F	72.3	F	77	F	41.3	E
18	NB El Cerro-El Pintado	52.7	F	60.4	F	64.2	F	44.6	E
19	NB El Pint-Stone Valley	51.7	F	58.1	F	61.3	F	48.6	F
20	NB Stone Vall off1-off2	59.5	F	61.2	F	64.7	F	55.6	F
21	NB Stone Valley off-on	68	F	66.8	F	68.5	F	64.1	F
22	NB Stone Valley-Livorna	41.2	E	41.2	E	41.2	E	41.2	E
23	NB Livorna off-on (HOV)	38.6	E	38.5	E	38.3	E	37.7	E
24	NB Livorna off-on	24.4	C	24.4	C	24.3	C	24.1	C
25	HOV End	24.4	C	24.4	C	24.3	C	24.1	C
26	680 NB N/O Livorna on	25.8	C	25.5	C	25.4	C	25.1	C

9.7 COLLISION DETAIL

Accident information was compiled by the severity of injuries (Table 100 and Table 101), by primary factor (Table 102 and Table 103) and by accident type (Table 104and Table 105). There were reductions in all types of accidents on both the study and control corridors between the "Before" and "After" conditions.

Table 100: Annual Severity of Sustained Injuries on the I-680 SB Study Corridor

Severity	"Before"				"After"	2006	05-07 AVG	2011
	2005	2006	2007	Average	2011	%	%	%
No Injury	169	185	138	164	72	70.1%	66.8%	58.5%
Complaint of Pain	57	47	49	51	34	17.8%	20.8%	27.6%
Visible Injury	28	30	21	26	14	11.4%	10.7%	11.4%
Severe Injury	7	1	3	4	3	0.4%	1.5%	2.4%
Fatal	1	1	0	1	0	0.4%	0.3%	0.0%
Total	262	264	211	246	123	100%	100%	100%

Source: SWITRS

Table 101: Annual Severity of Sustained Injuries on the I-680 NB Control Corridor

Severity	"Before"				"After"	2006	05-07 AVG	2011
	2005	2006	2007	Average	2011	%	%	%
No Injury	197	220	175	197	60	76.4%	71.9%	68.2%
Complaint of Pain	57	50	63	57	21	17.4%	20.7%	23.9%
Visible Injury	18	14	19	17	3	4.9%	6.2%	3.4%
Severe Injury	5	2	1	3	3	0.7%	1.0%	3.4%
Fatal	0	2	0	1	1	0.7%	0.2%	1.1%
Total	277	288	258	274	88	100%	100%	100%

Source: SWITRS

Table 102: Annual Collision Primary Factors on I-680 SB Study Corridor

Primary Factor Category	"Before" Study			"After" Study
	2005	2006	2007	2011
Unsafe Speed	130	151	108	61
Improper Turning	58	36	28	33
Unsafe Lane Change	43	43	33	17
Following too Closely	1	10	10	2
Driving Under the Influence	11	5	7	5
Other than Driver	8	6	15	2
Unsafe Starting or Backing	1	1	2	0
Traffic Signals and Signs	0	0	0	1
Hazardous Parking	0	0	0	1
Other Hazardous Violation	3	4	6	2
Improper Passing	0	1	0	0
Other Equipment	3	2	0	0
Wrong Side of Road	0	1	0	0
Not Stated	4	4	2	0
Total	262	264	211	124

Table 103: Annual Collision Primary Factors on I-680 NB Control Corridor

Primary Factor Category	"Before" Study			"After" Study
	2005	2006	2007	2011
Unsafe Speed	193	202	149	56
Improper Turning	17	26	19	4
Wrong Side of Road	0	0	0	1
Unsafe Lane Change	27	24	32	20
Following too Closely	15	16	27	3
Driving Under the Influence	8	4	11	3
Other than Driver	11	9	5	1
Unsafe Starting or Backing	3	1	4	0
Other Hazardous Violation	0	2	4	0
Improper Passing	1	0	0	0
Impeding Traffic	0	0	1	0
Pedestrian Violation	0	0	1	1
Traffic Signals and Signs	0	0	1	0
Other Equipment	0	0	0	1
Not Stated	2	4	4	0
Total	277	288	258	90

Table 104: Annual Collisions by Type on the I-680 SB Study Corridor

Type	"Before" Study			"After" Study
	2005	2006	2007	2011
Head-On	0	1	0	0
Sideswipe	44	44	38	18
Rear End	121	146	111	60
Broadside	7	3	3	2
Hit Object	73	57	45	37
Overturned	13	11	10	4
Vehicle/Pedestrian	1	0	0	0
Other	2	1	4	2
Not Stated	1	1	0	0
Total	262	264	211	123

Table 105: Annual Collisions by Type on the I-680 NB Control Corridor

Type	"Before" Study			"After" Study
	2005	2006	2007	2011
Head-On	0	1	2	1
Sideswipe	29	26	34	18
Rear End	205	214	178	62
Broadside	2	2	4	1
Hit Object	35	36	35	5
Overturned	3	2	4	1
Vehicle/Pedestrian	0	0	0	1
Other	2	6	1	0
Not Stated	1	1	0	0
Total	277	288	258	89

9.8 ITS TECHNOLOGIES FOR EXPRESS LANE ENFORCEMENT

The southbound I-680 Express Lanes were implemented using transponder and enforcement technology appropriate for the limited ingress/egress operation. Other types of Intelligent Transportation Systems (ITS) technologies are being developed and implemented for different toll lane operational and enforcement strategies.

California Express Lane Technology

There are several Express Lanes in operation in southern California.

The toll lanes on State Route 110 run from the SR 91 Freeway to Adams Boulevard in downtown Los Angeles, with recent implementation of 14 additional miles of Express Lanes on the I-10 Freeway between the I-605 Freeway and Alameda Street. Transponders used on these lanes are equipped with switches to identify whether the vehicle has multiple occupants (Figure 44). The California Highway Patrol has the authority to issue tickets of $401-plus for solo drivers who evade fares by placing their transponders on a carpool setting, and penalties of at least $154 for those driving in the lanes without the device. To help CHP officers know who to pull over, there are sensors along the 11-mile route, along with beacons to signal to officers whether cars have transponders and whether they're set to correctly reflect how many people are in the vehicle (Figure 45).[5]

Figure 44: Transponder with Carpool Switch Used in Southern California

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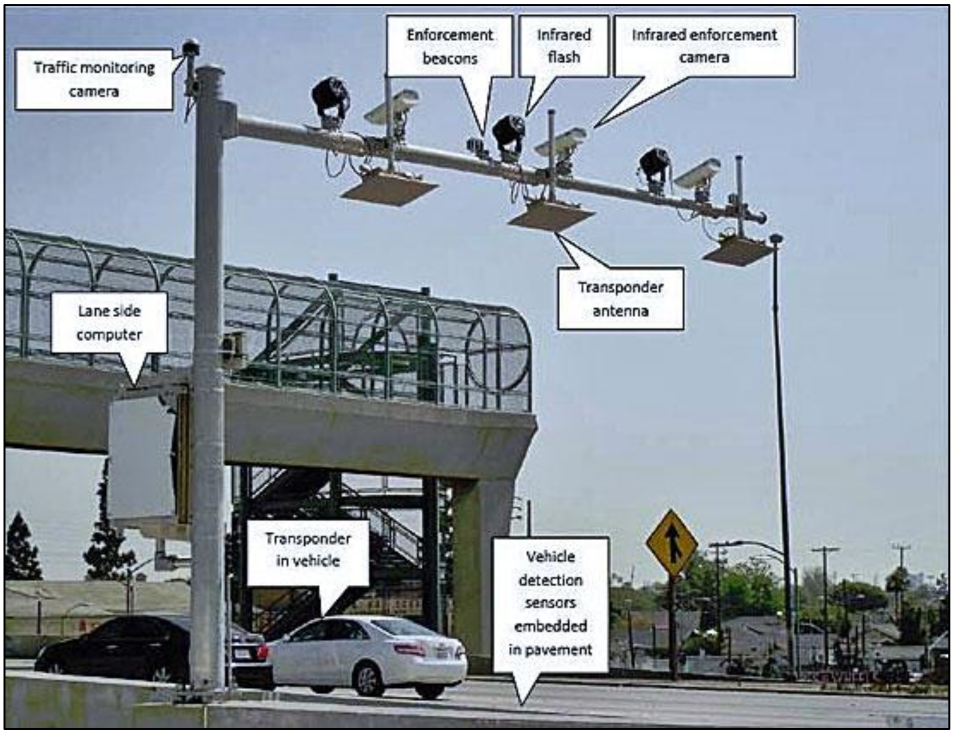
[5] Zev Yaroslavsky, LA County Supervisor, Third District website, 11/27/12.

Figure 45: Detector System on SR 110 Express Lane



The San Diego I-15 Express Lane system has run tests to determine if automated detection of the number of vehicle occupants could replace the manual visual detection that is used at present. The tests determined that the current state of the automated occupancy detection system is not reliable enough for everyday use.

Atlanta I-85 Express Lane Technology

Several innovative practices from the I-85 Express Lanes project in Atlanta, Georgia are summarized in this section.

The I-85 Express Lanes in Atlanta, Georgia span 16 miles from Chamblee Tucker Road, south of I-285, to Old Peachtree Road in Gwinnett and DeKalb counties. Due to the limited right of way in the high density urban area in Atlanta, double white line pavement markings are used to separate the Express Lane from the adjacent general purpose lanes—similar to the southbound I-680 Express Lane.

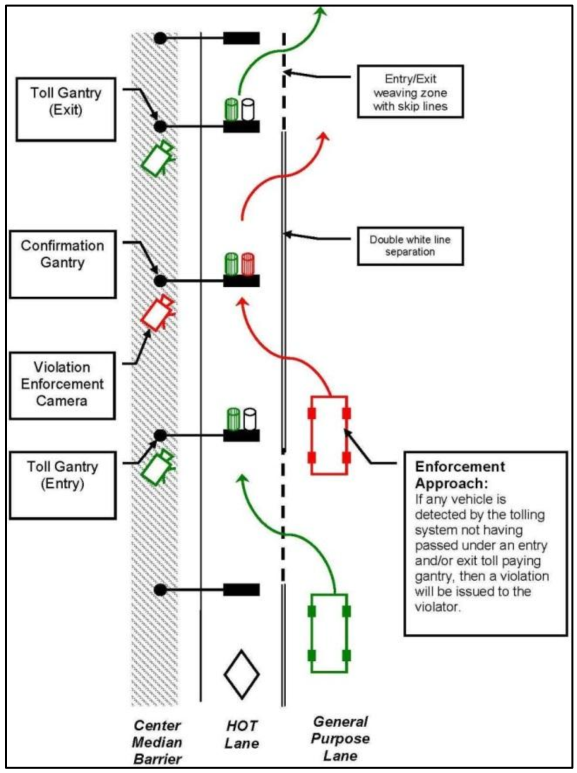
In October 2011, the I-85 Express Lanes started to operate 24 hours a day. All vehicles are required to have valid transponders in order to use the Express Lanes. HOV vehicles with three or more occupants are free to use the I-85 Express Lanes but these vehicles still require valid transponders in order to use the Express Lanes.

Technologies that can be considered for Express Lane enforcement are presented in two categories: double white line crossing enforcement and vehicle occupancy enforcement. Specific ITS technologies include Gantry Controlled Access (GCA), Mobile Enforcement Readers (MER), and Automated License Plate Readers (ALPR).

Double White Line Enforcement

Similar to the Southbound I-680 Express Lane, the I-85 Express Lanes in Atlanta specify designated entrance (ingress) and exit (egress) points along the corridor. Other than these designated ingress and egress points, the Express Lanes are separated from the adjacent general purpose lanes by double solid white lines. Due to the lack of shoulder width on the left side of the Express Lane and high operating costs of manual enforcement, the I-85 Express Lanes use patterned Gantry Controlled Access (GCA) to detect illegal crossings of the double white line (Figure 46).

Figure 46: Schematics of I-85 Gantry Controlled Access



Source: http://www.tollroadsnews.com/sites/default/files/TRB20070801.pdf

The GCA is designed to eliminate the need for any physical barrier. The GCA's "invisible barrier" is used for toll entry/exit gantries, confirmation gantries, and violation enforcement with still photo cameras along the Express Lane corridor. Wherever any vehicle is detected by the tolling system as not having entered the Express Lane by properly passing under an entry toll gantry, the gantry system records the identity of the violating vehicle. Vehicle identification is achieved with either a violation enforcement camera taking a photograph of the vehicle's license plate and/or by reading the vehicle's transponder. When the vehicle is recorded as having evaded the toll by improperly crossing the double white lines, a toll citation is issued via mail.

Currently, the tag readers are about 1/3 mile apart on the I-85 Express Lane. The I-85 Express Lane research team at the Center for Transportation Operations and Safety at the Georgia Institute of

Technology suggested that for a non-barrier separated Express Lane facility, the tag readers should ideally be placed every quarter mile[6].

The advantages of closely-spaced GCA are considered to be:

- Toll payment and entry/exit point violators receive violation notice by mail;
- 24/7 automated enforcement, allowing law enforcement officers to focus on other violations;
- With mailed citations, there is less need to stop violators, disrupt traffic flow, or risk officer safety;
- Less right-of-way is required, reducing design, engineering and construction costs, traffic disruption, and environmental impact; and
- The system provides greater flexibility to create and expand HOT networks.

Vehicle Occupancy Enforcement

The I-85 Express Lanes in Atlanta require three or more occupants for vehicles to not be required to pay the toll. Based on Georgia's experience, vehicle occupancy enforcement is still better conducted by humans, requiring additional police presence. Even though the human enforcement is valuable, technology innovations have demonstrated some abilities to help automate enforcement tasks for police officers.

While the I-85 Express Lanes were being developed, the agency proposed that all carpoolers with three or more occupants would have to self-identify as carpoolers. Frequent carpoolers were to be provided transponders with default account settings identifying their vehicles as carpoolers. Frequent non-carpooling users would be able to identify themselves as carpoolers by just calling or logging on to the service website. Two automated technologies help police officers identify which vehicles need to be checked for their occupancy level.

The first technology is Mobile Enforcement Readers (MER), which reads a vehicle's transponder and checks with the tolling system to verify the carpooling status of the vehicle automatically. The MER provides active feedback to the police officers by audible noise or with a visual cue for the officer to check the vehicle's occupancy level.

In addition to the MER, another enforcement technology is the mobile Automated License Plate Reader (ALPR), which assists police officers as they check for vehicles using the Express Lanes without transponders (Figure 47). The ALPR uses cameras mounted on the patrol vehicles to automatically identify license plate numbers and compare them with the tolling database to check carpooling status. It notifies the police officers as to which vehicles are registered carpoolers that need to have their occupancy level checked. Mobile ALPR can check up to several thousand plates during a normal patrol shift compared to a limit of several hundred for manually checked license plates.

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[6] http://transportation.ce.gatech.edu/sites/default/files/files/gantry-controlled_access-_a_combined_tolling_and_enforcement_system.pdf

Figure 47: Automatic License Plate Readers (ALPR) in Patrol Vehicles

Source: http://www.tollroadsnews.com/sites/default/files/TRB20070801.pdf