Qualitative Analysis of the Potential Regional Air Quality Impacts of HOT Lanes on the Capital Beltway in Virginia

Prepared by the

Metropolitan Washington Council of Governments

for Fluor Daniel

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1 Executive summary

Fluor Enterprises, Inc. (Fluor Daniel) is studying the feasibility of high-occupancy toll (HOT) lanes in the Washington, D.C. area. A HOT lane is a limited-access, buffer- or barrier-separated highway lane that provides free or reduced cost access to qualifying high-occupancy vehicles (HOVs) and provides tolled access to other vehicles that do not meet the passenger occupancy requirements. A HOT lane facility consists of one or more HOT lanes and is usually in the median of or adjacent to one or more lanes of general purpose (GP) traffic. Fluor is looking at the possibility of HOT lanes on the Capital Beltway (I-495) in Virginia, between Georgetown Pike and the Springfield interchange (I-395). The facility, which would open in 2009, would have 2 HOT lanes in each direction in the median of the Beltway, adjacent to 4 lanes in each direction of GP traffic.

This study is divided into two parts. The first part of this study is an investigation of experience elsewhere with HOT lane facilities. Currently there are only four operational HOT lane facilities in the United States:

- State Route 91 (SR-91) Express Lanes – Orange County, California
- I-15 FasTrak – San Diego, California
- Katy Freeway (I-10) QuickRide – Harris County, Texas
- Northwest Freeway (US-290) QuickRide – Harris County, Texas

The second part of the study involves using a sketch planning technique to estimate the average peak-hour volumes on the new facility and the likely resulting air quality mobile emissions impacts. Given the limited resources of this project, it was decided that there would be no new runs of the COG/TPB travel forecasting model (the "4-step model"). Instead, we would use the output from existing runs of the 4-step model as the input to our sketch planning analysis. The model outputs (daily link volumes for various segments of the Beltway) came from the latest air quality conformity analysis of record, that is the Air Quality Conformity Determination of the 2002 Constrained Long-Range Plan and the FY 2003-2008 Transportation Improvement Program. In this analysis, the following model runs were conducted: 2002, 2005, 2015, 2020, and 2025. Since 2015 was the first model year following the proposed 2009 opening date, we used model outputs from the 2015 highway network. The 2015 baseline configuration of the Beltway in Northern Virginia is 4 lanes of GP traffic in each direction and 1 lane of HOV3+ traffic in each direction. So the Fluor proposal would convert 1 lane of HOV3+ to HOV3+/HOT and add 1 lane of HOV3+/HOT traffic in each direction.

The emissions analysis described in this report assumes that there would be two distinct effects on emissions:

- Effect of lane management on speeds (Could increase or decrease emissions)
- Effect of adding highway capacity (Would likely increase emissions).

The basic methodology was as follows:

<u>Demand forecast</u>

- Three segments of the facility were chosen as representative of the whole facility. The proposed facility would traverse a section of the Beltway with 9 highway segments and 8 interchanges. The three representative segments were chosen to be:
  - Georgetown Pike to the Dulles Access/Toll Road (northern end of the facility)
  - VA Route 7 to I-66 (one of the heaviest volume segments)
  - Braddock Road to I-395 (southern end of the facility)
- Obtain estimated 2015 daily traffic volumes for the baseline configuration (HOV only) from the latest COG travel model runs.
- Convert the daily traffic to peak-hour traffic volumes.
- Assume that the HOT lanes could operate at a service flow rate of 1,600 passenger cars per hour per lane and still maintain the proposed 65 mph speed on the HOT lanes.
- Three forecasts of traffic under the HOT lane scenario were developed: a low, medium, and high forecast. In all three forecasts, we assume that traffic would be diverted from the GP lanes to the HOT lanes, and that the HOT lanes would fill up to their maximum service flow rate of 1,600 v/hr/ln. Since there are two HOT lanes in each direction, the capacity and flow rate of the HOT lanes becomes 3,200 v/hr in each direction. Thus, the difference between the three forecasts is not the level of traffic on the HOT lanes, which is always 3,200 v/hr, but rather the level of traffic on the adjacent GP lanes:
  - <u>Low forecast</u>: Assumes that, after traffic diverts from the congested GP lanes onto the free-flowing HOT lanes, the GP lanes do not fill up with any new traffic. The increase in traffic on the HOT lanes is equal to the decrease in traffic from the GP lanes. Consequently, there is no net increase in traffic on the Beltway.
  - <u>Medium forecast</u>: Assumes that, after traffic diverts from the congested GP lanes onto the free-flowing HOT lanes, the amount of traffic in the GP lanes increases by an amount equal to the capacity of the added lane of traffic in each direction (i.e., increases by 1,600 pc/h in each direction). This increase in traffic on the GP lanes would be due to traffic diverted from nearby arterials and/or induced traffic. Consequently, there is a net increase in traffic on the Beltway, compared to the base case.
  - <u>High forecast</u>: Assumes that, after traffic diverts from the congested GP lanes onto the free-flowing HOT lanes, the amount of traffic in the GP lanes increases, and returns to the same level of congestion as was found in the baseline case. This increase in traffic is equal to 3,200 v/hr minus the baseline HOV traffic, in each direction. Once again, this increase in traffic on the GP lanes would be due to traffic diverted from nearby arterials and/or induced traffic. Consequently, there is a net increase in traffic on the Beltway, compared to the base case.

<u>Emissions forecast</u>

- Calculate the volume-to-capacity ratio, speed, and LOS for each segment.
- Using average values for volume-to-capacity ratio, speed, and LOS , calculate the total running emissions for a peak hour for two pollutants: volatile organic compounds (VOC) and oxides of nitrogen (NOx).

Findings

A sketch planning technique was used to estimate both travel demand and mobile emissions for the 14-mile segment of the Beltway that would comprise the HOT lane facility. There were four demand forecasts and four emissions forecasts: base, action low, action medium, and action high. The medium and high demand forecasts were deemed to be the most likely of the three action or "build" scenarios.

- The proposed HOT lane facility would likely result in a slight increase in volatile organic compounds (VOC) – about 6% during the peak hour for the facility itself and about 0.05% on a daily basis at the regional level.

- The proposed HOT lane facility would likely result in a moderate increase in oxides of nitrogen (NOx) – about 15% during the peak hour for the facility itself and about 0.57% on a daily basis at the regional level.

- The foregoing emissions estimates are conservative, i.e., likely to overestimate emissions, because the increase in VMT in the medium and high travel forecasts is treated as 100% induced demand, meaning that it is all new VMT, not simply VMT moved from other facilities.

- The proposed HOT lane facility would likely result in three main benefits to users of the facility and its adjacent general purpose lanes on the Beltway:

    - <u>More travel choices</u>: In the base scenario, a user of this section of the Beltway had two travel options: SOV or HOV3+ (which includes 3+ person carpools, vanpools, and buses). In the action scenario, a user now has two new travel options: "SOV pay toll," and "HOV2 pay toll."

    - <u>Travel time savings</u>: In the base case, using the managed (HOV) lanes would save about 2.6 minutes over using the GP lanes, assuming one travels the full 14-mile segment. In the three action scenarios, using the managed lanes would save from 2.6 minutes to 4.8 minutes. However, simply stating the average time savings during the peak period for the base and action scenarios *understates* the total travel time benefit to users. For example, in the base case, only *one* class of users (HOV3+) could benefit from the 2.6-minute time savings, resulting in about 11,000 person-minutes of time savings, assuming an average vehicle occupancy of 3.6 persons per vehicle in the HOV3+ lanes. By contrast, in the action case, *three* classes of users (HOV3+, SOV pay toll, and HOV2 pay toll) could benefit from the 4.8-minute time savings (high forecast), resulting in about 43,000 person-minutes of time savings, assuming an average vehicle occupancy of 1.4 persons per vehicle in the HOT lanes. So the time savings in terms of person-minutes increases by a factor of about 4. Additionally, the aforementioned travel time savings represent the peak hour of an *average weekday* with no traffic incidents. On a day where there is a major incident, the travel time savings in the managed lanes will likely be much more than 4.8 minutes.

  - Consistency and dependability in travel times: The proposed HOT lane facility would maintain good levels of service on the managed lanes (anywhere from A to C) and would likely improve the level of service on the adjacent GP lanes, as compared to the base case. Users of existing HOT lane facilities in other states often report that one of the main perceived benefits of traveling on the HOT lanes is, in fact, the travel time dependability, which is ensured thanks to the variable pricing of the lanes.

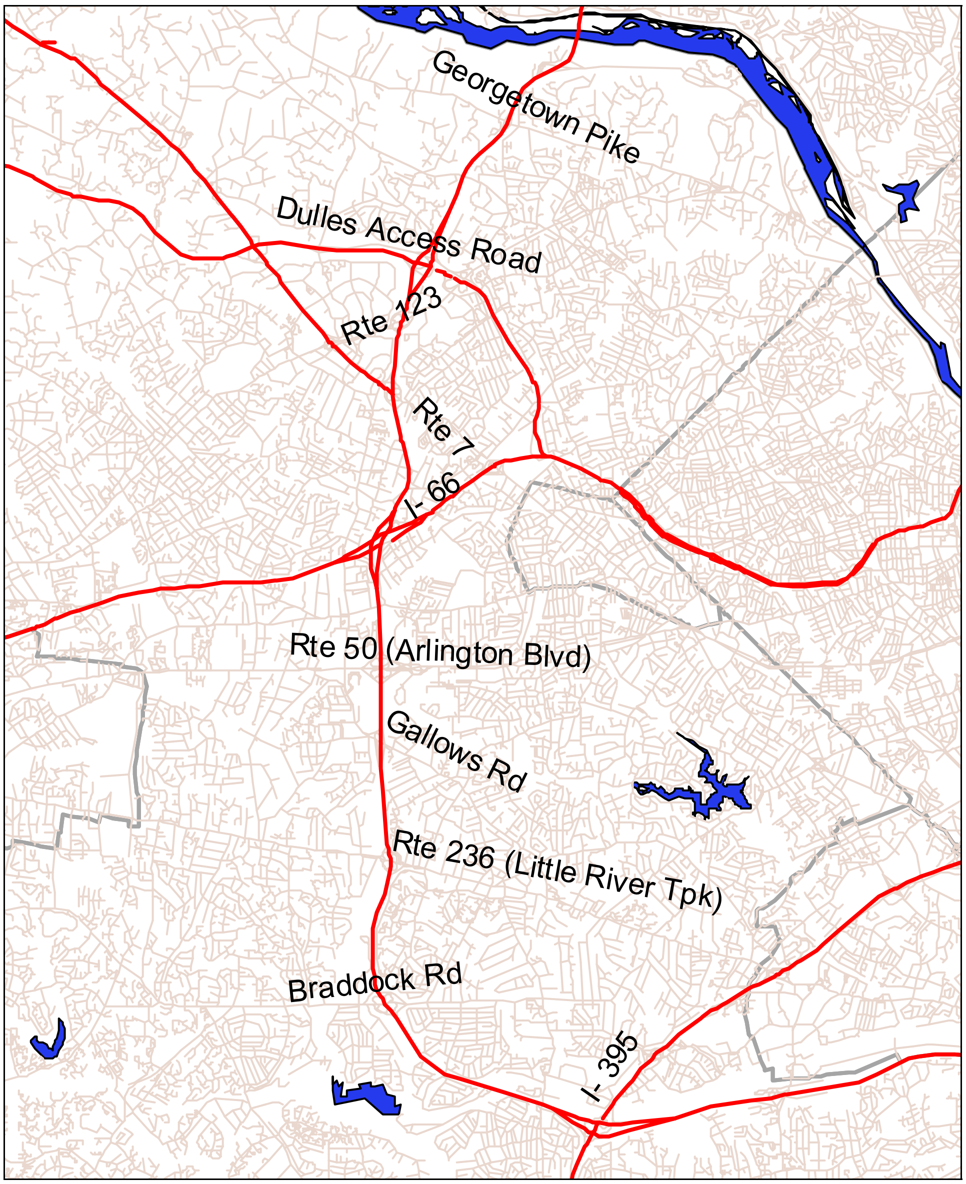
- Although the proposed HOT lane facility would result in both travel time savings and more consistent travel times, there would be even more user benefits if a *network* of HOT lanes were built in the region. Such a system is currently being proposed as a scenario for testing in the Regional Mobility and Accessibility Study, being conducted at Metropolitan Washington Council of Governments.

2 Scope of this study

2.1 Background

Fluor Enterprises, Inc. is studying the feasibility of high-occupancy toll (HOT) lanes in the Washington, D.C. area. Specifically, the firm is looking at the possibility of HOT lanes on the Capital Beltway (I-495) in Virginia, between Georgetown Pike and the Springfield interchange (I-395), shown in Figure 1. This conceptual proposal, which was submitted under Virginia's Public-Private Transportation Act, is being reviewed by VDOT.

Figure 1 Proposed HOT lane facility on I-495 from Georgetown Pike to I-395



Fluor is seeking a qualitative analysis of the air quality aspects of the Capital Beltway HOT lane concept as it relates to the TIP and projected regional air quality. The proposed HOT lanes would consist of two new lanes in each direction, located in the center of the Beltway, separated from the conventional lanes by a two to four-foot wide paved buffer area. On either side would be the existing four general-purpose traffic lanes. The final Beltway configuration would be 4-2-2-4 for a total of twelve lanes, four new and eight existing.

Access would be available at each end of the HOT lanes and at five intermediate locations. High-occupancy vehicles with three or more passengers (HOV-3), public buses, and emergency vehicles could use the HOT lanes without charge, while other vehicles would pay a toll that varies with the time of day. Direct access for HOV/HOT traffic would be constructed at the Dulles Airport Access and Toll Road and at the I-66 interchange. Three additional concurrent accesses, created by a break in the buffer area and upgradable to direct access connections, would be provided at Route 123, Braddock Road, and U.S. Route 50.

Operation of the HOT lanes would be 24 hours a day, seven days a week. Through use of a toll tag system comparable to that in use on the Dulles Toll Road, non HOV-3 motorists could use the road by paying a variable toll. Trucks would be prohibited from using these lanes, and speeds would be posted at least 10 mph higher than those posted in the adjacent conventional lanes. The toll rate would be set to ensure that users would be able to operate at the posted speed limit at all times. Fluor has assumed the initial maximum tolls would be $5.00 for 2009 and $6.00 for 2015. Initial off-peak tolls would be $1.00 for 2009 and $1.25 for 2015. Bus routes are anticipated to use the HOT lanes, generating 20 buses per hour during the peak and 7 buses per hour during the off-peak, based on existing bus service. Adding routes is anticipated to increase these figures by 24 buses per hour and 16 buses per hour, respectively.

2.2 Task 1— Investigation of Experience Elsewhere with HOT Lanes

Since HOT lanes are not currently being operated in the Washington region, TPB Staff will conduct a search of experience elsewhere. This will focus on the operating HOT lanes in San Diego, Los Angeles, and Houston, but will extend to other areas that investigation suggests should be pursued. Information that will be sought will include the performance of these HOT lane facilities, any data gathering (e.g. before and after surveys) that had been performed, and reviews in the literature regarding HOT lanes, including any emerging technical analysis methods. Information obtained from this investigation will be documented as a chapter in the final report to Fluor.

2.3 Task 2— Qualitative Analysis of HOT Lane Proposal for the Capital Beltway

Given the configuration described in the background section above, TPB Staff will conduct an analysis of likely impact of implementation of the HOT lane proposal for the Capital Beltway in Virginia. No detailed modeling of these lanes will be undertaken. Rather, it will be assumed that the facility will operate as specified by Fluor. Consequently, the performance of the adjacent conventional lanes will be estimated. This assessment will include likely level of service on both HOT lanes and conventional lanes and the likely resulting direction for regional

NOx and VOC emissions. The analysis will be for the year 2015 since this is the first analysis year beyond 2009 for which baseline emissions in the TIP and CLRP are available. The configuration of the Capital Beltway in the CLRP for that year is 4 lanes in each direction for mixed traffic, with one lane in each direction for HOV traffic between the Springfield Interchange and the American Legion Bridge.

2.4 Task 3— Findings Report

This report documents all of the information developed in Tasks 1 and 2.

3 Investigation of experience with HOT lanes around the U.S.

3.1 Introduction

A high-occupancy toll (HOT) lane is a limited-access, buffer- or barrier-separated highway lane that provides free or reduced cost access to qualifying high-occupancy vehicles (HOVs) and provides tolled access to other vehicles that do not meet the passenger occupancy requirements. A HOT lane facility consists of one or more HOT lanes and is usually in the median of or adjacent to one or more lanes of general purpose (GP) traffic. An HOV is defined as a carpool, a vanpool, or a bus. Traffic flow on a HOT lane is managed via the passenger occupancy requirement and the toll value, which typically varies throughout the day. The time-of-day toll variability can be either fixed or dynamic. A dynamic time-of-day toll is varied actively throughout the day, based on actual traffic congestion levels. A fixed time-of-day toll has pre-set values that can be published beforehand and are set based on historical patterns of congestion. Other terms used in relation to HOT lanes are "managed lanes," "value pricing," and "congestion pricing."

There are only four HOT lane facilities that are currently operating in the United States:

- State Route 91 (SR-91) Express Lanes – Orange County, California
- I-15 FasTrak – San Diego, California
- Katy Freeway (I-10) QuickRide – Harris County, Texas
- Northwest Freeway (US-290) QuickRide – Harris County, Texas

The last two facilities are both in the Houston, Texas area.

These four facilities share a number of similarities with each other (Perez and Sciara 2003). First, they are physically separated from the parallel general purpose (GP) lanes by continuous concrete barriers or a fence of collapsible pylons. Second, they each use fully automated electronic toll collection, with access restricted to HOVs and non-qualified, paying vehicles equipped with transponder tags. Thus, there are no tollbooths or queues associated with manual toll collection. Last, all systems have an information system of fixed or variable signs to provide users with information about access, occupancy requirements, hours, prices, and enforcement.

There are also a number of differences between these four facilities. The HOT lanes vary in width from one to four lanes (two in each direction). On the I-15 FasTrak in San Diego, HOV vehicles ride for *free*, while SOVs pay a toll. On the SR-91 Express Lanes in Orange County, HOV3+ carpools pay *reduced* tolls. In the Houston QuickRide program, which operates on both the Katy Freeway and US-290, HOV3+ vehicles ride for *free*, but HOV2 vehicles *pay* for use. I-15 FasTrak uses tolls whose value is dynamically adjusted every 6 minutes, whereas the rest of the facilities use fixed tolls whose value is a set amount given the time-of-day of the trip. Ownership and operating structures vary widely, from for-profit private developers to local planning organizations, transit agencies, or stated departments of transportation. Below is a brief description of each of the four facilities.

3.1.1 State Route 91 (SR-91) Express Lanes - Orange County, California

Opened in 1995, the SR-91 Express Lanes facility was the first HOT lane facility to open in the U.S. The facility is 10 miles long, has 2 lanes in each direction, and is located in the median of SR-91. Since SR-91 has 4 general purpose (GP) lanes in each direction, the total width of SR-91 is 12 lanes. On a typical day, roughly 250,000 vehicles use SR-91. Before the 91 Express Lanes opened, peak period delays of 20 to 40 minutes were common. The HOT lanes are separated from the GP lanes by a 2-foot buffer area highlighted by yellow, flexible pylons. Toll rates on the Express Lanes vary from $1.00 to $4.75 by time of day and day of week. Tolls for HOV3+ vehicles are reduced by 50%. Customers must have a transponder to use the facility. Two different views of the SR-91 Express Lanes are shown in Figure 2 and Figure 3. The SR-91 Express Lanes project was awarded on a concession basis to a private consortium, California Private Transportation Company (CPTC), which financed, built, and operated the new lanes, using project revenues to repay its debt and derive profit (Perez and Sciara 2003). Note that there is a system of public toll roads (about 67 miles) in Orange County, which are managed by the Transportation Corridor Agencies (TCA) (http://www.tcagencies.com/). This system of toll roads connects with, but does not include, SR-91. Both the toll road system and SR-91 are shown in Figure 4. In January 2003, CPTC sold the HOT lane facility to the Orange County Transportation Authority (OCTA).

Figure 2 SR-91 Express Lanes.

Overhead devices for electronic toll collection. Left lane is for HOV3+, which receives a 50% discount.

Source: Federal Highway Administration, Excellence in Highway Design, http://www.fhwa.dot.gov/eihd/91exp.htm

Figure 3 SR-91 HOT lanes

(Express Lanes to the left; General purpose lanes to the right)

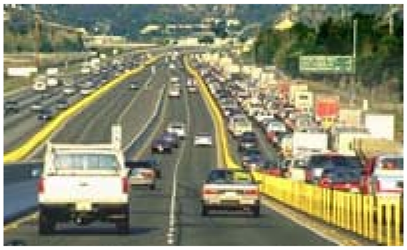


Photo courtesy of California Private Transportation Co.

Figure 4 Toll roads in Orange County, California.

SR-91 is at the top of figure. Public toll road network is south of SR-91.

Source: Federal Highway Administration, Excellence in Highway Design, http://www.fhwa.dot.gov/eihd/91exp.htm

3.1.2 I-15 FasTrak - San Diego, California

The I-15 FasTrak HOT lane facility was developed by converting an underutilized pre-existing 8-mile, 2-lane (reversible) HOV facility to peak-period reversible HOT. The HOT lane facility opened in 1996. The HOV facility had been operating since 1988. The I-15 FasTrak program allows SOVs to use the facility by paying a toll of $0.50 to $4.00 ($8.00 in extreme congestion); HOV2 and HOV3+ carpools travel for free. Customers must have a transponder to use the facility. The project is sponsored by the San Diego Association of Governments (SANDAG), the local metropolitan planning organization (MPO), which has earmarked a significant portion of the revenues derived from the HOT lane to fund transit improvements in the I-15 corridor. The lanes operate only during peak hours in the direction of the commute. From 5:30 AM to 11 AM, all vehicles in the HOT lanes travel southbound; from 11:30 AM to 7:30 PM, all vehicles travel northbound. SANDAG has committed to expanding the HOT lanes to four lanes (2 in each direction) and lengthening the system to 20 miles.

3.1.3 Katy Freeway (I-10) QuickRide - Harris County, Texas

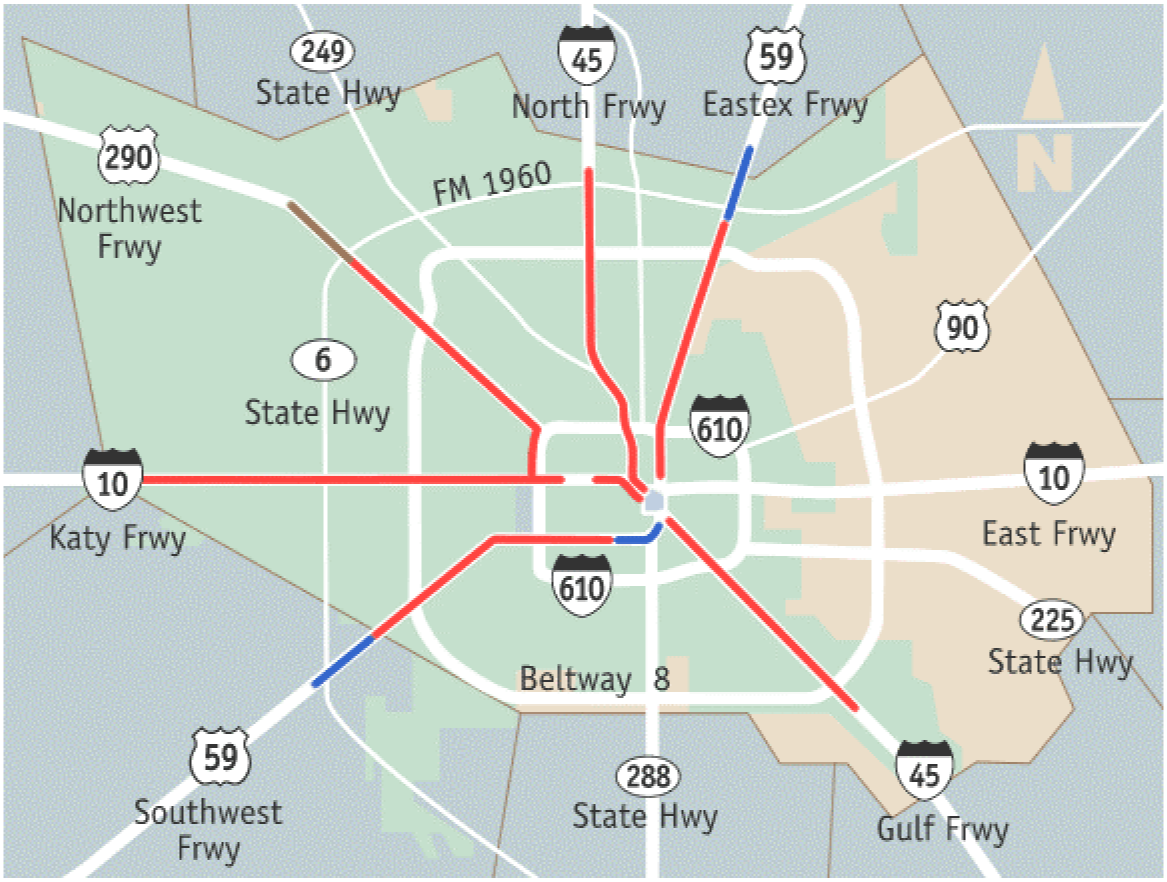
The Katy Freeway is an existing highway with a 13-mile, 6-lane freeway (3 each direction), with a 1-lane reversible HOV lane in the median, making a total of 7 lanes across. The HOV lane, which began in 1984, originally operated at HOV2, but the facility was too congested, so the occupancy constraint was raised to HOV3 to reduce congestion. However, this change resulted in excess capacity on the facility during the peak periods. As a result, the QuickRide program was introduced in 1998, allowing HOV2 vehicles to pay $2.00 per trip to use the facility during peak periods, while HOV 3+ vehicles continued to use the facility at no cost. Note that SOV traffic is never allowed on the QuickRide lane. Customers must have a QuickRide account, transponder, and windshield tag to use the facility. Figure 5 shows the extent of the HOV system in the Houston area, including the two HOT lane facilities, I-10 and US-290.

3.1.4 Northwest Freeway (US-290) QuickRide - Harris County, Texas

The US-290 QuickRide facility is a 15.5-mile long, 1-lane, reversible, barrier-separated facility that opened as HOV2+ in 1988. In 2000, the facility was converted to a HOT lane facility and is operated in a manner similar to the Katy Freeway. The US-290 QuickRide facility allows HOV2+ carpools to use the facility only in the morning peak period, when HOV3+ requirements are in effect. From 6:45 AM to 8:00 AM, the facility operates inbound, during which HOV3+ may use the lane for free, but HOV2 must pay a flat $2.00. Note that SOV traffic is never allowed on the QuickRide lane. Figure 5 shows the extent of the HOV system in the Houston area, including the two HOT lane facilities, I-10 and US-290.

Table 1 presents a comparison of the Fluor proposal and the four operating HOT lane facilities in the U.S.

Figure 5 HOV system in Houston, Texas



Source: Metropolitan Transit Authority of Harris County, Texas, http://www.hou-metro.harris.tx.us/services/areahovmap.asp

Table 1 Comparison of Fluor proposal to existing HOT lane facilities in the U.S.

	Proposed	Existing HOT lane facilities			
	I-495 Capital Beltway in Northern Virginia	**SR-91 Express Lanes - Orange County, California**	**I-15 FasTrak - San Diego, California**	**Katy Freeway (I-10) QuickRide - Harris Co., TX**	**Northwest Freeway (US-290) QuickRide - Harris Co., TX**
Type of facility	HOT, proposed	HOT	HOT	HOT	HOT
No. of lanes, HOT	2 each direction	2 each direction	2, reversible *	1, reversible	1, reversible
No. of lanes, general purpose (GP)	4 each direction	4 each direction	4 each direction	3 each direction	3 each direction
Length (miles)	14	10	8	13	15.5
Date opened	2009 proposed	1995	1996 (HOV since 1988)	1998 (HOV since 1984)	2000 (HOV since 1988)
Hours of operation, HOT lanes	24 hours	24 hours	Peak periods	Peak periods	Peak periods
Location of HOT lanes	In median	In median	In median	In median	In median
Facility type	In freeway ROW, buffer separated	In freeway ROW, buffer separated	In freeway ROW, barrier separated	In freeway ROW, barrier separated	In freeway ROW, barrier separated
Separation from GP lanes	2 to 4-ft wide paved buffer with yellow pylons	2-ft wide paved buffer with yellow pylons	Concrete barriers	Concrete barriers	Concrete barriers
Free use of HOT lanes	HOV 3+, buses, vanpools, emergency vehicles	Buses, vanpools, motorcycles; zero-emission vehicles; and vehicles with disabled persons license plates	HOV2, HOV3+, buses, vanpools	HOV 3+, buses, vanpools, motorcycles. HOV 2 is free during off peak hours.	HOV 3+, buses, vanpools, motorcycles
Toll required to use HOT lanes	SOV and HOV 2	SOV, HOV2, and HOV3+ (HOV3+ toll is 50% of SOV)	SOV	HOV 2 ($2 per trip) during AM & PM peak periods (6:45-8 AM and 5-6 PM)	HOV 2 ($2 per trip) during AM & PM peak periods
Not permitted on HOT lanes	Trucks	Trucks	Trucks	SOV, Trucks	SOV, Trucks
Pricing	Variable w/ congestion. Toll set so that users could operate at posted speed limit.	Varies from $1.00 to $4.75 by time of day and day of week. Not dynamic. 50% discount for HOV on posted toll amount.	Dynamic (real time); varies w/ congestion; adjusted every 6 minutes. Can go as high as $8.00.	$2 for HOV2 during AM and PM peak periods	$2 for HOV2 during AM and PM peak periods

* SANDAG is planning to widen facility to 4 lanes (2 in each direction).

3.2 Performance of HOT lanes

3.2.1 General findings

The traveler response to a HOT lane facility is likely to be similar to the traveler response to either a toll road and/or an HOV facility, since the HOT lane combines the lane management characteristics of these two types of facilities. Possible responses, in descending order of likeliness, include:

- Change in the route or path of a trip, i.e., diversion;
- Change in the departure time;
- Change in the travel mode;
- Change in the origin or destination of a trip; and
- Change in the propensity to make a trip.

Studies of the SR-91 corridor show that a diversion of some traffic from the general purpose lanes to the Express Lanes substantially improved peak period travel conditions in the general lanes. Additionally, the addition of the SR-91 HOT lanes also had the effect of shifting some traffic back to the state highway from parallel city streets (Perez and Sciara 2003). Several studies related to the SR-91 Express Lanes conducted by Cal Poly State University in San Luis Obispo are available on the Web (http://ceenve.calpoly.edu/sullivan/sr91/sr91.htm). For example, the report *Continuation Study to Evaluate the Impacts of the SR 91 Value-Priced Express Lanes* discusses a number of issues, including before and after observations, modeling of travel choices, and analysis of emissions. The report documents more than five years of field observations, including a year and a half of baseline conditions before the HOT lane facility opened.

The I-15 FasTrak Web site (http://argo.sandag.org/fastrak/library.html) provides access to a number of studies and reports conducted during the development of the I-15 HOT lanes, such as:

- **Worldwide Experience with Congestion Pricing**
  Reviews eleven worldwide examples of road pricing covering a wide range of sites, objectives, and implementation strategies.
- **Up-to-Date Results of the SR-91 Congestion Pricing Experiment**
  Discusses the results of the first project of its kind in the U.S., the State Route 91 (SR-91) Congestion Pricing experiment.
- **Phase I Air Quality Study**
  Estimates total emissions of volatile organic compounds, nitrogen oxides, particulate matter, and carbon monoxide for both the I-15 and I-8 corridors during 1996 and 1997.
- **Phase II Year Two Air Quality Study**
  Assesses the impact of the project on emissions in the I-15 corridor during 1998. Estimates total emissions of volatile organic compounds, nitrous oxides, particulate matter, and carbon monoxide for both the I-15 and I-8 corridors.
- **Phase II Year Three Air Quality Study**
  Assesses the impact of the project on emissions in the I-15 corridor during 1999. Estimates total emissions of volatile organic compounds, nitrous oxides, particulate matter, and carbon monoxide for both the I-15 and I-8 corridors.

Before and after studies of the Katy Freeway HOT lanes showed the following results:

- It increased the number of HOV3+ carpools during the peak period;
- It redistributed HOV2+ carpools to before and after the peak hour;
- It increased average traffic speed and improved the LOS on the HOV lanes; and
- It moved the same number of passengers, but moved them more efficiently (Perez and Sciara 2003).

3.2.2 Air Quality

The Washington area is currently designated as a "severe non-attainment" area for ground-level ozone (O_3). Since the precursors of ozone are volatile organic compounds (VOC) and oxides of nitrogen (NOx), these two pollutants will be the focus of discussions in this report. The latest air quality conformity determination was for the 2002 Constrained Long-Range Plan and the FY 2003-2008 Transportation Improvement Program (MWCOG 2002, available on the Web at http://www.mwcog.org/transportation/activities/quality/). The assessment years included 2002, 2005, 2015, 2020, and 2025.

A Guide for HOT Lane Development describes the air quality impact of HOT lanes as follows (p. 78):

> *One of the expected benefits of HOT lanes involves having more vehicles in the corridor moving at higher and more stable speeds. Generally speaking, this should result in a benefit (albeit small) in air quality, as faster moving vehicles generate less pollution. Slower, stop-and-go traffic – which would be expected with over-utilized general-purpose or HOV lanes – would produce more pollution. While air quality review may show an advantage for HOT lanes over general-purpose lanes (at least), that advantage is likely to be fairly small and may not provide a compelling argument on its own to justify the investment. However, in conjunction with other potential benefits, air quality improvements could be a factor in garnering support for HOT lane applications.*

The above statement, "this should result in a benefit (albeit small) in air quality," pertains to a case where there is no net increase in highway capacity when the HOT lane is created, e.g., converting an HOV lane to a HOT lane, or converting a general purpose lane to a HOT lane. In the Fluor proposal, however, there would be a net increase in highway capacity. Specifically, the base case in 2015 assumes a 10-lane Beltway with 8 general purpose lanes and 2 HOV3+ lanes; and the Fluor proposal assumes a 12-lane Beltway with 8 general purpose lanes and 4 HOT/HOV3+ lanes. Thus, there would be a net increase of 28 lane-miles (2 lanes times 14 miles). Therefore, any analysis of the air quality impacts of a major HOT lane facility should take into account these two phenomena:

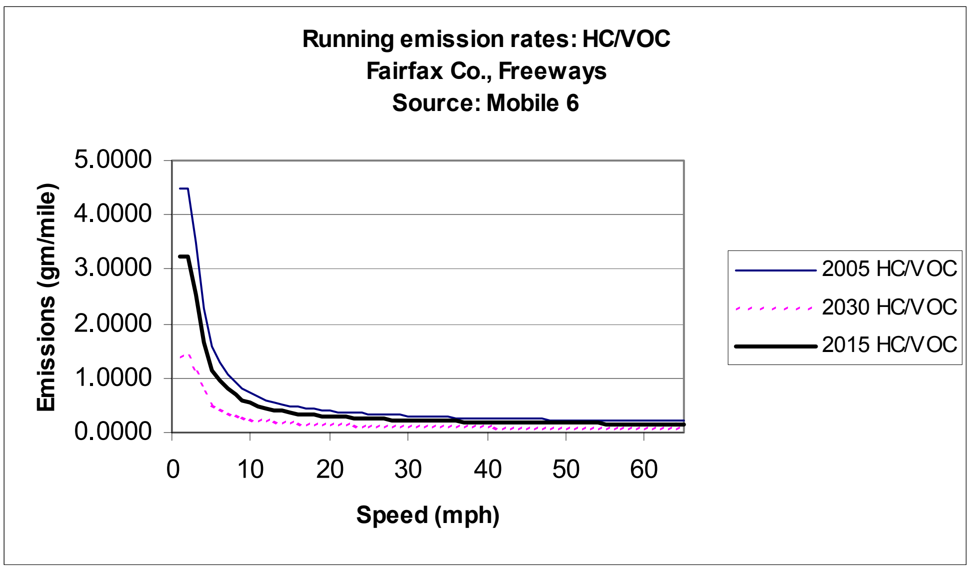
- Effect of lane management on speeds
- Effect of adding highway capacity

<u>Effect of lane management on speeds</u>: The dynamic lane management that occurs with HOT lanes should result in better operational levels of service (LOS), higher speeds, and more consistent travel times on the HOT lane facility, and, to some extent, through the corridor. The change in travel speeds has a direct impact on vehicle emissions, since running emissions, such as VOC and NOx, are a function of the vehicle speed. VOC running emissions generally drop as

speeds increase. The curve for NOx running emissions is "U" shaped. Consequently, changes in vehicles speeds could increase or decrease emissions, depending on the starting and ending point on the emissions/speed curve.
Effect of adding highway capacity: As the newly added highway capacity fills up with diverted traffic, or, potentially, induced travel, the added highway capacity should result in an increase in vehicle emissions (i.e., a degradation of air quality).

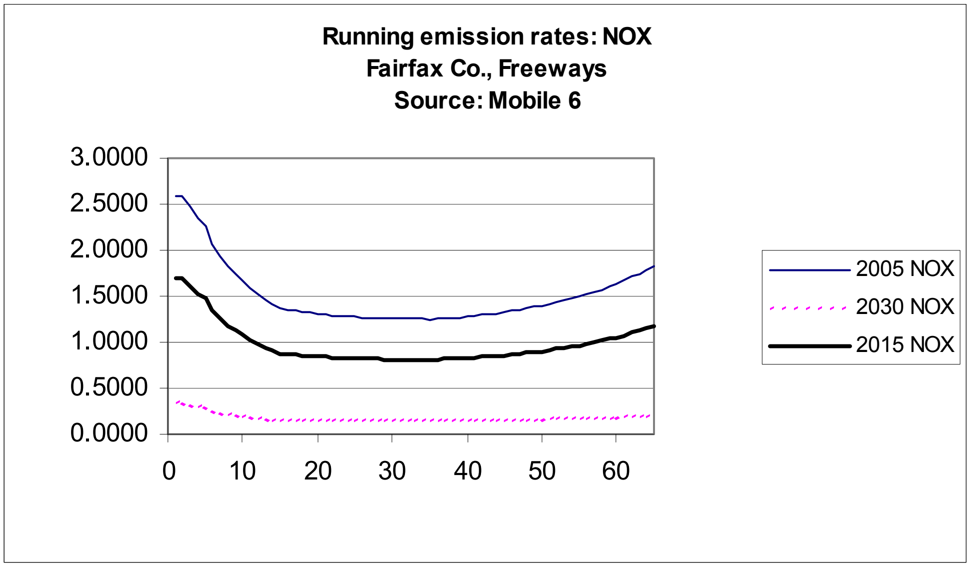
The sketch planning air quality assessment that will be used in this report will take into account these two phenomena. The EPA mobile emissions model, known as Mobile6, is used to develop a family of emissions factors that can be used to compute total mobile emissions. There is a separate set of emissions factors by pollutant (e.g., VOC or NOx), jurisdiction (e.g., D.C., Fairfax County), and facility type (e.g., freeway, arterial). Two examples of emission factors are shown in Figure 6 and Figure 7. Note that the 2015 curves are interpolated from emissions factors for 2005 and 2030.

Figure 6 Example emissions factors from Mobile6: Running VOC emissions for freeways in Fairfax Co., Va.



Note: 2015 values were interpolated from 2005 and 2030 values.
Ref: x215rnet_vol_ daily.xls

Figure 7 Example emissions factors from Mobile6: Running NOx emissions for freeways in Fairfax Co., Va.



Note: 2015 values were interpolated from 2005 and 2030 values.
Ref: x215rnet_vol_ daily.xls

According to the report *Continuation Study to Evaluate the Impacts of the SR 91 Value-Priced Express Lanes* (Sullivan, Edward 2000, p. 203):

1. *If dual HOV lanes had been constructed instead of the 91X toll lanes, and assuming no change in vehicle-miles of travel (VMT), the overall modeled emissions for March 1998 conditions would be approximately the same as with the existing 91X facility. (Section 7.4, Table 7-V.)*

2. *If general use lanes had been constructed instead of the 91X toll lanes, the modeled emissions for March 1998 would be approximately the same, assuming that induced traffic produced a 7% traffic (VMT) increase. For other assumptions on induced VMT, ranging from 0% to 10%, overall modeled emissions would vary from 6% less to 3.7% more than the values estimated for the existing 91X facility. (Section 7.5, Table 7-X through Table 7-XIII.)*

3. *If no additional capacity had been built, our best estimate is that VMT would be about 8% less and overall modeled emissions in March 1998 would be 18% less than the values for the existing 91X facility. This analysis is based on very limited data. (Section 7.6, Table 7-XV.)*

Point number 2 by Sullivan implies that whether there will be a degradation or improvement in air quality is a function of the amount of induced demand assumed: 0% induced demand results in a 6% drop in emissions, but 10% induced demand results in a 3.7% increase in emissions. The term "induced demand" means different things to different people, and often depends on one's window of analysis. If one is looking at only a corridor, there could be substantial "induced demand" due to added highway capacity. But if one's focus is the entire region, much of what seemed like new, induced demand could actually be diversion (path changes) and the actual net increase in demand at the regional level could be quite small or negligible.

4 Qualitative analysis of the Fluor HOT lane proposal for the Capital Beltway

Task 2 of the Fluor study is to conduct a *qualitative* analysis of the Fluor HOT lane proposal for the Virginia portion of the Capital Beltway. No detailed 4-step modeling of these lanes will be undertaken. Rather, it will be assumed that the facility will operate as specified by Fluor. Consequently, the performance of the adjacent conventional (general purpose) lanes will be estimated. This assessment will include likely level of service on both the HOT lanes and GP lanes, and the likely resulting direction for regional NOx and VOC emissions. The analysis year will be 2015, since this is the first analysis year beyond 2009 for which baseline emissions in the TIP and CLRP are available.

4.1 Review of technical methods to analyze HOT lanes

Technical methods to analyze HOT lanes can be divided into two groups: four-step modeling techniques and sketch planning techniques.

4.1.1 Four-step modeling

The "four-step" process for modeling travel demand is a trip-based process that includes four main steps: 1) trip generation, 2) trip distribution, 3) mode choice, and 4) traffic assignment. Some four-step models perform traffic assignment on a 24-hour, daily basis. Newer four-step models perform traffic assignment for two or more time-of-day periods, whose results can then be summed to obtain total daily (i.e., weekday) traffic. The time-of-day model usually occurs after mode choice and before traffic assignment, turning the process into a 5-step model: 1) trip generation, 2) trip distribution, 3) mode choice, 4) time-of-day choice, and 5) traffic assignment.

As stated earlier in this report, the traveler response to a HOT lane facility is likely to be similar to the traveler response to either a toll road and/or an HOV facility, since the HOT lane combines the lane management characteristics of these two types of facilities. Possible responses, in descending order of likeliness, are shown in Table 2.

Table 2 Likely traveler responses to a new HOT lane facility and the corresponding step in the 4-step model

Traveler responses to a new HOT lane facility	Relevant modeling step
Change in the route or path of a trip, i.e., diversion	Traffic assignment (step 5)
Change in the departure time	Time-of-day model (step 4)
Change in the travel mode	Mode choice (step 3)
Change in the origin or destination of a trip	Trip distribution (step 2)
Change in the propensity to make a trip	Trip generation (step 1)

The last item, change in the propensity to make a trip, is very unlikely to occur, since HOT lanes generally run in parallel with general purpose lanes and other parallel arterial roads. The second to last item, change in the origin or destination of a trip, is also rather unlikely, again, because the

HOT lane corridor generally has other alternative routes that do not have the occupancy restrictions or tolling. Consequently, the first three items in the list are the most likely traveler responses to a new HOT lane.

The National Capital Region Transportation Planning Board (COG/TPB) is currently in the process of moving to a new travel demand forecasting model. The current model, known as Version 1, is four-step model with a 24-hour traffic assignment. The newer model, known as Version 2 (Version 2.1, Release C), is also a four-step model, but includes a time-of-day model and traffic assignment using three time periods (AM peak period, PM peak period, and the off-peak period). The Version 2 model accounts for tolls in only the mode choice step and accounts for HOV travel in both the mode choice and traffic assignment steps. Consequently, the COG/TPB travel demand model is not set up to analyze HOT lanes. Although we eventually plan to modify the model to more fully incorporate tolls and HOT lanes, such a model revision was beyond the scope of this project. Consequently, we will use sketch planning techniques to analyze the likely air quality impacts of HOT lanes on the Beltway in Virginia.

4.1.2 Sketch planning techniques

4.1.2.1 A Guide for HOT Lane Development

In *A Guide For HOT Lane Development*, under a section entitled, "A Sketch Planning Methodology for Estimating HOT Lane Revenue,"the following sketch planning technique is proposed (Perez and Sciara 2003, p. 70):

> *First, peak traffic on the general-purpose lane is measured, and LOS determined. Utilizing this information, peak period congestion delays can be estimated, and the cost of those delays quantified based on hourly values of travel time. Then, based on the available capacity in the HOV lane (after "free" HOV vehicles are accounted for), SOV users are "shifted" to the HOT lane, just up to the point where free flow conditions can be maintained in the HOT lane. The HOT lane toll is modeled based on the degree of congestion in the general-purpose lane, and the cost of that congestion to SOV users. HOT lane revenues are then estimated after accounting for market penetration of electronic toll collection accounts.*

4.1.2.2 San Diego Association of Governments (SANDAG)

The San Diego Association of Governments (SANDAG) has used a similar approach. HOT lanes are not currently modeled in the four-step model. Instead, there is a post-traffic-assignment procedure, which is carried out in their geographic information system (GIS). The procedure is to:

1. Shift traffic from over-capacity main freeway lanes to adjacent "HOV/managed lanes" (HOT lanes) that have excess capacity; and
2. Shift traffic from over-capacity HOV/managed lanes to adjacent freeway main lanes.

In other words, on the general purpose freeway lanes, take the difference between the assigned volume and the capacity. In cases where the assigned volume is above the capacity, this volume surplus is shifted to the managed lanes, such that the managed lanes never drop below LOS C, which they define as 1,600 vehicles per hour per lane (v/h/ln).[1]

4.1.2.3 Spreadsheet Model for Induced Travel Estimation (SMITE)

SMITE is a sketch-planning tool that applies the principles of economic analysis to evaluate highway capacity expansion in an urban setting, taking into account new travel that may be induced by highway expansion over and above that which is simply diverted from other regional highways. The model is useful in cases where four-step travel models are either unavailable or are unable to forecast the full induced demand effects. The model is applied via an electronic spreadsheet (originally Lotus 123, then also in Microsoft Excel). For a case study of toll options on the Capital Beltway, a new version of SMITE was developed, called SMITE-Managed Lanes or SMITE-ML (DeCorla-Souza 2002). SMITE estimates induced traffic that might result from faster highway travel speeds, including new trips generated or attracted, existing trips diverted from other destinations, and existing trips diverted from other modes. SMITE uses demand elasticity with respect to travel time to estimate induced travel. SMITE-ML incorporates a pivot-point mode choice model. According to the study paper, "Impedance coefficients used in the model were those calibrated for the Washington, DC metropolitan area" Source: Sierra Research, Inc. and J. Richard Kuzmyak. COMMUTER Model User Manual for Analysis of Voluntary Mobile Source Emission Reduction and Commuter Choice Incentive Programs. U.S. EPA. Draft Final report. September 1999.

In the study entitled, "Evaluation of Toll Options Using Quick-Response Analysis Tools: A Case Study of the Capital Beltway," the author investigated six network alternatives to the base-case "no-build" alternative of an 8-lane Capital Beltway in Virginia. The first three alternatives involved adding HOV lanes, but no tolls, to the Beltway in Virginia. The last three alternatives involved making the HOV lanes into HOT lanes. The forecast year was 2020. Alternative 6 was the most similar to the Fluor proposal. Under Alternative 6, one would add two barrier-separated priced express lanes in each direction. Carpools and buses would travel on the express lanes for free.[2] We will summarize some of the study findings relating to Alternative 6. For the study, which was based on Virginia's Capital Beltway Study,[3] the Virginia portion of the Beltway was divided into three segments:

Table 3 Segments used in the VDOT draft EIS for the Virginia portion of the Beltway

Segment of Virginia portion of Beltway	Approximate length (miles)	Estimated traffic, 2020 (vehicles per day)
Southern	3	280,000
Middle	6	310,000
Northern	5	250,000

[1] Telephone conversation with Bill McFarlane, Senior Transportation Planner, San Diego Association of Governments, on January 31, 2003.
[2] In the Fluor proposal, HOV3+ and buses would travel for free; SOV and HOV2 would pay a toll. In the DeCorla-Souza study, it was not clear whether HOV2 would pay the toll, or only SOV.
[3] Virginia Department of Transportation and Federal Highway Administration. *Capital Beltway Study*. Draft Environmental Impact Statement. Volume 1. March 2002.

Note that these findings apply to only the "southern segment" of the Virginia portion of the Beltway. It was estimated that Alternative 6 (two HOT lanes each direction) would result in an additional 21,151 transit person trips in 2020 (30,051 daily trips vs. 8,900 daily trips in the no-build base case). Other results can be seen in Table 4.

Table 4 SMITE-ML model: Est. travel, 2020, for the southern segment of the Virginia portion of the Beltway

	No build	Alt 6	Diff
Total daily person trips	445,000	445,000	0
Total initial daily vehicle trips	333,689	309,371	-24,318
Peak period person trips			
(prior to induced travel effect)			
- Solo	178,000	149,104	-28,896
- Carpool	35,600	43,345	7,745
- Transit	8,900	30,051	21,151
- Total	222,500	222,500	0
Peak period mode shares:			
(prior to induced travel effect)			
- Solo	80.00%	67.01%	-12.99%
- Carpool	16.00%	19.48%	3.48%
- Transit	4.00%	13.51%	9.51%
- Total	100.00%	100.00%	0.00%
Induced vehicle trips	0	36,251	36,251
Total daily vehicle trips	333,689	345,622	11,933
Freeway daily vehicle trips	280,299	309,107	28,808
Arterial daily vehicle trips	53,390	36,515	-16,875
Total	333,689	345,622	11,933

Source: DeCorla-Souza, P. (2002) "Evaluation of Toll Options Using Quick-Response Analysis Tools: A Case Study of the Capital Beltway." Prepared for presentation at the TRB Annual Meeting in January 2003.
Ref: deCorla-Souza smiteml.xls

4.1.3 Recommended technique for demand analysis

Given the limited time available to conduct Task 2, we recommend the travel demand analysis be done using a sketch planning method similar to that used by SANDAG or discussed in *A Guide For HOT Lane Development*. This method involves analysis of the facility during peak-period congestion and relies on shifting excess traffic volume from the general purpose lanes to the HOT lanes, such that free flow conditions can be maintained in the HOT lanes.

4.1.3.1 Managed and maximum capacities

The HOT lane facility proposed by Fluor would operate at 65 mph. Tolls would be varied to keep the flow rate of traffic such that this 65 mph speed is maintained. The Beltway is composed of a series of "basic freeway segments," as defined in the Highway Capacity Manual. The level of service (LOS) for a basic freeway segment is a function of density and is shown in Table 5.

Table 5 LOS thresholds for a basic freeway segment

LOS	Density range (pc/mi/ln)
A	0 – 11
B	> 11 – 18
C	> 18 – 26
D	> 26 – 35
E	> 35 – 45
F	> 45

Source: 2000 Highway Capacity Manual, p. 23-3.

As the service flow rate (measured in passenger cars per hour per lane or pc/h/ln) on a basic freeway segment increases, the speed will decrease. At the lower LOSs, such as A or B, the speed drops very slightly. At LOS E, where the maximum flow rate occurs, the speed will have dropped 5 to 22 mph, depending on the free-flow speed of the facility. Exhibit 23-2 in the Highway Capacity Manual illustrates LOS criteria for basic freeway segments (reproduced here as Table 6). According to this table, for a facility with a free-flow speed (FFS) of 65 mph, you can achieve a maximum service flow rate of between 1170 pc/h/ln (speed = 65.0 mph) and 1680 pc/h/ln (speed = 64.6 mph).

According to *A Guide for HOT Lane Development* (p. 79):

> *. . . managed capacity levels may vary from one HOT facility to another depending on the number of access points, vehicle mix, roadway slope and configuration, separation treatments, and number of travel lanes. A single HOT lane will have a lower managed capacity than multiple HOT lanes. For example, flows on the Houston I-10 Katy Freeway QuickRide – a one lane, reversible-flow facility are kept to 1500 vehicles/hour. However, the SR 91 Express Lanes – which provide two travel lanes in each direction – have been able to operate at acceptable conditions with flow rates of 1800 vehicles/hour/lane.*
>
> *A safe range for establishing managed capacity for most project settings would be approximately 1700 hourly automobile equivalents per lane, with the understanding that road configuration, slopes and speed limits can drive this number up or down. This threshold is reflected in a number of HOV references and locally adopted policies, and is also appropriate for HOT lanes.*

Although the Guide for HOT Lane Development recommends using a maximum service flow rate of 1,700 vehicles per hour per lane, we recommend using a slightly lower figure, 1,600 v/h/ln, given the fact that the proposed facility will have five intermediate access points, which could reduce its capacity somewhat due to weaving.

Table 6 LOS criteria for basic freeway segments

EXHIBIT 23-2. LOS CRITERIA FOR BASIC FREEWAY SEGMENTS

Criteria	LOS				
	A	B	C	D	E
FFS = 75 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
Minimum speed (mi/h)	75.0	74.8	70.6	62.2	53.3
Maximum v/c	0.34	0.56	0.76	0.90	1.00
Maximum service flow rate (pc/h/ln)	820	1350	1830	2170	2400
FFS = 70 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
Minimum speed (mi/h)	70.0	70.0	68.2	61.5	53.3
Maximum v/c	0.32	0.53	0.74	0.90	1.00
Maximum service flow rate (pc/h/ln)	770	1260	1770	2150	2400
FFS = 65 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
Minimum speed (mi/h)	65.0	65.0	64.6	59.7	52.2
Maximum v/c	0.30	0.50	0.71	0.89	1.00
Maximum service flow rate (pc/h/ln)	710	1170	1680	2090	2350
FFS = 60 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
Minimum speed (mi/h)	60.0	60.0	60.0	57.6	51.1
Maximum v/c	0.29	0.47	0.68	0.88	1.00
Maximum service flow rate (pc/h/ln)	660	1080	1560	2020	2300
FFS = 55 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
Minimum speed (mi/h)	55.0	55.0	55.0	54.7	50.0
Maximum v/c	0.27	0.44	0.64	0.85	1.00
Maximum service flow rate (pc/h/ln)	600	990	1430	1910	2250

Note:
The exact mathematical relationship between density and v/c has not always been maintained at LOS boundaries because of the use of rounded values. Density is the primary determinant of LOS. The speed criterion is the speed at maximum density for a given LOS.

Source: 2000 Highway Capacity Manual, Exhibit 23-2, p. 23-4.

4.2 Travel demand and emissions estimate

4.2.1 Methodology overview

In this section of the report, we prepared a qualitative estimate of the mobile emissions impact of the Fluor Daniels HOT lane proposal for the Capital Beltway in Northern Virginia. The analysis, which makes use of sketch planning techniques, is for a typical peak hour. As stated earlier in the report, the emissions part of the analysis takes into account two, possibly competing, effects:

- Effect of lane management on speeds (Could increase or decrease emissions)
- Effect of adding highway capacity (Would likely increase emissions).

The general approach for the analysis was as follows:

Demand forecast

- Obtain estimated daily traffic volumes for the baseline configuration of the proposed facility. Estimated daily traffic volumes came from the COG/TPB 4-step model from model runs that were conducted for the latest air quality conformity analysis of record, i.e., the air quality conformity determination of the 2002 Constrained Long-Range Plan and the FY 2003-2008 Transportation Improvement Program. Note that no new 4-step model runs were performed for this analysis, but the results of existing runs were used as input to the sketch planning methods of this analysis. The proposed HOT lane facility is to open in 2009, but existing model run data was available only for analysis years of the regional air quality conformity determination: 2002, 2005, 2015, 2020, and 2025. We chose to use the 2015 model run output as the input to our analysis, since this is the first available analysis year following the proposed 2009 opening date.
- Convert daily traffic volumes to peak-hour traffic volumes.
- Assume that the HOT lanes could operate at a maximum service flow rate of 1,600 passenger cars per hour per lane – the point at which speeds would begin to drop below 65 mph. This service flow rate (1,600 pc/h/ln) corresponds to a level of service of C. Since the proposed facility would have 2 lanes in each direction, this implies a maximum service flow rate of 3,200 pc/h by direction.
- Estimated vehicle trips from the GP lanes were diverted to the HOT lanes until the HOT lanes were at their LOS C capacity of 1,600 pc/h/ln.
- Three forecasts of traffic under the HOT lane scenario were developed: a low, medium, and high forecast. In all three forecasts, we assume that traffic would be diverted from the GP lanes to the HOT lanes, and that the HOT lanes would fill up to their maximum service flow rate of 1,600 v/hr/ln. Since there are two HOT lanes in each direction, the capacity and flow rate of the HOT lanes becomes 3,200 v/hr in each direction. The amount of traffic *diverted* from the GP lanes to the HOT lanes is <u>assumed to be the same</u> in all three cases and is equal to

  (traffic diverted from GP lanes to HOT lanes) = 3,200 – (baseline HOV volume)

  Thus, the difference between the three forecasts is not the level of traffic on the HOT lanes, which is always 3,200 v/hr, but rather the level of traffic on the adjacent GP lanes:
  - Low forecast: Assumes that, after traffic diverts from the congested GP lanes onto the free-flowing HOT lanes, the GP lanes do not fill up with any new traffic. The increase in traffic on the HOT lanes is equal to the decrease in traffic from the GP lanes. Consequently, there is no net increase in traffic on the Beltway.
  - Medium forecast: Assumes that, after traffic diverts from the congested GP lanes onto the free-flowing HOT lanes, the amount of traffic in the GP lanes increases by an amount equal to the capacity of the added lane of traffic in each direction (i.e., increases by 1,600 pc/h in each direction). This increase in traffic on the GP lanes would be due to both the "diverted traffic" from nearby arterials and from "induced traffic." Induced traffic is defined as *new* trips that would not have occurred if capacity had not been added to the Beltway. Consequently, there is a net increase in traffic on the Beltway, compared to the base case.

- High forecast: Assumes that, after traffic diverts from the congested GP lanes onto the free-flowing HOT lanes, the amount of traffic in the GP lanes increases, and returns to the same level of congestion as was found in the baseline case. This increase in traffic is equal to 3,200 minus the baseline HOV traffic, in each direction. Once again, this increase in traffic on the GP lanes would be due to both "diverted traffic" from nearby arterials and "induced traffic." Consequently, there is a net increase in traffic on the Beltway, compared to the base case.

- Based on the estimated peak-hour traffic on each link, the following quantities were calculated, using lookup tables, for each link in the three freeway segments: volume-to-capacity ratio, speed, and LOS.

<u>Emissions forecast</u>

- Using the six GP links and six HOT links in the three freeway segments, average values were estimated for: volume-to-capacity ratio, speed, and LOS.
- Using the average values calculated in the previous step, we calculated total running emissions, for a peak hour, for two pollutants: VOC and NOx.

<u>Effect of diverted and induced travel on emissions</u>

There are four different traffic forecasts (baseline, action low, action medium, and action high) and four corresponding emissions forecasts. The low travel forecast assumes no new travel on the Beltway. By contrast, both the medium and high travel forecasts assume that there will be a net increase in traffic on the Beltway. The assumed increase in Beltway traffic under the medium and high travel forecasts would be made up of either "diverted traffic," or "induced traffic," or a combination of the two. Diverted traffic is traffic that was on other roads in the baseline case and moved over to the Beltway in the "action" case, due to the added capacity on the Beltway. Induced traffic is *new* traffic that did not exist in the base case, and was "created" due to the new highway capacity. If one were to assume that 100% of the new travel on the Beltway was "diverted travel," then, in the emissions analysis, one should both *add* the emissions due to the new travel on the Beltway <u>and</u> *subtract* (or "net out") the emissions due to the traffic that had been on other roads, but is now on the Beltway. If one were to assume that 100% of the new travel on the Beltway was "induced travel," then, in the emissions analysis, one should simply add the emissions due to the new travel on the Beltway. The reality is probably somewhere in between these two extremes. For our analysis, we have chosen to take the most conservative approach, i.e., the one that likely overestimates the running emissions. This approach corresponds to assuming that all of the new traffic on the Beltway is induced travel, meaning that one simply adds the new emissions without subtracting any emissions. So our analysis is likely to overstate the emissions impact of the proposed HOT lane facility.

4.2.2 Methodology details

The proposed project consists of a 14-mile segment of the Capital Beltway in Northern Virginia, starting from Georgetown Pike to the north, and ending at I-395 to the south of the corridor. This stretch of the Beltway includes 9 highway segments, delineated by 8 interchanges:

- Georgetown Pike
- Dulles Toll Road

- VA Route 123
- VA Route 7
- I-66
- US-50
- Gallows Road
- VA Route 236
- Braddock Road
- I-395

For our analysis, we have selected three representative segments that will represent the operations of the nine segments of the proposed HOT lane facility:

- Georgetown Pike to the Dulles Access/Toll Road
- VA Route 7 to I-66 (one of the heaviest volume segments)
- Braddock Road to I-395

The first representative segment is at the northern end of the facility. The second segment is in the middle of the facility and one of the highest volume segments on this section of the Beltway. The third segment is at the southern end of the facility.

We obtained a loaded-link 2015 highway network from the latest air quality conformity determination of record: the air quality conformity determination of the 2002 Constrained Long-Range Plan and the FY 2003-2008 Transportation Improvement Program.[4] Model runs were conducted for the current year (2002), the attainment year (2005), and the future years of 2015, 2020, and 2025. The year 2015 was selected because this was the first analysis year beyond the proposed 2009 opening date for the HOT lane facility.

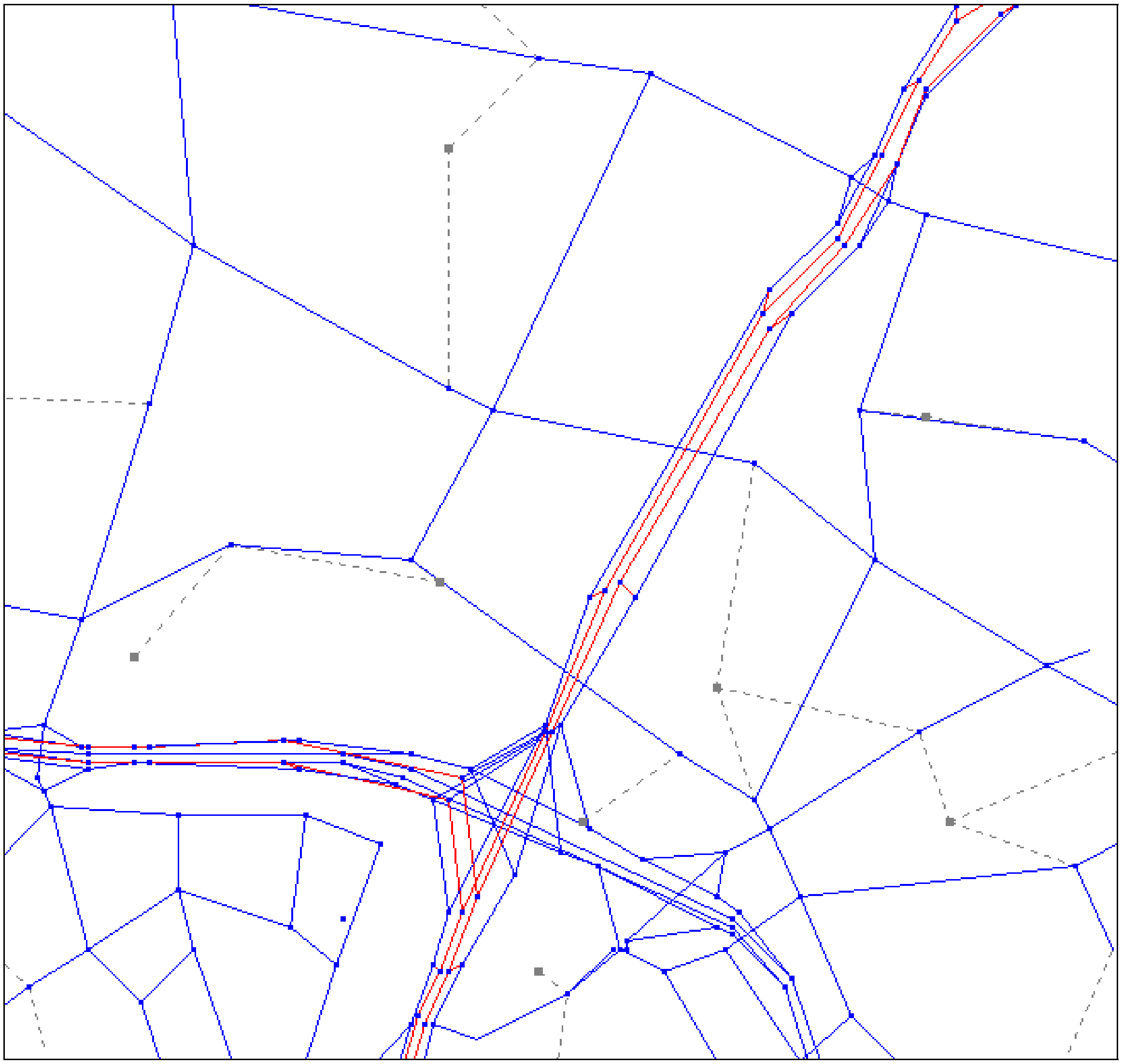
In the highway network, each segment of the Beltway is represented by four links, representing four distinct traffic flows:

- Outer loop, general purpose traffic (4 lanes)
- Outer loop, HOV3+ (1 lane in baseline, 2 lanes in proposal)
- Inner loop, HOV3+ (1 lane in baseline, 2 lanes in proposal)
- Inner loop, general purpose traffic (4 lanes)

On freeways without HOV traffic, each segment of freeway is represented by only two links, one for each direction. Arterial road segments are represented by one two-way link (actually two one-way links which lie on top of one another), which appear as a single line, instead of the parallel lines for freeways (See Figure 8).

[4] File name of loaded-link 2015 highway network: X215rnet.dat. Note that this network came from the air quality conformity determination of the 2001 Constrained Long-Range Plan and the FY 2002-2007 Transportation Improvement Program, since the model runs for the FY 2003-2008 conformity and the FY 2002-2007 conformity were identical.

Figure 8 2015 highway network: I-495 from Georgetown Pike to the Dulles Toll/Access Road



Source: MWCOG highway network for 2015 (X215rnet.dat) from air quality conformity determination of the 2002 Constrained Long-Range Plan and the FY 2003-2008 Transportation Improvement Program.

Next, the estimated 2015 daily traffic volumes for the four links in each of the three freeway segments were extracted from the loaded-link highway network (See Table 7). The average estimated daily volume for the three segments was about 128,000 for the general purpose lanes and 3,500 for the HOV lanes. The complete set of spreadsheets used in this analysis can be seen in Appendix A.

Table 7 Base case: Estimated 2015 *daily* traffic volumes for 3 representative segments of the Beltway

From	To	Loop	Link Type	HOV Req	Highway Network Nodes A Node	B Node	Lanes	Est daily volumes (4-step model) Vol	Vol / ln
G-town Pk	Dulles Toll Rd	Outer	GP		12797	12793	4	121,540	30,385
		Outer	HOV	3	12798	12794	1	4,282	4,282
							Total by direction	**125,822**	
		Inner	GP		12796	12800	4	128,277	32,069
		Inner	HOV	3	12795	12799	1	3,974	3,974
							Total by direction	**132,251**	
VA Route 7	I-66	Outer	GP		12717	12721	4	134,790	33,698
		Outer	HOV	3	12718	12722	1	3,020	3,020
							Total by direction	**137,810**	
		Inner	GP		12724	12720	4	132,967	33,242
		Inner	HOV	3	12723	12719	1	3,469	3,469
							Total by direction	**136,436**	
Braddock Rd	I-395	Outer	GP		12777	12781	4	130,140	32,535
		Outer	HOV	3	12778	12782	1	3,534	3,534
							Total by direction	**133,674**	
		Inner	GP		12784	12780	4	123,040	30,760
		Inner	HOV	3	12783	12779	1	2,680	2,680
							Total by direction	**125,720**	
Average, GP								128,459	32,115
Average, HOV/HOT								3,493	3,493
Average combined volume							**Total by direction**	**131,952**	

Daily volumes were converted to peak-hour volumes using two peak-hour factors, one for GP lanes and one for HOV lanes. The peak-hour factor for the GP lanes, 7.9%, is equal to 15.7% (the share of daily Beltway traffic occurring from 4 to 6 PM, based on observed ground counts) divided by 2 (the number of hours in the period). The peak-hour factor for the HOV lanes, 16%, was derived as follows:

$$pk\_hr\_fac\_hov = a * b * c$$

where

a = share of daily HOV traffic occurring in the period 6-9 AM and 4-7 PM (assumed to by 80%)

b = share of peak period HOV traffic in the period 4-7 PM (assumed to be 50%)

c = share of PM peak period HOV traffic in the peak hour (assumed to be 40%)

The estimated peak hour volumes are shown in Table 8. Volume to capacity ratios (v/c) were calculated using the LOS E capacities in Table 9. Since both the GP and HOV lanes in the baseline would operate at 55 mph, the 2,250 v/hr/ln figure was used. For the 2015 HOT lane forecasts, the 2,350 v/hr/ln figure was used for the HOT lanes only, since they are to operate at 65 mph.

Table 8 Base case: Estimated 2015 *peak-hour* volumes on 3 representative segments of the Beltway

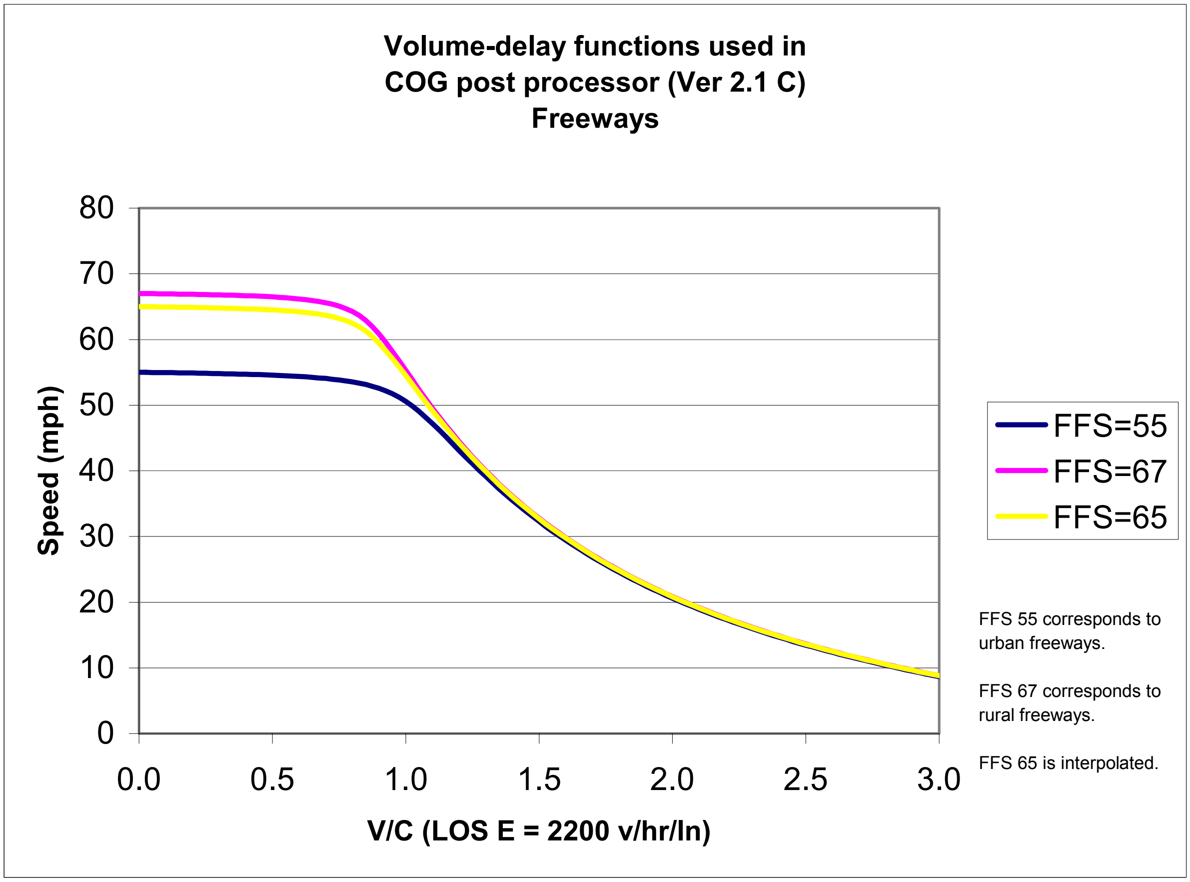
					Highway Network Nodes			Est daily volumes (4-step model)		Est peak-hour volumes (pk-hr factor)					
From	To	Loop	Link Type	HOV Req	A Node	B Node	Lanes	Vol	Vol / ln	Vol	Vol / ln	V/C	Free flow Speed (mph)	Restrain. Speed (mph)	LOS
G-town Pk	Dulles Toll Rd	Outer	GP		12797	12793	4	121,540	30,385	9,541	2,385	1.06	55	49	F
		Outer	HOV	3	12798	12794	1	4,282	4,282	685	685	0.30	55	55	B
							Total by direction	**125,822**		**10,226**					
		Inner	GP		12796	12800	4	128,277	32,069	10,070	2,517	1.12	55	47	F
		Inner	HOV	3	12795	12799	1	3,974	3,974	636	636	0.28	55	55	B
							Total by direction	**132,251**		**10,706**					
VA Route 7	I-66	Outer	GP		12717	12721	4	134,790	33,698	10,581	2,645	1.18	55	44	F
		Outer	HOV	3	12718	12722	1	3,020	3,020	483	483	0.21	55	55	A
							Total by direction	**137,810**		**11,064**					
		Inner	GP		12724	12720	4	132,967	33,242	10,438	2,609	1.16	55	45	F
		Inner	HOV	3	12723	12719	1	3,469	3,469	555	555	0.25	55	55	A
							Total by direction	**136,436**		**10,993**					
Braddock Rd	I-395	Outer	GP		12777	12781	4	130,140	32,535	10,216	2,554	1.14	55	46	F
		Outer	HOV	3	12778	12782	1	3,534	3,534	565	565	0.25	55	55	A
							Total by direction	**133,674**		**10,781**					
		Inner	GP		12784	12780	4	123,040	30,760	9,659	2,415	1.07	55	49	F
		Inner	HOV	3	12783	12779	1	2,680	2,680	429	429	0.19	55	55	A
							Total by direction	**125,720**		**10,087**					
Average, GP								128,459	32,115	10,084	2,521	1.12	55	47	F
Average, HOV/HOT								3,493	3,493	559	559	0.25	55	55	A
Average combined volume							**Total by direction**	**131,952**		**10,643**					

Table 9 LOS E capacities as a function of free-flow speed

FFS (mph)	Capacity
55	2,250
65	2,350

Peak-hour speeds were estimated using a lookup table, shown in graphical form Figure 9, that comes from the COG post processor model, which is the model COG uses to convert output from the 4-step travel model to input suitable for EPA's mobile emissions model, Mobile 6.

Figure 9 Volume delay function used in COG post processor model (for Ver. 2.1 travel model)



Note that the curve for FFS = 65 mph was interpolated from the curves for 55 and 67 mph.
Source: Memo from Ronald Milone, MWCOG, to Files. Subject: Description of the Version 2.1/TP+/MOBILE6 Emissions Post–Processor. March 12, 2003, Table 6, Speed Delay Functions Used in the MWCOG Mobile Emissions Post Processor.

Level of service estimates shown in Table 8 and subsequent tables comes from a lookup table from the 2000 Highway Capacity Manual, shown in Table 10.

Table 10 LOS as a function of V/C ratio and flow rate

FFS = 55					FFS = 65				
min flow	max flow	min v/c	max v/c	LOS	min flow	max flow	min v/c	max v/c	LOS
0	600	0.00	0.27	A	0	710	0.00	0.30	A
600	990	0.27	0.44	B	710	1170	0.30	0.50	B
990	1430	0.44	0.64	C	1170	1680	0.50	0.71	C
1430	1910	0.64	0.85	D	1680	2090	0.71	0.89	D
1910	2250	0.85	1.00	E	2090	2350	0.89	1.00	E
2250	2600	1.00	1.16	F	2350	2600	1.00	1.11	F

Source: 2000 Highway Capacity Manual, Exhibit 23-2, p. 23-4. Note that since the data stops at LOS E in the HCM, the LOS F information in this table was added.

Three forecasts of traffic under the HOT lane scenario were developed: a low, medium, and high forecast. In all three forecasts, we assume that traffic would be diverted from the GP lanes to the HOT lanes, and that the HOT lanes would fill up to their maximum service flow rate of 1,600 v/hr/ln. Since there are two HOT lanes in each direction, the capacity and flow rate of the HOT lanes becomes 3,200 v/hr in each direction. The amount of traffic *diverted* from the GP lanes to the HOT lanes is the same in all three cases and is equal to

(traffic diverted from GP lanes to HOT lanes) = 3,200 – (baseline HOV volume)

Thus, the difference between the three forecasts is not the level of traffic on the HOT lanes, which is always 3,200 v/hr, but rather the level of traffic on the adjacent GP lanes:

- Low forecast: Assumes that, after traffic diverts from the congested GP lanes onto the free-flowing HOT lanes, the GP lanes do not fill up with any new traffic. The increase in traffic on the HOT lanes is equal to the decrease in traffic from the GP lanes. Consequently, there is no net increase in traffic on the Beltway.
- Medium forecast: Assumes that, after traffic diverts from the congested GP lanes onto the free-flowing HOT lanes, the amount of traffic in the GP lanes increases by an amount equal to the capacity of the added lane of traffic in each direction (i.e., increases by 1,600 pc/h in each direction). This increase in traffic on the GP lanes would be due to traffic diverted from nearby arterials and/or induced traffic. Consequently, there is a net increase in traffic on the Beltway, compared to the base case.
- High forecast: Assumes that, after traffic diverts from the congested GP lanes onto the free-flowing HOT lanes, the amount of traffic in the GP lanes increases, and returns to the same level of congestion as was found in the baseline case. This increase in traffic is equal to 3,200 minus the baseline HOV traffic, in each direction. Once again, this increase in traffic on the GP lanes would be due to traffic diverted from nearby arterials and/or induced traffic. Consequently, there is a net increase in traffic on the Beltway, compared to the base case.

The medium and the high travel demand forecasts are probably the most realistic. The three forecasts are presented in Table 11, Table 12, and Table 13.

Table 11 Action, low forecast: Est. 2015 *peak-hour* volumes on 3 representative segments of the Beltway

Assumes traffic is diverted from GP lanes to HOT lanes, but no new traffic is added to GP lanes.

								Baseline		HOT lane Low est		Diff. in volume			
From	To	Loop	Link Type	HOV Req	FFS (mph)	Base Lanes	Prop Lanes	Vol	Vol / ln	Vol	Vol / ln	comp to baseline	V/C	Restrain. Speed (mph)	LOS
G-town Pk	Dulles Toll Rd	Outer	GP		55	4	4	9,541	2,385	7,026	1,757	-2,515	0.78	54	D
		Outer	HOT	3	65	1	2	685	685	3,200	1,600	2,515	0.68	64	C
		Total by direction						**10,226**		**10,226**		**0**			
		Inner	GP		55	4	4	10,070	2,517	7,506	1,876	-2,564	0.83	53	D
		Inner	HOT	3	65	1	2	636	636	3,200	1,600	2,564	0.68	64	C
		Total by direction						**10,706**		**10,706**		**0**			
VA Route 7	I-66	Outer	GP		55	4	4	10,581	2,645	7,864	1,966	-2,717	0.87	53	E
		Outer	HOT	3	65	1	2	483	483	3,200	1,600	2,717	0.68	64	C
		Total by direction						**11,064**		**11,064**		**0**			
		Inner	GP		55	4	4	10,438	2,609	7,793	1,948	-2,645	0.87	53	E
		Inner	HOT	3	65	1	2	555	555	3,200	1,600	2,645	0.68	64	C
		Total by direction						**10,993**		**10,993**		**0**			
Braddock Rd	I-395	Outer	GP		55	4	4	10,216	2,554	7,581	1,895	-2,635	0.84	53	D
		Outer	HOT	3	65	1	2	565	565	3,200	1,600	2,635	0.68	64	C
		Total by direction						**10,781**		**10,781**		**0**			
		Inner	GP		55	4	4	9,659	2,415	6,887	1,722	-2,771	0.77	54	D
		Inner	HOT	3	65	1	2	429	429	3,200	1,600	2,771	0.68	64	C
		Total by direction						**10,087**		**10,087**		**0**			
Average, GP					55			10,084	2,521	7,443	1,861	-2,641	0.83	53	D
Average, HOV/HOT					65			559	559	3,200	1,600	2,641	0.68	64	C
Average combined volume		**Total by direction**						**10,643**		**10,643**		**0**			

Table 12 Action, medium forecast: Est. 2015 *peak-hour* volumes on 3 representative segments of the Beltway

Assumes traffic is diverted from GP lanes to HOT lanes, and traffic on GP lanes increases by 1,600 v/hr in each direction.

								Baseline		HOT lane Medium est		Diff. in volume			
From	To	Loop	Link Type	HOV Req	FFS (mph)	Base Lanes	Prop Lanes	Vol	Vol / ln	Vol	Vol / ln	comp to baseline	V/C	Restrain. Speed (mph)	LOS
G-town Pk	Dulles Toll Rd	Outer	GP		55	4	4	9,541	2,385	8,626	2,157	-915	0.96	52	E
		Outer	HOT	3	65	1	2	685	685	3,200	1,600	2,515	0.68	64	C
		Total by direction						**10,226**		**11,826**		**1,600**			
		Inner	GP		55	4	4	10,070	2,517	9,106	2,276	-964	1.01	51	F
		Inner	HOT	3	65	1	2	636	636	3,200	1,600	2,564	0.68	64	C
		Total by direction						**10,706**		**12,306**		**1,600**			
VA Route 7	I-66	Outer	GP		55	4	4	10,581	2,645	9,464	2,366	-1,117	1.05	49	F
		Outer	HOT	3	65	1	2	483	483	3,200	1,600	2,717	0.68	64	C
		Total by direction						**11,064**		**12,664**		**1,600**			
		Inner	GP		55	4	4	10,438	2,609	9,393	2,348	-1,045	1.04	50	F
		Inner	HOT	3	65	1	2	555	555	3,200	1,600	2,645	0.68	64	C
		Total by direction						**10,993**		**12,593**		**1,600**			
Braddock Rd	I-395	Outer	GP		55	4	4	10,216	2,554	9,181	2,295	-1,035	1.02	51	F
		Outer	HOT	3	65	1	2	565	565	3,200	1,600	2,635	0.68	64	C
		Total by direction						**10,781**		**12,381**		**1,600**			
		Inner	GP		55	4	4	9,659	2,415	8,487	2,122	-1,171	0.94	52	E
		Inner	HOT	3	65	1	2	429	429	3,200	1,600	2,771	0.68	64	C
		Total by direction						**10,087**		**11,687**		**1,600**			
Average, GP					55			10,084	2,521	9,043	2,261	-1,041	1.00	51	F
Average, HOV/HOT					65			559	559	3,200	1,600	2,641	0.68	64	C
Average combined volume		**Total by direction**						**10,643**		**12,243**		**1,600**			

Table 13 Action, high forecast: Est. 2015 *peak-hour* volumes on 3 representative segments of the Beltway

Assumes traffic is diverted from GP lanes to HOT lanes, and traffic on GP lanes increases by 3,200 v/hr in each direction minus the baseline HOV traffic.

								Baseline		HOT lane High est		Diff. in volume			
From	To	Loop	Link Type	HOV Req	FFS (mph)	Base Lanes	Prop Lanes	Vol	Vol / ln	Vol	Vol / ln	comp to baseline	V/C	Restrain. Speed (mph)	LOS
G-town Pk	Dulles Toll Rd	Outer	GP		55	4	4	9,541	2,385	9,541	2,385	0	1.06	49	F
		Outer	HOT	3	65	1	2	685	685	3,200	1,600	2,515	0.68	64	C
							Total by direction	**10,226**		**12,741**		**2,515**			
		Inner	GP		55	4	4	10,070	2,517	10,070	2,517	0	1.12	47	F
		Inner	HOT	3	65	1	2	636	636	3,200	1,600	2,564	0.68	64	C
							Total by direction	**10,706**		**13,270**		**2,564**			
VA Route 7	I-66	Outer	GP		55	4	4	10,581	2,645	10,581	2,645	0	1.18	44	F
		Outer	HOT	3	65	1	2	483	483	3,200	1,600	2,717	0.68	64	C
							Total by direction	**11,064**		**13,781**		**2,717**			
		Inner	GP		55	4	4	10,438	2,609	10,438	2,609	0	1.16	45	F
		Inner	HOT	3	65	1	2	555	555	3,200	1,600	2,645	0.68	64	C
							Total by direction	**10,993**		**13,638**		**2,645**			
Braddock Rd	I-395	Outer	GP		55	4	4	10,216	2,554	10,216	2,554	0	1.14	46	F
		Outer	HOT	3	65	1	2	565	565	3,200	1,600	2,635	0.68	64	C
							Total by direction	**10,781**		**13,416**		**2,635**			
		Inner	GP		55	4	4	9,659	2,415	9,659	2,415	0	1.07	49	F
		Inner	HOT	3	65	1	2	429	429	3,200	1,600	2,771	0.68	64	C
							Total by direction	**10,087**		**12,859**		**2,771**			
Average, GP					55			10,084	2,521	10,084	2,521	0	1.12	47	F
Average, HOV/HOT					65			559	559	3,200	1,600	2,641	0.68	64	C
Average combined volume							**Total by direction**	**10,643**		**13,284**		**2,641**			

Based on the forecasted volumes, v/c ratios, speeds, and LOSs for these three segments of the Beltway, *average values* were calculated and appear at the bottom of Table 11, Table 12, and Table 13. These average values were then used to represent the entire 14-mile-long HOT lane facility.

The number of GP lane miles stays the same for all four scenarios (112 lane miles), but the total (GP plus managed) lane miles increase 20% (from 140 to 168), as shown in Table 14.

Table 14 Lane mile calculations

Analysis year: 2015	Baseline	Action Low	Action Medium	Action High
Length (miles)	14	14	14	14
Lanes, GP	8	8	8	8
Lanes, HOV/HOT	2	4	4	4
Lanes, total	10	12	12	12
Lane miles, GP	112	112	112	112
Lane miles, HOV/HOT	28	56	56	56
Lane miles, total	140	168	168	168

The estimated 2015 peak-hour volumes and vehicle miles of travel (VMT) used in this analysis are shown in Table 15. Comparing the "action high" forecast to the baseline, the estimated peak-hour volume is 25% higher, but the estimated peak-hour VMT is only 14% higher.

Table 15 Est. peak-hour 2015 volume and VMT

Analysis year: 2015		Baseline	Action Low	Action Medium	Action High
Est ave. peak-hour volume, GP		10,084	7,443	9,043	10,084
Est ave. peak-hour volume, HOV/HOT		559	3,200	3,200	3,200
	Total	10,643	10,643	12,243	13,284
	Pct diff	0%	0%	15%	25%
Est peak-hour VMT, GP		1,129,412	833,609	1,012,809	1,129,412
Est peak-hour VMT, HOV/HOT		15,649	179,200	179,200	179,200
	Total	1,145,061	1,012,809	1,192,009	1,308,612
	Pct diff	0%	-12%	4%	14%

Table 16 shows the assumed peak-hour values for speed, travel time over the 14-mile segment, volume-to-capacity ratio, and level of service.

Table 16 Est. peak-hour 2015 speeds, travel times, V/C, and LOS

Analysis year: 2015	Baseline	Action Low	Action Medium	Action High
Ave. peak-hour speed, GP	47	53	51	47
Ave. peak-hour speed, HOV/HOT	55	64	64	64
Travel time, GP (minutes)	17.9	15.7	16.6	17.9
Travel time, HOV/HOT	15.3	13.2	13.2	13.2
Travel time savings, GP minus HOV/HOT	2.6	2.6	3.4	4.8
Peak hour V/C, GP	1.12	0.83	1.00	1.12
Peak hour V/C, HOV/HOT	0.25	0.68	0.68	0.68
Peak hour LOS, GP (FFS = 55 mph)	F	D	F	F
Peak hour LOS, HOV/HOT (FFS = 55/65 mph)	A	C	C	C

In the base case, the free flow speed on both the GP lanes and the HOT/HOV3+ lanes is 55 mph, but the restrained speeds (shown in the table below) are estimated to be 47 mph on the GP lanes and 55 mph on the HOV3+ lanes. In the three action or "build" scenarios, the free flow speed on the HOT/HOV3+ lanes is raised 10 mph to 65 mph. The restrained speed on the HOT/HOV3+ lanes drops to approximately 64 mph, because of the LOS C (1,600 v/hr/ln) traffic. In the base case, using the managed (HOV) lanes would save about 2.6 minutes over using the GP lanes, assuming one travels the full 14-mile segment. In the three action scenarios, using the managed lanes would save from 2.6 minutes to 4.8 minutes.

However, simply stating the average time savings during the peak period for the base and action scenarios *understates* the total travel time benefit to users. For example, in the base case, only *one* class of users (HOV3+), traveling in about 1,000 vehicles (per hour), could benefit from the 2.6-minute time savings, resulting in about 3,000 vehicle-minutes of time savings or 11,000 person-minutes of time savings (assuming an average vehicle occupancy of 3.6 persons per vehicle in the HOV3+ lanes). See Table 17. By contrast, in the action case (high forecast), *three* classes of users (HOV3+, SOV pay toll, and HOV2 pay toll), traveling in about 6,400 vehicles (per hour), could benefit from the 4.8-minute time savings, resulting in about 31,000 vehicle-minutes of time savings or 43,000 person-minutes of time savings (assuming an average vehicle occupancy of 1.4 persons per vehicle in the HOT lanes). So the time savings in terms of vehicle-minutes increases by a factor of about 10 and the person-minutes of time savings increases by a factor of about 4 (See Table 17). Of course these travel times and time savings represent the peak hour of an *average weekday* with no traffic incidents. On a day where there is a major incident, the travel time savings in the managed lanes will likely be much more than the 4.8 minutes shown in the table.

Table 17 Average time savings during the peak hour, action vs. baseline (assuming the "action medium forecast")

Scenario	Lane type	Total lanes	Ave. speed (mph)	Veh per hr (each way)	Veh per hr (both ways)	User classes (auto mode)	Ave. travel time (min.)	Assumed ave. occu-pancy	Average Time Savings Min	Veh*min	Pers*min
Base	Gen. purp.	8	47	10,084	20,168	All auto modes	17.9				
	Managed	2	55	559	1,118	HOV3+	15.3	3.6	2.6	2,942	10,591
Action	Gen. purp.	8	47	10,084	20,168	All auto modes	17.9				
(High forecast)	Managed	4	64	3,200	6,400	HOV3+ SOV pay HOV2 pay	13.2	1.4	4.8	30,643	42,901
Difference	Gen. purp.	0	0	0	0	Same	0				
(Action - Base)	Managed	2	9	2,641	5,282	Two new user classes	-2.2	-2.2	2.2	27,701	32,310

Total length of facility (miles)	14

	Min	Veh*min	Pers*min
Percent difference (action vs. base)	82%	942%	305%
Ratio (action/base)	1.8	10.4	4.1

Ref: x215rnet_vol_ daily.xls

Table 18 shows the assumed values used for the emissions calculation. A column has been added to the right-hand side of this table, which represents the average of the emissions estimates from the medium and high demand forecasts, since these two demand forecasts are considered the most likely. Note that Table 18 contains two types of emissions estimates:

- Peak-hour estimates for the HOT lane facility (both GP and managed lanes), and
- Daily estimates for the region.

Peak-hour estimates for the HOT lane facility appear in the first 10 rows of the table and daily estimates for the region appear in the last 4 rows of the table.

The peak-hour running emissions by pollutant and by lane type (shown in the first four rows in the table) are the product of the relevant VMT (shown in Table 15) and the corresponding emissions factor (not shown in this table, but included in the appendix). Peak-hour running emissions by pollutant (summed across GP and HOV/HOT lanes) are shown the next two rows of the table and are shown graphically in Figure 10 and Figure 11.

To calculate the *daily* emissions impact of the proposed facility at the *regional* level we have added two numbers:

- The total daily mobile emissions from the Air Quality Conformity Analysis of the 2002 CLRP and the FY 2003-2008 TIP (also shown in Table 19), and
- The increment in peak-hour emissions (compared to the base case) times a factor of four. It was reasoned that the total daily emissions from the proposed facility would be equal to about four times the peak-hour emissions.

Table 18 Est. peak-hour 2015 running emissions, both specific to facility and region wide

Analysis year: 2015	Baseline	Action Low	Action Medium	Action High	Action (ave. of med+high)
Pk-hr emissions, VOC, GP (grams/hr)	202,616	139,880	174,001	202,616	188,309
Pk-hr emissions, VOC, HOV/HOT	2,607	28,780	28,780	28,780	28,780
Pk-hr emissions, NOX, GP	978,296	783,759	912,744	978,296	945,520
Pk-hr emissions, NOX, HOV/HOT	14,904	201,313	201,313	201,313	201,313
Pk-hr emissions, VOC, total (grams/hour)	205,224	168,659	202,780	231,396	217,088
Pk-hr emissions, NOX, total	993,201	985,073	1,114,057	1,179,610	1,146,833
Pk-hr emissions, VOC, total, difference from base	0	-36,564	-2,443	26,172	11,864
Pk-hr emissions, NOX, total, difference from base	0	-8,128	120,856	186,409	153,632
Pk-hr emissions, VOC, total, pct diff from base	0%	-18%	-1%	13%	6%
Pk-hr emissions, NOX, total, pct diff from base	0%	-1%	12%	19%	15%
Regional total, daily VOC + (pk-hr emiss.) * factor	86,545,424	86,399,166	86,535,650	86,650,114	86,592,882
Regional total, daily NOx + (pk-hr emiss.) * factor	107,864,266	107,831,753	108,347,690	108,609,901	108,478,795
Regional total, VOC, percent difference	0.00%	-0.17%	-0.01%	0.12%	0.05%
Regional total, NOx, percent difference	0.00%	-0.03%	0.45%	0.69%	0.57%

Factor used to multiply peak-hour emissions before adding to daily	4

Based on the average of the emissions estimates for the medium and high travel demand forecasts, we estimate that peak-hour running VOC emissions would increase slightly – about 6% during the peak hour for the facility itself and about 0.05% on a daily basis at the regional level. Similarly, we estimate that peak-hour running NOx emissions would increase moderately – about 15% during the peak hour for the facility itself and about 0.57% on a daily basis at the regional level. One should remember that, as stated earlier, the emissions estimates are conservative, i.e., likely to overestimate emissions, because the increase in VMT in the medium and high travel forecasts is treated as 100% induced demand, meaning that it is all new VMT, not simply VMT moved from other facilities.

Figure 10 Estimated 2015 peak-hour running emissions from the 14-mile segment of the Beltway: VOC

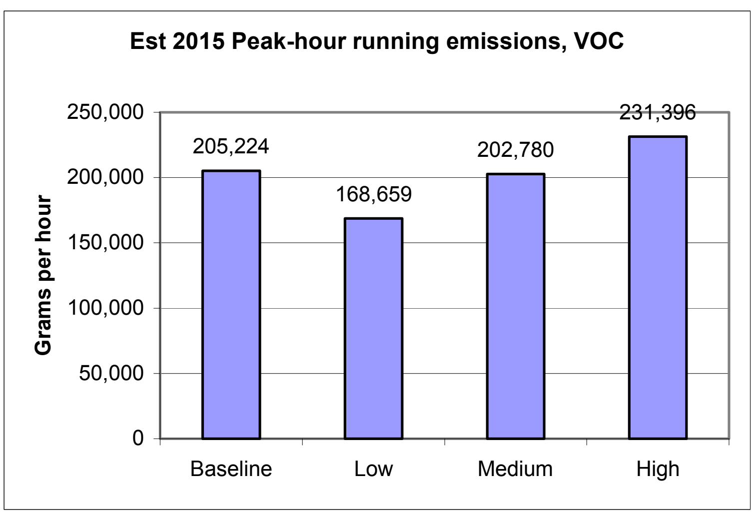


Figure 11 Estimated 2015 peak-hour running emissions from the 14-mile segment of the Beltway: NOx

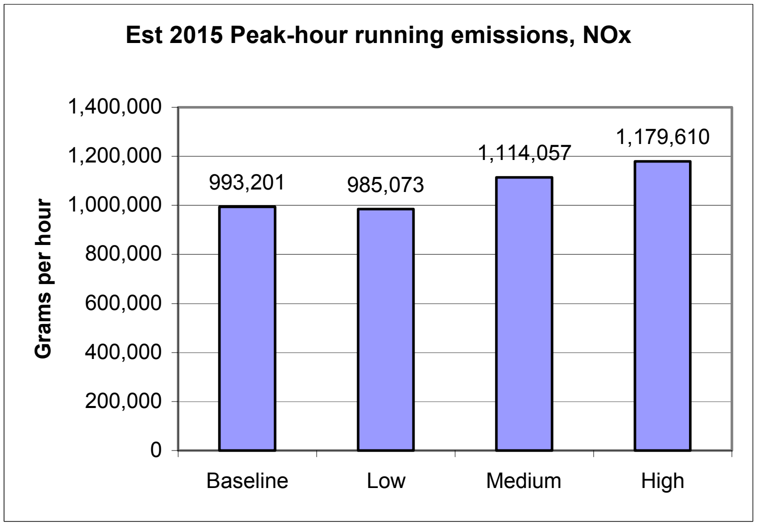


Table 19 Total daily mobile emissions from the Air Quality Conformity Analysis of the 2002 CLRP and the FY 2003-2008 TIP

Air Quality Conformity of 2002 CLRP & FY03-08 TIP		
	tons/day	grams/day
Mobile source VOC emissions, 2015	95.4	86,545,424
Mobile source NOx emissions, 2015	118.9	107,864,266
Conversion factor: grams per imperial ton	907,184.74	

Bus routes are anticipated to use the HOT lanes, generating 20 buses per hour during the peak and 7 buses per hour during the off-peak, based on existing bus service. Adding routes is anticipated to increase these figures by 24 buses per hour and 16 buses per hour, respectively. As can be seen in Table 20, this would add 40 passenger car equivalents (PCEs) to the baseline scenario and 88 PCEs to the HOT lane scenarios, assuming that each bus equals 2 passenger car equivalents. The effect of this bus service has not been explicitly accounted for in our analysis, since the number of PCEs is so small, and their inclusion would not have changed the emissions forecasts. Nonetheless, we think that the transit element is an important part of the project and should not be omitted when selling the project to potential sponsors.

Table 20 Conversion of buses to passenger car equivalents (PCEs)

	Buses			PCEs	
	Base	Added Service	Total Proposed	Base	Proposed
	(buses per hour)	(buses per hour)	(buses per hour)	(PCEs per hour)	(PCEs per hour)
Peak period	20	24	44	40	88
Off peak	7	16	23	14	46

Assumption:
Passenger car equivalents 1 bus = 2 PCEs

Ref: x215rnet_vol_ daily.xls

4.3 Findings

A sketch planning technique was used to estimate both travel demand and mobile emissions for the 14-mile segment of the Beltway that would comprise the HOT lane facility. There were four demand forecasts and four emissions forecasts: base, action low, action medium, and action high. The medium and high demand forecasts were deemed to be the most likely of the three action or "build" scenarios.

- The proposed HOT lane facility would likely result in a slight increase in volatile organic compounds (VOC) – about 6% during the peak hour for the facility itself and about 0.05% on a daily basis at the regional level.

- The proposed HOT lane facility would likely result in a moderate increase in oxides of nitrogen (NOx) – about 15% during the peak hour for the facility itself and about 0.57% on a daily basis at the regional level.

- The foregoing emissions estimates are conservative, i.e., likely to overestimate emissions, because the increase in VMT in the medium and high travel forecasts is treated as 100% induced demand, meaning that it is all new VMT, not simply VMT moved from other facilities.

- The proposed HOT lane facility would likely result in three main benefits to users of the facility and its adjacent general purpose lanes on the Beltway:

    - More travel choices: In the base scenario, a user of this section of the Beltway had two travel options: SOV or HOV3+ (which includes 3+ person carpools, vanpools, and buses). In the action scenario, a user now has two new travel options: "SOV pay toll," and "HOV2 pay toll."

- Travel time savings: In the base case, using the managed (HOV) lanes would save about 2.6 minutes over using the GP lanes, assuming one travels the full 14-mile segment. In the three action scenarios, using the managed lanes would save from 2.6 minutes to 4.8 minutes. However, simply stating the average time savings during the peak period for the base and action scenarios *understates* the total travel time benefit to users. For example, in the base case, only *one* class of users (HOV3+) could benefit from the 2.6-minute time savings, resulting in about 11,000 person-minutes of time savings, assuming an average vehicle occupancy of 3.6 persons per vehicle in the HOV3+ lanes. By contrast, in the action case, *three* classes of users (HOV3+, SOV pay toll, and HOV2 pay toll) could benefit from the 4.8-minute time savings (high forecast), resulting in about 43,000 person-minutes of time savings, assuming an average vehicle occupancy of 1.4 persons per vehicle in the HOT lanes. So the time savings in terms of person-minutes increases by a factor of about 4. Additionally, the aforementioned travel time savings represent the peak hour of an *average weekday* with no traffic incidents. On a day where there is a major incident, the travel time savings in the managed lanes will likely be much more than 4.8 minutes.

- Consistency and dependability in travel times: The proposed HOT lane facility would maintain good levels of service on the managed lanes (anywhere from A to C) and would likely improve the level of service on the adjacent GP lanes, as compared to the base case. Users of existing HOT lane facilities in other states often report that one of the main perceived benefits of traveling on the HOT lanes is, in fact, the travel time dependability, which is ensured thanks to the variable pricing of the lanes.

- Although the proposed HOT lane facility would result in both travel time savings and more consistent travel times, there would be even more user benefits if a *network* of HOT lanes were built in the region. Such a system is currently being proposed as a scenario for testing in the Regional Mobility and Accessibility Study, being conducted at Metropolitan Washington Council of Governments.

5 References and resources

Works cited

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Metropolitan Washington Council of Governments (MWCOG). (2002) *Air Quality Conformity Determination of the 2002 Constrained Long Range Plan and the FY 2003-2008 Transportation Improvement Program for the Washington Metropolitan Region*. Washington, D.C. July 31, 2002.

Perez, B.G. and Sciara, G.C. (2003) *A Guide For HOT Lane Development* (Web document). URL: http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/13668.html Prepared by Parsons Brinckerhoff, Inc., Texas Transportation Institute, and Federal Highway Administration. Likely to be released in printed form in April 2003.

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Kim, Eugene J. (2000) HOT Lanes: A Comparative Analysis of Costs, Benefits, and Performance. Ph.D. dissertation. University of California, Los Angeles.

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Small, Kenneth A. (1997) "I-15 Congestion Pricing Project Monitoring And Evaluation Services, Task 1.1 Worldwide Experience with Congestion Pricing." Prepared for San Diego Association of Governments by San Diego State University. June 10, 1997.

Small, Kenneth A., Janusz Supernak, Tom Collins, and Eric Schreffler. (1997) "I-15 Congestion Pricing Project Monitoring And Evaluation Services, Task 1.2 Up-To-Date Results Of The SR-91 Congestion Pricing Experiment." Prepared for San Diego Association of Governments by San Diego State University. June 10, 1997.

Sullivan, Edward (1998) *Evaluating the Impacts of the SR 91 Variable-Toll Express Lane Facility*, Final Report. Prepared for the California Department of Transportation (Caltrans) by Cal Poly State University, San Luis Obispo, California. May 1998.

Sullivan, Edward (2000) *Continuation Study to Evaluate the Impacts of the SR 91 Value-Priced Express Lanes*, Final Report. Prepared for the California Department of Transportation (Caltrans) by Cal Poly State University, San Luis Obispo, California. December 2000.

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Turner, Shawn M., Gary A. Carlin, and Russell H. Henk. (1995) *Quantifying the Benefits of High-Occupancy Vehicle Facilities Using Automatic Vehicle Identification Technology*. Report No. SWUTC/95/465020-1. November 1995

Worldwide Web Links

HOT lanes, HOV lanes, Value pricing: General links

A Guide for HOT Lane Development: http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/13668.html#_Toc17693436
California Department of Transportation (Caltrans): http://www.dot.ca.gov/
FHWA, Office of Transportation Management: http://ops.fhwa.dot.gov/Travel/
FHWA, Office of Transportation Management, HOV facilities: http://ops.fhwa.dot.gov/Travel/traffic/hov/index.htm
FHWA Value Pricing Pilot Project Web site: http://www.fhwa.dot.gov/policy/vppp.htm
FHWA value pricing stuff: http://www.tfhrc.gov/pubrds/marapr99/pricing.htm
FHWA analysis tools to estimate the effects of pricing (e.g., STEAM, SMITE): http://www.fhwa.dot.gov/steam/links.htm
Hubert Humphrey Institute's value pricing homepage: http://www.hhh.umn.edu/centers/slp/projects/conpric/index.htm
Texas Transportation Institute, Managed lanes Web site: http://managed-lanes.tamu.edu/
Urban Transport Pricing in Europe: http://www.transport-pricing.net/

HOT lanes, facility-specific

SR-91 Express Lanes in Orange County, California

Official Web page: http://www.91expresslanes.com/
State Route 91 Study Products: http://ceenve.calpoly.edu/sullivan/sr91/sr91.htm
Southern California Association of Governments (SCAG): http://www.scag.ca.gov/index.htm
Transportation Corridor Agencies (TCA). Formed in 1986 to plan, finance, construct and operate Orange County's 67-mile public toll road system: http://www.tcagencies.com/

I-15 Express Lanes in San Diego, California

Official Web page: http://argo.sandag.org/fastrak/index.html
I-15 project-related reports: http://argo.sandag.org/fastrak/library.html
San Diego Association of Governments (SANDAG): http://www.sandag.org

Houston's QuickRide System

QuickRide: http://www.hou-metro.harris.tx.us/services/quickride.asp
Metropolitan Transit Authority of Harris Co., Texas (Houston Metro): http://www.hou-metro.harris.tx.us/homepage.asp
Houston-Galveston Area Council (HGAC): http://www.hgac.cog.tx.us/
Texas Transportation Institute: http://tti.tamu.edu/

MPOs not already listed above

Maricopa Association of Governments (MAG): http://www.mag.maricopa.gov/display.cms

Appendix A
Spreadsheets used in demand and emissions estimates

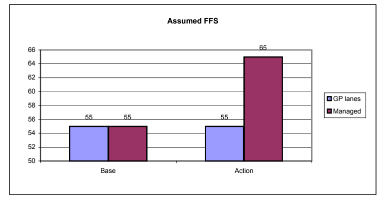
Ref: x215rnet_vol_daily.xls

Estimated traffic volumes on three representative segments of the Capital Beltway:
Converting daily volumes to hourly volumes

Baseline conditions assumed for 2015

Assumed Free Flow Speeds (mph)

	Base	Action
GP lanes	55	55
Managed	55	65



From	To	Loop	Link Type	HOV Req	Highway Network Nodes A Node	B Node	Lanes	Est daily volumes (4-step model) Vol	Vol / ln	Est peak-hour volumes (pk-hr factor) Vol	Vol / ln	V/C	Free flow Speed (mph)	Restrain. Speed (mph)	LOS
G-town Pk	Dulles Toll Rd	Outer	GP		12797	12793	4	121,540	30,385	9,541	2,385	1.06	55	49	F
		Outer	HOV	3	12798	12794	1	4,282	4,282	685	685	0.30	55	55	B
						Total by direction		**125,822**		**10,226**					
		Inner	GP		12796	12800	4	128,277	32,069	10,070	2,517	1.12	55	47	F
		Inner	HOV	3	12795	12799	1	3,974	3,974	636	636	0.28	55	55	B
						Total by direction		**132,251**		**10,706**					
VA Route 7	I-66	Outer	GP		12717	12721	4	134,790	33,698	10,581	2,645	1.18	55	44	F
		Outer	HOV	3	12718	12722	1	3,020	3,020	483	483	0.21	55	55	A
						Total by direction		**137,810**		**11,064**					
		Inner	GP		12724	12720	4	132,967	33,242	10,438	2,609	1.16	55	45	F
		Inner	HOV	3	12723	12719	1	3,469	3,469	555	555	0.25	55	55	A
						Total by direction		**136,436**		**10,993**					
Braddock Rd	I-395	Outer	GP		12777	12781	4	130,140	32,535	10,216	2,554	1.14	55	46	F
		Outer	HOV	3	12778	12782	1	3,534	3,534	565	565	0.25	55	55	A
						Total by direction		**133,674**		**10,781**					
		Inner	GP		12784	12780	4	123,040	30,760	9,659	2,415	1.07	55	49	F
		Inner	HOV	3	12783	12779	1	2,680	2,680	429	429	0.19	55	55	A
						Total by direction		**125,720**		**10,087**					
Average, GP								128,459	32,115	10,084	2,521	1.12	55	47	F
Average, HOV/HOT								3,493	3,493	559	559	0.25	55	55	A
Average combined volume						**Total by direction**		**131,952**		**10,643**					

Assumptions about peaking on Beltway

		Value	Var.	Notes
GP lanes	Share of daily Beltway traffic from 4 to 6 PM	15.7%	A	Source: Observed ground counts
	Hours in period	2	B	
	Factor to convert daily vol to hourly, GP lanes	**7.9%**	= A / B	
HOV lanes	Share of daily HOV traffic occurring 6-9 AM, 4-7 PM	80.0%	C	
	Share of peak-per HOV traffic in 4-7 PM	50.0%	D	
	Share of PM peak-per HOV traffic in peak hour	40.0%	E	
	Factor to convert daily vol to hourly, HOV lanes	**16.0%**	= C*D*E	

LOS E capacity (veh/hour/lane)

FFS (mph)	Capacity
55	2,250
65	2,350

Estimated traffic volumes under Fluor HOT lane proposal (peak hour)
Low, Medium, and High forecast

Maxiumum allowable volume for HOT lanes 1,600 v/hr/ln

Low forecast

From	To	Loop	Link Type	HOV Req	FFS (mph)	Base Lanes	Prop Lanes	Baseline Vol	Baseline Vol / ln	HOT lane Low est Vol	HOT lane Low est Vol / ln	Diff. in volume comp to baseline	V/C	Restrain. Speed (mph)	LOS
G-town Pk	Dulles Toll Rd	Outer	GP		55	4	4	9,541	2,385	7,026	1,757	-2,515	0.78	54	D
		Outer	HOT	3	65	1	2	685	685	3,200	1,600	2,515	0.68	64	C
							Total by direction	**10,226**		**10,226**		**0**			
		Inner	GP		55	4	4	10,070	2,517	7,506	1,876	-2,564	0.83	53	D
		Inner	HOT	3	65	1	2	636	636	3,200	1,600	2,564	0.68	64	C
							Total by direction	**10,706**		**10,706**		**0**			
VA Route 7	I-66	Outer	GP		55	4	4	10,581	2,645	7,864	1,966	-2,717	0.87	53	E
		Outer	HOT	3	65	1	2	483	483	3,200	1,600	2,717	0.68	64	C
							Total by direction	**11,064**		**11,064**		**0**			
		Inner	GP		55	4	4	10,438	2,609	7,793	1,948	-2,645	0.87	53	E
		Inner	HOT	3	65	1	2	555	555	3,200	1,600	2,645	0.68	64	C
							Total by direction	**10,993**		**10,993**		**0**			
Braddock Rd	I-395	Outer	GP		55	4	4	10,216	2,554	7,581	1,895	-2,635	0.84	53	D
		Outer	HOT	3	65	1	2	565	565	3,200	1,600	2,635	0.68	64	C
							Total by direction	**10,781**		**10,781**		**0**			
		Inner	GP		55	4	4	9,659	2,415	6,887	1,722	-2,771	0.77	54	D
		Inner	HOT	3	65	1	2	429	429	3,200	1,600	2,771	0.68	64	C
							Total by direction	**10,087**		**10,087**		**0**			
Average, GP					55			10,084	2,521	7,443	1,861	-2,641	0.83	53	D
Average, HOV/HOT					65			559	559	3,200	1,600	2,641	0.68	64	C
Average combined volume							**Total by direction**	**10,643**		**10,643**		**0**			

Medium forecast

From	To	Loop	Link Type	HOV Req	FFS (mph)	Base Lanes	Prop Lanes	Baseline Vol	Baseline Vol / ln	HOT lane Medium est Vol	HOT lane Medium est Vol / ln	Diff. in volume comp to baseline	V/C	Restrain. Speed (mph)	LOS
G-town Pk	Dulles Toll Rd	Outer	GP		55	4	4	9,541	2,385	8,626	2,157	-915	0.96	52	E
		Outer	HOT	3	65	1	2	685	685	3,200	1,600	2,515	0.68	64	C
							Total by direction	**10,226**		**11,826**		**1,600**			
		Inner	GP		55	4	4	10,070	2,517	9,106	2,276	-964	1.01	51	F
		Inner	HOT	3	65	1	2	636	636	3,200	1,600	2,564	0.68	64	C
							Total by direction	**10,706**		**12,306**		**1,600**			
VA Route 7	I-66	Outer	GP		55	4	4	10,581	2,645	9,464	2,366	-1,117	1.05	49	F
		Outer	HOT	3	65	1	2	483	483	3,200	1,600	2,717	0.68	64	C
							Total by direction	**11,064**		**12,664**		**1,600**			
		Inner	GP		55	4	4	10,438	2,609	9,393	2,348	-1,045	1.04	50	F
		Inner	HOT	3	65	1	2	555	555	3,200	1,600	2,645	0.68	64	C
							Total by direction	**10,993**		**12,593**		**1,600**			
Braddock Rd	I-395	Outer	GP		55	4	4	10,216	2,554	9,181	2,295	-1,035	1.02	51	F
		Outer	HOT	3	65	1	2	565	565	3,200	1,600	2,635	0.68	64	C
							Total by direction	**10,781**		**12,381**		**1,600**			
		Inner	GP		55	4	4	9,659	2,415	8,487	2,122	-1,171	0.94	52	E
		Inner	HOT	3	65	1	2	429	429	3,200	1,600	2,771	0.68	64	C
							Total by direction	**10,087**		**11,687**		**1,600**			
Average, GP					55			10,084	2,521	9,043	2,261	-1,041	1.00	51	F
Average, HOV/HOT					65			559	559	3,200	1,600	2,641	0.68	64	C
Average combined volume							**Total by direction**	**10,643**		**12,243**		**1,600**			

High forecast

From	To	Loop	Link Type	HOV Req	FFS (mph)	Base Lanes	Prop Lanes	Baseline Vol	Baseline Vol / ln	HOT lane High est Vol	HOT lane High est Vol / ln	Diff. in volume comp to baseline	V/C	Restrain. Speed (mph)	LOS
G-town Pk	Dulles Toll Rd	Outer	GP		55	4	4	9,541	2,385	9,541	2,385	0	1.06	49	F
		Outer	HOT	3	65	1	2	685	685	3,200	1,600	2,515	0.68	64	C
							Total by direction	**10,226**		**12,741**		**2,515**			
		Inner	GP		55	4	4	10,070	2,517	10,070	2,517	0	1.12	47	F
		Inner	HOT	3	65	1	2	636	636	3,200	1,600	2,564	0.68	64	C
							Total by direction	**10,706**		**13,270**		**2,564**			
VA Route 7	I-66	Outer	GP		55	4	4	10,581	2,645	10,581	2,645	0	1.18	44	F
		Outer	HOT	3	65	1	2	483	483	3,200	1,600	2,717	0.68	64	C
							Total by direction	**11,064**		**13,781**		**2,717**			
		Inner	GP		55	4	4	10,438	2,609	10,438	2,609	0	1.16	45	F
		Inner	HOT	3	65	1	2	555	555	3,200	1,600	2,645	0.68	64	C
							Total by direction	**10,993**		**13,638**		**2,645**			
Braddock Rd	I-395	Outer	GP		55	4	4	10,216	2,554	10,216	2,554	0	1.14	46	F
		Outer	HOT	3	65	1	2	565	565	3,200	1,600	2,635	0.68	64	C
							Total by direction	**10,781**		**13,416**		**2,635**			
		Inner	GP		55	4	4	9,659	2,415	9,659	2,415	0	1.07	49	F
		Inner	HOT	3	65	1	2	429	429	3,200	1,600	2,771	0.68	64	C
							Total by direction	**10,087**		**12,859**		**2,771**			
Average, GP					55			10,084	2,521	10,084	2,521	0	1.12	47	F
Average, HOV/HOT					65			559	559	3,200	1,600	2,641	0.68	64	C
Average combined volume							**Total by direction**	**10,643**		**13,284**		**2,641**			

Calculation of peak-hour running emissions

Analysis year: 2015	Baseline	Action Low	Action Medium	Action High			
Length (miles)	14	14	14	14		A	
Lanes, GP	8	8	8	8		B	
Lanes, HOV/HOT	2	4	4	4		C	
Lanes, total	10	12	12	12	calc	D = B+C	
Lane miles, GP	112	112	112	112	calc	E = A*B	
Lane miles, HOV/HOT	28	56	56	56	calc	F = A*C	
Lane miles, total	140	168	168	168	calc	G = E+F	
Est ave. peak-hour volume, GP	10,084	7,443	9,043	10,084		H	
Est ave. peak-hour volume, HOV/HOT	559	3,200	3,200	3,200		I	
Est ave. daily vol, GP (not used in emis. calc.)	128,459	(Not used in analysis)				J	Not used
Est ave. daily vol, HOV/HOT (not used in emis. calc.)	3,493	(Not used in analysis)				K	Not used
Est peak-hour VMT, GP	1,129,412	833,609	1,012,809	1,129,412	calc	L = E*H	
Est peak-hour VMT, HOV/HOT	15,649	179,200	179,200	179,200	calc	M = F*I	
Est daily VMT, GP (not used in emis. calc.)	14,387,408	(Not used in analysis)			calc	N = E*J	Not used
Est daily VMT, HOV/HOT (not used in emis. calc.)	97,809	(Not used in analysis)			calc	O = F*K	Not used
Ave. peak-hour speed, GP	47	53	51	47		P	
Ave. peak-hour speed, HOV/HOT	55	64	64	64		Q	
Emissions factor, VOC, GP	0.1794	0.1678	0.1718	0.1794	calc	R = lookup	
Emissions factor, VOC, HOV/HOT	0.1666	0.1606	0.1606	0.1606	calc	S = lookup	
Emissions factor, CO, GP	5.6164	6.2030	5.9382	5.6164	calc	T = lookup	
Emissions factor, CO, HOV/HOT	6.2848	7.1380	7.1380	7.1380	calc	U = lookup	
Emissions factor, NOX, GP	0.8662	0.9402	0.9012	0.8662	calc	V = lookup	
Emissions factor, NOX, HOV/HOT	0.9524	1.1234	1.1234	1.1234	calc	W = lookup	
Pk-hr emissions, VOC, GP (grams/hr)	202,616	139,880	174,001	202,616	calc	X = L*R	
Pk-hr emissions, VOC, HOV/HOT	2,607	28,780	28,780	28,780	calc	Y = L*S	
Pk-hr emissions, CO, GP	6,343,227	5,170,877	6,014,263	6,343,227	calc	Z = L*T	
Pk-hr emissions, CO, HOV/HOT	98,353	1,279,130	1,279,130	1,279,130	calc	AA = L*U	
Pk-hr emissions, NOX, GP	978,296	783,759	912,744	978,296	calc	BB = L*V	
Pk-hr emissions, NOX, HOV/HOT	14,904	201,313	201,313	201,313	calc	CC = L*W	
Pk-hr emissions, VOC, total (grams/hour)	205,224	168,659	202,780	231,396	calc	DD = X+Y	
Pk-hr emissions, CO, total	6,441,580	6,450,007	7,293,392	7,622,357	calc	EE = Z+AA	
Pk-hr emissions, NOX, total	993,201	985,073	1,114,057	1,179,610	calc	FF = BB+CC	
Pk-hr emissions, VOC, total, difference from base	0	-36,564	-2,443	26,172	calc		
Pk-hr emissions, CO, total, difference from base	0	8,427	851,812	1,180,776	calc		
Pk-hr emissions, NOX, total, difference from base	0	-8,128	120,856	186,409	calc		
Pk-hr emissions, VOC, total, pct diff from base	0%	-18%	-1%	13%	calc		
Pk-hr emissions, CO, total, pct diff from base	0%	0%	13%	18%	calc		
Pk-hr emissions, NOX, total, pct diff from base	0%	-1%	12%	19%	calc		
Regional total, daily VOC + (pk-hr emiss.) * factor	86,545,424	86,399,166	86,535,650	86,650,114			Factor = 4
Regional total, daily NOx + (pk-hr emiss.) * factor	107,864,266	107,831,753	108,347,690	108,609,901			
Regional total, VOC, percent difference	0.00%	-0.17%	-0.01%	0.12%			
Regional total, NOx, percent difference	0.00%	-0.03%	0.45%	0.69%			
Travel time, GP (minutes)	17.9	15.7	16.6	17.9	calc		
Travel time, HOV/HOT	15.3	13.2	13.2	13.2	calc		
Travel time savings, GP minus HOV/HOT	2.6	2.6	3.4	4.8	calc		
Peak hour V/C, GP	1.12	0.83	1.00	1.12			
Peak hour V/C, HOV/HOT	0.25	0.68	0.68	0.68			
Peak hour LOS, GP (FFS = 55 mph)	F	D	F	F			
Peak hour LOS, HOV/HOT (FFS = 55/65 mph)	A	C	C	C			

Air Quality Conformity of 2002 CLRP & FY03-08 TIP

	tons/day	grams/day
Mobile source VOC emissions, 2015	95.4	86,545,424
Mobile source NOx emissions, 2015	118.9	107,864,266
Conversion factor: grams per imperial ton	907,184.74	

Summary tables (values are read from main table above)

Analysis year: 2015	Baseline	Action Low	Action Medium	Action High
Length (miles)	14	14	14	14
Lanes, GP	8	8	8	8
Lanes, HOV/HOT	2	4	4	4
Lanes, total	10	12	12	12
Lane miles, GP	112	112	112	112
Lane miles, HOV/HOT	28	56	56	56
Lane miles, total	140	168	168	168

Analysis year: 2015		Baseline	Action Low	Action Medium	Action High
Est ave. peak-hour volume, GP		10,084	7,443	9,043	10,084
Est ave. peak-hour volume, HOV/HOT		559	3,200	3,200	3,200
	Total	10,643	10,643	12,243	13,284
	Pct diff	0%	0%	15%	25%
Est peak-hour VMT, GP		1,129,412	833,609	1,012,809	1,129,412
Est peak-hour VMT, HOV/HOT		15,649	179,200	179,200	179,200
	Total	1,145,061	1,012,809	1,192,009	1,308,612
	Pct diff	0%	-12%	4%	14%

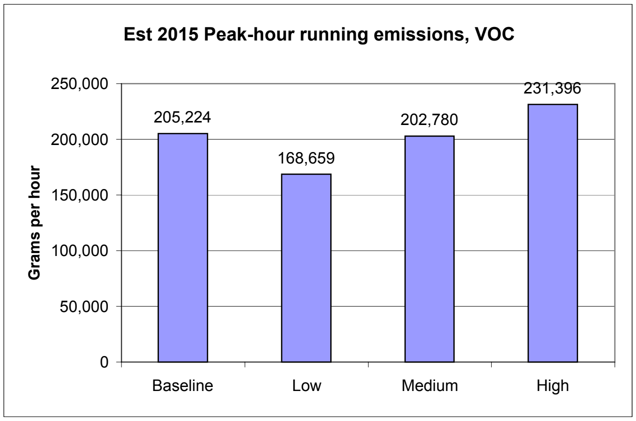
Analysis year: 2015	Baseline	Action Low	Action Medium	Action High
Ave. peak-hour speed, GP	47	53	51	47
Ave. peak-hour speed, HOV/HOT	55	64	64	64
Travel time, GP (minutes)	17.9	15.7	16.6	17.9
Travel time, HOV/HOT	15.3	13.2	13.2	13.2
Travel time savings, GP minus HOV/HOT	2.6	2.6	3.4	4.8
Peak hour V/C, GP	1.12	0.83	1.00	1.12
Peak hour V/C, HOV/HOT	0.25	0.68	0.68	0.68
Peak hour LOS, GP (FFS = 55 mph)	F	D	F	F
Peak hour LOS, HOV/HOT (FFS = 55/65 mph)	A	C	C	C

Analysis year: 2015	Baseline	Action Low	Action Medium	Action High	Action (ave. of med+high)
Pk-hr emissions, VOC, GP (grams/hr)	202,616	139,880	174,001	202,616	188,309
Pk-hr emissions, VOC, HOV/HOT	2,607	28,780	28,780	28,780	28,780
Pk-hr emissions, NOX, GP	978,296	783,759	912,744	978,296	945,520
Pk-hr emissions, NOX, HOV/HOT	14,904	201,313	201,313	201,313	201,313
Pk-hr emissions, VOC, total (grams/hour)	205,224	168,659	202,780	231,396	217,088
Pk-hr emissions, NOX, total	993,201	985,073	1,114,057	1,179,610	1,146,833
Pk-hr emissions, VOC, total, difference from base	0	-36,564	-2,443	26,172	11,864
Pk-hr emissions, NOX, total, difference from base	0	-8,128	120,856	186,409	153,632
Pk-hr emissions, VOC, total, pct diff from base	0%	-18%	-1%	13%	6%
Pk-hr emissions, NOX, total, pct diff from base	0%	-1%	12%	19%	15%
Regional total, daily VOC + (pk-hr emiss.) * factor	86,545,424	86,399,166	86,535,650	86,650,114	86,592,882
Regional total, daily NOx + (pk-hr emiss.) * factor	107,864,266	107,831,753	108,347,690	108,609,901	108,478,795
Regional total, VOC, percent difference	0.00%	-0.17%	-0.01%	0.12%	0.05%
Regional total, NOx, percent difference	0.00%	-0.03%	0.45%	0.69%	0.57%

Factor used to multiply peak-hour emissions before adding to daily	4

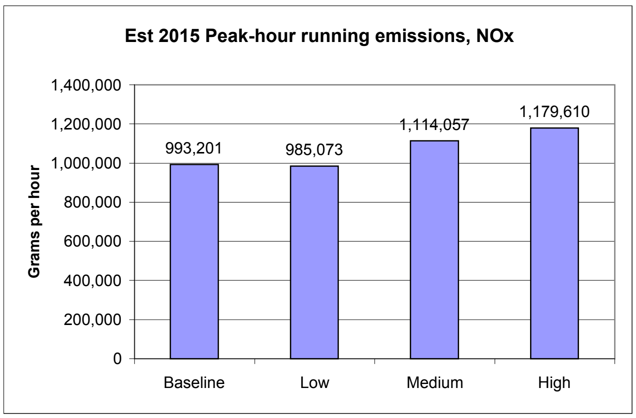
Air Quality Conformity of 2002 CLRP & FY03-08 TIP

	tons/day	grams/day
Mobile source VOC emissions, 2015	95.4	86,545,424
Mobile source NOx emissions, 2015	118.9	107,864,266
Conversion factor: grams per imperial ton	907,184.74	



Assumed Free Flow Speeds (mph)

	Base	Action
GP lanes	55	55
Managed	55	65



Average time savings: Action vs. Base

Scenario	Lane type	Total lanes	Ave. speed (mph)	Veh per hr (each way)	Veh per hr (both ways)	User classes (auto mode)			Ave. travel time (min.)	Assumed ave. occupancy	Average Time Savings Min	Veh*min	Pers*min
Base	Gen. purp.	8	47	10,084	20,168	All auto modes			17.9				
	Managed	2	55	559	1,118	HOV3+			15.3	3.6	2.6	2,942	10,591
Action	Gen. purp.	8	51	9,043	18,086	All auto modes			16.6				
(Medium forecast)	Managed	4	64	3,200	6,400	HOV3+	SOV pay	HOV2 pay	13.2	1.4	3.4	21,905	30,667
Difference	Gen. purp.	0	4	-1,041	-2,082	Same			-1.4				
(Action - Base)	Managed	2	9	2,641	5,282	Two new user classes			-2.2	-2.2	0.8	18,963	20,076

Total length of facility (miles)	14

	Min	Veh*min	Pers*min
Percent difference (action vs. base)	30%	645%	190%
Ratio (action/base)	1.3	7.4	2.9

Assumed Free Flow Speeds (mph)

	Base	Action
GP lanes	55	55
Managed	55	65

Average time savings: Action vs. Base (High forecast)

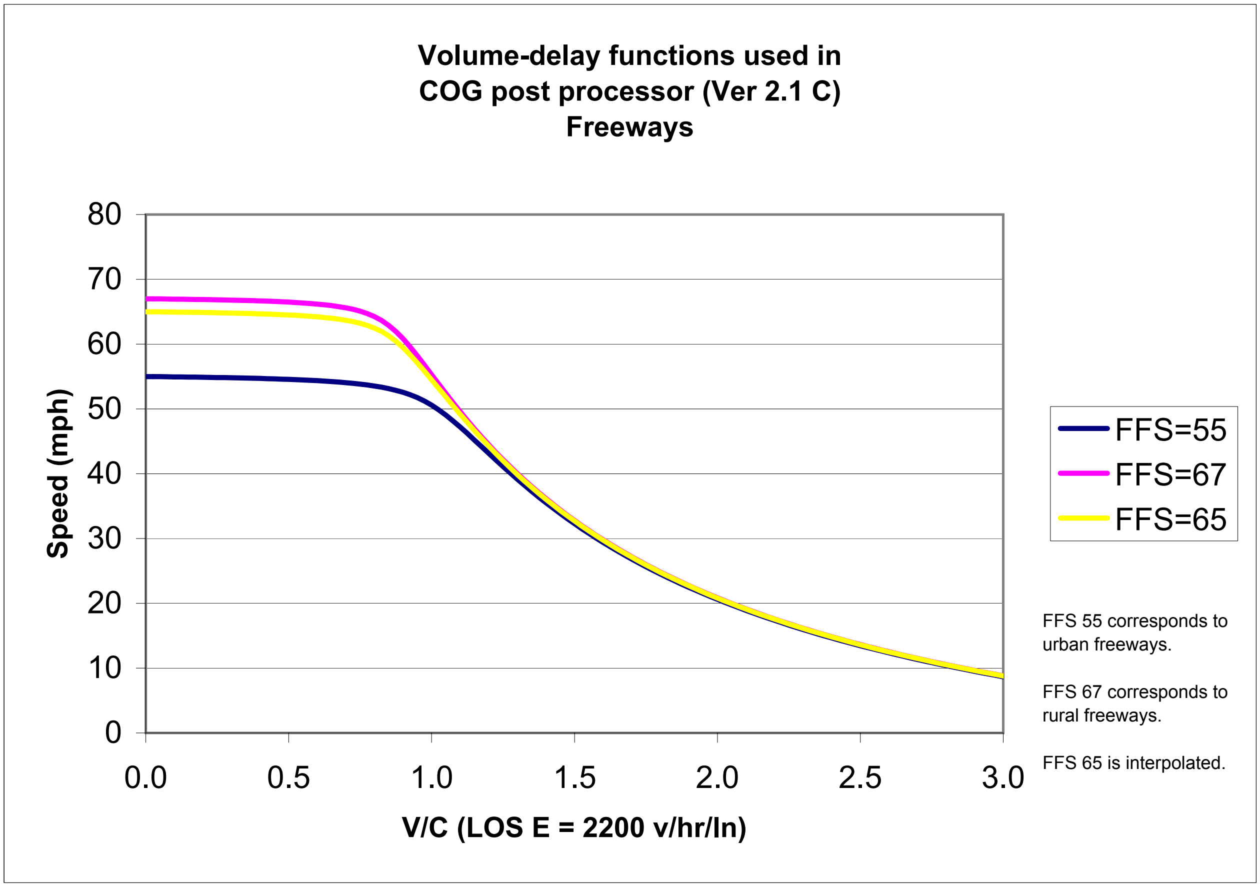
Scenario	Lane type	Total lanes	Ave. speed (mph)	Veh per hr (each way)	Veh per hr (both ways)	User classes (auto mode)			Ave. travel time (min.)	Assumed ave. occupancy	Average Time Savings Min	Veh*min	Pers*min
Base	Gen. purp.	8	47	10,084	20,168	All auto modes			17.9				
	Managed	2	55	559	1,118	HOV3+			15.3	3.6	2.6	2,942	10,591
Action	Gen. purp.	8	47	10,084	20,168	All auto modes			17.9				
(High forecast)	Managed	4	64	3,200	6,400	HOV3+	SOV pay	HOV2 pay	13.2	1.4	4.8	30,643	42,901
Difference	Gen. purp.	0	0	0	0	Same			0				
(Action - Base)	Managed	2	9	2,641	5,282	Two new user classes			-2.2	-2.2	2.2	27,701	32,310

Total length of facility (miles)	14

	Min	Veh*min	Pers*min
Percent difference (action vs. base)	82%	942%	305%
Ratio (action/base)	1.8	10.4	4.1

Assumed Free Flow Speeds (mph)

	Base	Action
GP lanes	55	55
Managed	55	65



Density (pc/mile)	V/C	FFS=55 55	FFS=67 67	FFS=65 65
0	0.00	55.00	67.00	65.00
1	0.03	54.99	66.99	64.99
2	0.05	54.98	66.98	64.98
3	0.08	54.96	66.96	64.96
4	0.10	54.95	66.95	64.95
5	0.13	54.94	66.93	64.93
6	0.15	54.92	66.92	64.92
7	0.18	54.90	66.90	64.90
8	0.20	54.89	66.88	64.88
9	0.23	54.87	66.86	64.86
10	0.25	54.85	66.84	64.84
11	0.28	54.83	66.82	64.82
12	0.30	54.81	66.79	64.80
13	0.33	54.79	66.77	64.77
14	0.35	54.76	66.74	64.74
15	0.38	54.73	66.71	64.71
16	0.40	54.71	66.67	64.68
17	0.43	54.67	66.63	64.64

18	0.45	54.64	66.59	64.60
19	0.48	54.60	66.54	64.55
20	0.50	54.57	66.49	64.50
21	0.53	54.52	66.42	64.44
22	0.55	54.47	66.35	64.37
23	0.58	54.42	66.27	64.30
24	0.60	54.37	66.18	64.21
25	0.63	54.30	66.07	64.11
26	0.65	54.23	65.94	63.99
27	0.68	54.15	65.79	63.85
28	0.70	54.06	65.60	63.68
29	0.73	53.96	65.37	63.47
30	0.75	53.84	65.09	63.21
31	0.78	53.70	64.72	62.88
32	0.80	53.54	64.26	62.47
33	0.83	53.36	63.66	61.94
34	0.85	53.14	62.90	61.27
35	0.88	52.88	61.96	60.45
36	0.90	52.56	60.84	59.46
37	0.93	52.19	59.57	58.34
38	0.95	51.74	58.19	57.12
39	0.98	51.21	56.75	55.83
40	1.00	50.58	55.28	54.50
41	1.03	49.86	53.82	53.16
42	1.05	49.05	52.37	51.82
43	1.08	48.16	50.95	50.49
44	1.10	47.21	49.57	49.18
45	1.13	46.21	48.23	47.89
46	1.15	45.19	46.93	46.64
47	1.18	44.17	45.68	45.43
48	1.20	43.14	44.47	44.24
49	1.23	42.12	43.30	43.10
50	1.25	41.11	42.17	41.99
51	1.28	40.12	41.08	40.92
52	1.30	39.16	40.02	39.88
53	1.33	38.21	39.01	38.88
54	1.35	37.29	38.03	37.90
55	1.38	36.40	37.08	36.97
56	1.40	35.53	36.16	36.06
57	1.43	34.69	35.28	35.18
58	1.45	33.87	34.42	34.33
59	1.48	33.07	33.59	33.50
60	1.50	32.29	32.79	32.71
61	1.53	31.54	32.01	31.93
62	1.55	30.81	31.26	31.18
63	1.58	30.10	30.53	30.46
64	1.60	29.41	29.82	29.75
65	1.63	28.74	29.13	29.07
66	1.65	28.09	28.47	28.40
67	1.68	27.46	27.82	27.76
68	1.70	26.84	27.19	27.13
69	1.73	26.25	26.58	26.53
70	1.75	25.66	25.99	25.93

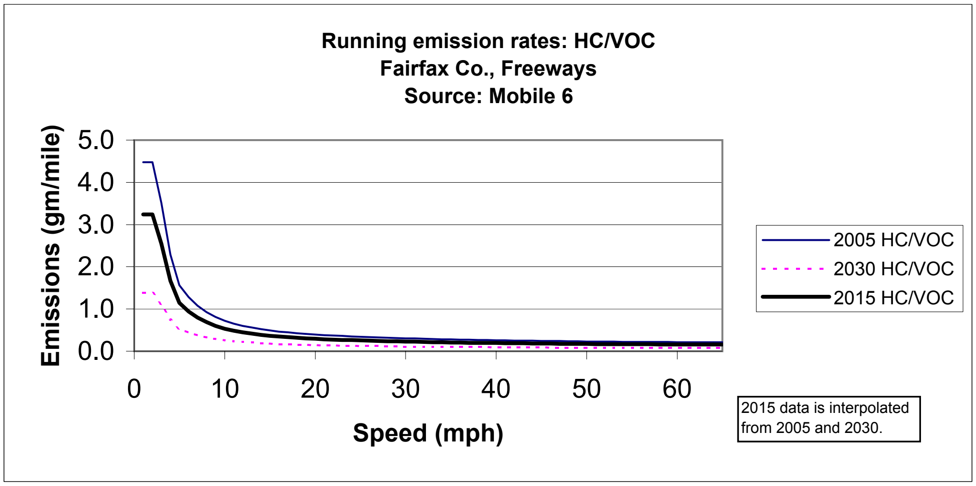
71	1.78	25.10	25.41	25.36
72	1.80	24.55	24.85	24.80
73	1.83	24.01	24.30	24.25
74	1.85	23.48	23.77	23.72
75	1.88	22.97	23.25	23.21
76	1.90	22.48	22.75	22.70
77	1.93	21.99	22.26	22.21
78	1.95	21.52	21.78	21.74
79	1.98	21.06	21.31	21.27
80	2.00	20.61	20.86	20.82
81	2.03	20.17	20.41	20.37
82	2.05	19.74	19.98	19.94
83	2.08	19.32	19.56	19.52
84	2.10	18.91	19.14	19.10
85	2.13	18.52	18.74	18.70
86	2.15	18.13	18.34	18.31
87	2.18	17.74	17.96	17.92
88	2.20	17.37	17.58	17.55
89	2.23	17.01	17.21	17.18
90	2.25	16.65	16.85	16.82
91	2.28	16.30	16.50	16.47
92	2.30	15.96	16.16	16.12
93	2.33	15.62	15.82	15.79
94	2.35	15.30	15.49	15.46
95	2.38	14.98	15.16	15.13
96	2.40	14.66	14.85	14.82
97	2.43	14.35	14.54	14.51
98	2.45	14.05	14.23	14.20
99	2.48	13.76	13.94	13.91
100	2.50	13.47	13.64	13.61
101	2.53	13.18	13.36	13.33
102	2.55	12.90	13.08	13.05
103	2.58	12.63	12.80	12.77
104	2.60	12.36	12.53	12.50
105	2.63	12.10	12.27	12.24
106	2.65	11.84	12.01	11.98
107	2.68	11.59	11.75	11.73
108	2.70	11.34	11.50	11.48
109	2.73	11.10	11.26	11.23
110	2.75	10.86	11.02	10.99
111	2.78	10.62	10.78	10.75
112	2.80	10.39	10.55	10.52
113	2.83	10.16	10.32	10.29
114	2.85	9.94	10.09	10.07
115	2.88	9.72	9.87	9.85
116	2.90	9.50	9.65	9.63
117	2.93	9.29	9.44	9.42
118	2.95	9.08	9.23	9.21
119	2.98	8.88	9.03	9.00
120	3.00	8.68	8.82	8.80
121	3.03	8.48	8.62	8.60
122	3.05	8.28	8.43	8.40
123	3.08	8.09	8.23	8.21

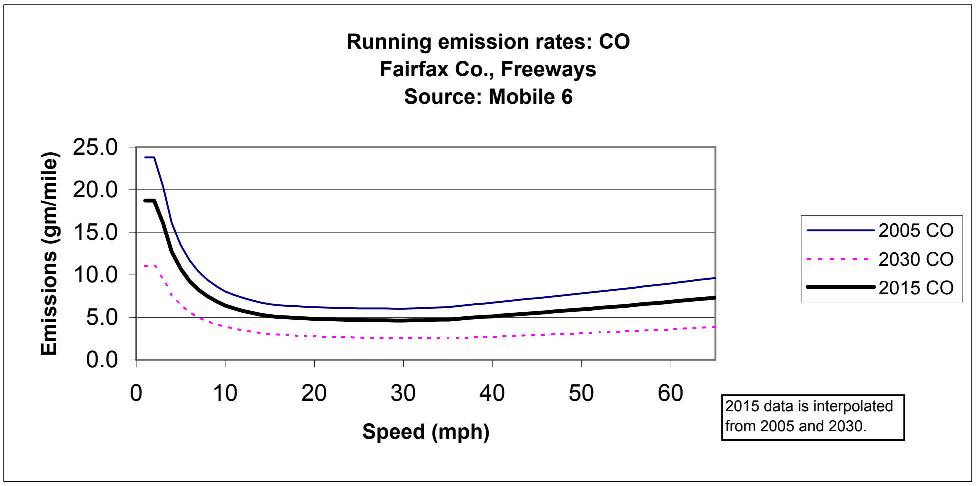
124	3.10	7.90	8.04	8.02
125	3.13	7.72	7.86	7.83
126	3.15	7.53	7.67	7.65
127	3.18	7.35	7.49	7.47
128	3.20	7.18	7.31	7.29
129	3.23	7.00	7.14	7.12
130	3.25	6.83	6.97	6.94
131	3.28	6.66	6.80	6.77
132	3.30	6.49	6.63	6.61
133	3.33	6.33	6.46	6.44
134	3.35	6.17	6.30	6.28
135	3.38	6.01	6.14	6.12
136	3.40	5.85	5.98	5.96
137	3.43	5.70	5.83	5.81
138	3.45	5.54	5.67	5.65
139	3.48	5.39	5.52	5.50
140	3.50	5.24	5.37	5.35

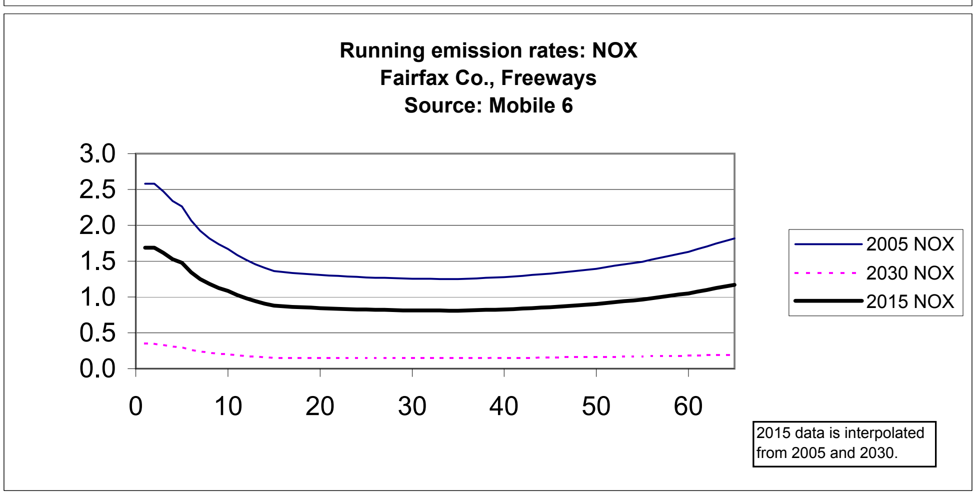
Mobile 6 running emission rates
Freeways in Fairfax

	Mobile 6 running emissions			Mobile 6 running emissions			Interpolated running emiss.		
Speed (mph)	2005 HC/VOC	2005 CO	2005 NOX	2030 HC/VOC	2030 CO	2030 NOX	2015 HC/VOC	2015 CO	2015 NOX
1	4.4770	23.7930	2.5790	1.3840	11.0970	0.3470	3.2398	18.7146	1.6862
2	4.4770	23.7930	2.5790	1.3840	11.0970	0.3470	3.2398	18.7146	1.6862
3	3.5060	20.3640	2.4740	1.0980	9.5630	0.3310	2.5428	16.0436	1.6168
4	2.2920	16.0770	2.3410	0.7400	7.6470	0.3100	1.6712	12.7050	1.5286
5	1.5630	13.5050	2.2620	0.5250	6.4970	0.2980	1.1478	10.7018	1.4764
6	1.2810	11.6880	2.0650	0.4370	5.6320	0.2650	0.9434	9.2656	1.3450
7	1.0800	10.3900	1.9240	0.3730	5.0150	0.2420	0.7972	8.2400	1.2512
8	0.9280	9.4170	1.8190	0.3250	4.5510	0.2250	0.6868	7.4706	1.1814
9	0.8110	8.6600	1.7360	0.2880	4.1910	0.2110	0.6018	6.8724	1.1260
10	0.7170	8.0540	1.6710	0.2580	3.9030	0.2000	0.5334	6.3936	1.0826
11	0.6540	7.6370	1.5870	0.2370	3.6700	0.1870	0.4872	6.0502	1.0270
12	0.6030	7.2900	1.5170	0.2180	3.4760	0.1760	0.4490	5.7644	0.9806
13	0.5600	6.9960	1.4570	0.2040	3.3110	0.1670	0.4176	5.5220	0.9410
14	0.5210	6.7440	1.4070	0.1900	3.1700	0.1590	0.3886	5.3144	0.9078
15	0.4900	6.5250	1.3630	0.1790	3.0480	0.1520	0.3656	5.1342	0.8786
16	0.4660	6.4410	1.3490	0.1700	2.9790	0.1520	0.3476	5.0562	0.8702
17	0.4440	6.3670	1.3370	0.1620	2.9180	0.1520	0.3312	4.9874	0.8630
18	0.4260	6.3020	1.3270	0.1550	2.8630	0.1510	0.3176	4.9264	0.8566
19	0.4090	6.2430	1.3170	0.1490	2.8150	0.1510	0.3050	4.8718	0.8506
20	0.3950	6.1900	1.3090	0.1430	2.7710	0.1510	0.2942	4.8224	0.8458
21	0.3820	6.1610	1.3010	0.1380	2.7380	0.1500	0.2844	4.7918	0.8406
22	0.3710	6.1340	1.2930	0.1350	2.7080	0.1500	0.2766	4.7636	0.8358
23	0.3610	6.1090	1.2860	0.1300	2.6810	0.1500	0.2686	4.7378	0.8316
24	0.3520	6.0870	1.2800	0.1270	2.6560	0.1490	0.2620	4.7146	0.8276
25	0.3430	6.0660	1.2740	0.1250	2.6330	0.1490	0.2558	4.6928	0.8240
26	0.3350	6.0570	1.2700	0.1210	2.6120	0.1490	0.2494	4.6790	0.8216
27	0.3280	6.0480	1.2660	0.1180	2.5920	0.1490	0.2440	4.6656	0.8192
28	0.3200	6.0390	1.2630	0.1150	2.5740	0.1480	0.2380	4.6530	0.8170
29	0.3140	6.0310	1.2590	0.1130	2.5560	0.1480	0.2336	4.6410	0.8146
30	0.3070	6.0240	1.2560	0.1100	2.5400	0.1480	0.2282	4.6304	0.8128
31	0.3010	6.0650	1.2550	0.1090	2.5420	0.1480	0.2242	4.6558	0.8122
32	0.2940	6.1030	1.2530	0.1060	2.5440	0.1480	0.2188	4.6794	0.8110
33	0.2880	6.1380	1.2520	0.1040	2.5460	0.1480	0.2144	4.7012	0.8104
34	0.2830	6.1720	1.2510	0.1020	2.5470	0.1470	0.2106	4.7220	0.8094
35	0.2780	6.2040	1.2500	0.1010	2.5490	0.1470	0.2072	4.7420	0.8088
36	0.2730	6.3200	1.2550	0.0980	2.5900	0.1480	0.2030	4.8280	0.8122
37	0.2700	6.4290	1.2610	0.0970	2.6280	0.1490	0.2008	4.9086	0.8162
38	0.2670	6.5330	1.2660	0.0960	2.6640	0.1490	0.1986	4.9854	0.8192
39	0.2620	6.6320	1.2710	0.0950	2.6990	0.1500	0.1952	5.0588	0.8226
40	0.2600	6.7260	1.2760	0.0940	2.7310	0.1500	0.1936	5.1280	0.8256
41	0.2560	6.8440	1.2860	0.0930	2.7740	0.1520	0.1908	5.2160	0.8324
42	0.2530	6.9560	1.2960	0.0910	2.8140	0.1530	0.1882	5.2992	0.8388
43	0.2500	7.0630	1.3060	0.0900	2.8520	0.1540	0.1860	5.3786	0.8452
44	0.2470	7.1650	1.3150	0.0890	2.8890	0.1550	0.1838	5.4546	0.8510
45	0.2450	7.2630	1.3240	0.0880	2.9240	0.1560	0.1822	5.5274	0.8568
46	0.2410	7.3820	1.3390	0.0870	2.9680	0.1570	0.1794	5.6164	0.8662
47	0.2390	7.4970	1.3540	0.0860	3.0100	0.1590	0.1778	5.7022	0.8760
48	0.2360	7.6070	1.3680	0.0850	3.0500	0.1600	0.1756	5.7842	0.8848
49	0.2340	7.7120	1.3810	0.0840	3.0890	0.1610	0.1740	5.8628	0.8930

50	0.2310	7.8130	1.3940	0.0830	3.1260	0.1620	0.1718	5.9382	0.9012
51	0.2290	7.9350	1.4150	0.0830	3.1730	0.1640	0.1706	6.0302	0.9146
52	0.2270	8.0520	1.4360	0.0830	3.2170	0.1660	0.1694	6.1180	0.9280
53	0.2250	8.1650	1.4550	0.0820	3.2600	0.1680	0.1678	6.2030	0.9402
54	0.2230	8.2740	1.4740	0.0820	3.3010	0.1700	0.1666	6.2848	0.9524
55	0.2210	8.3780	1.4920	0.0810	3.3400	0.1710	0.1650	6.3628	0.9636
56	0.2190	8.5100	1.5210	0.0810	3.3950	0.1740	0.1638	6.4640	0.9822
57	0.2190	8.6370	1.5490	0.0810	3.4480	0.1760	0.1638	6.5614	0.9998
58	0.2170	8.7590	1.5760	0.0810	3.5000	0.1780	0.1626	6.6554	1.0168
59	0.2170	8.8780	1.6030	0.0810	3.5490	0.1800	0.1626	6.7464	1.0338
60	0.2150	8.9920	1.6280	0.0810	3.5970	0.1820	0.1614	6.8340	1.0496
61	0.2140	9.1280	1.6680	0.0820	3.6550	0.1850	0.1612	6.9388	1.0748
62	0.2140	9.2590	1.7070	0.0810	3.7110	0.1880	0.1608	7.0398	1.0994
63	0.2130	9.3860	1.7450	0.0820	3.7660	0.1910	0.1606	7.1380	1.1234
64	0.2130	9.5080	1.7820	0.0820	3.8190	0.1940	0.1606	7.2324	1.1468
65	0.2110	9.6280	1.8170	0.0820	3.8700	0.1970	0.1594	7.3248	1.1690


Running emission rates: HC/VOC
Fairfax Co., Freeways
Source: Mobile 6
Emissions (gm/mile)
5.0
4.0
3.0
2.0
1.0
0.0
0
10
20
30
40
50
60
Speed (mph)
2005 HC/VOC
2030 HC/VOC
2015 HC/VOC
2015 data is interpolated from 2005 and 2030.


Running emission rates: CO
Fairfax Co., Freeways
Source: Mobile 6
Emissions (gm/mile)
25.0
20.0
15.0
10.0
5.0
0.0
0
10
20
30
40
50
60
Speed (mph)
2005 CO
2030 CO
2015 CO
2015 data is interpolated from 2005 and 2030.


Running emission rates: NOX
Fairfax Co., Freeways
Source: Mobile 6
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
2005 NOX
2030 NOX
2015 NOX
2015 data is interpolated from 2005 and 2030.