ATTACHMENT A

Impacts of 5% Reduction in ExpressLanes Traffic Volume

PURPOSE

To gain insight into the effect of Clean Air Vehicles (CAVs) on the performance of ExpressLanes, this analysis examines the operational impacts of reducing traffic volumes in the Metro ExpressLanes by 5% during the peak periods. This is based on data from November 2017 indicating that CAVs constitute 4-6% of traffic in the ExpressLanes during the AM Peak.

BASIC PRINCIPLE

This analysis takes advantage of the natural fluctuations in traffic from day to day to estimate the effects of reducing traffic volumes in the ExpressLanes by 5% by comparing conditions during normal or average traffic days to conditions in days where traffic volumes were 5% lower than the average. Details, assumptions, and parameters used to perform this quantitative analysis are documented in Appendix A.

FINDINGS

Based on this analysis methodology, impacts with respect to travel times and average speeds have been calculated for each of the ExpressLanes corridors during their respective peak periods. Table 1 summarizes these findings.

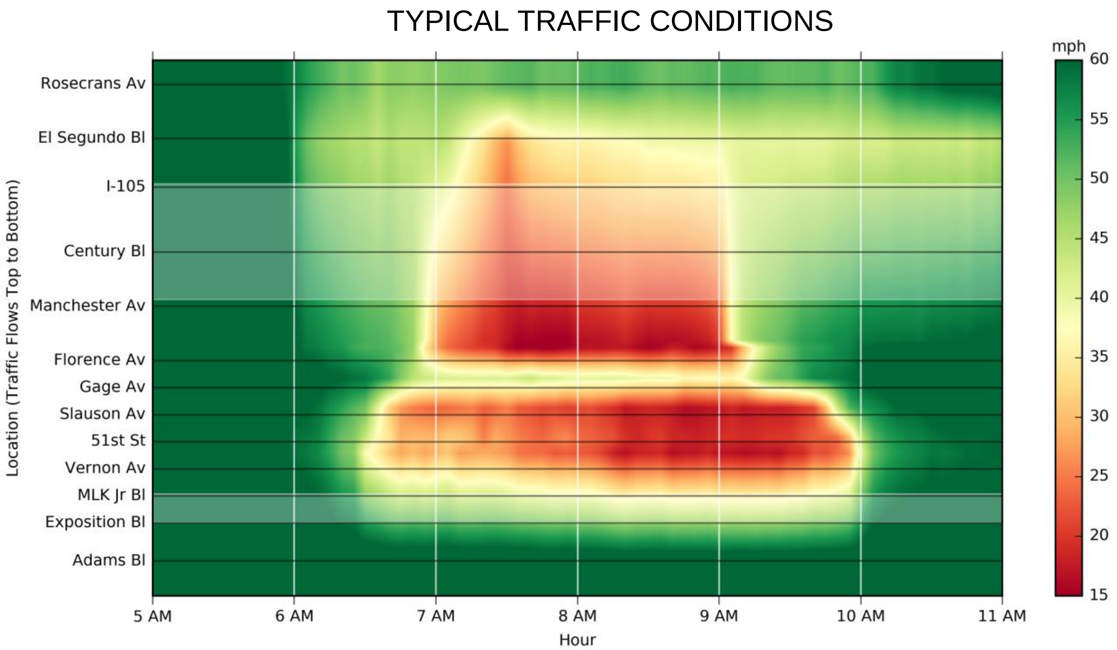
Table 1. Summary of Performance Impacts for each ExpressLanes Corridor during Peak Periods

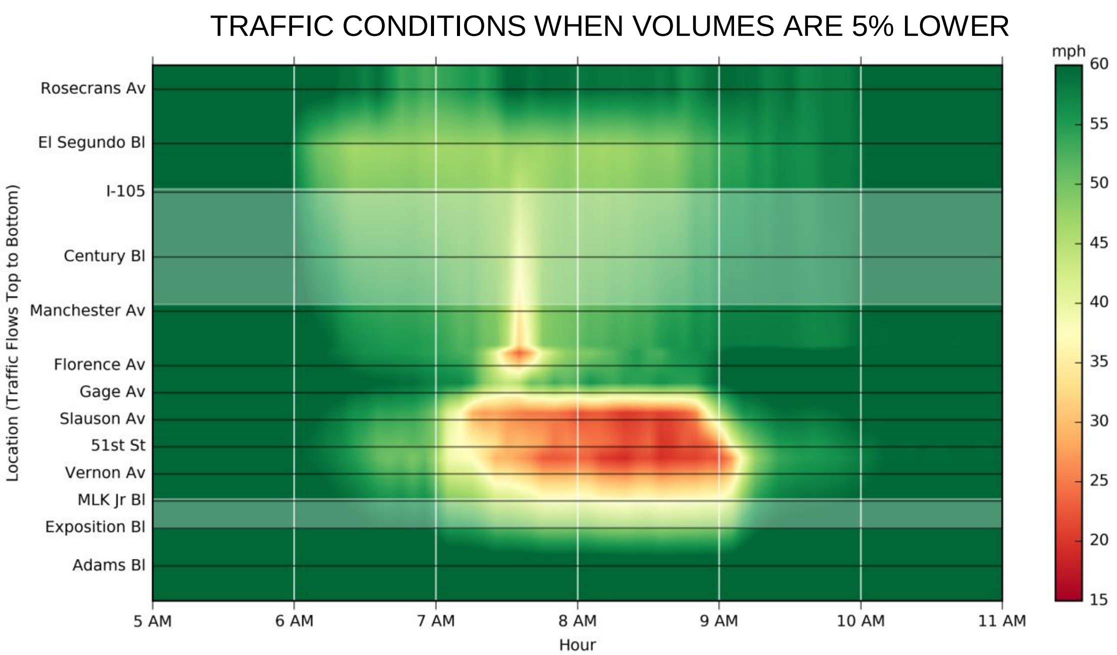
Performance Metric	I-110 North ExpressLanes	I-110 South ExpressLanes	I-10 West ExpressLanes	I-10 East ExpressLanes
End-to-End Travel Time Peak Hour Benefit	48% faster (15 minutes faster)	13% faster (2 minutes faster)	32% faster (7 minutes faster)	38% faster (10 minutes faster)
Peak Hour Speed Improvement	40% faster (13 mph faster)	3% faster (1 mph faster)	24% faster (11 mph faster)	18% faster (8 mph faster)

To illustrate the speed improvements on a more detailed level, Figure 1 provides a side-by-side comparison of speeds for an entire corridor (again, I-110 North during the AM Peak) under typical traffic conditions, and as calculated for a 5% reduction in traffic volumes. Similar figures for the other ExpressLanes corridors are provided in Appendix B.

To illustrate the travel time improvements on a more detailed level, Figure 2 compares the median travel times for one corridor (I-110 North during the AM Peak) under typical traffic conditions, and the calculated new median travel times based on a 5% reduction in traffic volumes. Similar figures for the other ExpressLanes corridors are provided in Appendix C.

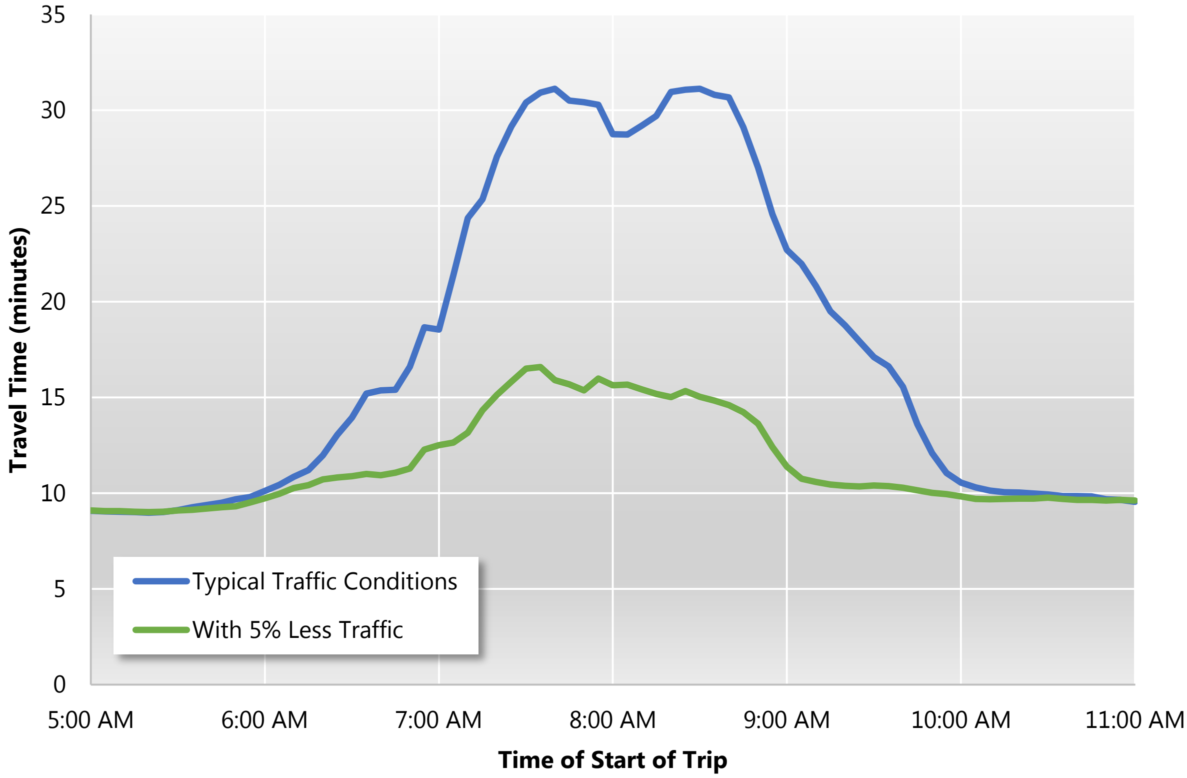
Figure 1. Comparison of speeds on I-110 North ExpressLanes during the AM Peak





Note: Lighter bands in the figures indicate areas where detector coverage was poor and where results may be less reliable.

Figure 2. Comparison of End-to-End travel times on I-110 North ExpressLanes during the AM Peak



INTERPRETATION OF RESULTS

As Table 1 and the preceding figures reveal, a relatively minor reduction in traffic volumes can have a significant and substantial impact on performance when a facility is operating at capacity. This includes not only reductions in travel times and improvements in speeds, but also reductions in the duration of congestion and the extent of slow-moving traffic. This is readily appreciated in Figure 1, by noting that the yellow and red areas are more compressed horizontally (meaning that the peak period does not last as long) and vertically (meaning that fewer sections of the freeway are congested during the peak period) in the case of a 5% reduction in traffic volumes.

It is important to note that these results should not be interpreted as a direct prediction of impacts for charging CAVs a discounted toll, but rather as a source of insight into the difference that a change in traffic volume of 5% can have on facility performance. In practice, actually achieving a reduction in volumes of 5% is complicated by the fact that as some trips are removed, other trips quickly take their place as drivers shift from other routes, other times of day, and other travel modes to take advantage of the improved facility performance afforded by the original 5% volume reduction. This “induced demand” effect is the reason that dynamic roadway pricing is so critical to the ongoing achievement of performance targets, as congestion pricing controls demand and keeps it from exceeding target levels. This demand control ensures that the ExpressLanes continue to perform at their optimal level without being mired in congestion. Conversely, when ExpressLanes price signals are undermined by the provision of toll exemptions or moderate-to-substantial toll discounts for a non-trivial fraction of vehicles, the prices become ineffective at controlling demand as intended, and traffic conditions more readily degrade in the ExpressLanes, resulting in congestion.

Care should be used when interpreting the results for corridors with significant congestion at the downstream exit from the ExpressLanes, such as on I-10 East, because of the probability of correlation between VMT in the ExpressLanes and VMT in the freeway general-purpose (GP) lanes. More precisely, the dates used for the “reduced traffic volume” scenario for ExpressLanes may correspond to reduced-VMT dates for the freeway mainline as well, which could account for a non-trivial proportion of the reduced congestion at the point where the ExpressLanes end and the ExpressLanes traffic is forced back into the freeway mainline. This is not an issue at any ExpressLanes access points where traffic is not forced to queue up to exit.

Appendix A: Detailed Analysis Methodology

This appendix describes the source data used, the methods applied to perform the analysis, and the parameters associated with the methodology. Assumptions are declared in these sections as they are made.

SOURCE DATA

Disaggregate Data

Data from inductive loops are used to measure flow, speed, and occupancy at fixed locations along Caltrans roadway facilities by lane. These data are publicly available in various aggregation intervals ranging between 30 seconds and 1 day through the Caltrans Performance Measurement System (PeMS) web site. For the purposes of this analysis, 5-minute detector data for the ExpressLanes (i.e., HOT lanes) are used unless otherwise specified.

Data Filtering

When data are not properly reported for a given time interval and lane location, PeMS automatically attempts to impute the missing data using other available data from its nearest neighbors in space and time (i.e., from other measured data at other locations for the same time interval, and from other measured data at the same location for other time intervals). The level of imputation is reported with all PeMS data as a “percent observed” quality rating, where a value of 100% means that the given data was fully measured in the field and 0% means that the given data was entirely imputed. For the purposes of this analysis, data with a “percent observed” less than 70% was discarded.

Aggregated VMT Data

In addition to these high resolution 5-minute PeMS detector data, this analysis also uses aggregated hourly data for vehicle miles traveled (VMT) at each detector location. VMT is a derivative quantity based on measured flow and the distance to the next available detectors immediately upstream and immediately downstream on the facility. VMT is calculated as the product of flow and effective detector coverage zone, where the effective detector coverage zone is measured by calculating the two midpoints between the detector and either of its immediate neighbors (i.e., the nearest neighbor upstream and the nearest neighbor downstream) and taking the distance between those two midpoints.

Because this analysis relies only on VMT for its relative magnitudes and fluctuations from day to day, but not on its absolute magnitude, data imputation may be reasonably expected to have a minimal impact on overall results assuming that imputation trends by detector remain relatively consistent throughout the analysis period (i.e., a detector that is highly imputed in one month will also be highly imputed in other months, and vice versa). Experience with PeMS data has shown this to be a highly appropriate and justifiable assumption. Therefore, no filtering by “percent observed” is done for VMT data.

PARAMETERS

The following list summarizes key analysis parameters for the described methodology.

- The AM Peak applies to I-110 North and I-10 West, and spans the 5–11 AM period.
- The PM Peak applies to I-110 South and I-10 East, and spans the 2–8 PM period.
- PeMS data are used for the period between January 1 and December 31, 2017. Only weekdays are considered.

- Spatial analysis extents for each corridor are as follows, where post-miles (PMs) follow Caltrans “absolute milepost” measurement system.
- I-10: Between Alameda St (PM 15.3) and I-605 (PM 29.7)
- I-110: Between SR 91 (PM 10.6) and Adams Blvd (PM 20.5)

METHODOLOGY

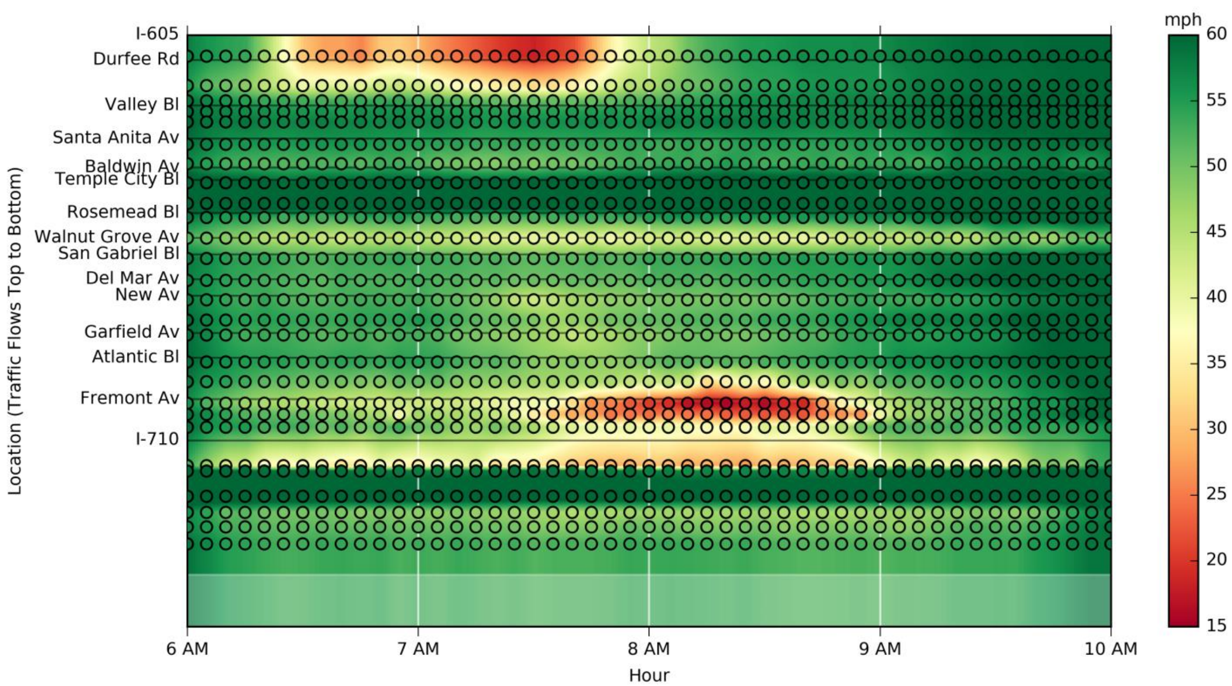
Evaluating Corridor Speed Contours

A speed contour plot shows the distribution of speeds on a corridor in time and space. In other words, its shows how speeds vary by location along the corridor by time—and in this case, by time of day. In this analysis, speed contours are prepared by linearly interpolating between detector point speed measurements. Figure 3 shows the available data points as solid-colored circles, superimposed on the resultant speed contour plot.

When multiple days of data are available, the measurements for a given location and time of day are averaged using the statistical median to characterize the typical traffic patterns. Because of the asymmetrical distribution of speed data and the frequent occurrence of outliers caused by incidents, the median is a more reasonable and justifiable measure of expected value than the arithmetic mean.

In some instances, particularly when the source data set contains few usable dates to draw upon, there may be segments of roadway where detector coverage is relatively poor and the displayed speeds may be less reliable. On the speed contour plots, these cases are defined as any portions of roadway that are more than 0.75 miles from the nearest available valid detector data, and are indicated by lighter shading on those areas as shown at the bottom of Figure 3.

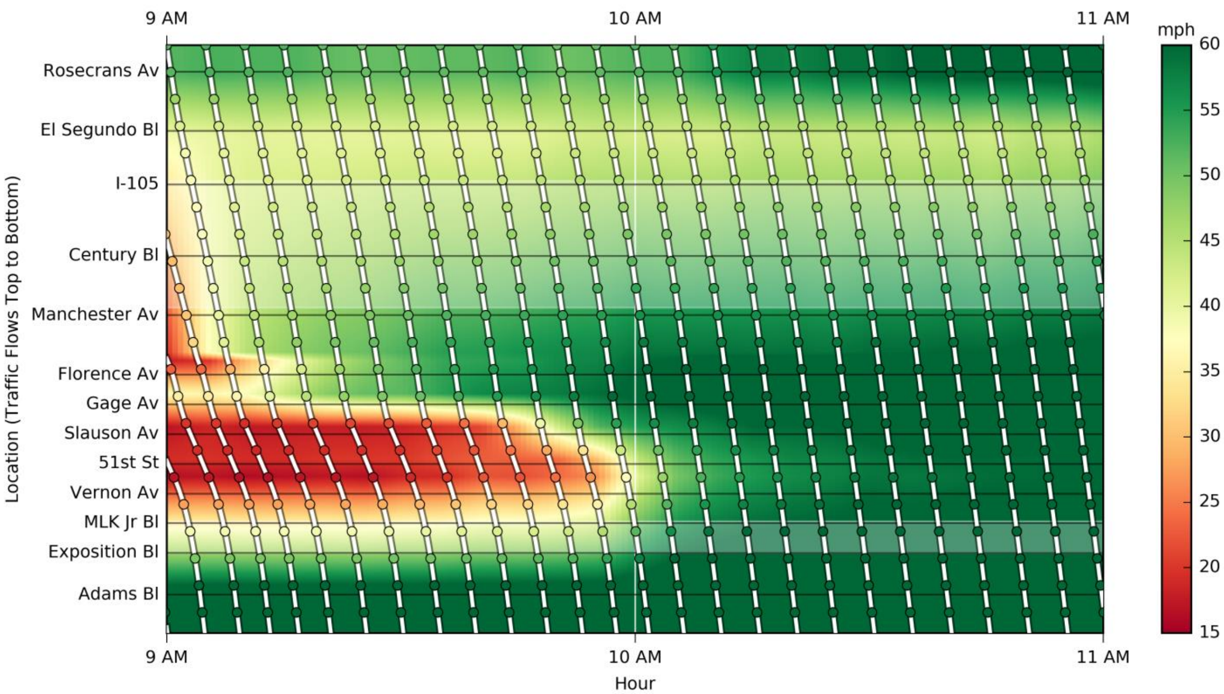
Figure 3: Speed contour plot with source data points superimposed



Measuring Corridor Travel Times

In this analysis, travel times are estimated from point measurements along a given corridor (e.g., from inductive loop data) by simulating the progress of virtual vehicles from one end of the corridor to the other. In the case of this analysis, these vehicles are dispatched from the upstream end of the corridor every 5 minutes and their progress is re-evaluated every 45 seconds or every 30 feet along the corridor—whichever occurs first. The time between successive re-evaluations is called the simulation time-step. Generally, the distance threshold will govern, and vehicle progress will be re-evaluated every 30 feet. However, if traffic speeds drop very low, the time threshold of 45 seconds will be reached first, and progress will be re-evaluated after that amount of time. This is included as a protection to ensure that time steps do not grow excessively long when speeds are particularly low. At the start of each simulation time-step, the speed of the vehicle is calculated using the exact location and timestamp of the vehicle at that moment, using linear interpolation between the nearest 5-minute detector data in time and space. The vehicle is then assumed to proceed at that speed for the duration of the simulation time-step. Figure 4 shows the progress of simulated vehicles for the I-110 North ExpressLanes using this approach.

Figure 4: Simulated vehicle progress across a corridor for a given set of speed conditions.



In Figure 4, the white lines are the simulated vehicle trajectories traversing the corridor, where the top represents the upstream start of the corridor and the bottom represents the downstream end. Time is represented on the horizontal axis, such that the slopes of the white trajectory lines correspond to vehicle speeds. Consequently, steeper trajectories indicate faster-moving vehicles, and vice versa. The colored dots along each trajectory indicate the assumed speed of each simulated vehicle at that moment, based on the underlying speed contour plot data. Note that for visualization purposes, only every 250th dot is shown on the trajectories. In other words, the actual vehicle simulations involve re-evaluating vehicle progress much more often than the figure suggests (250 times more often, to be precise).

Measuring Corridor Traffic Volume
While flows are a direct and reasonable measure of traffic volume at a point location, total VMT is a more suitable measure of flows across an entire corridor as the effective detector coverage zone gives proper weights to each detector's measured flow. Using VMT rather than aggregate detector flows on a corridor also avoids issues associated with counting the same vehicles at multiple detector locations along the roadway, since the unit of measure is vehicle-miles for VMT (which can be summed across locations) rather than vehicle count (which cannot be summed across locations without high risk of counting many vehicles more than once). Therefore, in this analysis, total corridor VMT will be used as a measure of total corridor traffic volume. As this analysis considers only the HOT lanes, only the VMT from the HOT lanes will be aggregated.

Identifying Days with Typical Traffic Volumes
To identify dates with typical traffic volumes, VMT data are aggregated for each corridor across all hours of the respective peak period for that corridor (see the Parameters section) to yield a measure of total VMT for a given peak period and date. The distribution of total VMT throughout the year is then analyzed and the median or 50th percentile value identified. All days with VMT reasonably close to this median value then constitute the set of days with typical traffic volumes, where "reasonably close" is defined as the range between the 40th and 60th percentile total VMT values.

Identifying Days with Reduced Traffic Volumes
Once the 40th and 60th percentile total VMT value are established, these two values are reduced by 5% to identify a new VMT range to define days where traffic volumes were 5% less than typical or average (median) values. All days with VMT within this modified range constitute the set of days with traffic volumes reduced by 5%.

Addressing a Complication of VMT and Congestion
The intent of this analysis is to focus on the effect of taking 5% of vehicles off the road, rather than by reducing capacity so that 5% fewer vehicles can use the road. Unfortunately, either scenario can have the overall effect of reducing VMT by 5%, depending on the particular nature of the roadway congestion (i.e., the specific distribution of speeds in time and space). For example, compared to typical commuter traffic conditions, VMT can be expected to decrease on holidays (i.e., less congestion and higher speeds due to taking some vehicles off the road) and also on days with severe congestion that substantially limits the flow of vehicles on the roadway during the analysis period (e.g., a major incident near the downstream end of the corridor).

Fortunately, measurements of traffic density can be used to focus only on the days where VMT decreased due to a reduction in the number of vehicles on the road at any given time rather than the days when VMT decreased due to severe congestion and reduced capacity, as density decreases in the former situation and increases in the latter case. This is intuitive (but can be shown theoretically), as vehicles are packed more closely together on the road when congestion worsens, whereas they have more space between them when traffic gets lighter.

While density cannot be measured directly by inductive loops, occupancy data can be used in its place assuming traffic is roughly stationary (i.e., does not change in characteristics rapidly in time or space) in each detector's effective coverage zone for each 5-minute period. When traffic is stationary, occupancy and density are directly proportional to each other, assuming that the distribution of vehicle lengths on the road does not change over time.

Therefore, for this analysis, average peak period detector occupancy is calculated for each corridor and date using the 5-minute detector data, weighted by the length of each detector's effective coverage zone. The median detector occupancy value is calculated for the “typical traffic volumes” days and the “reduced traffic volume” days combined. Any days in the “typical traffic volumes” set that are lower than the median detector occupancy are filtered out, and any days in the “reduced traffic volume” set that are higher than the median are filtered out, to ensure the overall traffic density decreases when going from the “typical traffic volume” set to the “reduced traffic volume” set as desired.

Characterizing Traffic Patterns for Days with Typical and Reduced Volumes

Travel time data are reported as median travel times by time of day, where the median value is calculated across all days in the data set. A median value is used in place of the arithmetic mean due to the asymmetrical nature of travel time distributions and a tendency for extreme outliers to exist more often on the higher end of the distribution. Using the median travel times by time of day, the peak hour can be identified to within 5 minutes, based on the one-hour interval with the highest total travel times in it (recall that travel times are evaluated every 5 minutes). The difference between the total travel times for this peak hour in the “typical traffic volume” and “reduced traffic volume” sets is then calculated and reported as both a percentage and an absolute value, where the absolute value is divided by the total number of travel time data points included in the peak hour analysis (i.e., 12 points) to represent an expected time savings for a single given trip.

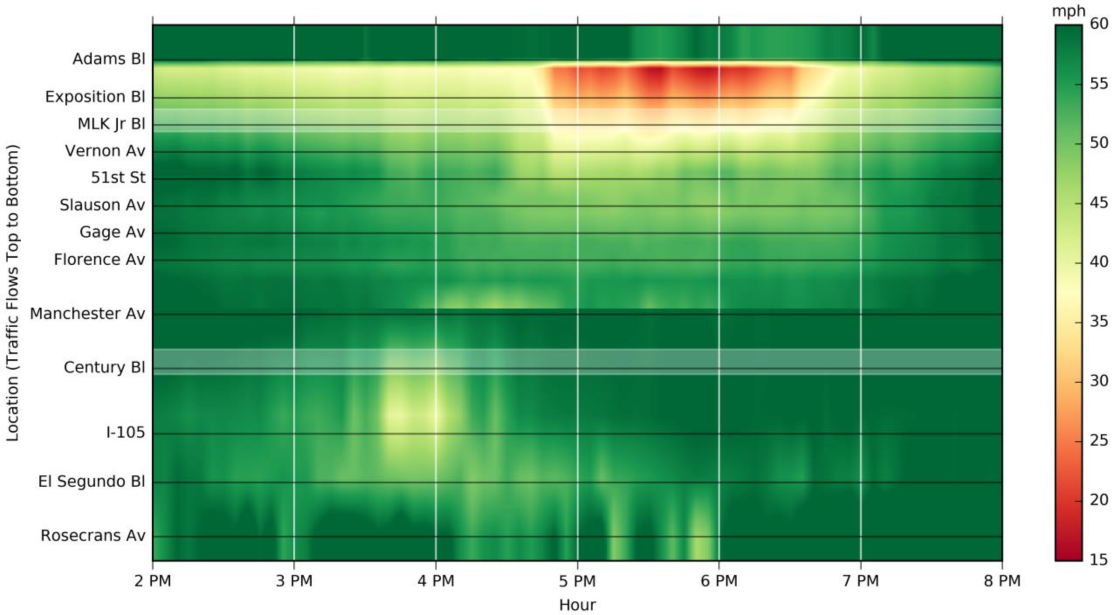
Using the peak hour identified from the travel time data, the peak hour average speed for the corridor can also be calculated by taking the median speed data for the corridor and computing the arithmetic mean value across all detectors for the peak hour. In the latter case, the arithmetic mean is appropriate given that the median has already been used in an earlier calculation step as a form of outlier filtering that could have otherwise skewed the results, and that taking a median of a median set can generate misleading results due to the definition of the median. Furthermore, when characterizing speeds across two dimensions (time and space), it can be an asset rather than a liability to use a statistic (i.e., the mean) that gives equal consideration, weight, and influence to each source data point regardless of its value. Finally, because the ultimate quantity of interest is a difference between two datasets (i.e., the “typical traffic volume” and “reduced traffic volume” sets), issues of detector bias that can otherwise create issues with using the arithmetic mean instead of the median are less of a concern, as the bias would be present in both datasets being compared.

Once average speeds for the peak periods are calculated for both the “typical traffic volume” and “reduced traffic volume” datasets, the difference between the two is calculated and reported as both a percentage and an absolute value.

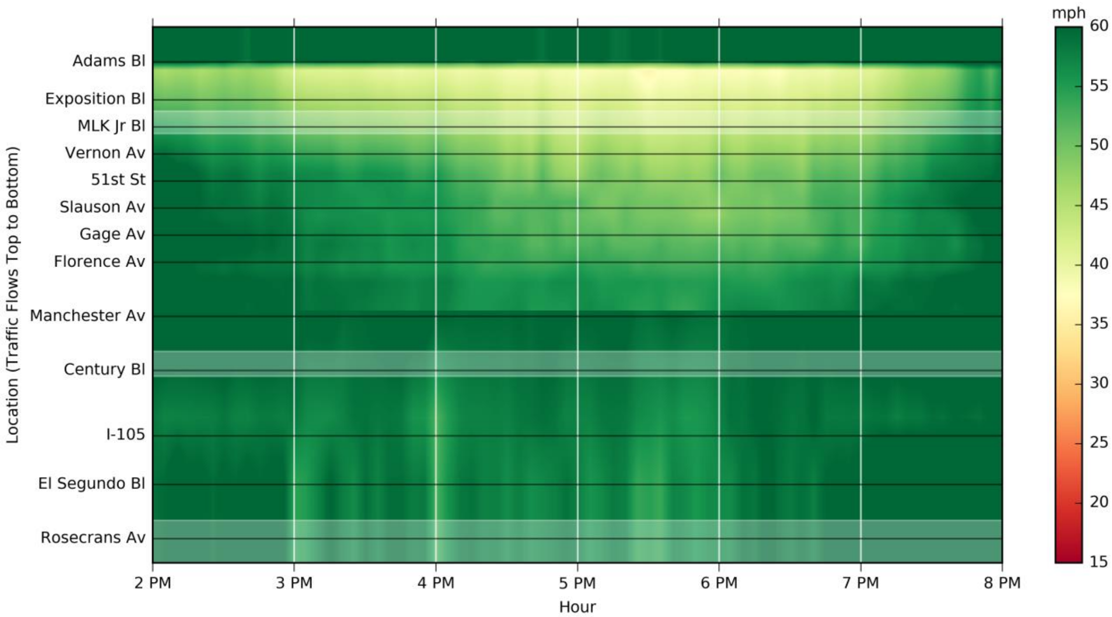
Appendix B: Speed Data for other ExpressLanes corridors
Results for I-110 North are provided in the main body of the technical memo.

Figure 5. Comparison of speeds on I-110 South ExpressLanes during the PM Peak

TYPICAL TRAFFIC CONDITIONS



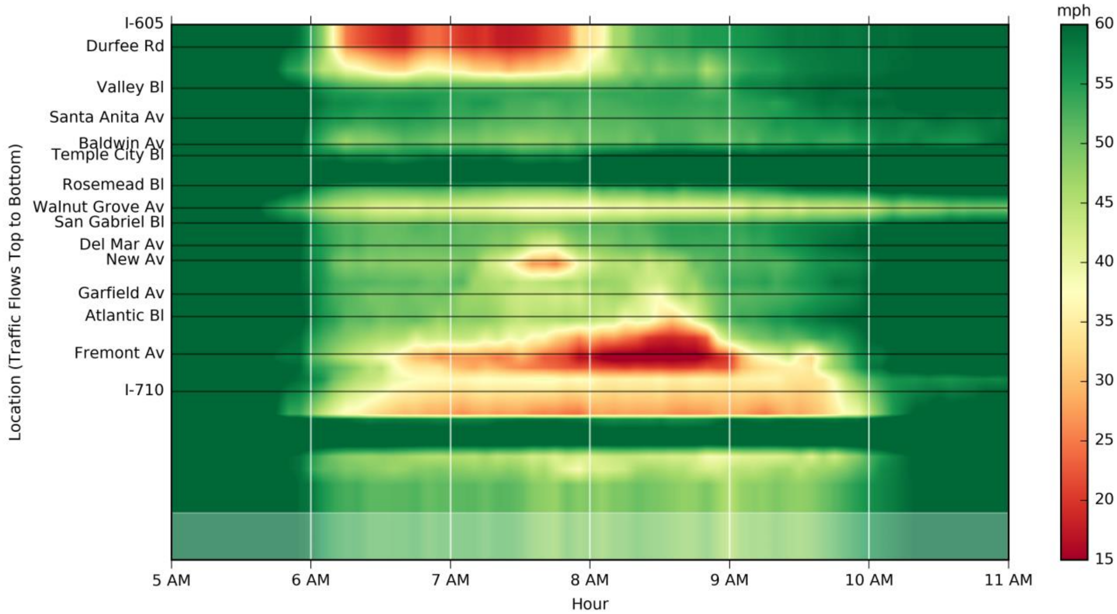
TRAFFIC CONDITIONS WHEN VOLUMES ARE 5% LOWER



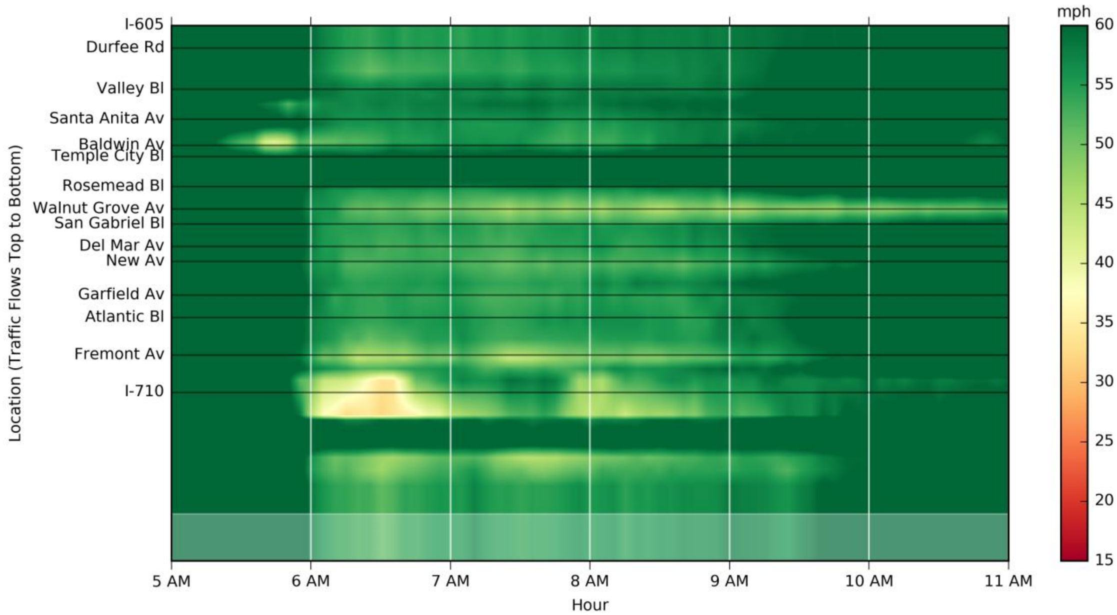
Note: Lighter bands in the figures indicate areas where detector coverage was poor and where results may be less reliable.

Figure 6. Comparison of speeds on I-10 West ExpressLanes during the AM Peak

TYPICAL TRAFFIC CONDITIONS



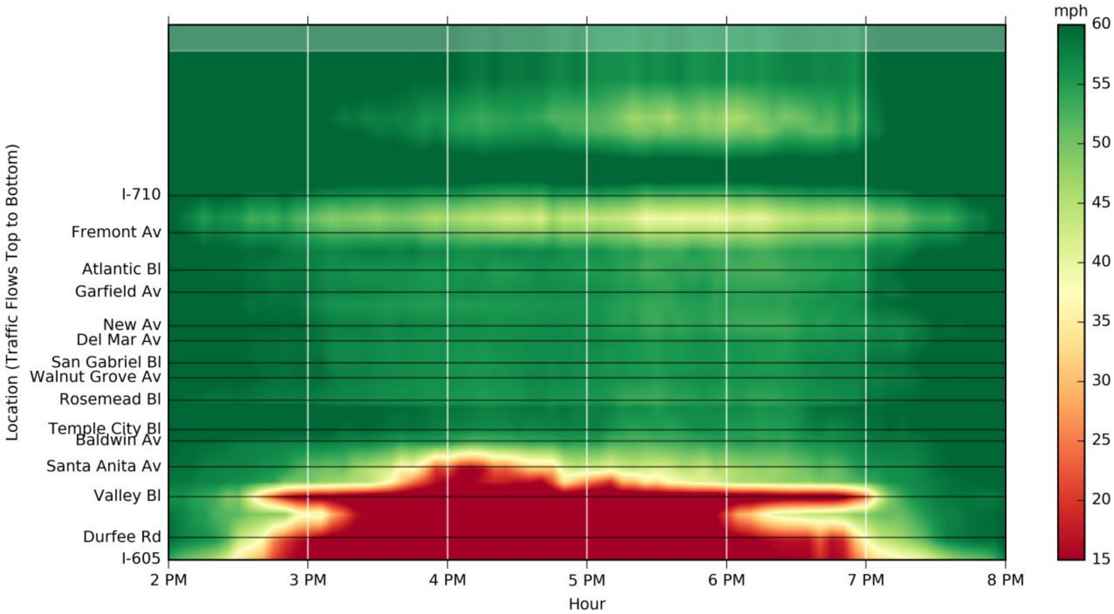
TRAFFIC CONDITIONS WHEN VOLUMES ARE 5% LOWER



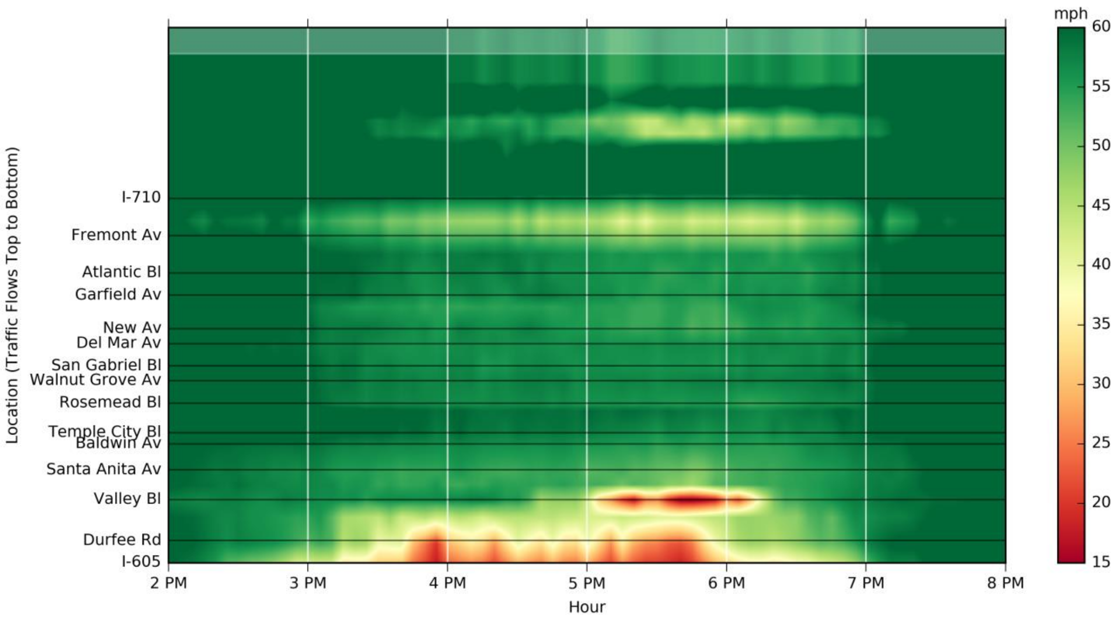
Note: Lighter bands in the figures indicate areas where detector coverage was poor and where results may be less reliable.

Figure 7. Comparison of speeds on I-10 East ExpressLanes during the PM Peak

TYPICAL TRAFFIC CONDITIONS



TRAFFIC CONDITIONS WHEN VOLUMES ARE 5% LOWER



Note: Lighter bands in the figures indicate areas where detector coverage was poor and where results may be less reliable.

Appendix C: Travel Times for other ExpressLanes Corridors
Results for I-110 North are provided in the main body of the technical memo.

Figure 8. Comparison of End-to-End travel times on I-10 West ExpressLanes during the AM Peak

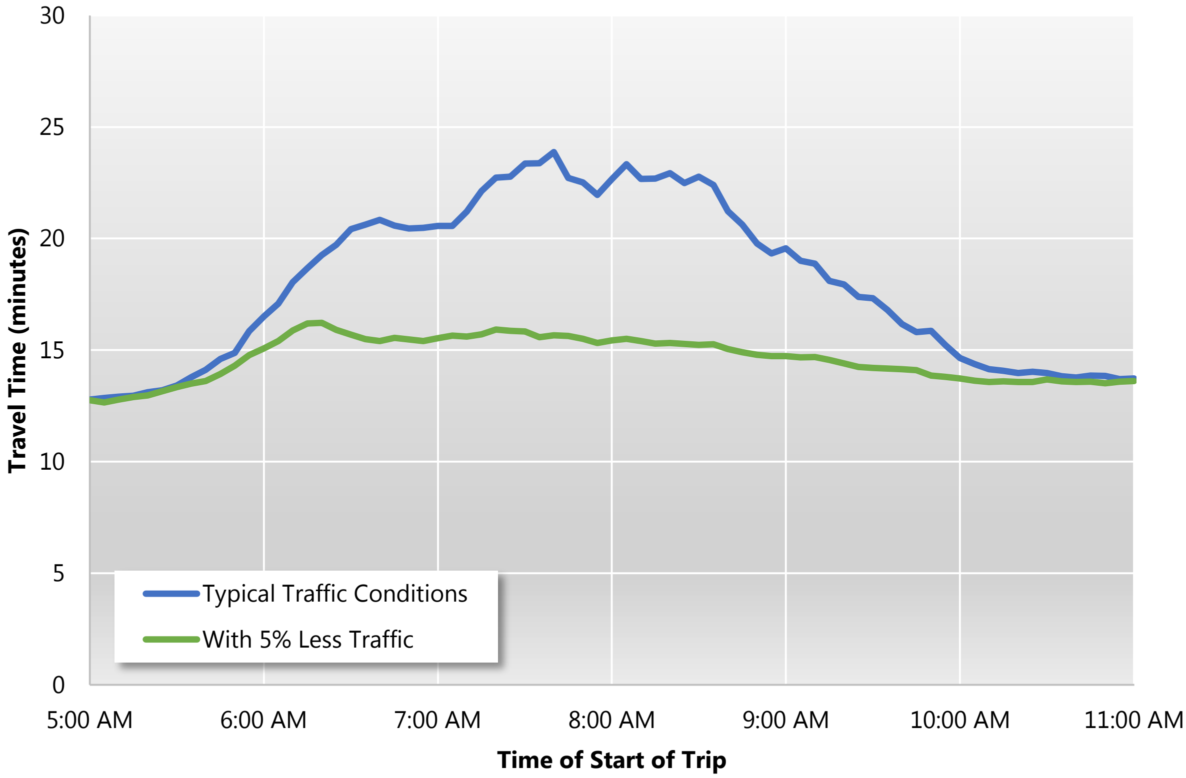


Figure 9. Comparison of End-to-End travel times on I-10 East ExpressLanes during the PM Peak

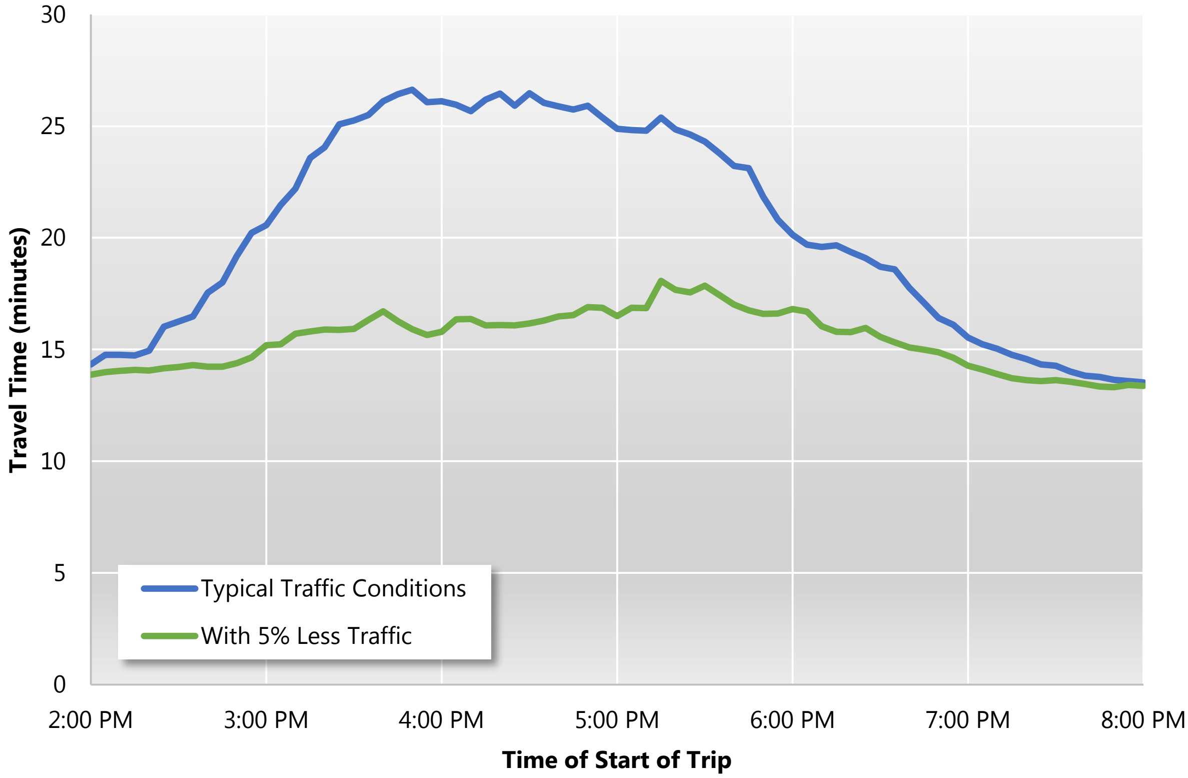


Figure 10. Comparison of End-to-End travel times on I-110 South ExpressLanes during the PM Peak