



Managed Lanes and Other Strategies to Improve Mobility on the I-25 South Corridor

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EXECUTIVE SUMMARY

The section of I-25 between 6th Avenue and 470 experiences high levels of congestion during peak travel times and the expected growth in residents and employment along the corridor is expected to exacerbate the situation in future years.

Transportation agencies have traditionally addressed congestion by widening roadways. Due to extensive development along this corridor since it was last widened in 2006, the further widening of I-25 in this area would be extremely expensive. In addition, the previous addition of new highway lanes only provided a short term improvement in congestion.

In 2006, at the cost of \$1.67 billion, the Transportation Expansion (T-REX) project, which widened I-25 and added parallel transit service, was completed. Congestion along the corridor improved, but the improvements were short lived. By 2010, just four years after completion, congestion had returned to the level experienced when construction began in 2001.

To improve mobility on this corridor, transportation planners should consider the conversion of one lane in each direction to a managed lane, providing drivers a congestion-free option. Revenues from the managed lane would be focused on aggressive transportation demand management (TDM) efforts to provide transportation alternatives to travelers in the corridor. Efforts could include expanded EcoPass programs, lower transit fares and improving first- and final-mile connections around transit stations, along with carpool, vanpool and employer shuttle programs.

These TDM programs give commuters additional options that would increase mobility on the corridor, allowing a larger number of people to travel along the corridor while maintaining existing conditions on the general purpose lanes.

Conversion of existing lanes to managed lanes, along with aggressive TDM, could provide drivers a congestion-free option and give travelers more choices – without increasing congestion in the remaining general purpose lanes – at much lower cost than trying to expand the highway.

I. INTRODUCTION

The approximately 13-mile stretch of I-25 between Logan Ave and 470 experiences high levels of congestion despite the major reconstruction done between 2001 and 2006. Dubbed T-REX (TRansportation EXpansion), the project widened the interstate and added light rail service parallel to the corridor. Only four years after the T-REX project was finished, average congestion levels in this corridor reached the same level they were at before construction began. Thus, the \$1.67 billion infrastructure project gave Denver drivers only four years of reduced congestion before reverting to pre-T-REX levels.

With overall traffic volumes along this corridor forecast by the Colorado Department of Transportation (CDOT) to increase approximately 37 percent by 2035, congestion can only be expected to worsen.¹ Traditionally, state departments of transportation (DOTs) have relied on roadway expansion to reduce congestion. However, a growing body of work indicates that while increasing highway capacity might temporarily reduce congestion, in the long run it encourages more people to drive until congestion returns to high levels.² This dynamic, called induced demand, is based on the idea that if you reduce the cost of something (for example, by reducing the time needed to make a vehicle trip) the demand for this product will increase. If an expanded highway offers a faster (and hence less expensive due to the value of time) way to reach a destination, more people will choose to drive on this route. Eventually, the new expanded roadway will return to the same levels of congestion as new traffic fills in the new capacity. This dynamic makes it difficult to justify the cost of highway expansion if the congestion benefits are so short-lived.

The T-REX corridor is an excellent example of induced demand and how it creates congestion on highways. T-REX also shows that even incorporating transportation alternatives (such as light rail) may not address the congestion problem. Transit has many benefits, but if more people use transit along the corridor, others will be more likely to drive due to reduced congestion on the roadway. Aside from congestion issues, the addition of transit will increase the capacity of a corridor, allowing more users than the highway alone could accommodate which can increase economic output.

There are additional barriers to adding more lanes to the T-REX corridor, including a lack of space to expand and a lack of funding.

When the T-REX project was built, as wide a trench as possible was dug for roadway expansion with the idea that one big expansion would be done at the time, eliminating the need for future roadway expansion. There has been considerable development adjacent to the corridor since the completion of T-REX in 2006, making any attempt to further expand the freeway very difficult, both politically and economically.

¹ This percentage is based on the difference between 2014 and 2035 AADT on the corridor between mile markers 194 and 207. <http://dtdapps.coloradodot.info/otis/TrafficData>.

² Gilles Duranton and Matthew Turner. 2011. The Fundamental Law of Road Congestion: Evidence from US cities. <http://www.nber.org/papers/w15376>.

Even if there were additional room to expand, CDOT faces significant funding challenges and lacks the funding to complete other major highway expansions that are already planned (I-70 East, I-25 North, I-70 Mountain, and I-270).

Lacking the means to further expand the interstate in this area requires that transportation planners think creatively about how to increase mobility and accommodate larger numbers of travelers in the corridor. One potential way forward would be to convert one of the existing lanes in each direction to a high occupancy toll (HOT) or managed lane which would ensure that drivers have a congestion-free option for driving in the corridor. Research indicates that one of the most effective long-term strategies to reduce roadway congestion is to charge drivers for use of the roadways.³ A 2012 report from the Government Accountability Office (GAO) found that “HOT lane projects... have reduced congestion by increasing vehicle throughput with increased speeds and decreased travel times in the priced and unpriced lanes.”⁴ To improve mobility for all travelers, revenue generated from the managed lanes would be used in an aggressive Transportation Demand Management (TDM) and mode-shift campaign to provide additional and more convenient alternatives to the reliance on single-occupancy vehicles along the corridor. Such an effort could include increasing transit ridership through reduced prices, increased capacity, increased penetration of EcoPass, support for first- and last-mile solutions around transit stations, additional vanpool service, increased carpool promotion and more employer shuttles.

In coming years, the Denver metropolitan area will be increasingly connected by managed lanes. Currently, there are managed lanes on US 36 between Denver and Boulder and on I-25 between downtown and 120th Ave. A future extension to the I-25 corridor is planned that will go to the E-470 junction. I-70 east of I-25 will feature at least one managed lane in each direction when it is completed. Additional managed lanes are planned on C-470 between I-25 and Wadsworth Boulevard.

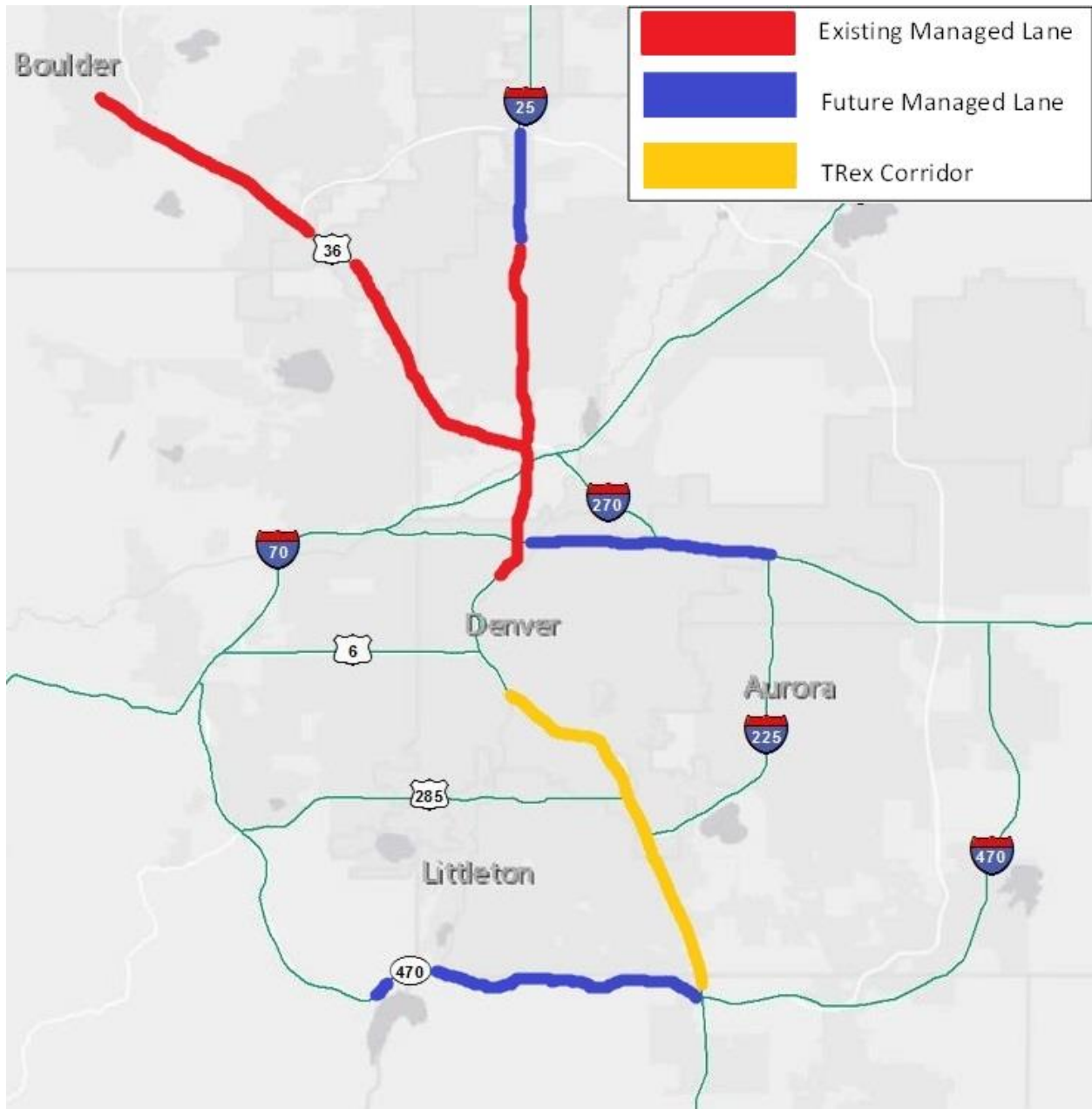
Incorporating the section of I-25 that passes through Denver into the region’s managed lane network could be an important step for regional mobility and livability.

This report examines conditions along the T-REX corridor and proposes a solution that will increase mobility on the corridor at a significantly lower cost than adding new lanes.

³ Litman, Todd. 2011. London Congestion Pricing: Implications for Other Cities. <http://www.vtpi.org/london.pdf>.

⁴ Government Accountability Office. 2012. Road Pricing Can Help Reduce Congestion, but Equity Concerns May Grow.

Figure 1 | Existing and Future Managed Lanes in the Denver Metro Area



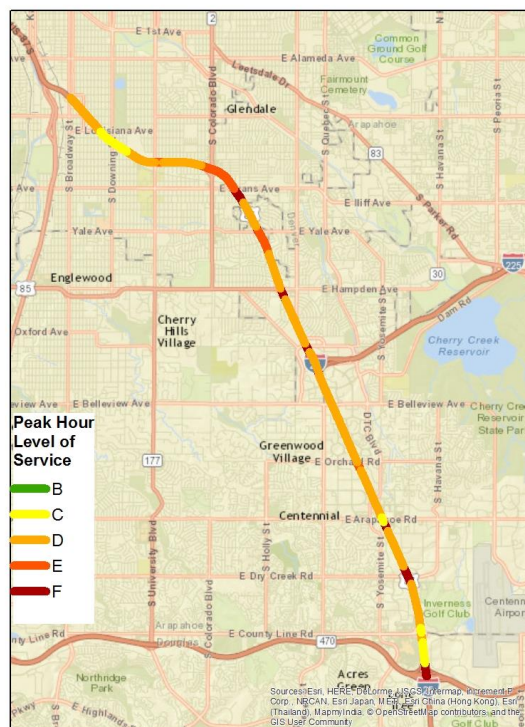
II. CURRENT CONDITIONS OF THE T-REX CORRIDOR

The 2014 Congestion and Mobility Report published by the Denver Regional Council of Governments (DRCOG) identifies the entire I-25 corridor in metro Denver as a congested roadway, meaning it has a congestion grade of D or F.⁵ The volume-to-capacity ratio, (or V/C ratio, a measure of roadway congestion) for the segment of I-25 expanded under T-REX is essentially the same for the entire I-25 corridor through metro Denver. Both the T-REX corridor and the rest of the I-25 corridor have a V/C ratio of 0.92. (A ratio of 1.0 indicates that the roadway is at full capacity.)

Figure 2 | Northbound Level of Service

Current Northbound Peak Hour Level of Service

2035 Northbound Peak Hour Level of Service



Figures 2 and 3 show the level of service (LOS) for individual roadway segments during the peak hour of traffic for both northbound and southbound lanes for the current year and projected to 2035.

For many segments of the northbound lanes, LOS is already at level D or worse. By 2035, the increased traffic volumes result in essentially the entire corridor experiencing LOS of level F during the peak traffic hour. Southbound traffic currently has slightly lower volumes than northbound during peak hours, but by 2035 still will experience LOS of level F throughout most of the corridor.

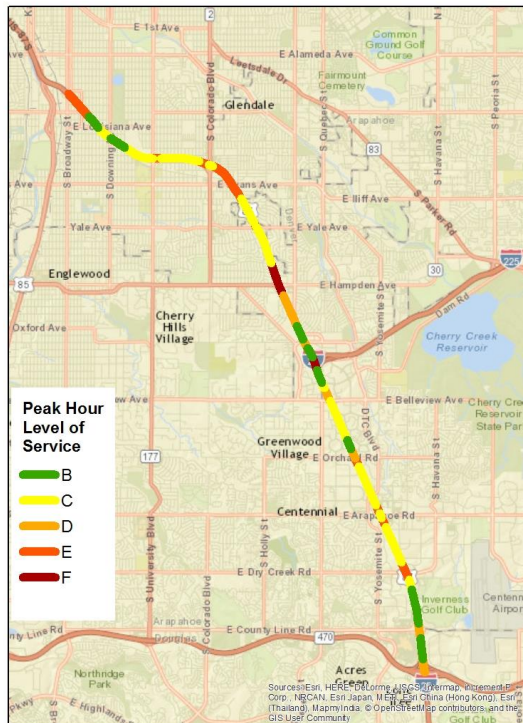
⁵ Denver Regional Council of Governments. 2015. 2014 Annual Report on Roadway Traffic Congestion in the Denver Region. <https://drcog.org/sites/drcog/files/resources/2014%20Annual%20Congestion%20Report.pdf>.

(See Appendix A for a detailed explanation of how these figures were developed.) In addition to worsening peak congestion, the additional vehicles will also increase the number of hours in a day that experience congestion.

Figure 3 | Southbound Level of Service

Current Southbound Peak Hour Level of Service

2035 Southbound Peak Hour Level of Service



The current levels of congestion on the corridor result in delays for vehicles. Real-time traffic data from CDOT shows the average traffic speed at several points along the corridor and gives an indication of the travel time penalty from congestion.⁶ The segment of the corridor between I-225 and 470 is relatively congestion free during morning peak periods, with average speeds around 60 mph. The sections of the corridor between 6th Avenue and I-225 generally have lower speeds ranging between 30 and 45 mph. To travel the 11 miles between 6th Avenue and I-225 at 60 mph would take 11 minutes. To cover the same distance at 37 mph would require 17.8 minutes. While not a huge time differential for each individual commuter, this results in 6,186 total hours (or nearly nine months) of delay when multiplied by the approximately 58,000 vehicles that travel this corridor in both directions each morning.

⁶ Colorado Department of Transportation. 2016. <http://www.cotrip.org/highways.htm?commuteRouteId=34>.

III. HOW TO IMPROVE MOBILITY ON THE CORRIDOR

One method of improving mobility in the corridor would be to convert one or two existing lanes in each direction to managed lanes. These lanes would provide congestion-free travel by accommodating only vehicles with three or more passengers, transit vehicles, and those that are willing to pay a toll.

To maintain relatively free flow conditions, the volume in the managed lane would need to be capped at around 1,400 vehicles per hour. For most of the day, this level of traffic volume in the managed lane would not result in greater traffic volumes in the general purpose lanes because it is equal or higher than the average hourly volume per lane. However, in certain locations during peak periods and especially during the peak traffic hour, the new managed lane would have lower volumes than the general purpose lanes and could therefore increase volumes in the general purpose lanes, unless other steps are taken to shift travel from single occupant vehicles.

Higher vehicle occupancies in the managed lane would allow more people to make use of the interstate. If three or more people are required to use the managed lane for free, the average vehicle occupancy for these lanes would increase significantly over that of the general purpose lanes.

Table 1 | Average Vehicles and People during Peak Hour per Lane, General Purpose (GP) and Managed

Lane	Vehicles/Lane during Peak Hour	People/Lane during Peak Hour
Northbound GP Lane	1,847	1,995
Southbound GP Lane	1,581	1,707
Managed Lane	1,400	1,927

In the Denver metro region, the average vehicle occupancy for commute trips is 1.08 people.⁷ At this level of occupancy, 1,847 vehicles per lane per hour (northbound) would translate to 1,995 people per lane per hour and 1,581 vehicles per hour (southbound) would translate to 1,707 people per lane per hour. A managed lane allowing 1,400 vehicles per hour, where 14 percent of vehicles had occupancies of three or more, would translate to at an estimated 1,927 people per hour. This is nearly the same as the highest level achieved in the current general purpose lanes.⁸

Mobility Improving Measures to Complement Managed Lanes

By itself, the conversion of an existing general purpose lane to a managed lane could result in minor increases in vehicle volumes and congestion in the remaining general purpose lanes during the peak traffic volume hour. To help reduce the number of vehicles on the road and increase mobility along the corridor, aggressive transportation demand management (TDM) strategies, funded by toll

⁷ Denver Regional Council of Governments. 2013. VMT and Trip Reduction Calculation Packet.

⁸ Approximately 14 percent of vehicles using the I-85 HOT lane in Georgia are not paying a toll and are HOV3+ vehicles. <http://www.georgiatolls.com/programs/i-85-travel-data/>.

revenue collected in the new managed lanes, would be pursued. TDM aims to adopt strategies and policies that promote transit, walking, biking, ridesharing and teleworking. Increased TDM efforts will improve mobility along the corridor by giving more people access to congestion-free travel alternatives and increase the ability of the existing transportation system to serve more people. Using the managed lanes to create a new revenue stream is critical because the state faces a significant funding challenge and is unlikely to be able to invest resources in TDM along the corridor.

Managed lanes are a fair and economically efficient mechanism for generating revenue for transportation, as the people who get the most benefit pay tolls to help pay for the projects.

However, there are questions of equity across income ranges when public rights of way and public funds are invested in managed lanes. Survey data shows that users of tolled express lanes are largely, although not exclusively, members of high income households.^{9,10} However, both carpools and transit are used by a far broader range of income levels, so managed lanes can be made much more equitable by designing them to include carpools and vanpools while simultaneously supporting transit service.^{11,12}

Using managed lanes to serve high occupancy vehicles and to promote transit gives travelers more choices and offers greater transportation benefits.

Current Capacity of Southeast Corridor Rail Lines

Currently, RTD's E, F and H rail lines that serve the Southeast Corridor have capacity to handle additional passengers during the peak hour. During the peak hour, the E line is operating at 52 percent capacity (629 peak riders with a capacity of 1,200), the F line at 64 percent capacity (1,022/1,600) and the H line at 75 percent capacity (1,195/1,600).¹³ Across the three lines there is currently peak hour ridership of 2,846 and unused capacity to accommodate up to 1,554 additional riders.

While not ideal because they encourage travelers to drive for at least part of their trip, park and rides can help support transit ridership along major corridors like I-25. RTD has 12 park-and-rides along the Southeast Corridor that collectively have approximately 1,600 unutilized parking spaces. The number of available spaces varies significantly along the corridor, with a number of park-and-rides (Colorado, Belleview, and Yale) operating at full capacity while others (Arapahoe and County Line) are well under capacity.

⁹ Corona Research. 2008. HOV/Express Lane User Study. Exhibit 6-8, Household Income.

¹⁰ US DOT. 2008. FHWA Primer, Income-Based Equity Impacts OF Congestion Pricing: A Primer. http://ops.fhwa.dot.gov/publications/fhwahop08040/cp_prim5_00.htm.

¹¹ US Census. Table B08119: Means of Transportation to Work by Workers' Earnings in the Past 12 Months, 2007-2011 American Community Survey 5-Year Estimates for the Denver-Aurora-Boulder Combined Statistical Area.

¹² RTD 2011 Customer Satisfaction Survey, Demographic Comparisons, Annual Household Income; US Census. Table B19011: Household Income in the Past 12 Months, 2007-2011 American Community Survey 5-Year Estimates for the Denver-Aurora-Boulder Combined Statistical Area.

¹³ Personal correspondence via email from Lee Cryer at RTD.

SE Rail Extension

Construction began in May 2016 on an extension of the Southeast (SE) light rail line that will add three new stations to better serve the communities of Lone Tree, Parker, Highlands Ranch and northern Douglas County starting in 2019. Upon completion of the extension, the combined daily ridership for the SE rail is expected to be over 50,000.¹⁴ Some of these additional riders are likely to be people who previously drove along the I-25 corridor due to a lack of convenient light rail stations.

First and Final Mile

An important tool to increase transit usage along the corridor is to invest in first and final mile improvements at the major transit stations. First and final mile strategies focus on making it easier and safer to travel to and from major transit stations by improving pedestrian and bicycle access and wayfinding in the area. Examples include adding sidewalks, crosswalks, under- or over-passes, bike lanes or bike paths, bicycle parking and bike sharing.

In a 2012 report, the South I-25 Urban Corridor Transportation Management Association identified 105 first- and final-mile projects (pedestrian, bicycle, wayfinding) surrounding six stations along the Southeast Corridor Line.¹⁵ They also provide a high and low estimate for the cost of these projects. Completing all the identified projects would cost between \$3.2 and \$16.4 million. The list was then narrowed down to the 33 projects that would most effectively improve access to the station. Completing these 33 projects was estimated to cost between \$518,000 and \$1.2 million.

While the report did not attempt to estimate how much these improvements would increase light rail ridership, it is clear that they would make a positive difference.

Employer Shuttles to Serve First- and Final-Mile Destinations

Another method to improve first and final mile connections is to provide shuttle service between major transit centers and employers along the corridor. RTD offers “Call and Ride” services that connect people at transit stations to their workplaces, but this currently operates at a relatively small scale.

Employer shuttle service could follow a number of different models. Shuttles could be funded, owned and operated by employers, the Regional Air Quality Council (RAQC), RTD, the local transportation management association (TMA), or some combination of the above. Any employer shuttle service would likely need to be coordinated with RTD.

In an innovative move along the corridor, the City of Centennial is attempting to address final mile issues by offering reduced costs for Uber and Lyft rides from the Dry Creek light rail station. The reduced fares are to be set at levels that would resemble those of driverless vehicles (removing the

¹⁴ Ibid.

¹⁵ South I-25 Urban Corridor Transportation Management Association. 2012. Last One-Half Mile Transportation Solutions.

cost of the driver) to test the potential for this technology to increase ridesharing with transportation network companies.

Expanded EcoPass

One way to increase transit use along the T-REX corridor would be to aggressively expand EcoPass programs to businesses and communities located near the corridor. Providing people with unlimited, “free” transit trips could increase transit use in the area significantly. According to a 2011 survey, those with EcoPasses are 4-6 times more likely to use transit.¹⁶

Average weekday transit ridership on the Southeast Corridor is 43,110 (based on 2015 data).¹⁷ During the morning peak period, total ridership on the corridor is estimated at 11,837.¹⁸ Dividing by four peak period hours gives peak hour ridership of 2,959.

As calculated above, peak hour ridership on the combined SE Rail lines is 2,846, with the potential for up to 1,554 additional passengers.

To add 1,400 new light rail riders during the peak hour (leaving some spare capacity) by increasing the number of EcoPasses offered on the corridor would require a significant number of new EcoPasses to be issued.

In 2013, RTD issued 107,747 EcoPasses through their employer program; this resulted in 15.6 million transit trips by these EcoPass holders.¹⁹ On average, each employer EcoPass issued results in 145 transit trips annually. Therefore, based on the existing EcoPass program, it would be necessary to issue 3.3 EcoPasses in order to create one full-time commuter (two daily trips and 480 annual trips).²⁰ Because an expansion of EcoPasses among employees along the corridor could not focus only on morning peak hour travelers, there would need to be enough new EcoPasses issued to increase ridership across the entire day with the assumption that peak period users would make up the same percentage of riders compared to current usage.

To get 1,400 new riders (essentially a 50 percent increase in ridership) during the peak hour would require that ridership for the entire day increase by 50 percent, or the addition of 21,555 new trips on the corridor over the course of the day. To create this many new trips it would require approximately 10,777 ($21,555/2$) new full time riders over the course of the day. This would translate to 1,392 new riders during the peak hour. Based on average vehicle occupancy, these additional transit riders would displace 1,288 vehicles during the peak hour or 161 vehicles per lane.

¹⁶ 36 Commuting Solutions. 2016. US 36 RTD Master Ecopass Pilot Program First of Its Kind in Colorado. <http://36commutingsolutions.org/us-36-rtd-master-ecopass-pilot-program-first-of-its-kind-in-colorado/>

¹⁷ RTD. 2016. Southeast Corridor Light Rail Line. <http://www.rtd-denver.com/FF-SoutheastCorridor.shtml>

¹⁸ E, F and H Lines January 2016 Ridership by Route and Stop. Personal communication via email by Lee Cryer at RTD.

¹⁹ Livable Places Consulting. 2015. Reducing Transportation Costs in the Denver Region through Expanded Transit Pass Programs. <http://milehighconnects.org/downloads/reducing-transportation-costs-in-the-denver-region-through-expanded-transit-pass-programs/>.

²⁰ 48 weeks per year multiplied by 10 weekly trips.

To create this many full-time riders would require that 35,566 ($10,777 \times 3.3$) new EcoPasses be issued. The cost of issuing these EcoPasses would be \$6.1 million ($\$173 \times 35,566$).

A 50 percent increase in ridership, while perhaps on the high end of what is possible, is not unrealistic and this scale of increase is supported by a recent study. The most relevant research focused on expanding EcoPasses in the City and County of Boulder. An expansion to all employees in the City of Boulder was estimated to increase transit ridership between 10 and 41 percent (depending on the assumed elasticity of transit demand) in the first year of the program.²¹ As the estimated percentage of current Ecopass holders who work along the I-25 corridor is about half the percentage of EcoPass holders in the City of Boulder, we would expect an increase of transit ridership at the higher end.

36 Commuting Solutions is running a pilot program to give EcoPasses to employees along the US 36 corridor. Approximately 1,000 employees from 25 employers within a quarter mile of the corridor received subsidized EcoPasses through the program. The EcoPasses were free to employers in the first year (2015) and 70 percent of the cost was subsidized by 36 Commuting Solutions in 2016. This program appears to be effective at encouraging transit use; a survey of participants found that they used transit 111 percent more often once they received their EcoPass.²²

Table 2 | Summary of Ecopass Expansion

New Peak Hour Riders	1,392
Reduced Peak Hour Vehicles	1,288
Reduced Peak Hour Vehicles per Lane	161
Cost	\$6.1 million
Cost/Reduced Peak Hour Vehicle	~\$4,800

Lower Light Rail Fares

Like the majority of goods and services, increasing or decreasing the cost of transit service will impact how many people will use it. This relationship between price and consumption is referred to as elasticity. For RTD's light rail service, the elasticity for a regional full price ticket is estimated by RTD to be -0.2 percent, meaning that a one percent decrease in price would lead to a 0.2 percent increase in ridership.^{23, 24} Table 3 shows the impact of different levels of fare decreases on overall ridership on the corridor and specifically during peak periods.²⁵ These calculations assume that 42 percent of light rail riders on this corridor are using EcoPasses (this is the average across all light rail lines) and are therefore not impacted by the decrease in fares. So the increase in ridership is based on the assumption of 25,000 rides that are sensitive to changes in price.

²¹ Boulder County. 2014. Countywide EcoPass Feasibility Study.

²² 36 Commuting Solutions. 2016. US 36 Master Ecopass Pilot Program and Local Employers Team Together to Reduce Drive Alone Trips. <http://36commutingsolutions.org/us-36-master-ecopass-pilot-program-and-local-employers-team-together-to-reduce-drive-alone-trips/>.

²³ RTD FARES Model.

²⁴ Due to the wide range of price decreases considered we have applied the arc elasticity formula to determine the relationship between change in price and change in ridership.

²⁵ These calculations make the simplifying assumption that all non-EcoPass riders are paying the full light rail fare.

Table 3 | Impact of Lowering Light Rail Fares

Decrease in Price	5%	10%	20%
Increase in Ridership	0.9%	1.8%	3.5%
Increase in Riders	243	470	882
Ridership Increase Peak Hour	18	35	66
Decrease in Peak Hour Vehicles	16	31	59
Decrease in Peak Hour Vehicles per Lane	2	4	7
Cost	~\$1.1 million	~\$2.2 million	~\$4.6 million
Cost/Decreased Peak Hour Vehicle	~\$68,000	~\$72,000	~\$79,000

The current cost of a regional one-way ticket is \$4.50. A 20 percent decrease would reduce the fare to \$3.60. The cost to provide this discounted fare for all non-EcoPass rides on this corridor would be the difference between the original revenue ($25,000 * \$4.50 = \$112,500$) less the new revenue ($25,882 * \$3.60 = \$93,177$) or \$19,323 per weekday. Assuming 240 workdays during the year, this would come to approximately \$4.6 million annually.

Vanpool Expansion

DRCOG works with RTD on the *Way To Go* program that currently supports 114 vanpools carrying 621 commuters every weekday. The vanpool program is supported by \$700,000 of annual funding from RTD.

An expanded vanpool program targeting the T-REX corridor could help get drivers out of their single occupancy vehicles and improve mobility for everyone.

If \$1,000,000 of managed lane revenue were dedicated to expanding the vanpool program along the T-REX corridor, the number of displaced trips could be doubled. An additional 114 vans carrying 621 commuters along the corridor during peak travel times would result in 549 fewer single-occupancy vehicles on the road. Minus the number of vans, this would give a net reduction of 435 vehicles. We will assume that the vans will be spread out over two hours of the morning peak period resulting in approximately 218 fewer vehicles on the road (or 27 fewer vehicles per lane) during the peak hour.

Table 4 | Impact of Expanding Vanpool

Reduced Peak Hour Vehicles	218
Reduced Peak Hour Vehicles/Lane	27
Cost	~\$1,000,000
Cost/Reduced Peak Hour Vehicle	\$4,587

Table 5 | Impact of Expanding Carpool

Reduced Peak Hour Vehicles	266
Reduced Peak Hour Vehicles/Lane	33
Cost	\$750,000
Cost/Reduced Peak Hour Vehicle	\$2,820

Carpool Expansion

One method to encourage carpooling would be to offer commuters an initial incentive to try out carpooling. While not all those that try out a carpool will always use it or continue to use it, a number of participants are likely to continue carpooling once they get over the initial barrier of starting to carpool. 36 Commuting Solutions offered commuters along the corridor a one-time \$75 incentive for signing up for a carpool program. After three months, follow up surveys showed that 46 percent of participants were still carpooling (eight percent had carpooled before the program).

If 10,000 commuters were offered a \$75 sign-up incentive, we can assume that 4,600 participants would continue to carpool. Subtracting the assumed eight percent who were already carpooling, this results in 3,800 new carpoolers along the corridor. Along the US 36 corridor, each carpool participant eliminated 123 one-way vehicle trips annually, or 61.5 round trips. Assuming there are 240 commuting days, this means that each participant reduced their annual number of commuting trips by 25.6 percent. Based on peak hour trips making up 27.7 percent of peak period trips (when most commute trips are occurring) this comes to participants reducing peak hour trips by seven percent. With 3,800 participants, this would result in 266 fewer peak period vehicle trips or 33 fewer trips per lane.

To maintain and grow the share of carpoolers along the corridor, the introduction of a carpooling app such as Carma (currently available in the Bay Area) would be helpful. In the Bay Area, Carma matches riders with drivers. Riders pay for the trip on a per-mile basis, with most of this payment going to the driver. Drivers also benefit from not having to pay tolls if enough people are in the vehicle. Carma has also offered a one-time \$50 incentive for those signing up for the app.

The numbers of vehicles that could be removed from the road due to the levels of TDM investment in Table 6 compare favorably with the additional vehicles that would be shifted into remaining general purpose lanes if one lane in each direction was converted to a managed lane (see Table 7). The total number of additional vehicles (in the northbound and southbound directions) in the general purpose lanes (447+181=628) is approximately half the number of vehicles that could be reduced due to aggressively expanding the EcoPass program. This indicates that, if the managed lanes are paired with aggressive TDM measures, there would potentially be no additional congestion in the remaining general purpose lanes.

Table 6 | Summary Table of Quantifiable Mobility Improvement Measures

	Expanded EcoPass	Expanded Vanpool	Expanded Carpool	Reduced Light Rail Fare (20%)
Reduced Vehicles During Peak Hour	1,288	218	266	59
Reduced Vehicles Per Lane	161	27	33	7
Annual Cost (approximate)	~\$6.1 million	~\$1 million	~\$750,000	~\$4.6 million
Cost per Reduced Peak Hour Vehicle	~\$4,800	~\$4,600	~\$2,800	~\$79,000

Table 7 | Displaced Vehicles Due to Managed Lanes

	Northbound GP Lanes	Southbound GP Lanes
Vehicles/Lane during Peak Hour	1,847	1,581
Vehicles/Managed Lane during Peak Hour	1,400	1,400
Vehicles Displaced to Remaining GP Lanes	447	181
Displaced Vehicles Per GP Lane	112	65

Additional Efforts to Improve Mobility in the Corridor

There are a number of additional TDM efforts that could be undertaken to help reduce peak period vehicle trips along the corridor. Examples include telecommuting and shifting commute times. The Denver South TMA recently published a report that examines additional ideas for improving mobility and connectivity in the corridor.²⁶

As part of its RoadX program, CDOT has also undertaken a six month ramp metering pilot project called the Managed Motorways Project.²⁷ The project will use real time traffic data on a 15-mile section of I-25 south of downtown to adjust the ramp meter timing to enter the interstate; if traffic is slowing in a given area, ramp times can be adjusted to help reduce congestion in that area. This ramp metering program is one component of an Intelligent Transportation Systems (ITS) project in Australia that incorporates additional measures such as “variable speed limits, dynamic lane control, expedited incident management and use the use of hard shoulder lanes during peak periods.”²⁸ The Australian program has led to 25 percent higher throughput during peak travel times. CDOT does not have plans to add on other elements of the Australian program at this time. However, there may be significant synergies if the Managed Motorways approach were combined with a HOT lane conversion and investment of toll revenues in TDM programs.

Potential Revenue Generation from HOT Lanes

In evaluating the inclusion of a managed lane on I-25, it is useful to consider how much revenue could be generated by the collection of tolls. Revenue generated from the managed lanes could be used to support TDM which aims to adopt strategies and policies that promote transit, walking, biking, ridesharing and teleworking. Increased TDM efforts will reduce the number of single occupancy vehicles, thereby helping to improve mobility along the corridor. The estimates made below are a rough estimate of the magnitude of revenue that could be generated through managed lanes.

²⁶ Denver South Transportation Management Association. 2016. South 1-25 Urban Corridor Study.

²⁷ Colorado Department of Transportation. 2016. Colorado's Vision: RoadX.
https://www.codot.gov/programs/roadx/roadx-vision/at_download/file.

²⁸ ENR Mountain States. 2015. CDOT Will Pilot First-Time Use in the U.S. of Australian Traffic Management Technology.
<http://www.enr.com/articles/37556-cdot-will-pilot-first-time-use-in-the-u-s-of-australian-traffic-management-technology>.

While it is impossible to predict exactly what mixture of paying and non-paying (HOV3) vehicles would make use of the managed lane, we can make an estimate based on experience in other corridors.²⁹ Along Georgia's Interstate 85 in Atlanta, HOV lanes were converted in 2011 to HOT lanes requiring three or more passengers to avoid paying a toll. Over the last year, approximately 14 percent of vehicles using the HOT lanes have not paid a toll; the vast majority of these are vehicles with three or more passengers. The remaining 86 percent of vehicles are assumed to pay a toll for use of the HOT lane.

If this 86/14 percent split is applied to the potential I-25 managed lanes, we can make an estimate of the revenue that the lane could generate. If 86 percent of the 2,000 vehicles using the toll lane per hour were paying the toll, (i.e., 1,000 in each direction, assuming that the managed lanes will not be full) then that would be 1,720 vehicles per hour.

While corridor-specific tolling rates would need to be developed for this section of I-25, we can use the current rates on the I-25 HOT lanes north of downtown Denver to help make an estimate of revenue. Drivers on the I-25 Express Lanes currently pay an average of \$0.383 per mile during peak periods.³⁰

The length of the T-REX corridor is approximately 13.5 miles, which means the average vehicle would pay \$5.09 for use of the lane. Assuming a \$5 toll for the corridor, 1,720 vehicles would generate \$8,600 per hour during peak periods. There would be a total of 8 peak hours in each direction, which would result in \$69,000 daily revenue generated during peak periods.³¹

The vast majority of toll paying vehicles would be during peak hours but based on the patterns in the I-25 Express Lanes there will be some number of drivers willing to pay to use the lanes during off-peak hours. On the I-25 Express Lanes, 85 percent of vehicles that pay the toll use the lanes during peak travel periods. If the same percentage held true for the T-REX managed lanes, then we could expect to see 32,428 vehicles paying to use the HOT lanes during off-peak periods. The I-25 Express Lanes currently charge off-peak vehicles \$0.106 per mile so a similarly priced trip on the T-REX corridor would cost \$1.40. Therefore, these off peak vehicles would bring in an estimated \$3,400 daily.

On weekends, the number of toll payers per day on the I-25 Express Lanes drops to approximately 11 percent of the weekday volume. If we assume the same ratio, there would be an estimated 1,780 paying users on an average weekend day. This would result in an additional \$2,500 in revenue for each weekend day.

Due to uncertainties regarding the assumptions made above we have assumed a range around these estimates to provide a rough estimate of total revenues.

²⁹ To date, no corridors in Colorado have begun to require three or more passengers in vehicles to use managed lanes free of charge. Therefore we have looked at what data is available outside of Colorado to make assumptions about HOV percentages in managed lanes.

³⁰ This is the average rate for drivers who have a transponder. Toll rates are higher for other users.

³¹ There are currently eight hours of low, mid and high-peak pricing on the I-25 Express Lanes throughout the day. From 6 AM to 10 AM and from 3 PM to 7 PM. All other hours are the off-peak price.

While this is only a very rough estimate of the potential revenue from the managed lanes, it does seem to indicate that \$13-20 million would be available annually to fund both TDM efforts along the corridor and to pay for the construction and maintenance of the managed lanes.

Table 8 | Estimate of Annual Revenue from HOT Lanes

	Number of Paying Vehicles	Toll per Vehicle	Total per Day	Estimate of Annual Total
Weekday Peak Period	10,000-15,000	\$5.00	\$50,000-\$75,000	\$12.5-\$18.7 million
Weekday Off Peak Period	2,000-4,000	\$1.40	\$2,800-\$4,200	\$700,000-\$1.1 million
Weekend Day	1,000-2,000	\$1.40	\$1,400-\$2,800	\$160,000-\$320,000
Total				\$13.3-20.1 million

Cost of Managed Lanes

An exact estimate of the costs of converting one lane in each direction of I-25 to a managed lane is not possible in this report because there is very little experience of converting a general purpose lane to an HOT lane. In almost all situations, an HOT lane has been converted from an existing HOV lane or has been built as a new lane.³² Therefore, it is difficult to make an accurate estimate of the cost of creating some kind of separation or buffer for an HOT lane along with tolling capacity. One former CDOT official estimated that the total conversion and technology costs would be approximately \$5 million per mile, or \$65 million for the whole corridor.³³

Some costs from the recently completed US-36 HOT lanes provide some insight into elements of the costs of converting and operating the T-REX corridor. The US-36 HOT lanes had a capital cost of \$18.5 million for tolling equipment for a project covering 18 miles. The T-REX corridor analyzed in this report is 13.5 miles long; assuming a similar cost per mile, the costs for tolling equipment would be approximately \$13.5 million, or \$500,000 per lane mile.

The operating and maintenance costs of the US 36 HOT lanes are projected to be \$3.4 million. Almost half of this (\$1.6 million) cost goes towards repayment of the loan that was used to purchase the tolling equipment so this may or may not be applicable to the I-25 project, depending on how the tolling equipment is financed. The remaining costs are \$1.4 million annually for operations and \$150,000 per year for enforcement. We can assume that the I-25 corridor would have slightly lower maintenance costs due to its shorter length.

While both the estimates of potential revenue from HOT lanes and the potential costs of converting the lanes are speculative, they show it may be possible to use HOT lane revenue to convert the lanes, operate them and still have surplus revenue that could be invested in the TDM strategies discussed previously.

³² Two exceptions, one in the state of Washington and one in Minnesota, are discussed below.

³³ Email correspondence with former CDOT official who wished to be anonymous.

IV. LEGAL AUTHORITY UNDER STATE AND FEDERAL LAW

The Funding Advancements for Surface Transportation and Economic Recovery (FASTER) Act of 2009 states that the High Performance Transportation Enterprise (HPTE) created by FASTER has the authority to “impose user fees on a highway segment or highway lanes that have previously served vehicular traffic on a user-fee free basis.” The conditions to be met include receiving federal approval and the approval of impacted local governments. Under FASTER, the HPTE is also allowed to invest user fee revenue in “multi-modal transportation projects that promote mobility.” CDOT would need to receive approval from the federal government, whenever an existing interstate lane is converted to a managed lane.

CDOT has already considered converting one existing lane to a managed lane on I-25 between Highway 7 and Highway 66. This stretch of interstate already has three lanes in each direction (which is CDOT’s vision for the entire corridor between Denver and Fort Collins) so there was discussion of converting one lane in each direction to a managed lane. The revenue generated from the managed lanes would have been used to help develop a public-private partnership to add a third lane throughout the corridor. However, this proposal did not move forward due to objections by local governments along the corridor.

Generally, the Federal Highways Administration (FHWA) does not allow tolls to be charged on existing interstate capacity. However, with the approval of the Secretary of Transportation, the FHWA’s Value Pricing Pilot Program (VPPP) can grant an exemption to allow the imposition of tolls on existing capacity as a congestion management strategy.

To date, Washington State DOT and Minnesota DOT have used this program to convert a general purpose lane to a managed lane. In Washington this was done on SR 520 in Seattle and in Minnesota on I-35E. To participate in the VPPP program, CDOT would need to obtain one of a limited number of spots in the program (there are currently several openings) and would need to provide documentation, such as a transportation study demonstrating how conversion to a managed lane would benefit the corridor.

V. HOT LANE CONVERSIONS IN OTHER AREAS

In 2015, a managed lane was created by converting an existing HOV lane to a managed lane on I-405 outside of Seattle. The new managed lanes allow carpoolers with at least three people to use the lanes for free and drivers with lower occupancies can pay a variable toll to use the lane. Transit buses also make use of the new managed lane. Area transit systems have seen both decreased travel times and increased ridership.³⁴ On I-405, the new managed lane has improved travel times for the express lane users but also for those using the general purpose lanes in most sections.³⁵

³⁴ Seattle Times. February 3, 2016. “Outraged Drivers May Get Some Relief from I-405 Tolls.

<http://www.seattletimes.com/seattle-news/transportation/state-may-lift-i-405-tolls-at-night-on-weekends-holidays/>.

³⁵ Washington State Department of Transportation. 2016. Washington State Transportation Commission. I-405 Express Toll Lanes. https://res.cloudinary.com/sagacity/image/upload/v1463775799/Item_7_I405_SixMthUpdate_qcgrvy.pdf.

The possibility of converting a general purpose lane to a managed lane is being considered along the Highway 101 corridor connecting San Francisco and Silicon Valley. Like I-25 in Denver, this corridor is already experiencing high levels of congestion and anticipates significant growth over the next decade. This conversion is proposed as a low-cost alternative to highway expansion. With the money saved from lower costs and additional revenue generated from the managed lanes, the region could invest in TDM alternatives such as expanded public and private transit, vanpools and carpools. Conversion to a managed lane along with aggressive TDM is estimated to decrease the number of vehicles on the road while increasing the number of people using the corridor. A recent analysis by the area's Metropolitan Transportation Commission concluded that an "optimized HOT lane" conversion was the best option for Highway 101.³⁶

IV: CONCLUSION: HOW MANAGED LANES CAN IMPROVE TRAVEL FOR EVERYBODY

With already high levels of congestion and significant barriers to additional highway expansion, the portion of the I-25 corridor between 6th Avenue and 470 presents a challenge to transportation planners. And as population and employment increases along the corridor, issues of congestion are only expected to become worse.

The conversion of one lane in each direction to a managed lane and the dedication of the revenue earned from tolling to aggressive TDM measures offers the opportunity to increase the number of people using the corridor while limiting the growth of congestion.

Managed lanes will provide both a congestion-free alternative for drivers and a funding source to increase access to transit via improving first and last mile infrastructure, issuing more EcoPasses for the corridor's employees, and expanding employer-based shuttles. Expanded carpool and vanpool programs will also increase vehicle occupancy, meaning more people will be able to make use of the existing roadway capacity. In an environment of limited funding for transportation projects, the conversion to managed lanes can be accomplished at the fraction of the cost of any significant highway additions or expansion. And the conversion can be implemented much sooner, providing both short and long term improvements to mobility along the corridor.

³⁶ Transform. 2015. MTC Analysis Confirms: Optimized HOT is the Best Choice for Highway 101. <http://www.transformca.org/transform-blog-post/mtc-analysis-confirms-optimized-hot-best-choice-highway-101>.

APPENDIX: METHODOLOGY TO REPRESENT/CHARACTERIZE EXISTING CONDITIONS ON THE T-REX CORRIDOR

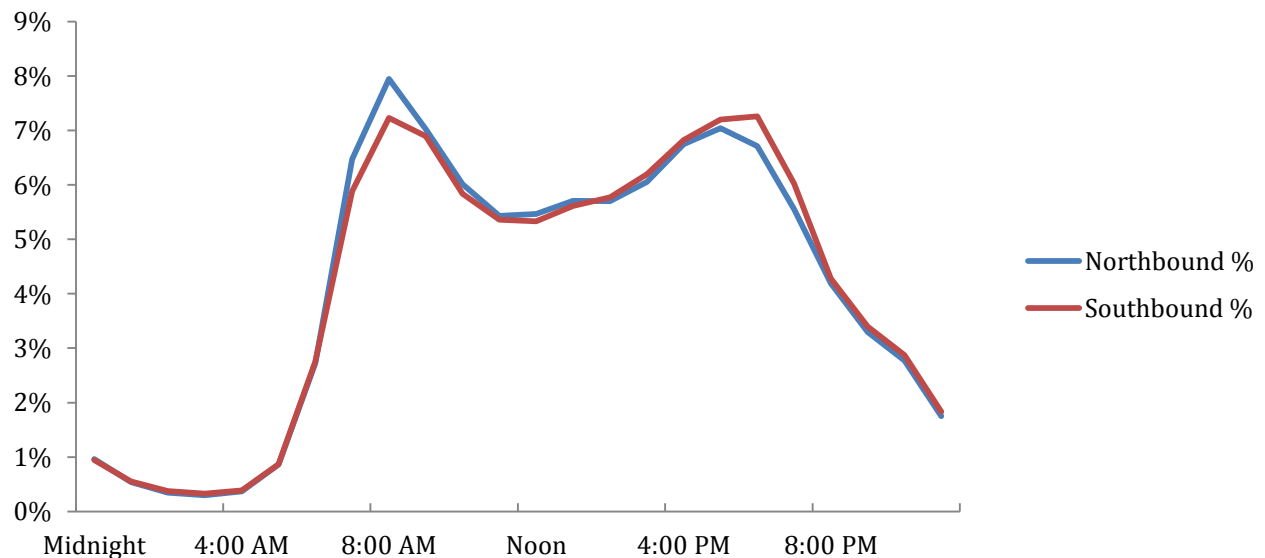
CDOT provides data on the average annual daily traffic (AADT) for roadways across the state. While this measure gives an idea of the volume of daily traffic on each roadway, it is necessary to look at roadway volumes during peak traffic hours in order to understand congestion.

CDOT maintains a system of permanent and temporary traffic counters on the state highway system that provide data on hourly traffic volumes. Unfortunately, there are no permanent traffic counters set up in the T-REX project area. However, there are two on either end of this zone: one is located just south of the intersection of I-25 and 6th Ave and the other just south of the intersection of I-25 and 470. In the T-REX corridor, the last continuous counts covering a full 24 hours were conducted in the fall of 2010.

Applying the hourly traffic patterns from 2010 to the most current AADT estimates along the corridor allows us to get an idea of the number of vehicles using the corridor during peak and off-peak periods.

Using data from 15 short-duration counters (from the fall of 2010) we can see when peak traffic conditions occur on along the corridor. For Figure A-1, the sums of the traffic volumes for each hour were calculated from the 15 traffic counters; the percentage of total traffic occurring each hour is shown. One can see that the northbound and southbound routes follow very similar peak traffic patterns. In the morning, peak traffic occurs from 7:00 AM to 10:00 AM, with the highest level at 8:00 AM for both north and southbound lanes. During the afternoon, the peak period occurs between 3:00 PM and 7:00 PM, with the greatest volumes at 5:00 PM and 6:00 PM.

Figure A-1 | Percentage of Total Traffic Volume by Hour for the Entire T-REX Corridor



The 2014 AADT for each road segment was then matched up with the 24 hour traffic pattern from 2010 to develop a distribution for the 2014 AADT.

For example, the 2014 AADT (173,000) for the interstate segment between miles 194.3 and 195.1 (just north of 470) was applied to the 24-hour traffic count taken at the same location in 2010. From the 2010 traffic count, there was a 50/50 split in total northbound and southbound traffic at this site. We focused our analysis only on the AM Peak to simplify the process; the AM and PM peaks were fairly similar although the AM peak was slightly higher. Over this stretch of highway, 9.9 percent of total northbound traffic took place during the morning peak hour between from 8:00 AM to 9:00 AM. For southbound traffic, 9.6 percent took place during the morning peak hour. This allows us to estimate the total number of vehicles using this section of I-25 during the AM peak hour; 8,642 northbound vehicles and 8,333 southbound vehicles. To better characterize how these vehicles would be spread over the roadway, data for the total number of thru and auxiliary lanes was taken from CDOT's database for each segment of road. As there were generally several shifts in the number of lanes over the area covered by one traffic counter, each vehicle count would be applied to several roadway configurations. For example, in the segment between miles 194.3 and 195.1, the road goes from three to five through lanes and the number of auxiliary lanes varies between zero and three. So even though this stretch of interstate has the two vehicle counts cited earlier, the number of vehicles per lane per hour varies as the number of lanes changes. For this one segment of the interstate, the average vehicles per lane during peak hour would be 1,870. Therefore, we are able to make an estimate of the number of vehicles per hour per lane for each road segment.³⁷

After doing this analysis for each segment of roadway we calculated the average volume per lane during traffic's peak hour for the extent of the T-REX project. For southbound traffic, an average of 1,581 vehicles per lane occurs during peak hour. For northbound traffic, this figure is 1,847 vehicles per lane.

Over the entire interstate segment, auxiliary lanes handle an average of approximately 1,100 vehicles per lane per hour due to there being stretches without any auxiliary lanes.

While this segment of roadway is already congested, by 2035 traffic volumes will be projected to be 37 percent higher. CDOT projects that the average AADT for the entire corridor will increase from 211,000 in 2014 to 289,000 in 2035. If all of this new traffic demand were to be absorbed by the highway's existing lanes and evenly distributed throughout the day, we estimate that by 2035, there would be an estimated 2,503 vehicles per lane going southbound and 2,579 vehicles per lane going northbound during the peak hour. As these numbers are beyond the capacity that a highway could reasonably serve it seems likely that the high levels of congestion would reduce the number of vehicles per hour.

³⁷ Auxiliary lanes are estimated to carry 95% of the volume of thru lanes. Transform. 2013. Innovation Required: Moving More People with Less Traffic. <http://www.transformca.org/resource/innovation-required-moving-more-people-less-traffic>.

Table A-1 | Average Vehicles per Lane During Peak Hour Over the Entire Corridor

	2014	2035
Northbound	1,847	2,579
Southbound	1,581	2,503

Table A-2 | Level of Service Classifications used for the Level of Service shown in Figures 2 and 3³⁸

Level of Service	Vehicles per Lane per Hour
A	0-660
B	661-1,100
C	1,101-1,510
D	1,510-1,800
E	1,801-2,100
F	2,100+

³⁸ City/County Association of Governments of San Mateo County. 2014. Traffic Level of Service Calculation Methods. ccag.ca.gov/wp-content/uploads/2014/07/cmp_2005_Appendix_B.pdf.