Los Angeles County
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Los Angeles, CA

Board Report

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AD HOC CONGESTION, HIGHWAY AND ROADS COMMITTEE
APRIL 11, 2018

SUBJECT: EXPRESSLANES CLEAN AIR VEHICLE POLICY

ACTION: APPROVE RECOMMENDATION

RECOMMENDATION

ADOPT the Clean Air Vehicle toll discount policy.

ISSUE

Current ExpressLanes policy allows designated Clean Air Vehicles (CAVs) with valid DMV decals to access the Metro ExpressLanes for free at all times. However, as CAV penetration rates have risen, the ability to effectively manage ExpressLanes demand and to continue to meet performance targets regarding speed, reliability, and value to ExpressLanes customers has suffered because CAV users are artificially segregated from the population of paying customers and cannot be controlled using price signals.

At the time of the opening of the ExpressLanes, the number of CAV decals issued statewide was 30,000. Since then, that number has increased almost 1000% to 302,453 as of January 1, 2018, with an average annual increase of approximately 54,000 decals per year.

Concurrently, over the past two years, the penetration rate of Clean Air Vehicles in the most congested segment of the ExpressLanes has doubled. Measurements on I-110 North ExpressLanes in the vicinity of Slauson Ave from the first half of 2016 during the weekday AM Peak showed that CAVs constituted 3% of all ExpressLanes traffic. Corresponding measurements from the second half of 2017 revealed that this penetration rate had jumped to 6%.

For insight into the effect of CAVs on the current performance of ExpressLanes, a 6% change in peak period volumes corresponds to a travel time savings of 15 minutes and a speed improvement of 13 mph on I-110 North ExpressLanes. Additional details are shown in Attachment A.

It should be noted that the rise in CAV penetration rates in the ExpressLanes is only one of several variables correlated with the decline in speeds. Other contributing factors may include increases in occupancy switch setting violation rates, overall growth in traffic volumes in the ExpressLanes, and increased occurrence of illegal ExpressLanes ingress and egress to circumvent toll charges.

DISCUSSION

Background

Congestion Pricing is widely recognized as an effective method to practically mitigate congestion in real time. When traffic is uncongested, flow and density increase proportionally, and all vehicles get to travel at full speed. When demand exceeds the maximum capacity of a road, conditions shift from being uncongested to being congested-queues form, delays rise, and speeds drop. Once demand exceeds capacity and traffic shifts from an uncongested state to a congested state, additional flow-related inefficiencies often occur (which often reduce roadway capacity even more, thereby further exacerbating the congestion), and it can take a substantial amount of time for the facility performance to fully recover. This underscores the importance of keeping traffic demand from rising above roadway capacity to ensure travelers can still reach their destinations expeditiously.

An increase in CAVs on the ExpressLanes has been a contributing factor in the growth of ExpressLanes traffic volumes placing additional stress on the ExpressLanes system. CAVs are currently allowed to travel toll-free, effectively removing the price of the trip from their decision-making and reducing the ability to effectively manage ExpressLanes demand. The impacts of this situation are threefold:

- increased congestion severity in the ExpressLanes (i.e., slower speeds)
- longer durations of congestion in the ExpressLanes
- higher toll prices for paying customers of the ExpressLanes

Currently, Metro ExpressLanes allows CAVs with valid DMV decals to access the ExpressLanes for free. Originally, CAVs were required to receive a 100% toll discount in the ExpressLanes, but Metro received an exemption from this requirement for the demonstration phase, during which time CAVs were treated no differently than other ExpressLanes traffic. After that exemption expired, Metro maintained compliance with the law by directing CAVs to declare themselves as HOV 3+ vehicles (regardless of actual occupancy) when using the ExpressLanes, thereby traveling toll free. At the time the exemption expired, the resultant impacts of CAVs on ExpressLanes operations were minimal, as the number of eligible DMV CAV decal holders was substantially lower than present levels.

In 2014, the legislature demonstrated their concurrence with charging a toll to CAVs by including language in AB 1721 (and again when the legislation was renewed in 2017 with AB 544), authorizing High-Occupancy Toll (HOT) lane operators to charge partial tolls to CAVs for more effective traffic demand management. Since then, technological advancements as well as rising CAV volumes and increasing demand for the ExpressLanes have made investment in a system that enables charging CAVs practical and reasonable.

Finally, from an equity perspective, it is justified to charge solo drivers in the ExpressLanes a toll regardless of the type of vehicle they drive. While CAVs mitigate negative air quality impacts, they do nothing to alleviate roadway congestion. The CAV discount policy also ensures that CAVs contribute toward the maintenance and management costs of the roadway-something that CAVs have largely been able to avoid to date, given that these fees are generally collected through gasoline taxes. For example, the average gas tax paid per month is $11.50 for conventional internal combustion engine vehicles, $6.57 for hybrid CAVs, and $0 for alternative fuel CAVs.

Recommended Solution

To mitigate this issue and improve the performance of the ExpressLanes for all users, staff is recommending that the CAV toll policy be revised to allow for a 15% toll discount for CAVs in place of the current 100% discount policy. This recommendation is based on the following considerations:

- Economic analysis showing that the discount rate should be as low as possible; and,
- Literature review showing that the discount rate should be at least 10% to convey meaningful value.

Supporting Research and Analysis

The above recommendation is based on a detailed investigation into the issue, its potential solutions, and the experiences of other peer agencies across the state and country. Below is a summary of the findings with respect to the handling of CAVs in comparable facilities in California and throughout the US:

- **Provisions in California and Federal law explicitly grant authority to charge CAVs for ExpressLanes use.** At the state level, this provision is found in Section (h) of AB-544, which was signed into law on October 10, 2017. The relevant portion of the law is provided below.

  > *Notwithstanding Section 21655.9, and except as provided in paragraph (2), a vehicle described in subdivision (a) that displays a valid decal, label, or identifier issued pursuant to this section shall be granted a toll-free or reduced-rate passage in high-occupancy toll lanes as described in Section 149.7 of the Streets and Highways Code unless prohibited by federal law.*

  At the federal level, the FAST Act granted public authorities the ability to offer HOV access for clean air vehicles at partially discounted toll rates through 2025. California authorization for CAV access to HOV lanes is scheduled to end at the same time as federal authorization. The following is a more detailed chronology of the California HOT-lane legislation as it applies to CAVs.
    - September 27, 2012: AB-2405 grants CAVs free access to ExpressLanes. (Metro ExpressLanes is granted an exemption to this for its first year of operation)
    - September 28, 2013: SB-286 again grants CAVs free access to ExpressLanes.
    - September 21, 2014: AB-1721 grants CAVs “toll-free or reduced-rate passage” in ExpressLanes.
    - October 10, 2017: AB-544 again grants CAVs “toll-free or reduced-rate passage” in ExpressLanes.
- **A majority of Express Lane facilities across the country are already charging clean air vehicles the same price as solo drivers.** A survey of the 37 Express Lane facilities currently in operation across the country reveals that 68% of them offer no discount for drivers of clean air vehicles. A listing of each facility and CAV discount policy (if any) is provided in Attachment B. Although none of the Express Lane facilities in California are currently offering partial discounts to CAVs, several are currently in the planning stages for such programs.
- **Most FasTrak facilities across the state are already charging clean air vehicles a partial**

or full toll price. A survey of the 18 FasTrak roadway facilities which includes bridges in California reveals that 78% of them have implemented some degree of tolling for CAVs, including 7 facilities that offer a discount of less than 50%, and an additional 5 facilities that offer no discount at all to CAVs. A listing of each facility and CAV discount policy (if any) is provided in Attachment C.

- **Unrestricted (or free) access to HOV and HOT facilities for Clean Air Vehicles is not a widely used strategy in 2018.** 80% of the states in the country are not currently offering HOV -lane access as an incentive for CAV drivers. A commonly cited reason for not offering CAV access to HOV lanes is the negative impact that such access would have on congestion in those lanes.
- **There are up to 17 other incentive programs offered in California to encourage CAV ownership and adoption in addition to the CAV decal program.** These include tax exclusions, exclusive parking access, rebates, utility discounts, registration discounts, and several financial incentive programs.
- **Metro ExpressLanes is currently subsidizing Clean Air Vehicle users $2.2 million annually when considering just the AM Peak alone,** as a result of the existing 100% discount policy. Implementing a 15% discount policy would allow Metro ExpressLanes to recapture approximately $1.9 million (85%) of this subsidy if all Clean Air Vehicles choose to continue using the lanes. If they choose to forgo their trip or utilize other travel means this would result in a reduction of traffic on the ExpressLanes.
- **According to economic theory as applied to a freeway facility, the optimal ExpressLanes discount for CAVs would be 0%.** Therefore, the ideal CAV discount rate for the ExpressLanes should be as low as possible, subject to considerations of customer perceptions and consistency. The more traffic that is allowed an exemption, or the more significant the discount offered, the greater the difficulty in achieving optimum traffic volumes and delivering maximum benefits to society with respect to mobility. This is further substantiated by data on the negative effects of congestion and inadequate demand management shown in Attachment D.
- **According to marketing research, the discount should be no less than 10% to ensure it is perceived by customers as a meaningful discount.** Research has shown that discounts should be at least 10% to successfully influence decision-making behavior and perceptions of 91%-94% of those surveyed (Ingene & Levy, Journal of Marketing, Vol 46).

ALTERNATIVES CONSIDERED

The Board may elect not to modify the current CAV policy. This alternative is not recommended, as it would result in the continued inability to effectively manage a rapidly growing segment of the population of ExpressLanes users through market pricing of increasingly scarce roadway capacity.

NEXT STEPS

Upon Board approval, staff will take the necessary steps to implement the new CAV toll discount policy and notify customers of the change with an outreach strategy and educational campaign. This will include email announcements, web site updates, welcome booklet enhancements, and close coordination with stakeholders. Staff will also provide supportive training to all customer service staff regarding CAV policy, and will update all ExpressLanes policies and procedures to reflect the new

CAV discount. Pending Board approval of this CAV discount policy, implementation is expected to be complete in the second half of 2018.

Furthermore, staff will periodically review the CAV policy to ensure it continues to serve the best interests of the ExpressLanes, and will return to the Board with any further recommendations for enhancements to the policy, as appropriate.

ATTACHMENTS

Attachment A - Impact of 5% Reduction in ExpressLanes Traffic Volume
Attachment B - CAV Treatment on Express Lanes Facilities in the United States
Attachment C - CAV Treatment on FasTrak Roadway Facilities in California
Attachment D - The Importance of Managing Demand

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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

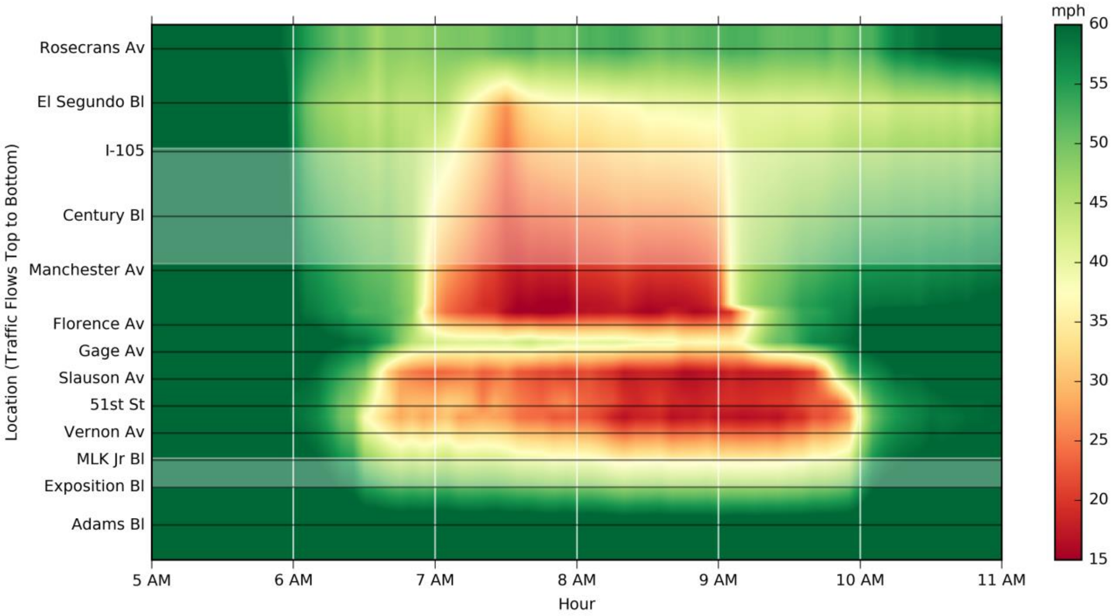
Performance Metric	I-110 North ExpressLanes	I-110 South ExpressLanes	I-10 West ExpressLanes	I-10 East ExpressLanes
End-to-End Travel Time Peak Hour Benefit	48% faster (15 minutes faster)	13% faster (2 minutes faster)	32% faster (7 minutes faster)	38% faster (10 minutes faster)
Peak Hour Speed Improvement	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.

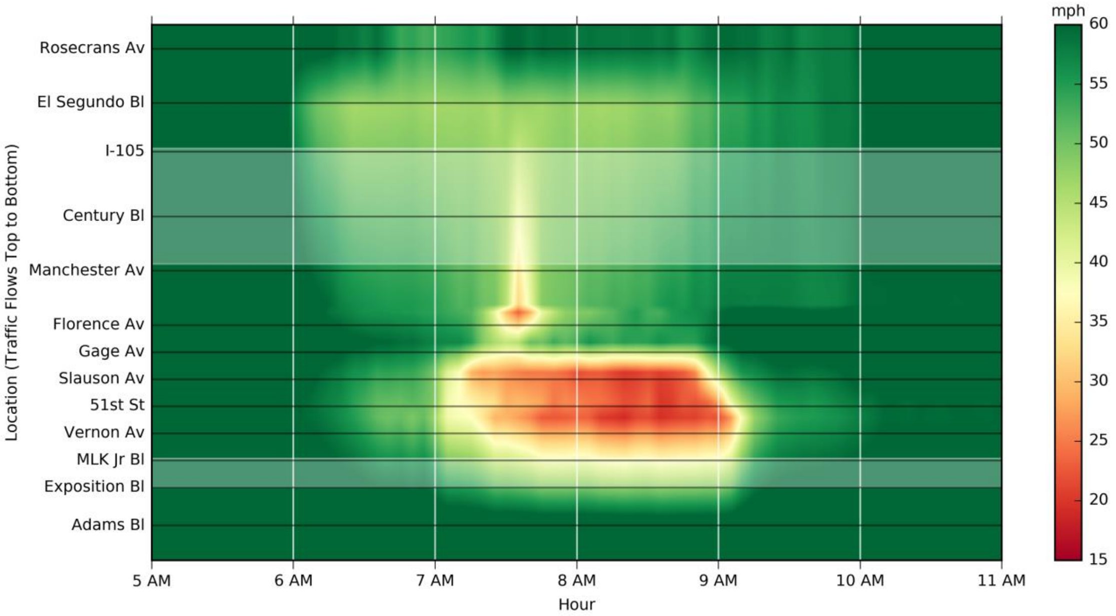
To illustrate the travel time improvements on a more detailed level, Figure 2 compares the median travel times for one corridor (I-110 North during the AM Peak) under typical traffic conditions, and the calculated new median travel times based on a 5% reduction in traffic volumes. Similar figures for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

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

TYPICAL TRAFFIC CONDITIONS

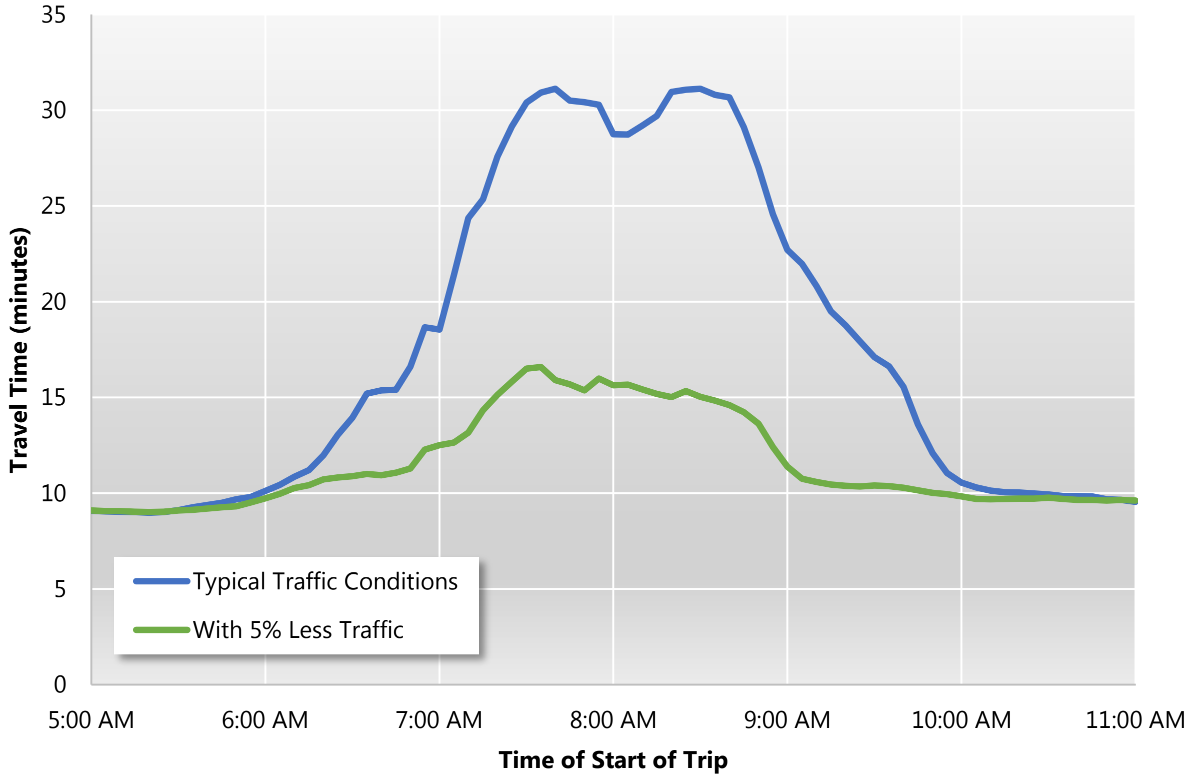


TRAFFIC CONDITIONS WHEN VOLUMES ARE 5% LOWER



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

Figure 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

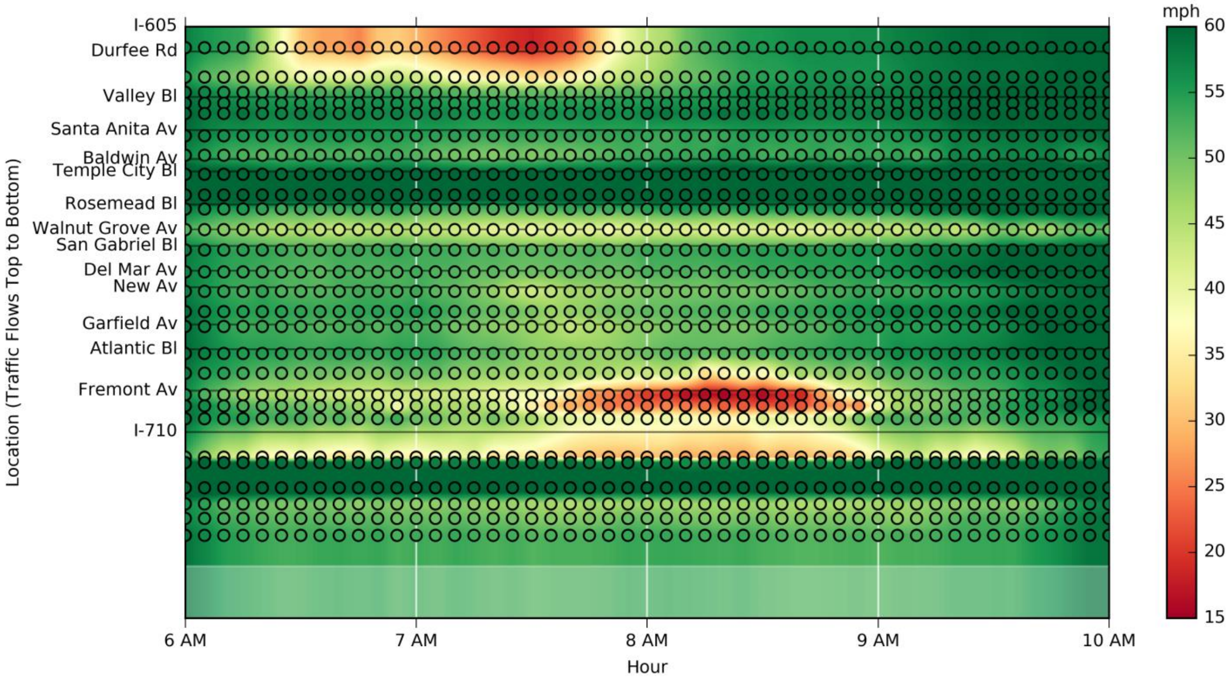
Evaluating Corridor Speed Contours

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.

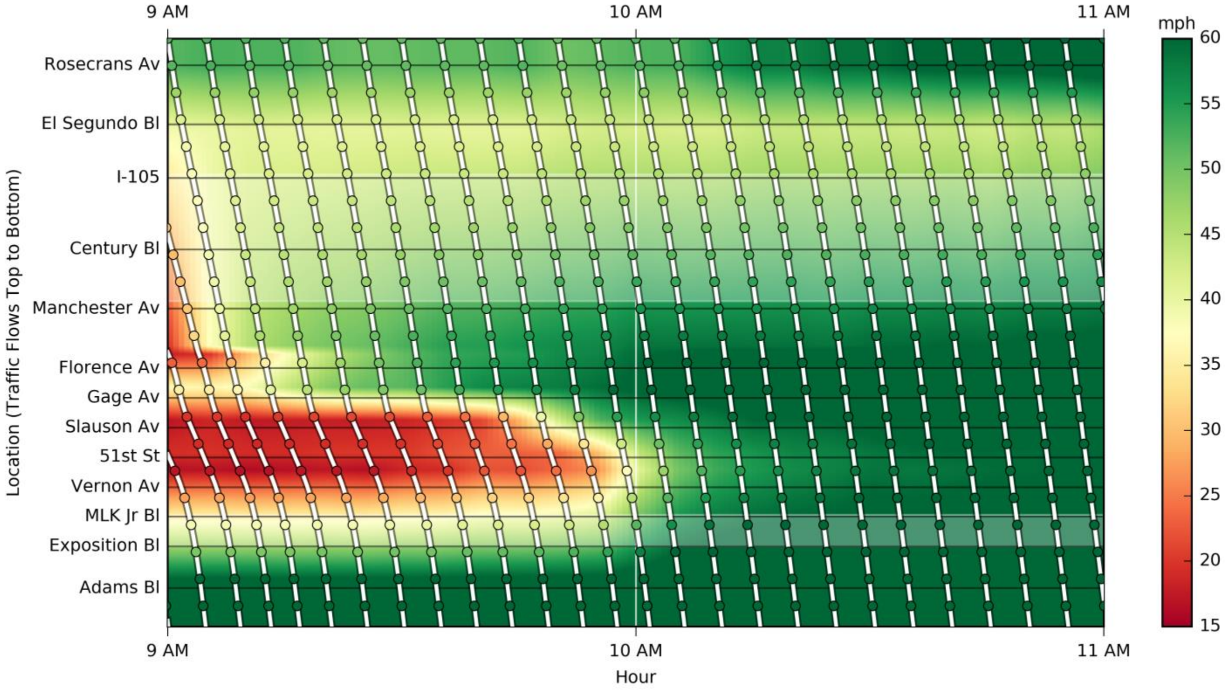
Figure 3: Speed contour plot with source data points superimposed



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.

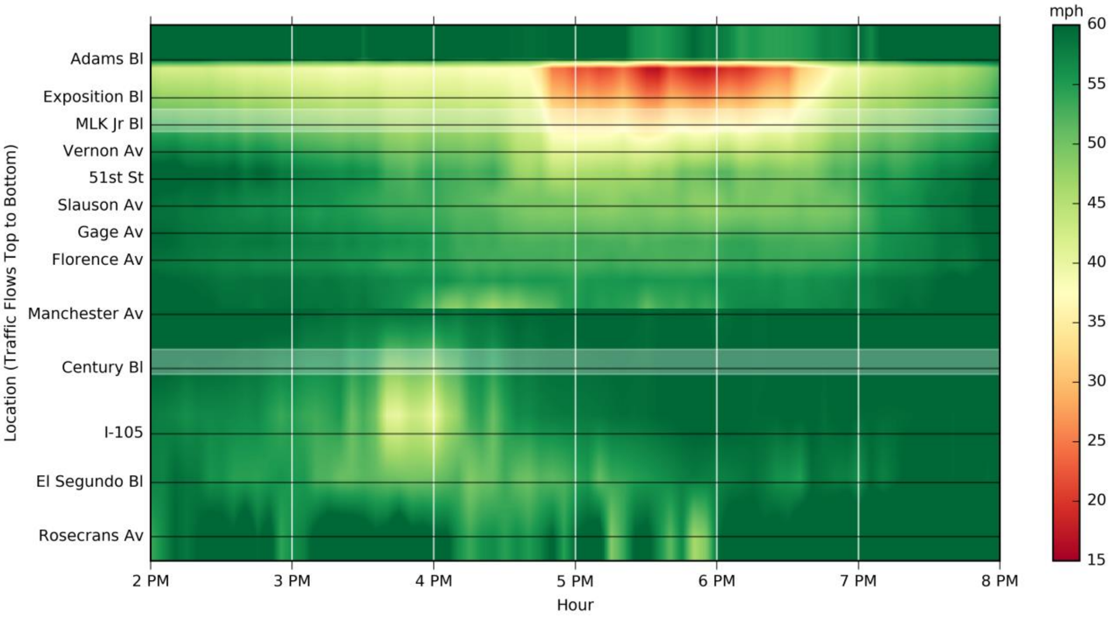
Using the peak hour identified from the travel time data, the peak hour average speed for the corridor can also be calculated by taking the median speed data for the corridor and computing the arithmetic mean value across all detectors for the peak hour. In the latter case, the arithmetic mean is appropriate 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.

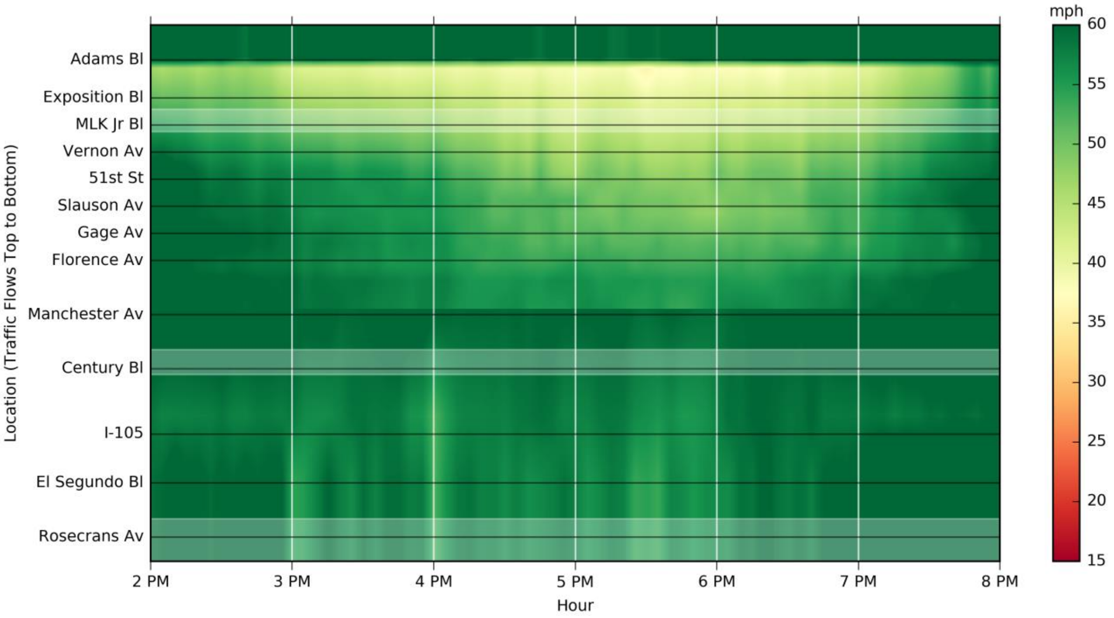
Appendix B: Speed Data for other ExpressLanes corridors
Results for I-110 North are provided in the main body of the technical memo.

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

TYPICAL TRAFFIC CONDITIONS



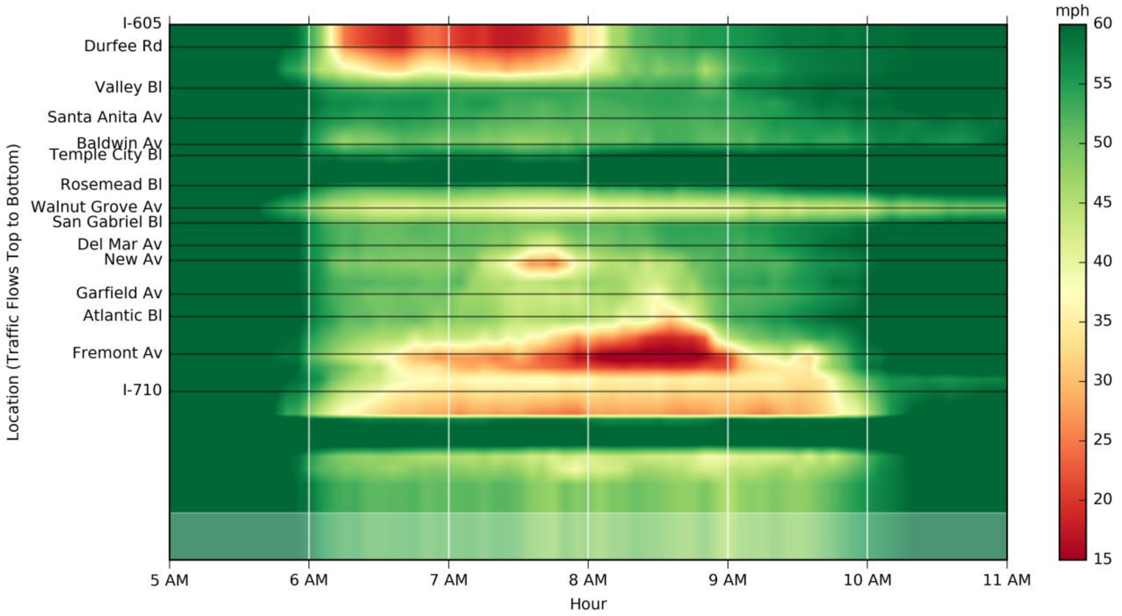
TRAFFIC CONDITIONS WHEN VOLUMES ARE 5% LOWER



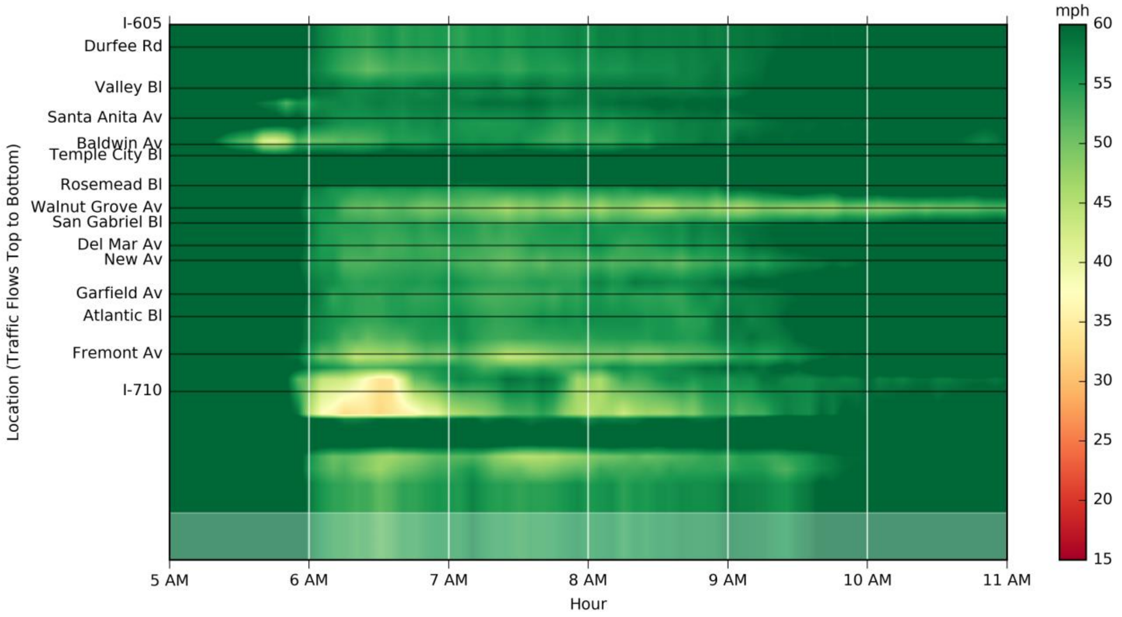
Note: Lighter bands in the figures indicate areas where detector coverage was poor and where results may be less reliable.

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

TYPICAL TRAFFIC CONDITIONS



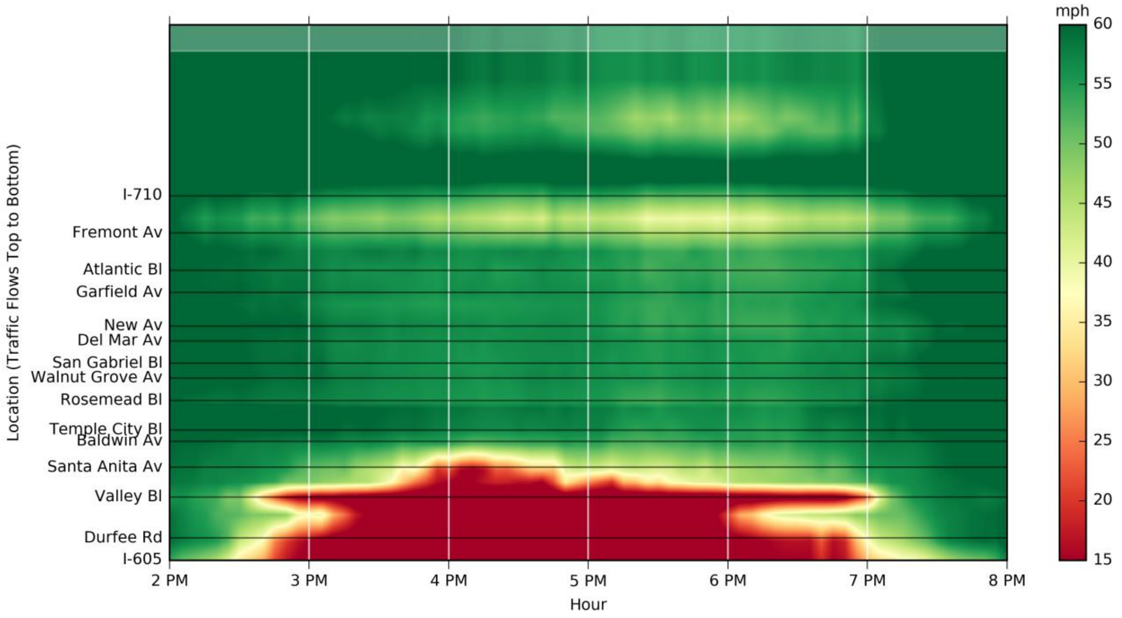
TRAFFIC CONDITIONS WHEN VOLUMES ARE 5% LOWER



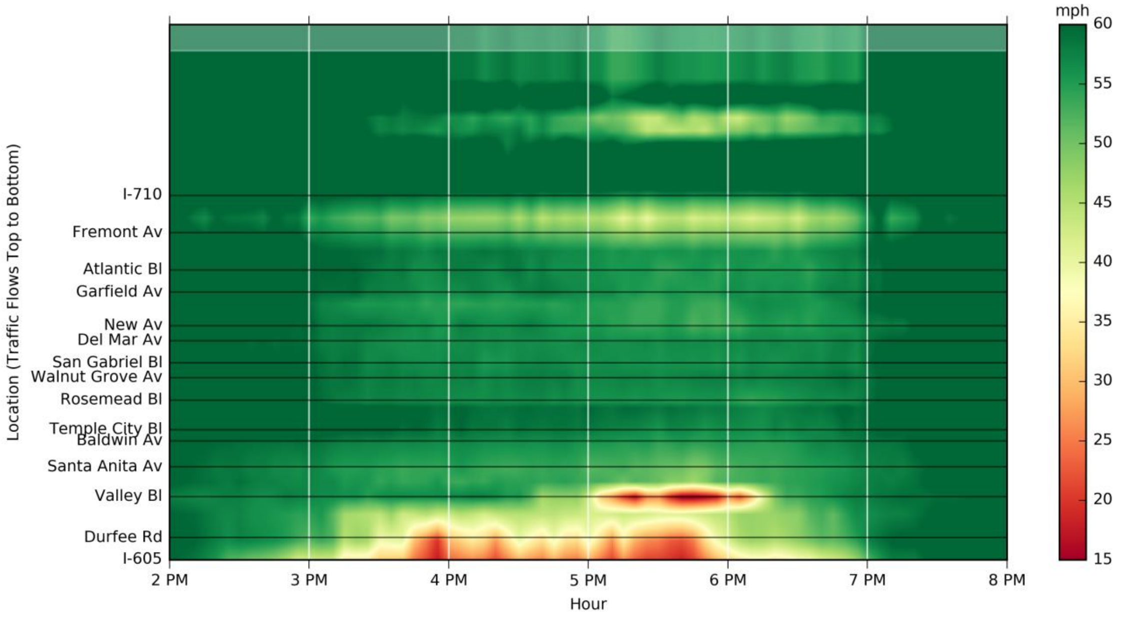
Note: Lighter bands in the figures indicate areas where detector coverage was poor and where results may be less reliable.

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

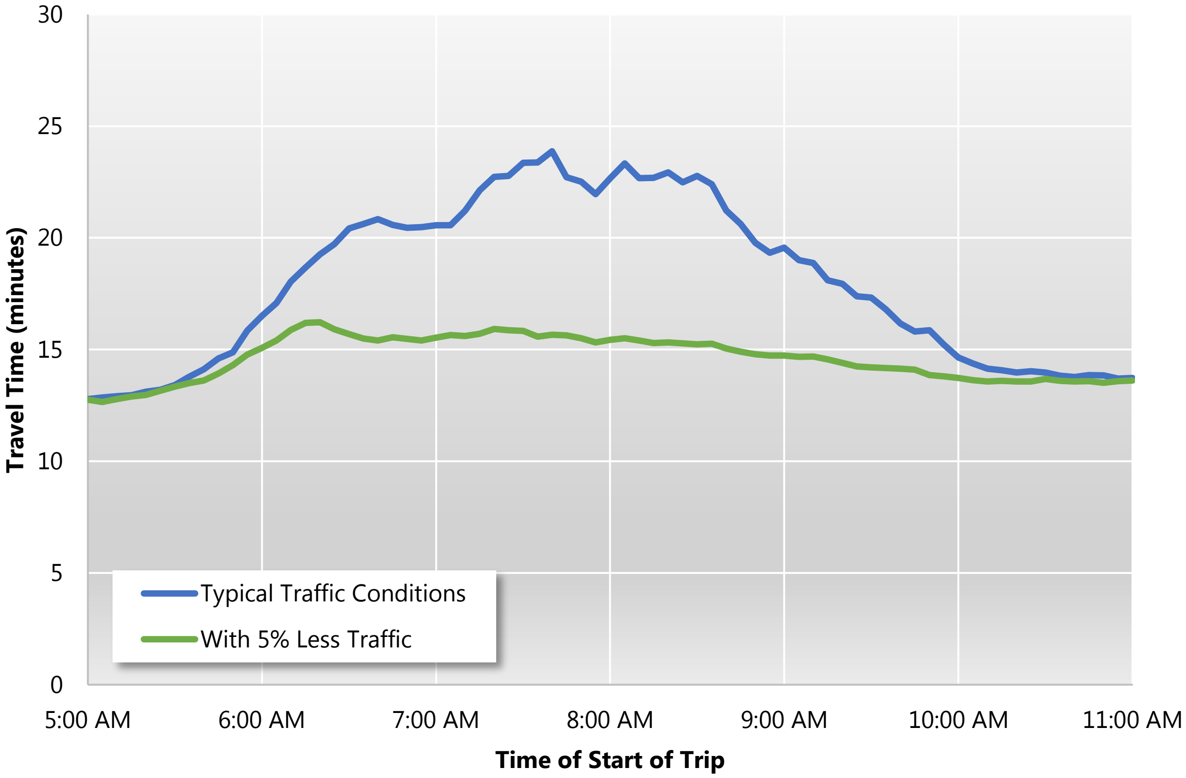


Figure 9. Comparison of End-to-End travel times on I-10 East ExpressLanes during the PM Peak

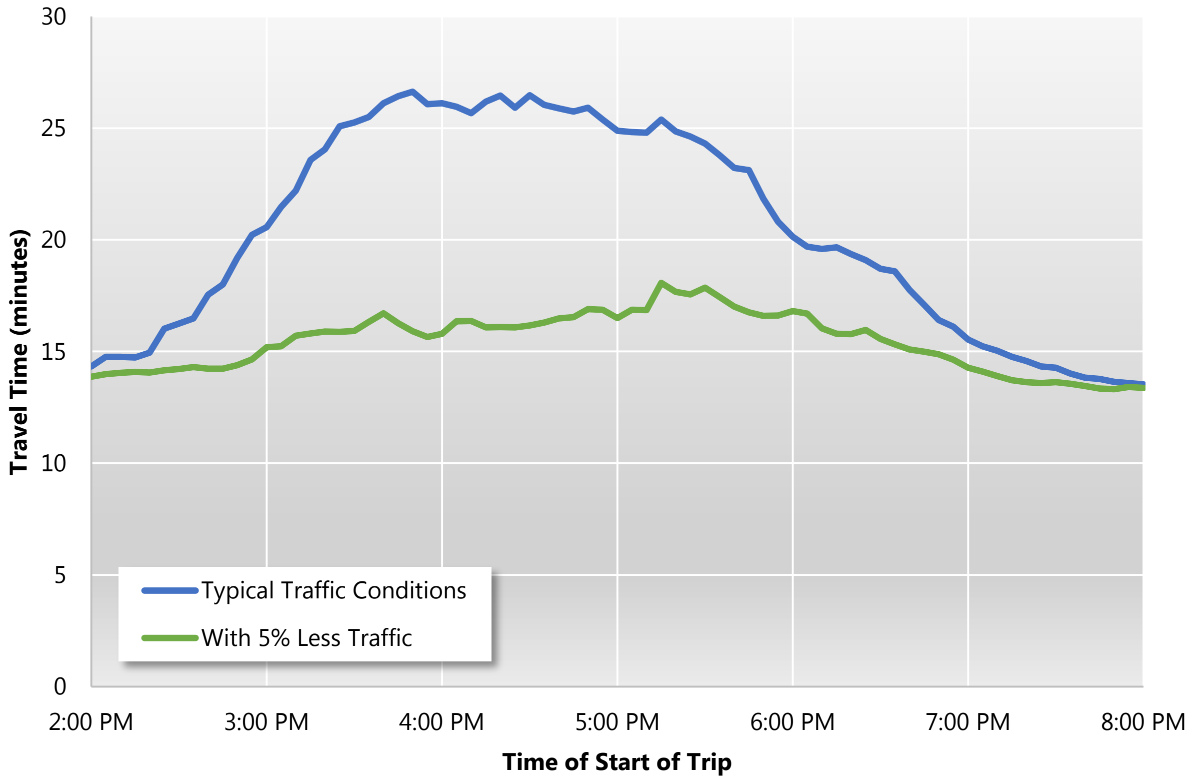
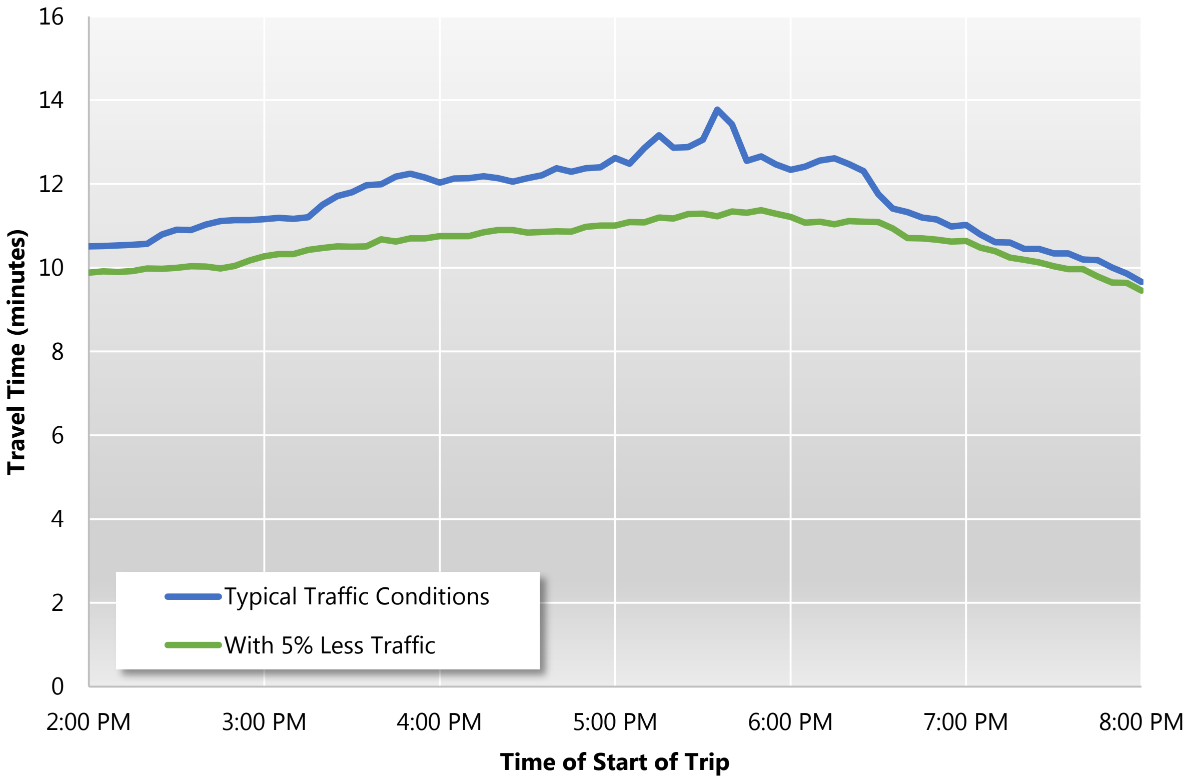


Figure 10. Comparison of End-to-End travel times on I-110 South ExpressLanes during the PM Peak



ATTACHMENT B

CAV Treatment on Express Lanes Facilities in the United States

State	Facility	CAV Discount
CA	SR 91 Express Lanes	100%, except 50% during PM Peak (EB only)
	I-15 Express Lanes	100%
	I-580 Express Lanes	100%
	I-680 Express Lanes	100%
	SR 237 & I-880 Express Lanes	100%
CO	I-25 Central Express Lanes	100%
	US 36	100%
	I-25 North Segment	100%
	I-70 Mountain Express Lane	100%
FL	I-95 Express Lanes	100%
	I-595	0%
GA	I-85 Express Lanes	100%
	I-75 Express Lanes	0%
MD	I-95 Express Toll Lanes	0%
MN	I-394 Managed Lanes	0%
	I-35W Managed Lanes	0%
	I-35E Managed Lanes	0%
TX	I-10 Katy Fwy Managed Lanes	0%
	I-45 North Fwy HOT Lanes	0%
	I-45 Gulf Fwy HOT Lanes	0%
	US 59 Eastex Fwy HOT Lanes	0%
	US 59 Southwest Fwy HOT Lanes	0%
	US 290 Northwest Fwy HOT Lanes	0%
	LBJ TEXpress Lanes and I-635 East Express	0%
	DFW Connector TEXpress Lanes	0%
	NTE (I-35W) TEXpress Lanes	0%
	I-30 TEXpress Lanes	0%
	MoPac Loop 1 Express Toll	0%
	SH 71 Toll Express	0%
	I-35E TEXpress Lanes	0%
	SH 114 TEXpress Lanes	0%
UT	I-15 Express Lanes	100%
VA	I-495 Express Lanes	0%
	I-95 Express Lanes	0%
	I-66 Express Lanes	0%
WA	SR 167 HOT Lanes	0%
	I-405 Express Lanes	0%

Sources:

- Individual agency informational materials, phone calls, and press releases.
- Turnbull, K. *Impact of Exempt Vehicles on Managed Lanes.* Texas A&M Transportation Institute. Report FHWA-HOP-14-006. March 2014.

ATTACHMENT C

CAV Treatment on FasTrak Roadway Facilities in California

Agency	Facility	Effective CAV Discount
OCTA and RCTC	SR 91 Express Lanes	97%[1]
SANDAG	I-15 Express Lanes	100%
	SR 125 South Bay Expressway	0%
ACTC	I-580 Express Lanes	100%
	I-680 Express Lanes	100%
VTA	SR 237 & I-880 Express Lanes	100%
TCA	SR 73	0%
	SR 133	0%
	SR 241	0%
	SR 261	0%
BATA	Antioch Bridge (SR 160)	19%.[2]
	San Francisco-Oakland Bay Bridge (I-80)	21%.[2]
	Benicia-Martinez Bridge (I-680)	18%.[2]
	Carquinez Bridge (I-80)	16%.[2]
	Dumbarton Bridge (SR 84)	28%.[2]
	Richmond-San Rafael Bridge (I-580)	20%.[2]
	San Mateo-Hayward Bridge (SR 92)	24%.[2]
Golden Gate Bridge District	Golden Gate Bridge (US 101)	6%.[3]

Notes

1. 50% during PM Peak (EB only). 100% all other situations. The volume-weighted average discount is approximately 97%.
2. Based on a 50% discount during the peak periods, and no discount at all other times. Traffic volumes are used to calculate a weighted average of the two discount levels to obtain an effective overall average.
3. Based on a 30% discount during the peak periods, and no discount at all other times. Traffic volumes are used to calculate a weighted average of the two discount levels to obtain an effective overall average.

ATTACHMENT D

The Importance of Managing Demand

Congestion Pricing is widely recognized as an effective, justifiable method for transportation demand management (TDM). This briefing document provides an overview of the reasons that TDM is such an important topic, particularly in the context of facilities carrying vehicular traffic such as freeways.

GOVERNING PRINCIPLE

According to traffic flow theory, there is a key fundamental relationship between the flow of vehicles in a given lane and the corresponding density of vehicles in that lane. When traffic is uncongested, flow and density increase proportionally, and all vehicles get to travel at full speed. This is intuitive, and can be easily seen in Figure 1 and Figure 2, where density doubles when flow doubles, but speeds remain the same because the lane has not yet reached its capacity threshold.

Figure 1: ExpressLanes traffic conditions for a demand of 360 vehicles per hour

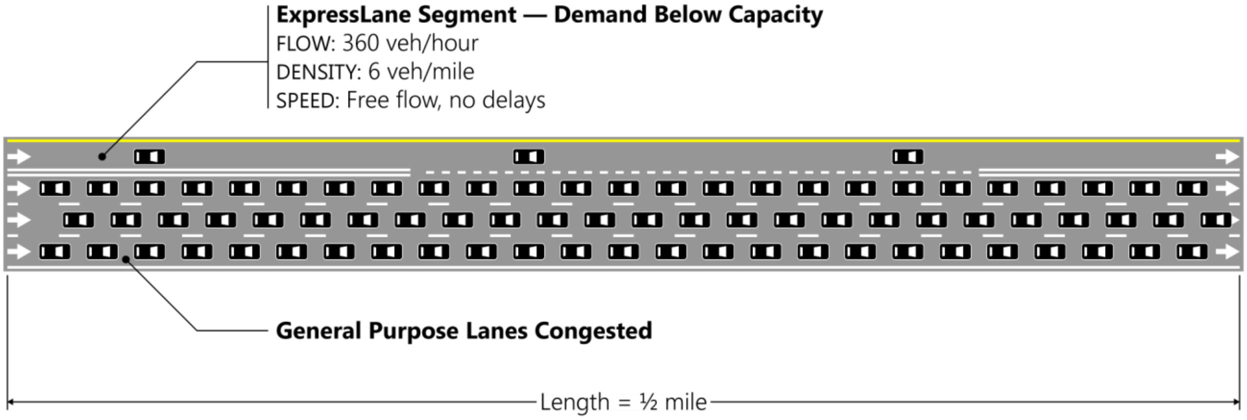
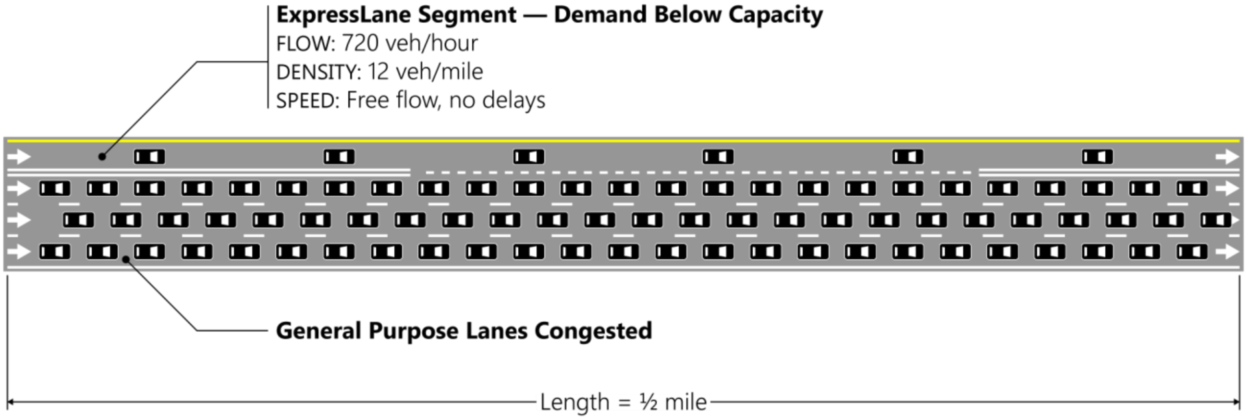
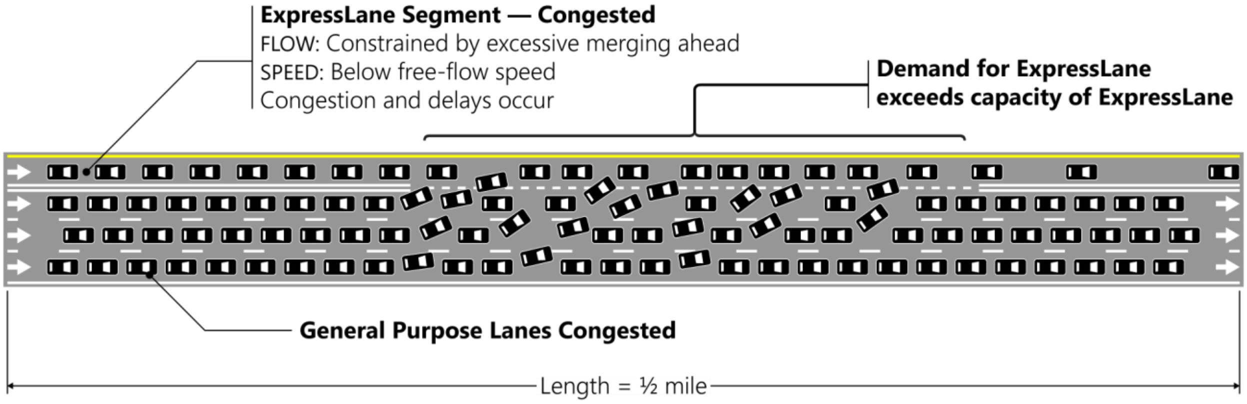


Figure 2: ExpressLanes traffic conditions when demand doubles to 720 vehicles per hour



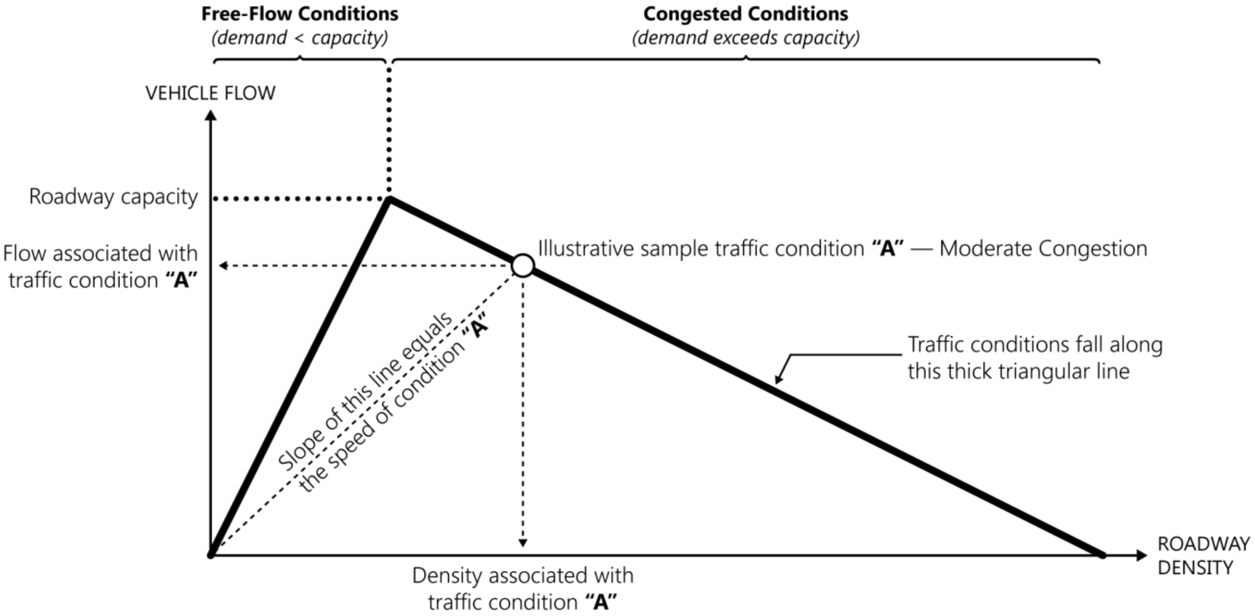
When demand exceeds the maximum capacity of a road, conditions shift from being uncongested to being congested and the relationship between flow and density changes drastically—yet predictably. Flow becomes constrained as more vehicles attempt to access the road than it can accommodate. Queues form, delays rise, and speeds drop. In these congested conditions, the more constrained the flow becomes (or the greater the imbalance between demand and capacity), the farther the speeds drop. This condition is shown in Figure 3.

Figure 3: ExpressLanes traffic conditions when demand exceeds capacity



The relationship between speed, flow, and density can be represented visually in what is referred to as the “fundamental diagram,” which is shown in Figure 4. As the figure shows, traffic speeds start dropping immediately once demand rises above capacity. The extents of the resultant delays caused by the congestion are specific to each roadway configuration and demand profile.

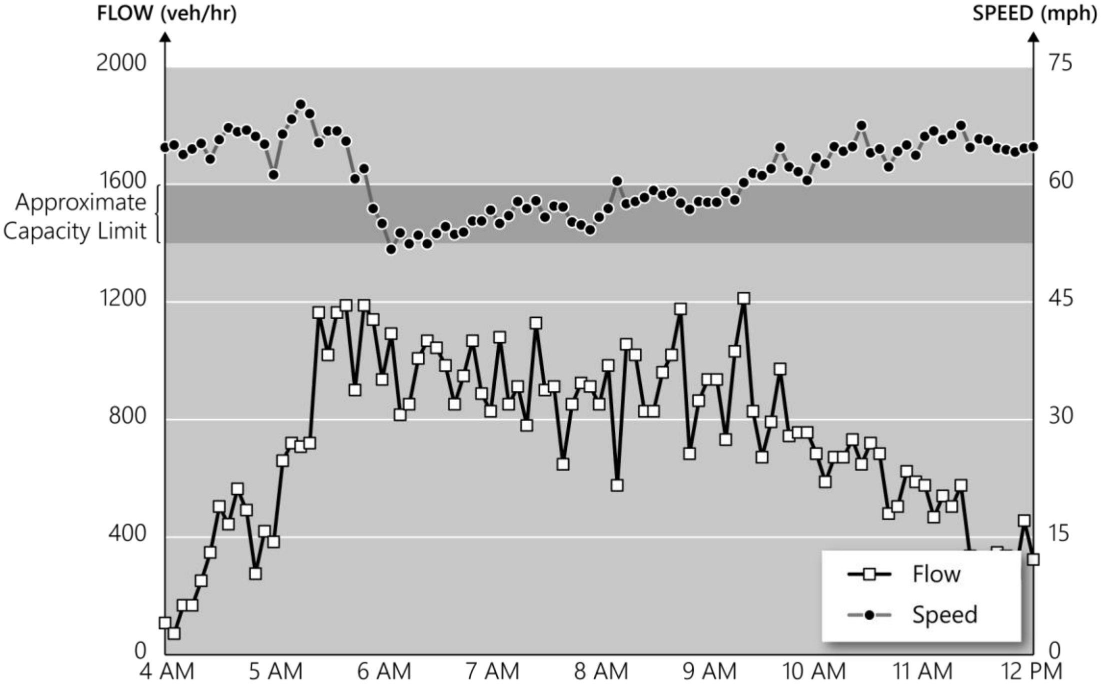
Figure 4: Fundamental diagram showing relationship between traffic flow, density, and speed



REAL-WORLD DATA

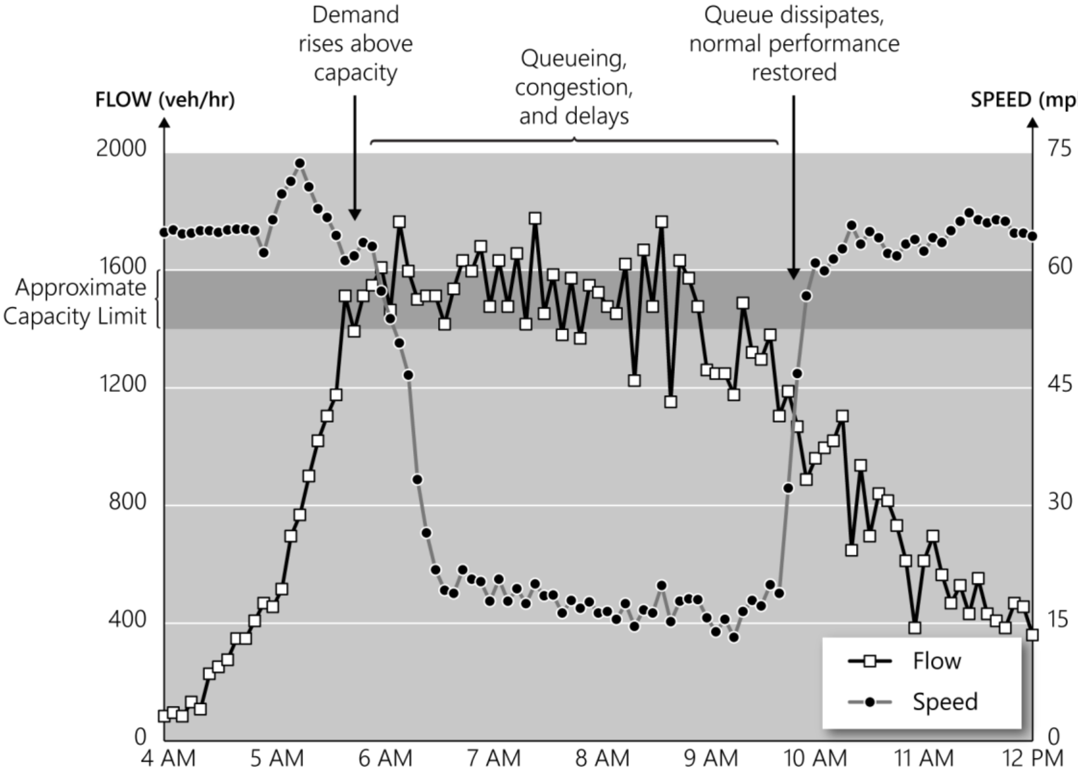
The effects described in the previous theoretical discussion can be readily observed in the Metro ExpressLanes. Measurements taken from the I-10 Westbound ExpressLanes at the 710 Freeway split reveal the negative impacts of allowing demand to exceed capacity. Figure 5 shows traffic data from a date where the traffic demand never exceeded the ExpressLanes capacity, which is approximately 1,400–1,600 vehicles per hour on this segment. As the speed data reveal, the ExpressLanes continued to provide customers with a high-speed journey the entire time.

Figure 5: Speed and flow data from I-10 West ExpressLanes at I-710 when demand stays below capacity



In contrast, Figure 6 shows traffic data from a date where the traffic demand exceeded capacity during the AM Peak period, resulting in an extended period of congestion as indicated by the lower speeds. During this period of excessive demand, flows were constrained to approximately 1,600 vehicles per hour, queues formed upstream, and travelers experienced delays. Demand eventually dropped, allowing the queues to dissipate and the ExpressLanes to return to normal operations (e.g., free-flow speeds).

Figure 6: Speed and flow data from I-10 West ExpressLanes at I-710 when demand exceeds capacity



Once demand exceeds capacity and traffic shifts from an uncongested state to a congested state, additional flow-related inefficiencies often occur (which often reduce roadway capacity even more, thereby further exacerbating the congestion), and it can take a substantial amount of time for the facility performance to fully recover. This underscores the importance of keeping traffic demand from rising above roadway capacity to ensure travelers can still reach their destinations expeditiously.

METRO EXPRESSLANES

Clean Air Vehicle Policy

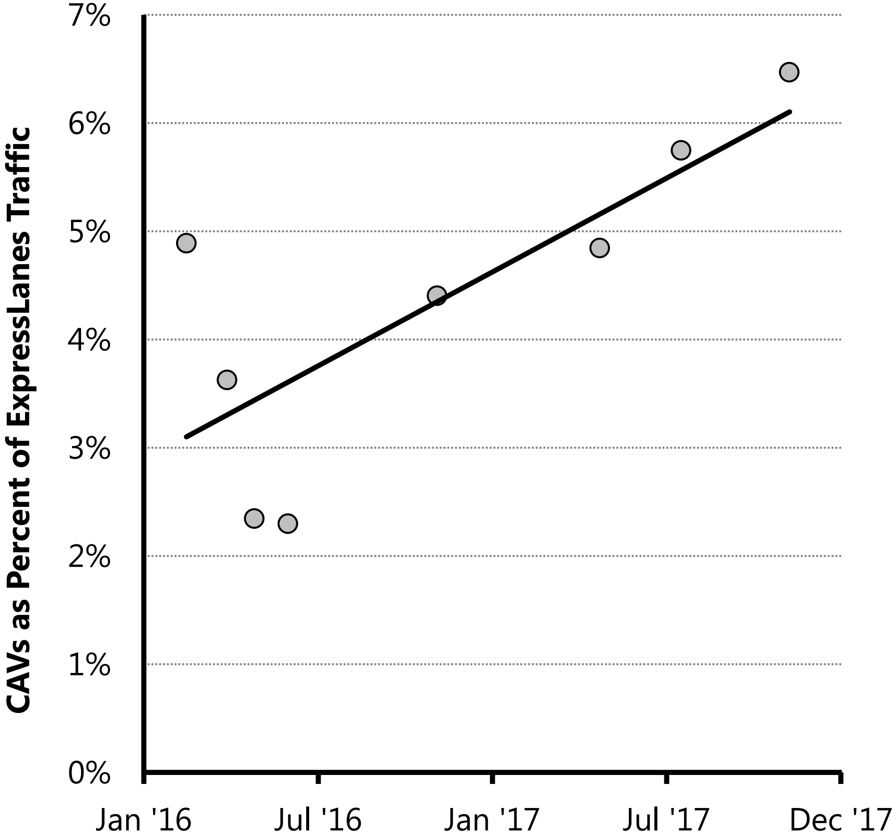
ISSUE:

Existing CAV Policy Contributes to ExpressLanes Congestion

- Clean Air Vehicles (CAVs) are a growing class of ExpressLanes users. AM Peak CAV volumes have doubled since 2016.
- CAVs contribute to congestion just as much as any other vehicle type.
- Without pricing to control CAV volumes, ExpressLanes congestion increases.

CAVs in ExpressLanes

Northbound I-110 at Slauson Ave, 6–9 AM



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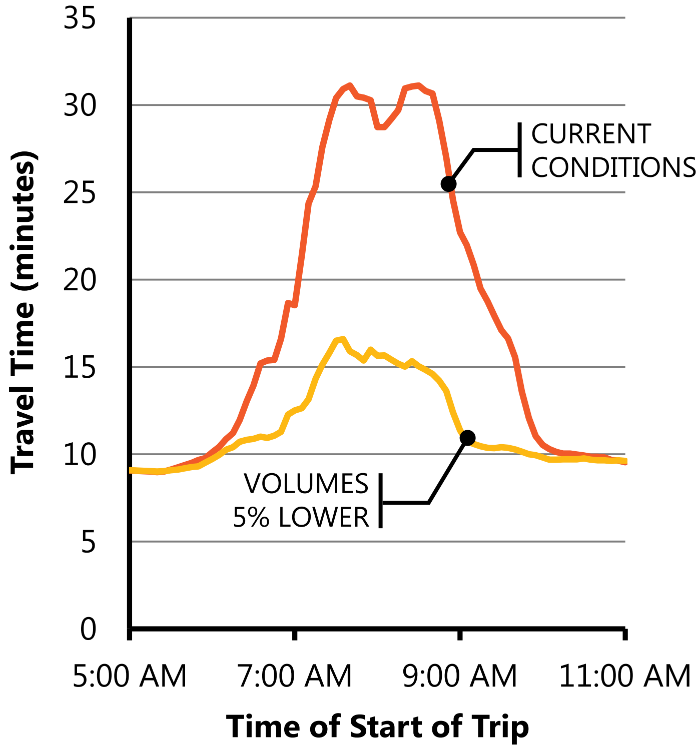
CONTEXT:

Impact of a Reduction in ExpressLanes Traffic Volume

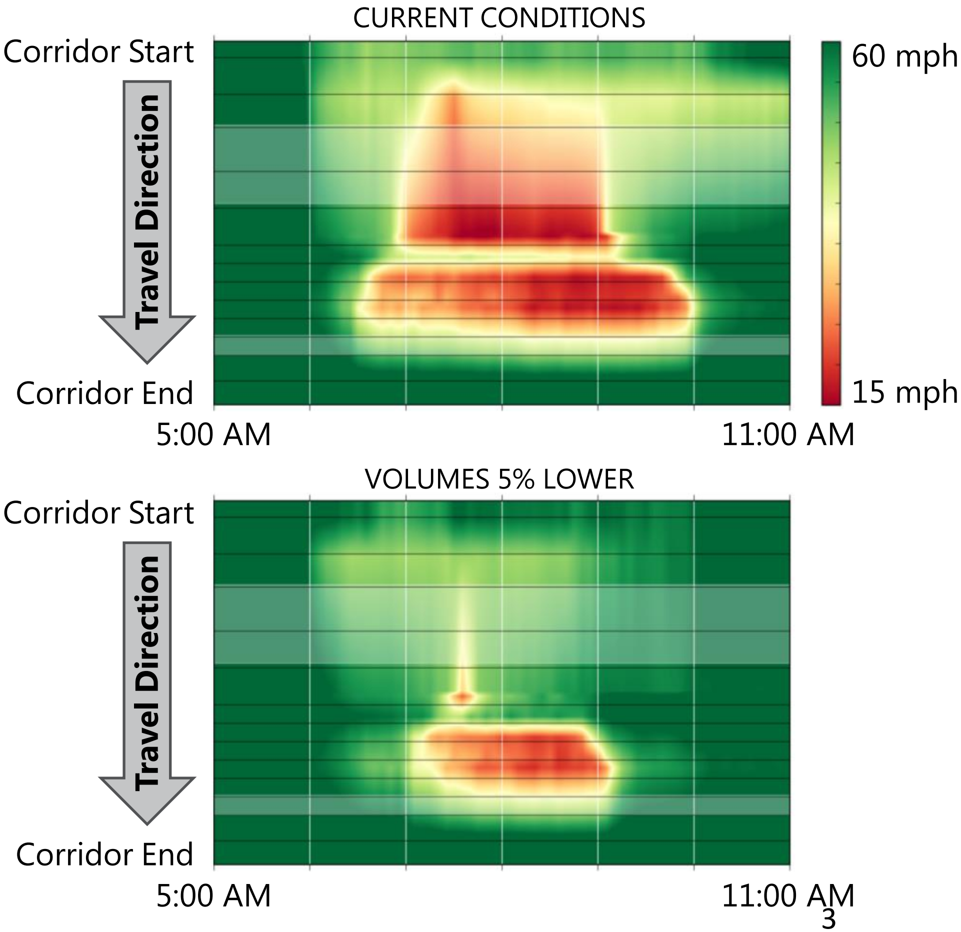
End-to-End Travel Times

Northbound I-110 during AM Peak



Corridor Speeds

Northbound I-110 during AM Peak



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KEY ANALYSIS:

Research on CAV Policies in California and Across the Country

- Provisions in California and Federal law explicitly grant authority to charge CAVs a discounted toll for ExpressLanes use.
- 68% of Express Lane facilities across the country are already charging clean air vehicles the full toll price.
- 78% of FasTrak facilities across the state are already charging clean air vehicles a partial or full toll price.
- 80% of the states in the country are not currently offering free HOV-lane access as an incentive for CAV drivers.
- There are up to 17 other incentive programs offered in California to encourage CAV ownership and adoption in addition to the CAV decal program.

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RECOMMENDATION:
Adopt a Toll Discount for CAVs

- Recommended a 15% Discount based on:
    - Maximizing mobility benefits
    - Economic theory
    - Research on price perception and consumer behavior

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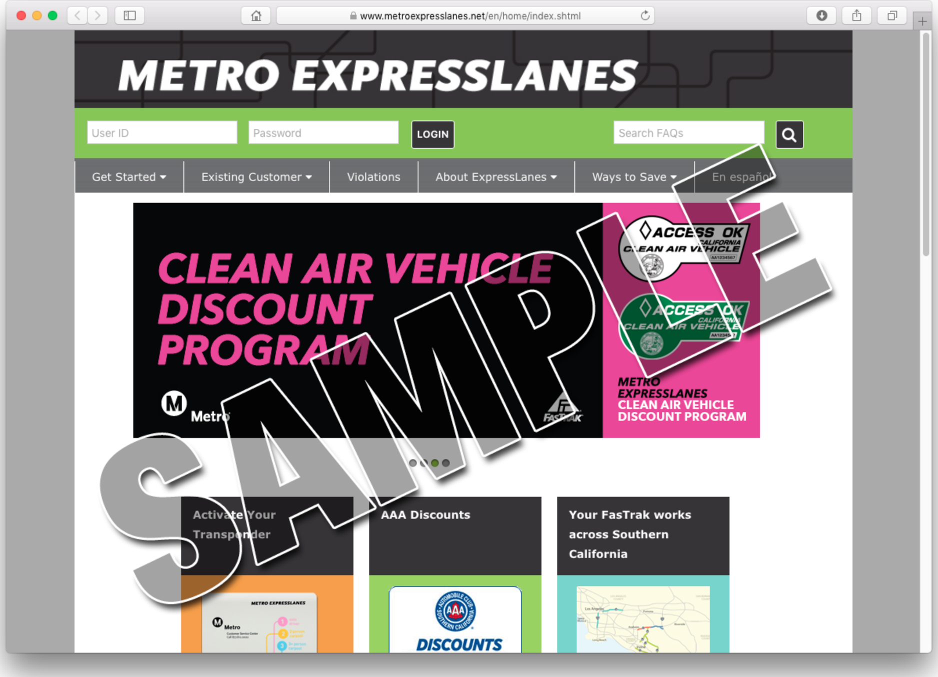
NEXT STEPS:

Outreach Plan for CAV Discount Policy

- Educational campaign will include:
    - E-mail announcements
    - Web site updates
    - Welcome booklet enhancements



Thank you

Metro