Congestion Relief Provided by Virginia Railway Express

Analysis Conducted By
Texas A&M Transportation Institute
Texas A&M University System

For
Virginia Railway Express

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Texas A&M Transportation Institute

Executive Summary

The contribution of the Virginia Railway Express operation to congestion relief is significant and could be greater if service was expanded and ridership increased. This technical memorandum documents the congestion relieving contributions of the Virginia Railway Express operations in two northern Virginia travel corridors. Congestion reduction was examined in two cases: 1) estimating the effect on parallel Interstate mainlanes from the existing VRE service, and 2) estimating the effect on those mainlanes if VRE ridership were doubled. The method combined data from Virginia Railway Express, the Virginia Department of Transportation and INRIX, a leading provider of travel time and speed information.

Three congestion relief effects were considered:

1. Travel delay reduction effects
2. Corridor capacity added by VRE represented in terms of highway lane miles
3. Reliability of travel time on VRE relative to driving

The congestion relief effects were described with two cases:

- Case 1: What is the existing contribution of VRE service to congestion relief?
- Case 2: What could the contribution of VRE be if ridership were increased by transferring drivers to commuter rail service?

Sixteen scenarios representing a range of alternative travel modes (e.g., driving in the freeway mainlanes, riding bus service or using a carpool) were used to describe possible outcomes. The Fiscal Year 2013 average ridership of 18,880 daily riders was used as a basis for this analysis.

- All of the scenarios show much greater congestion benefits in the evening peak period. Afternoon peak roadway congestion is typically more intense and the Virginia Railway Express service contribution to congestion reduction is about twice as large as in the morning.
- Virginia Railway Express trains offer reliable travel times, and times that are more reliable than the freeways. The Fredericksburg line provides afternoon travel times that are faster than average day on the freeway, and save commuters more than a half-hour on the worst commute of the month.
- The Virginia Railway Express service provides travel capacity for trips that otherwise would use the freeways. And ridership growth can be accommodated with additional cars and trains.
- Because freeway lanes cannot be added as ‘parts of lanes’, one lane each direction would have to be constructed to replicate the service provided by the Virginia Railway Express, at an estimated cost of more than $1 billion.

Travel Delay Reduction

The existing ridership contributes to a delay reduction of between eight and 18 percent in freeway travel delay in the two VRE corridors. The highest value is for the scenario where all riders would otherwise be in single-occupant vehicles driving on the freeways, with lower values resulting if it is assumed that higher ridership would be accommodated in carpools and transit modes. The delay savings effects range between 1.6 million hours to 3.8 million hours from the existing VRE service and ridership.

- The Fredericksburg line provides between two and three times the savings of the Manassas line.
- The evening peak period travel time savings are four to five times that of the morning congestion relief.

The higher congestion levels in the I-95 and I-66 corridors also result in significant delay savings if there were an increase in VRE ridership. The upper end of the scenarios – a doubling of VRE ridership by attracting riders from single-occupant vehicles – yields a 13 percent delay reduction for all traffic in the two corridors.

- The additional delay savings would range between 700 thousand and 2.8 million person hours each year.

Corridor Capacity Provided by Virginia Railway Express Service

Expanding Virginia Railway Express ridership would "free-up" about the same amount of freeway capacity for other trips, or to accommodate growth in the corridor. This analysis allows a direct comparison of the feasibility, cost and implementation period of VRE improvements and freeway capacity. The existing Virginia Railway Express train fleet, for example, provides capacity for approximately 5,000 persons per hour during peak service (or the equivalent of 4,500 vehicles). This would require adding at least one freeway lane in each direction in both VRE corridors to provide the same person-moving capacity.

- In road terms, between one-half and 1.2 lanes of freeway capacity are saved by the two Virginia Railway Express lines (adding the morning and evening peak periods).
- Because lanes cannot be added in partial increments, about 90 miles of construction in each direction (180 lane-miles of freeway) would be required on the highways corridors adjacent to the VRE lines (I-95/395, I-66 and I-495) to provide the equivalent capacity of an expanded VRE.
- Using cost estimates derived from Fairfax County projects, the 180 lane-miles would cost at least $1 billion to construct, with additional costs for right-of-way or if extensive elevated roadway were needed.

Travel Time Reliability Benefits

Virginia Railway Express defines an 'on-time' trip as a train that reaches a station within five minutes of its scheduled time. This is a logical connection to the way commuters use the service: they choose a train based on the departure and arrival times. Road users have a variety of "late tolerances," making a "late time" measure difficult to identify. Arriving on-time for 95 percent of the important trips (19 out of 20) appears to be a good target for the time that travelers might need to allow for important trips. Therefore, the travel time for which only 5 percent of trips (for example, 1 trip to work each month) are longer was used to measure roadway travel time reliability.

The extensive travel time data sets from VRE and VDOT clearly show several relevant travel time reliability points:

- 96% of VRE trips on the Fredericksburg and Manassas lines arrive on-time. That is, almost every train that VRE operates during the year has a very dependable "average" travel time.
- Road user travel time varies quite a bit, especially during the peak travel hours. The 95th percentile travel time for road users (i.e., the time someone must allow to ensure an on-time arrival) is longer than the scheduled VRE time for nine of the 13 daily Fredericksburg trains.
- Average travel time between the outer ends of both lines and Union Station are longer for VRE trains than by car for only four of the 25 peak period train trips.
- The I-66 mainlanes inside the Beltway are reserved for carpools in the peak direction between 6:30 and 9:00 a.m. and 4:00 and 6:30 p.m.; their travel time is low and very reliable. The VRE train times in this corridor are very reliable but not as fast as the carpool-only period on I-66. All 12 of the VRE train travel times are longer than the 95th percentile I-66 carpool lane travel times.

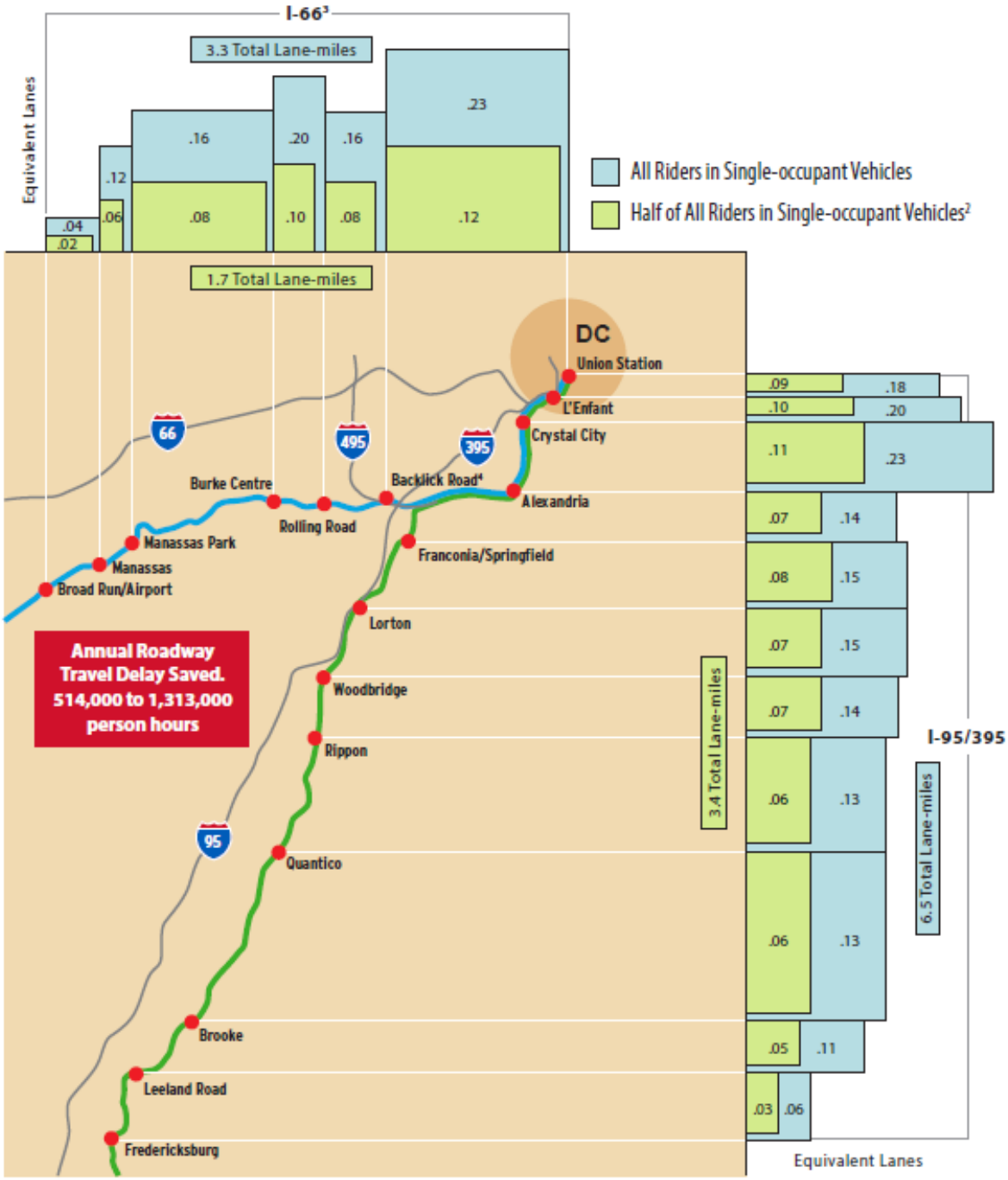
An Illustration of the Congestion Relief Provided by Virginia Railway Express

Exhibits ES-1 and ES-2 illustrate the travel delay and road space savings for morning and evening travel periods for the highest and lowest congestion effect scenarios. The Interstates, the VRE rail lines and VRE stations are shown in the middle of the maps. The equivalent road space accommodated on the commuter rail service is noted in the height of the bar graph that leads away from the VRE lines. Travel delay savings for the two scenarios in each peak period are also noted.

EXHIBIT ES-1

Morning Travel Period[1]

Road Space Accomodated By VRE Service



NOTES:

[1]5:00 AM to 8:00 AM

[2]This scenario assumes half of VRE riders would be carried on buses and auto occupancy is 1.10 person per vehicle.

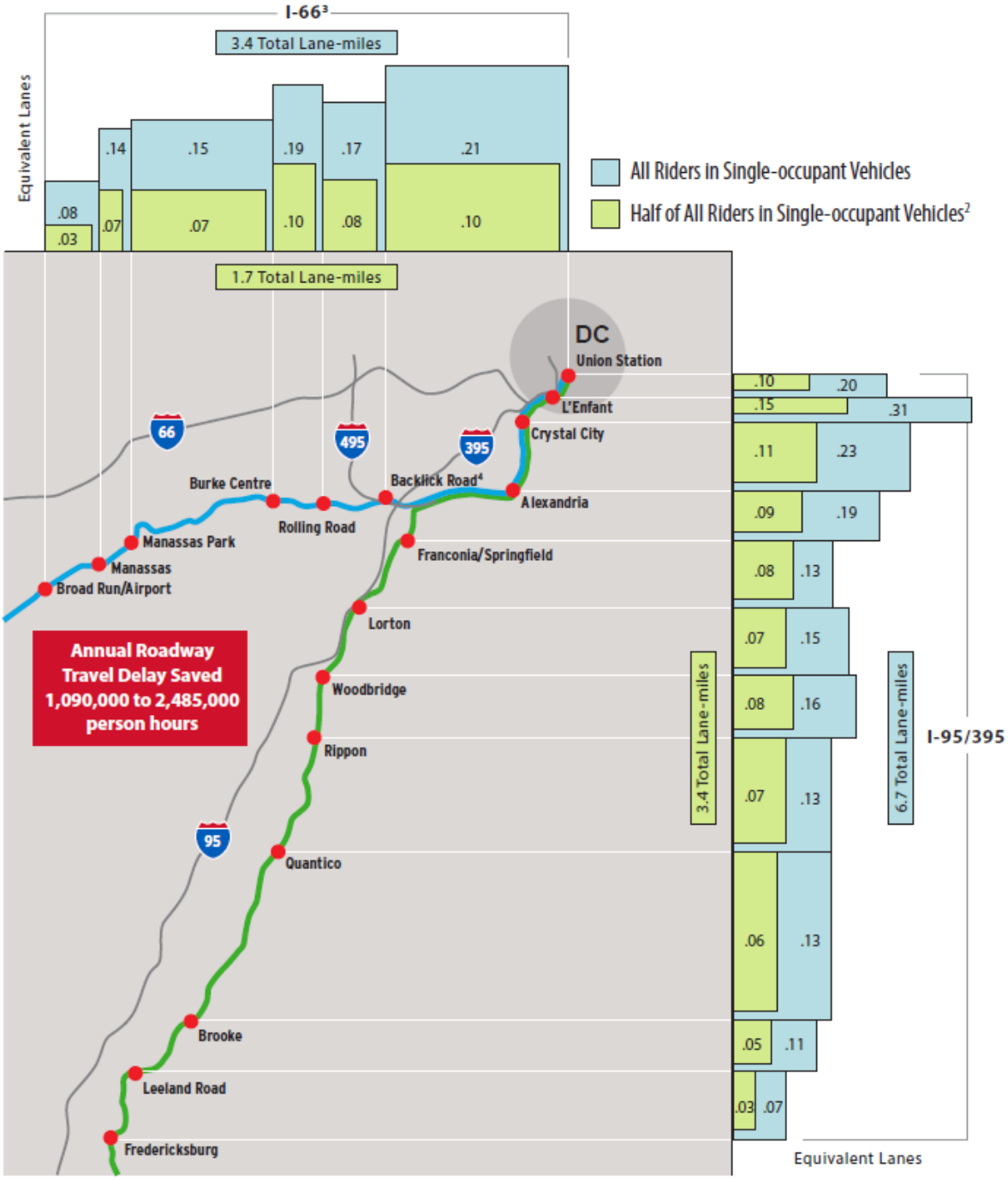
[3]28% of the Manassas Line VRE riders are assumed to use I-495 to access the Alexandria, Pentagon and Crystal City areas.

[4]Manassas Line VRE riders from Backlick Station to D.C. were assigned to I-95/395.

EXHIBIT ES-2

Evening Travel Period[1]

Road Space Accomodated By VRE Service



NOTES:

[1]3:30 PM to 7:00 PM

[2]This scenario assumes half of VRE riders would be carried on buses and auto occupancy is 1.10 persons per vehicle.

[3]28% of Manassas Line VRE riders are assumed to use I-495 from the Alexandria, Pentagon, and Crystal City areas.

[4]Manassas Line VRE riders from Backlick Station to D.C. were assigned to I-95/395.

Introduction

This technical memorandum documents an analysis of the congestion relieving contributions of the Virginia Railway Express operations in two northern Virginia travel corridors. Congestion reduction was examined in two scenarios: 1) estimating the effect on parallel Interstate highway mainlanes from the existing VRE service, and 2) estimating the effect on those mainlanes if VRE ridership were doubled. The method combined data from Virginia Railway Express (*1,2,3,4*), the Virginia Department of Transportation (*5*) and INRIX (*6*), a leading provider of travel time and speed information. Analytical procedures that have been used for several years by TTI along with a set of 16 different assumptions were used to test the sensitivity of the results. In general, the analysis examined traffic volume shifts and congestion on major freeways in the northern Virginia area; these were applied using the FY 2013 VRE daily ridership of 18,880 trips.

The analysis goals were described in two cases:

- Case 1: What is the existing contribution of VRE service to congestion relief?
- Case 2: What could the contribution of VRE be if ridership were increased by transferring drivers to commuter rail service?

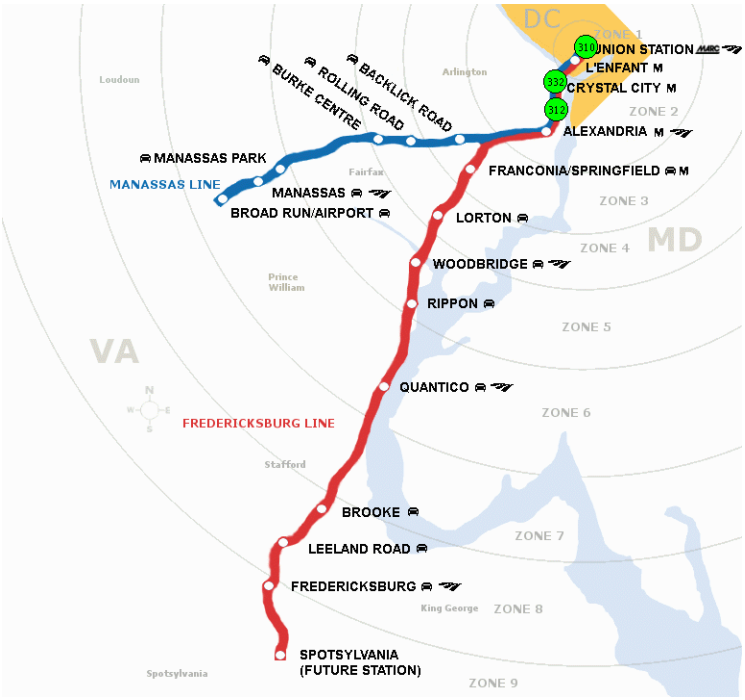
The estimated amount of congestion averted and number of mainlanes "not needed" due to existing VRE service were calculated for various travel mode scenarios were calculated to quantify the contribution from existing service. The effect of service expansion was likewise quantified by estimating the reduction in congestion and the number of mainlanes needed to achieve such a reduction for the same travel mode choice scenarios. Additionally, both the average travel time and the travel time reliability were studied; train riders often cite the certainty of arrival time as a significant reason for choosing commuter rail for a trip that, on an average day, could be made by car in less travel time.

Existing Service and Travel Times

Service on the Fredericksburg and Manassas lines during the morning and evening peak periods was catalogued and data from the I-66 and I-95 mainlanes was compiled to determine the existing operating environment. Exhibit 1 illustrates the VRE service and the station locations. The Manassas line generally draws patrons from the I-66 corridor until the line is close to Arlington, and the Fredericksburg line generally parallels I-95. Ridership origins were estimated from station boarding survey data, and the roadway travel times and volumes used the station area as the point where additional travel or removed trips would begin.

Exhibit 2 includes the train number, initial departure time and the VRE travel time based on the published schedules. While most of the trains stop at every station, some trains skip stations, resulting in shorter travel times. Approximately 96 percent of all trains in 2012 operated on-time according to the schedule. Interstate freeway mainlane performance was measured with the mainlane average travel time and the 95th percentile travel time. The times were calculated for the freeway mainlanes from the end of each line beginning at the train departure time (approximately 54 miles on I-95 and 34 miles on I-66) in an attempt to mirror the travel patterns of train riders. The 95th percentile travel time is a good measure of the roadway service reliability and provides the same type of information as the percentage of on-time trains measure. This is the time that a traveler must allow to be late for only one commute trip per month (i.e., be on time for 19 trips out of 20, or 95 percent of workdays).

Exhibit 1. Virginia Railway Express Routes



Reliability of Existing Service

Surveys show that transit riders generally, and VRE riders in particular value the predictable travel time offered by transit service, as compared to the mainlane roadway travel times. The shaded travel times in Exhibit 2 illustrate the VRE service times where train travel time is lower than vehicle travel times. There are several trains that are faster and much more reliable than auto travel, including most of the afternoon Fredericksburg trains where even the average I-95 travel time is longer than the VRE train time.

It should be noted that the I-66 mainlanes inside the Beltway are reserved for carpools in the peak direction between 6:30 and 9:00 a.m. and 4:00 and 6:30 p.m.; comparing the VRE train times in this corridor illustrates the low congestion levels experienced during the carpool-only period. Outside the Beltway, the left lane is reserved for peak direction carpoolers between 5:30 and 9:30 a.m. and 3:00 and 7:00 p.m.

Exhibits 3 and 4 provide comparisons of train and freeway travel times in the Fredericksburg and Manassas Virginia Railway Express corridors.

Exhibit 2. Summary of 2012 Travel Time - VRE and Freeway Mainlanes

Fredericksburg Line							
Northbound Train Number	**300**	**302**	**304**	**306**	**308**	**310**	**312**
Train Depart Time	5:05	5:15	5:40	6:05	6:30	7:15	7:40
Train Travel Time	1:24	1:37	1:34	1:32	1:34	1:32	1:29
Mainlane Travel Time	1:00	1:07	1:19	1:24	1:27	1:21	1:19
95th percentile Travel Time	1:04	1:13	1:30	1:37	1:40	1:35	1:31

Fredericksburg Line						
Southbound Train Number	**303**	**305**	**307**	**309**	**311**	**313**
Train Depart	15:35	16:10	16:40	17:15	18:00	18:40
Train Travel Time	1:34	1:32	1:39	1:32	1:30	1:28
Mainlane Travel Time	1:37	1:46	1:44	1:35	1:17	1:04
95th percentile TT	2:11	2:10	2:03	1:53	1:34	1:21
On-Time Fredericksburg Trains			96%			

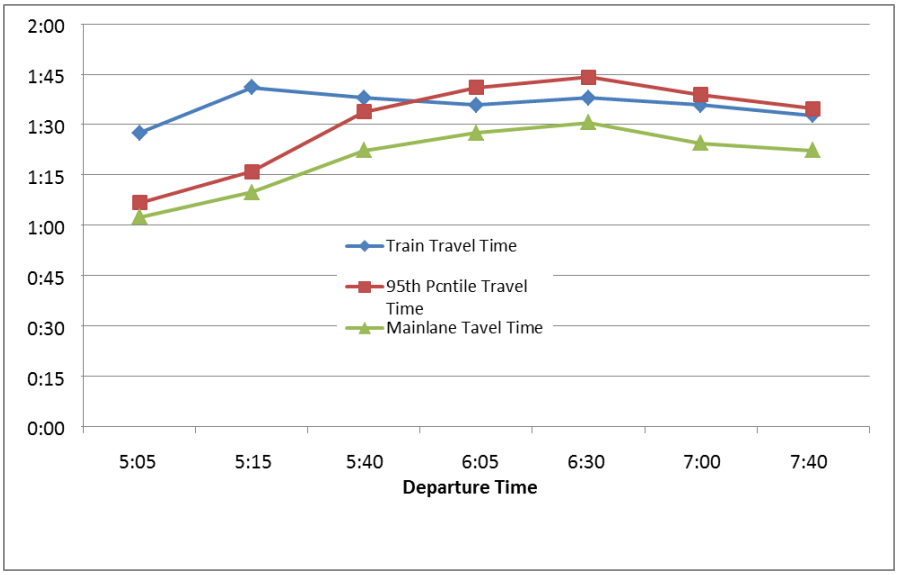
Manassas Line						
Eastbound Train Number	**322**	**324**	**326**	**328**	**330**	**332**
Train Depart	5:05	5:45	6:15	6:40	7:20	7:50
Train Travel Time	1:13	1:15	1:15	1:15	1:15	1:15
Mainlane Travel Time	0:34	0:43	0:49	0:54	1:01	0:59
95th percentile TT	0:36	0:47	0:53	1:00	1:09	1:06

Manassas Line						
Westbound Train Number	**327**	**329**	**331**	**333**	**335**	**337**
Train Depart	15:45	16:25	17:05	17:30	18:10	18:50
Train Travel Time	1:15	1:14	1:19	1:15	1:14	1:13
Mainlane Travel Time	0:56	0:52	0:52	0:51	0:45	0:45
95th percentile TT	1:05	0:57	0:58	0:56	0:50	0:49
On-Time Manassas Trains			96%			

Note: The shaded freeway vehicle travel times are longer than the VRE train travel times.

Exhibit 3. 2012 Morning and Evening Peak Period Travel Time Comparison – VRE Fredericksburg Line and I-95 Freeway Mainlanes

Morning Peak Period



Evening Peak Period

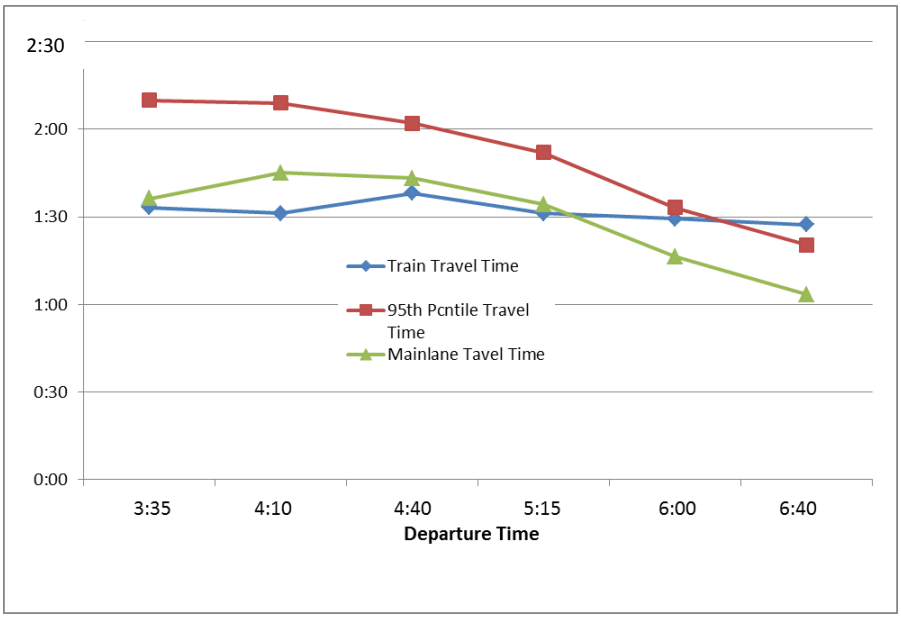
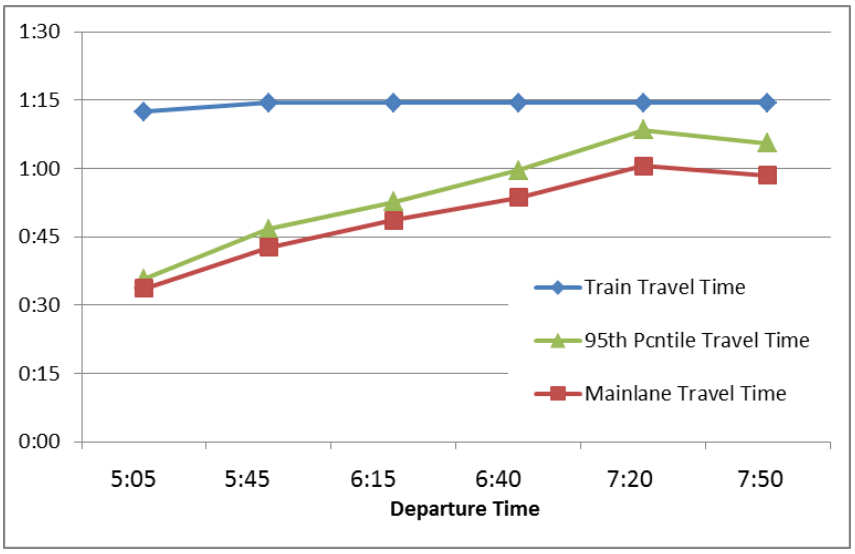
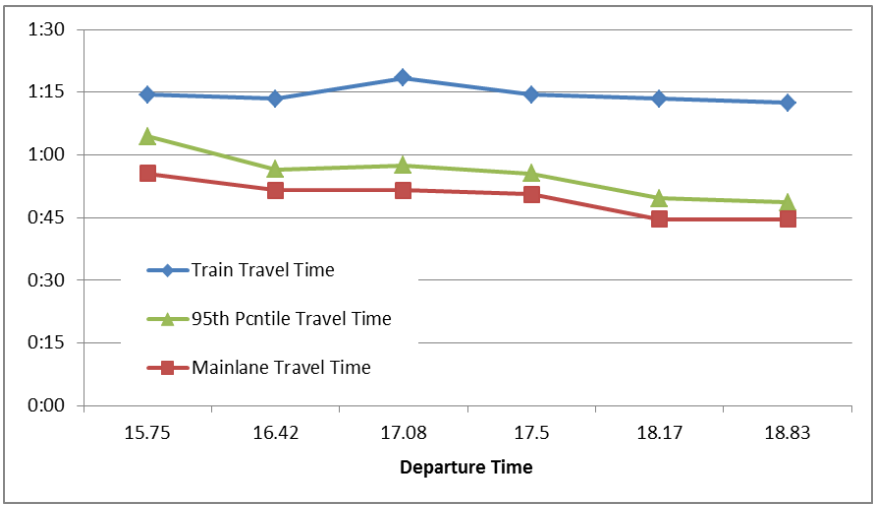


Exhibit 4. 2012 Morning and Evening Peak Period Travel Time Comparison – VRE Manassas Line and I-66 Freeway Mainlanes

Morning Peak Period



Evening Peak Period



Travel Time Reliability Comparison

Virginia Railway Express defines an 'on-time' trip as a train that reaches a station within five minutes of its scheduled time. This is a logical connection to the way commuters use the service: they choose a train based on the departure and arrival times. There is no directly comparable reliability statistic for road and transit service. Road users have a variety of "late tolerances," so it is not possible to know each person's "on-time" status. A good substitute for that knowledge is the time that travelers might need to allow for important trips. Arriving on-time for 95 percent of the trips (19 out of 20) appears to be a good target (*7*). Therefore, the travel time for which only 5 percent of trips is longer (for example, 1 trip to work each month) was used to measure roadway travel time reliability. This "planning time" concept has been used by highway agencies to assess reliability performance of the roadway network.

The extensive travel time data sets from VRE and VDOT clearly show several relevant points:

- 96% of VRE trips on the Fredericksburg and Manassas lines arrive on-time. That is, almost every train that VRE operates during the year has an "average" travel time.
- Road user travel time, on the other hand, varies quite a bit, especially during the peak travel hours. The 95th percentile travel time for road users (i.e., the time someone must allow to ensure an on-time arrival) is longer that the scheduled VRE time for nine of the 13 daily Fredericksburg trains.
- Average travel time between the outer ends of both lines and Union Station are longer for car trips than VRE trains for four of the 25 train trips.
- The I-66 mainlanes inside the Beltway are reserved for carpools in the peak direction between 6:30 and 9:00 a.m. and 4:00 and 6:30 p.m.; comparing the VRE train times in this corridor illustrates the low congestion levels experienced during the carpool-only period. All 12 of the VRE train travel times are more than the 95th percentile I-66 travel times.

Congestion Reduction Analysis Cases

Case 1 - Existing Contribution of VRE Service

The Virginia Railway Express operation serves a population with a substantial number of riders who could make their trip by private auto. The most recent survey on previous travel mode is a good guide of travel alternatives of VRE riders. Roughly half of VRE users drove alone before using VRE, 20 percent carpooled and 30 percent used transit. One approach to estimating the congestion benefit from existing VRE service is to assume travelers returned to some combination of other travel modes, and then estimate the resulting congestion levels.

Several scenarios were developed to describe a range of possible alternative mode choices; the first is derived from the previous mode survey. The estimate of conditions if all of those commuters were not able to take rail service was created using the following overarching assumptions:

- The VRE ridership surveys indicate most riders have access to some other travel. All riders, therefore, are assumed to make the trip to their destination in some way.
- Most riders of long distance commuter rail service will use the parallel interstates (I-66 and I-95) if the VRE service did not exist.

- The two VRE lines are treated similarly
- VRE riders are transferred to existing bus service, HOV facilities, and the general purpose lanes in each corridor apportioned at the levels specified in Exhibit 5. The morning travel period is from 5:00 a.m. to 8:00 a.m. and the evening from 3:30 p.m. to 7:00 p.m.
- Half of the riders are assigned to the peak hours (6:00 to 7:00 a.m. in morning and 4:45 to 5:45 p.m.) within the periods, while the remainder is assigned to the shoulders of the peak hours (5:00 to 6:00 a.m., 7:00 to 8:00 a.m. and 3:30 to 4:45 p.m. and 5:45 to 7:00 p.m.)

Exhibit 5 shows the 16 scenarios that were prepared to analyze the re-assignment of the existing VRE ridership onto some combination of the following facilities: I-66 and I-95 freeway mainlanes, the I-66 and I-95 HOV lanes, and existing bus transit service near the I-66 and I-95 corridors. The VRE ridership was initially apportioned to the general purpose freeway lanes, bus service or the HOV lanes according to the percentages in the second, third and fourth columns. Those person volumes were converted into vehicles for the purpose of estimating the increased congestion that would result from the additional vehicles using the vehicle occupancy rates in the fifth, sixth and seventh columns. The annual survey of VRE riders asks for the previous travel mode; the first scenario in Exhibit 5 was designed from these responses.

Exhibit 5. VRE Ridership and Vehicle Scenarios

Scenario	Percentage of Ridership Assigned to Facility			Occupancy Rate (persons/vehicle)		
	General Purpose	Carpool	Bus Service	General Purpose	Carpool	Bus Service
Previous Mode	50	20	30			
Mainlane 1	100			1.00		
Mainlane 2	100			1.10		
Mainlane 3	100			1.25		
HOV 1	75	25		1.00	Existing rate	
HOV 2	75	25		1.10	Existing rate	
HOV 3	75	25		1.25	Existing rate	
HOV 4	50	50		1.00	Existing rate	
HOV 5	50	50		1.10	Existing rate	
HOV 6	50	50		1.25	Existing rate	
Bus 1	75		25	1.00		Existing rate
Bus 2	75		25	1.10		Existing rate
Bus 3	75		25	1.25		Existing rate
Bus 4	50		50	1.00		Existing rate
Bus 5	50		50	1.10		Existing rate
Bus 6	50		50	1.25		Existing rate

Note: The existing occupancy rate is 1.10 persons per vehicle.

Case 2 – Contribution if VRE Ridership Was Increased

Another approach to examining the role of the VRE service is to estimate conditions if ridership were expanded. This would be accomplished with some combination of filling existing empty seats, additional trains and more cars on each train. This analysis did not examine the operational feasibility of *creating* this capacity, although some additional passing sidings may be required and operating agreements with the freight railroads would have to be re-negotiated. While this would not be cost-free, it might be substantially easier than creating the same person-moving capacity on the road network.

The same set of scenarios used in Case 1 were used in Case 2, with the opposite effect – road, bus and HOV travelers were transferred from their existing auto or bus mode and placed in VRE service. Road congestion levels were re-calculated for all 16 scenarios with the revised vehicle volume and new speed and delay quantities estimated.

Virginia Railway Express Ridership and Operating Schedule

The commuter rail riders were assigned to the facilities based on the VRE schedule and 2012 ridership (e.g., if they ride the 7:30 train from Fredericksburg, they were assigned to a 7:30 time slot on I-95 in Mainlane Scenario 1). The ridership values summarized in Exhibit 6 were disaggregated to individual stations to mirror actual train and road loadings to the extent possible. For both lines, the peak operating periods were approximately three hours long.

Exhibit 7 shows the assignment of morning and evening VRE passengers to each station during the peak periods. As the VRE lines approach the Potomac River in the morning, ridership declines with more riders departing than entering at stations inside of the Woodbridge and Backlick Road stations.

Appendix A shows more detailed information on how the station boardings were spread across the peak periods. The few midday trains were not included in the analysis because congestion levels and ridership are not high during those times and therefore there is likely little effect on mainlane travel conditions. It should be noted that several trains are over or near the seated capacity for existing service. In the expanded ridership case, these trains would require additional cars or trains to carry the new passenger loads.

Exhibit 6. Existing Virginia Railway Express Train Ridership

Train Number	Departure Time	Seating Capacity	Midweek Ridership	Occupancy
Fredericksburg Northbound Line				
300	5:05 AM	645	625	97%
302	5:15 AM	819	825	101%
304	5:40 AM	798	730	92%
306	6:05 AM	1098	900	82%
308	6:30 AM	798	865	108%
310	7:15 AM	846	630	75%
312	7:40 AM	531	400	75%
Fredericksburg Southbound Line				
303	3:35 PM	819	990	121%
305	4:10 PM	798	1,035	130%
307	4:40 PM	1098	930	85%
309	5:15 PM	798	975	122%
311	6:00 PM	846	615	73%
313	6:40 PM	645	290	45%
Manassas Eastbound Line				
322	5:05 AM	819	555	68%
324	5:45 AM	855	725	85%
326	6:15 AM	1107	870	79%
328	6:40 AM	1095	910	83%
330	7:20 AM	819	860	105%
332	7:50 AM	819	670	82%
Manassas Westbound Line				
327	3:45 PM	819	855	104%
329	4:25 PM	1095	985	90%
331	5:05 PM	1107	950	86%
333	5:30 PM	819	660	80%
335	6:10 PM	855	490	57%
337	6:50 PM	819	220	27%

Exhibit 7. 2012 VRE Ridership – Morning and Evening Entering and Exiting Passengers

Morning Entering and Exiting Passengers

Fredericksburg Line	Entering	Exiting	Manassas Line	Entering	Exiting
Fredericksburg	1770	0	Broad Run	1290	0
Leeland Rd	1080	20	Manassas	880	0
Brooke	630	0	Manassas Park	880	0
Quantico	310	230	Burke Centre	920	0
Rippon	545	0	Rolling Rd	395	0
Woodbridge	400	55	Backlick Rd	130	40
Lorton	215	295	Alexandria	10	415
Franconia	30	260	Crystal City	5	865
Alexandria	15	615	L'Enfant	0	2050
Crystal City	10	920	Union Station	0	1135
L'Enfant	0	1675			
Union Station	0	930			

Evening Entering and Exiting Passengers

Fredericksburg Line	Entering	Exiting	Manassas Line	Entering	Exiting
Union Station	930	0	Union Station	1135	0
L'Enfant	1675	0	L'Enfant	2050	0
Crystal City	920	10	Crystal City	1280	5
Alexandria	615	15	Alexandria	40	10
Franconia	260	32	Backlick Rd	0	130
Lorton	295	217	Rolling Rd	0	395
Woodbridge	55	402	Burke Centre	0	920
Rippon	0	545	Manassas Park	0	880
Quantico	230	309	Manassas	0	880
Brooke	0	628	Broad Run	0	1290
Leeland Rd	20	1076			
Fredericksburg	0	1765			

Summary of Speed and Equivalent Lane-Mile Estimation Methodology

The methodology to estimate the congestion reduction generated by the VRE ridership was based on the relationship between traffic density (traffic per lane) and speed. Generally, as the traffic per lane decreases, freeway speeds increase. Person-trips that are carried on VRE service rather than traveling on the freeway results in an increase in freeway travel speed. The benefits of higher travel speed also extend to non-VRE freeway travelers. The calculations provide the following quantities:

- Delay experienced by the VRE patrons if they used the road network
- Additional delay that would be experienced in the freeway corridors if VRE patrons used the road network (all non-VRE patrons would see an increase in their delay due to higher traffic volumes caused by VRE riders moving to private autos, buses or carpools).

The mobility contribution of VRE can also be shown in terms of the amount of roadway that is saved because the VRE service exists. This was accomplished by determining the traffic volume per lane at the highest person volume location after the VRE patrons were "placed back onto" the roadways. This higher volume was compared to the traffic volume per lane at the same location with VRE in operation. The increased number of lanes required to keep traffic speeds at the 2012 levels with the higher volume of person travel was the basis for the estimate of the equivalent roadway lanes of capacity that is created by VRE service.

By utilizing the relationship between traffic density (traffic per lane) and speed, the amount of additional lanes can be calculated for each roadway segment along the corridor. For example, as motorists are added to the freeway corridor, the traffic density value increases. In order for the traffic density value to be held constant, a certain amount of lane-miles has to accompany the new vehicle- miles of travel. These additional lane-miles are determined for each segment through the corridor and summed to give an estimate of the total additional lane-miles of roadway that would need to be added (if VRE patrons were added to the corridor) or the number of lane-miles of capacity that would be available (if additional freeway corridor patrons became VRE ridership). Appendix B shows the traffic density and speed relationship.

In the Manassas corridor, approximately 29 percent of the riders were destined for the Alexandria and Crystal City stations. These riders were assumed to leave I-66 at the I-495 Beltway; all other Manassas ridership was assumed to remain on I-66 into the District. The congestion benefit to I-495 from these riders was also estimated. I-66 was assumed to remain an HOV-only facility in the peak direction during the peak periods.

Congestion-Reducing Effects of Virginia Railway Express Service

The estimated congestion reduction provided by Virginia Railway Express service can be described in several ways:

- Between 65 and 70 percent of daily delay reduction is estimated for the evening peak periods (congestion levels are much greater in the evening than the morning).
- The delay savings attributable to VRE service is greater in the I-95/395 corridor, where congestion is much greater than the I-66 corridor. About 60 percent of the congestion benefits were in the I-95/395 Fredericksburg corridor.
- The I-66 HOV-only restriction maintains high travel speeds, reducing potential delay benefits.
- Ridership is higher on the Fredericksburg line and the VRE service is approximately 20 miles longer there than on the Manassas line.

Case 1. What is the existing contribution of VRE service to congestion relief?

The scenarios from Exhibit 5, the ridership data from Exhibit 6 and the travel time information in Exhibit 2 were combined to estimate the annual delay savings for each of the scenario conditions (Exhibit 8). The existing ridership contributes to a delay reduction of between eight and 18 percent in freeway travel delay in the two VRE corridors. The highest value is for the scenario where all riders would otherwise be in single-

occupant vehicles (e.g., GP=100), with the lower values assuming higher ridership drawn from carpools or transit modes. The effects range between 1.6 million hours and 3.8 million hours of delay savings for the existing VRE service and ridership.

In road terms, in order to maintain the same congestion levels, between 0.5 and 1.2 lanes of freeway capacity are being saved by the Virginia Railway Express service. Because lanes cannot be added in partial increments, about 90 miles of construction in each direction would be required on the highways corridors adjacent to the VRE (I-95/395, I-66 and I-495) to accommodate the trips that would otherwise ride the expanded VRE. The existing Virginia Railway Express train fleet, for example, provides capacity for approximately 5,000 persons per hour during peak service (or the equivalent of 4,500 vehicles). Accommodating these trips on the roads would require adding at least one freeway lane in each direction in both VRE corridors (about 180 lane-miles of freeway). So while Exhibit 8 includes partial lanes, it should be noted that the physical roadway amounts would be much greater.

Another estimate of the contribution of VRE service is to place a value on the construction of the additional Interstate lanes using average per-mile construction costs. The scale of this analysis precludes a specific investigation of a detailed cost estimate, but typical roadway costs provide a basis for comparison. Exhibit 9 shows the per-lane-mile construction costs obtained from Fairfax County projects (*8*) and the resulting construction cost estimates. The total estimated construction cost for the Interstate lanes required to provide capacity to carry VRE passengers is over $1 billion.

Case 2: What could the contribution of VRE be if ridership were increased by transferring drivers to commuter rail service?

Exhibit 10 illustrates the benefits that could be gained by doubling VRE ridership. The lower end estimates are similar to those in Exhibit 8, but the high congestion levels in the I-95 and I-66 corridors result in much more delay savings from a ridership increase; the upper end of the scenarios yield about 13 percent reduction in delay. The additional delay savings would range between 700 thousand and 2.8 million person hours. The expanded VRE ridership would "free-up" between 0.5 and 1.2 freeway lanes of capacity for other trips, or to accommodate growth in the corridor. This analysis allows a direct comparison of the feasibility, cost and implementation period of VRE improvements and freeway capacity.

Exhibits 11 and 12 provide route level estimates of the congestion reduction benefits from Virginia Railway Express services.

Exhibit 8. Congestion Reducing Effects of Existing Virginia Railway Express Service

Scenario	Alternate Mode Percentage and Vehicle Occupancy	Annual Delay Savings (million person-hours)	Percent Delay Reduction	Lanes Not Needed	Corridor Lane-Miles Not Needed
Previous Mode	GP-50, Carpool-20, Bus-30, Occup 1.10	1.74	8%	0.5	10.1
Mainlane 1	GP-100, Carpool-0, Bus-0, Occup 1.00	3.83	18%	1.2	21.9
Mainlane 2	GP-100, Carpool-0, Bus-0, Occup 1.10	3.60	17%	1.1	19.9
Mainlane 3	GP-100, Carpool-0, Bus-0, Occup 1.25	3.33	16%	1.0	17.6
HOV 1	GP-75, Carpool-25, Bus-0, Occup 1.00	2.83	13%	0.9	18.6
HOV 2	GP-75, Carpool-25, Bus-0, Occup 1.10	2.68	13%	0.8	16.9
HOV 3	GP-75, Carpool-25, Bus-0, Occup 1.25	2.50	12%	0.7	15.1
HOV 4	GP-50, Carpool-50, Bus-0, Occup 1.00	1.77	8%	0.6	15.2
HOV 5	GP-50, Carpool-50, Bus-0, Occup 1.10	1.74	8%	0.5	14.0
HOV 6	GP-50, Carpool-50, Bus-0, Occup 1.25	1.69	8%	0.5	12.7
Bus 1	GP-75, Carpool-0, Bus-25, Occup 1.00	2.76	13%	0.9	16.5
Bus 2	GP-75, Carpool-0, Bus-25, Occup 1.10	2.61	12%	0.9	15.1
Bus 3	GP-75, Carpool-0, Bus-25, Occup 1.25	2.40	11%	0.7	13.3
Bus 4	GP-50, Carpool-0, Bus-50, Occup 1.00	1.70	8%	0.6	11.2
Bus 5	GP-50, Carpool-0, Bus-50, Occup 1.10	1.66	8%	0.5	10.2
Bus 6	GP-50, Carpool-0, Bus-50, Occup 1.25	1.62	8%	0.5	9.0

Exhibit 9. Construction Costs for Freeway Lane-Miles to Replace VRE Service

Corridor Lane-Miles	**Rural**	**Urban**	**Dense Urban**
I-95	54	34	
I-395			20
I-66	31	13	9
I-495			18
Cost per Lane-Mile ($ Million)	$4	$6	$8.5
Cost	$340	$285	$395
Total Estimated Project Cost			**$1,020**

Note: Distances are lane-miles (one lane in each direction).

Source: Reference 8

Note: Rural/Urban dividing point was estimated to be at Fairfax County Parkway in the I-66 corridor and VA 234 in the I-95 corridor. Urban/Dense Urban dividing point was I-495 in both corridors.

Exhibit 10. Additional Congestion-Reducing Effects of Increased Virginia Railway Express Service

Scenario	Alternate Mode Percentage and Vehicle Occupancy	Annual Delay Savings (million person-hours)	Percent Delay Reduction	Lanes Not Needed	Corridor Lane-Miles Not Needed
Previous Mode	GP-50, Carpool-20, Bus-30, Occup 1.10	0.76	4%	0.5	10.1
Mainlane 1	GP-100, Carpool-0, Bus-0, Occup 1.00	2.80	13%	1.2	21.9
Mainlane 2	GP-100, Carpool-0, Bus-0, Occup 1.10	2.68	13%	1.1	19.9
Mainlane 3	GP-100, Carpool-0, Bus-0, Occup 1.25	2.53	12%	1.0	17.6
HOV 1	GP-75, Carpool-25, Bus-0, Occup 1.00	1.43	7%	0.9	18.5
HOV 2	GP-75, Carpool-25, Bus-0, Occup 1.10	1.37	7%	0.8	16.9
HOV 3	GP-75, Carpool-25, Bus-0, Occup 1.25	1.30	6%	0.7	15.1
HOV 4	GP-50, Carpool-50, Bus-0, Occup 1.00	0.82	4%	0.6	15.0
HOV 5	GP-50, Carpool-50, Bus-0, Occup 1.10	0.75	4%	0.5	13.9
HOV 6	GP-50, Carpool-50, Bus-0, Occup 1.25	0.69	3%	0.5	12.8
Bus 1	GP-75, Carpool-0, Bus-25, Occup 1.00	1.39	7%	0.9	16.6
Bus 2	GP-75, Carpool-0, Bus-25, Occup 1.10	1.33	6%	0.8	15.1
Bus 3	GP-75, Carpool-0, Bus-25, Occup 1.25	1.26	6%	0.7	13.3
Bus 4	GP-50, Carpool-0, Bus-50, Occup 1.00	0.83	4%	0.6	11.2
Bus 5	GP-50, Carpool-0, Bus-50, Occup 1.10	0.77	4%	0.5	10.2
Bus 6	GP-50, Carpool-0, Bus-50, Occup 1.25	0.71	3%	0.5	9.0

Exhibit 11. Congestion Effects of Existing Virginia Railway Express Service (By Route)

Fredericksburg Line (I-95/I-395)

Scenario	Alternate Mode Percentage and Vehicle Occupancy	Annual Delay Savings (million person-hours)	Percent Delay Reduction	Lanes Not Needed	Corridor Lane-Miles Not Needed
Previous Mode	GP-50, Carpool-20, Bus-30, Occup 1.10	1.25	10%	0.3	6.7
Mainlane 1	GP-100, Carpool-0, Bus-0, Occup 1.00	2.89	23%	0.6	14.4
Mainlane 2	GP-100, Carpool-0, Bus-0, Occup 1.10	2.74	20%	0.5	13.2
Mainlane 3	GP-100, Carpool-0, Bus-0, Occup 1.25	2.56	22%	0.5	11.6
HOV 1	GP-75, Carpool-25, Bus-0, Occup 1.00	1.93	15%	0.4	12.5
HOV 2	GP-75, Carpool-25, Bus-0, Occup 1.10	1.84	16%	0.4	11.5
HOV 3	GP-75, Carpool-25, Bus-0, Occup 1.25	1.72	14%	0.4	10.3
HOV 4	GP-50, Carpool-50, Bus-0, Occup 1.00	1.23	10%	0.3	10.5
HOV 5	GP-50, Carpool-50, Bus-0, Occup 1.10	1.21	10%	0.3	9.7
HOV 6	GP-50, Carpool-50, Bus-0, Occup 1.25	1.17	9%	0.2	8.9
Bus 1	GP-75, Carpool-0, Bus-25, Occup 1.00	1.93	15%	0.4	10.9
Bus 2	GP-75, Carpool-0, Bus-25, Occup 1.10	1.83	15%	0.4	10.0
Bus 3	GP-75, Carpool-0, Bus-25, Occup 1.25	1.72	14%	0.4	8.8
Bus 4	GP-50, Carpool-0, Bus-50, Occup 1.00	1.23	10%	0.3	7.5
Bus 5	GP-50, Carpool-0, Bus-50, Occup 1.10	1.20	10%	0.3	6.8
Bus 6	GP-50, Carpool-0, Bus-50, Occup 1.25	1.16	9%	0.2	6.0

Manassas Line (I-66)

Scenario	Alternate Mode Percentage and Vehicle Occupancy	Annual Delay Savings (million person-hours)	Percent Delay Reduction	Lanes Not Needed	Corridor Lane-Miles Not Needed
Previous Mode	GP-50, Carpool-20, Bus-30, Occup 1.10	0.50	8%	0.2	3.4
Mainlane 1	GP-100, Carpool-0, Bus-0, Occup 1.00	0.94	16%	0.5	7.5
Mainlane 2	GP-100, Carpool-0, Bus-0, Occup 1.10	0.86	14%	0.4	6.7
Mainlane 3	GP-100, Carpool-0, Bus-0, Occup 1.25	0.77	13%	0.4	6.0
HOV 1	GP-75, Carpool-25, Bus-0, Occup 1.00	0.89	15%	0.4	6.1
HOV 2	GP-75, Carpool-25, Bus-0, Occup 1.10	0.84	14%	0.3	5.4
HOV 3	GP-75, Carpool-25, Bus-0, Occup 1.25	0.78	13%	0.3	4.8
HOV 4	GP-50, Carpool-50, Bus-0, Occup 1.00	0.54	9%	0.2	4.7
HOV 5	GP-50, Carpool-50, Bus-0, Occup 1.10	0.53	9%	0.2	4.3
HOV 6	GP-50, Carpool-50, Bus-0, Occup 1.25	0.52	9%	0.2	3.8
Bus 1	GP-75, Carpool-0, Bus-25, Occup 1.00	0.83	14%	0.4	5.6
Bus 2	GP-75, Carpool-0, Bus-25, Occup 1.10	0.78	13%	0.3	5.1
Bus 3	GP-75, Carpool-0, Bus-25, Occup 1.25	0.69	12%	0.3	4.5
Bus 4	GP-50, Carpool-0, Bus-50, Occup 1.00	0.47	8%	0.2	3.7
Bus 5	GP-50, Carpool-0, Bus-50, Occup 1.10	0.46	8%	0.2	3.4
Bus 6	GP-50, Carpool-0, Bus-50, Occup 1.25	0.46	8%	0.2	3.0

Exhibit 12. Congestion Effects of Increased Virginia Railway Express Service (By Route)

Fredericksburg Line (I-95/I-395)

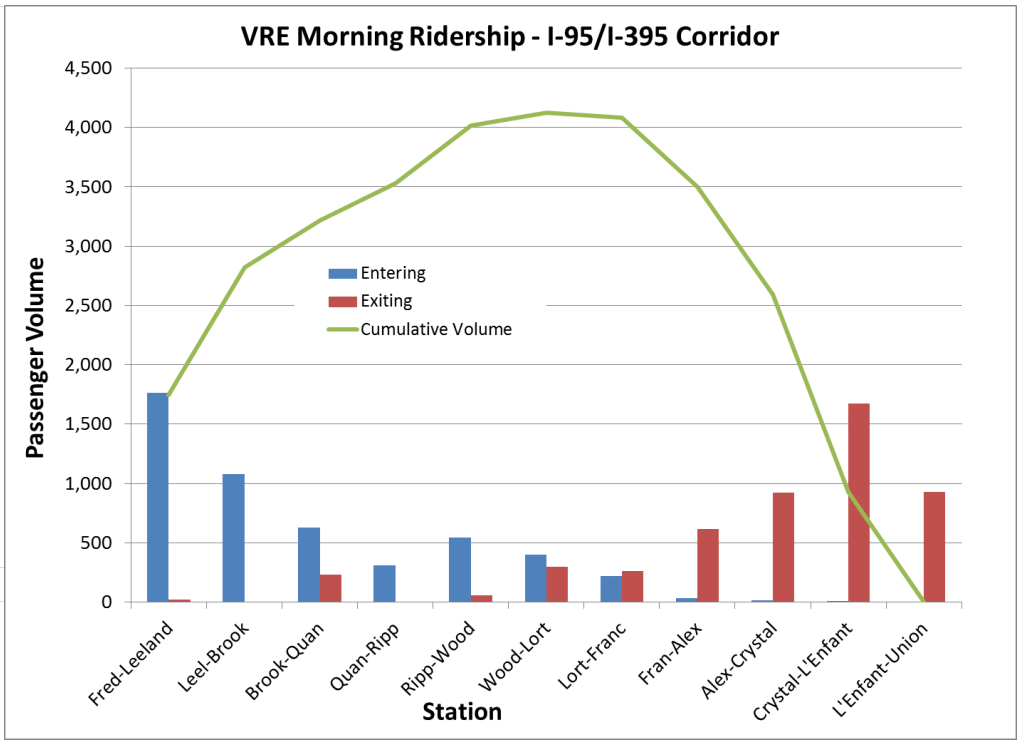
Scenario	Alternate Mode Percentage and Vehicle Occupancy	Annual Delay Savings (million person-hours)	Percent Delay Reduction	Lanes Not Needed	Corridor Lane-Miles Not Needed
Previous Mode	GP-50, Carpool-20, Bus-30, Occup 1.10	0.45	4%	0.3	6.7
Mainlane 1	GP-100, Carpool-0, Bus-0, Occup 1.00	1.87	15%	0.6	14.4
Mainlane 2	GP-100, Carpool-0, Bus-0, Occup 1.10	1.77	14%	0.5	13.2
Mainlane 3	GP-100, Carpool-0, Bus-0, Occup 1.25	1.64	13%	0.5	11.6
HOV 1	GP-75, Carpool-25, Bus-0, Occup 1.00	0.93	7%	0.4	12.5
HOV 2	GP-75, Carpool-25, Bus-0, Occup 1.10	0.88	7%	0.4	11.5
HOV 3	GP-75, Carpool-25, Bus-0, Occup 1.25	0.83	7%	0.4	10.3
HOV 4	GP-50, Carpool-50, Bus-0, Occup 1.00	0.47	4%	0.3	10.5
HOV 5	GP-50, Carpool-50, Bus-0, Occup 1.10	0.41	3%	0.3	9.7
HOV 6	GP-50, Carpool-50, Bus-0, Occup 1.25	0.37	3%	0.2	9.0
Bus 1	GP-75, Carpool-0, Bus-25, Occup 1.00	0.90	7%	0.4	11.0
Bus 2	GP-75, Carpool-0, Bus-25, Occup 1.10	0.85	7%	0.4	10.0
Bus 3	GP-75, Carpool-0, Bus-25, Occup 1.25	0.80	6%	0.4	8.8
Bus 4	GP-50, Carpool-0, Bus-50, Occup 1.00	0.50	4%	0.3	7.5
Bus 5	GP-50, Carpool-0, Bus-50, Occup 1.10	0.46	4%	0.3	6.8
Bus 6	GP-50, Carpool-0, Bus-50, Occup 1.25	0.41	3%	0.2	6.0

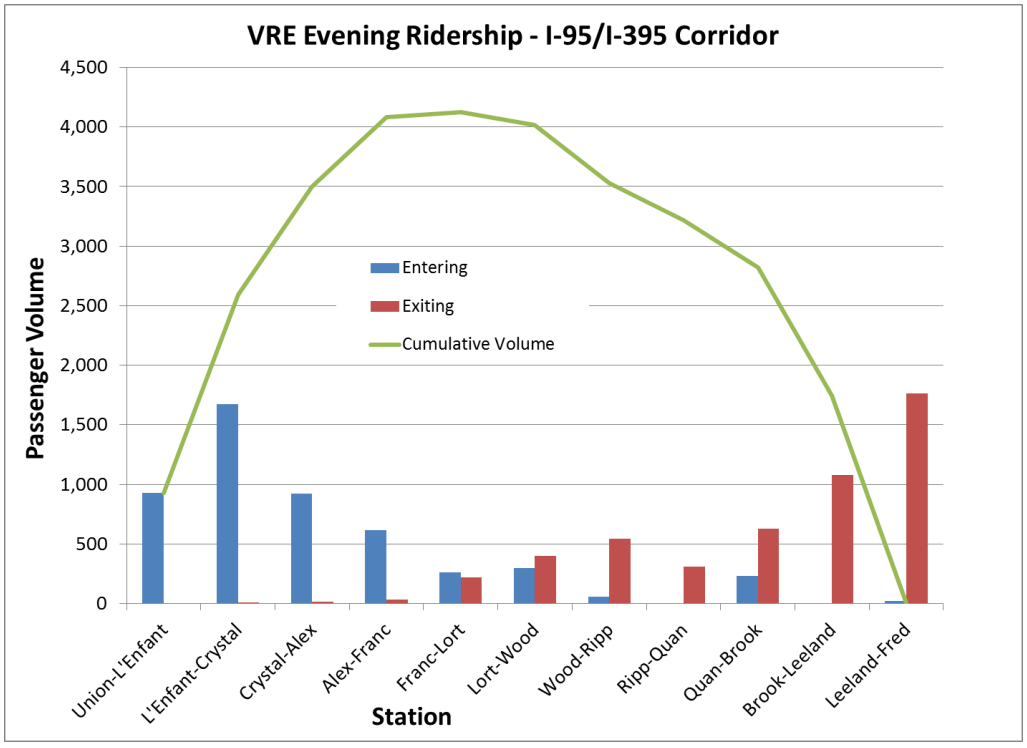
Manassas Line (I-66)

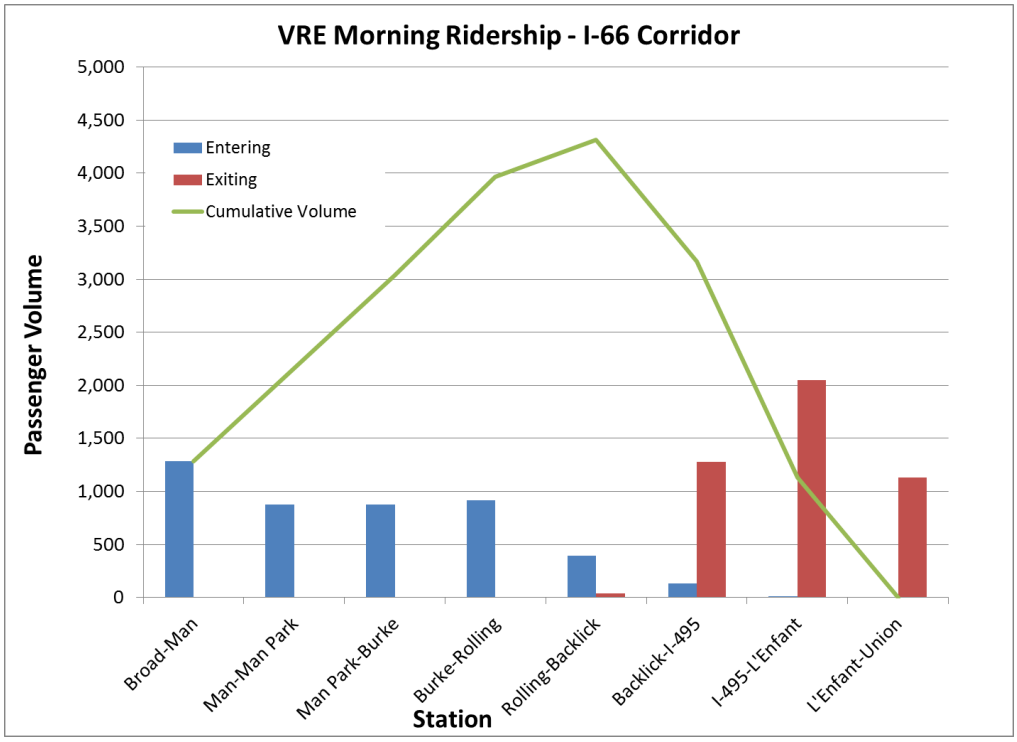
Scenario	Alternate Mode Percentage and Vehicle Occupancy	Annual Delay Savings (million person-hours)	Percent Delay Reduction	Lanes Not Needed	Corridor Lane-Miles Not Needed
Previous Mode	GP-50, Carpool-20, Bus-30, Occup 1.10	0.31	5%	0.2	3.4
Mainlane 1	GP-100, Carpool-0, Bus-0, Occup 1.00	0.93	15%	0.5	7.5
Mainlane 2	GP-100, Carpool-0, Bus-0, Occup 1.10	0.91	15%	0.4	6.7
Mainlane 3	GP-100, Carpool-0, Bus-0, Occup 1.25	0.89	14%	0.4	6.0
HOV 1	GP-75, Carpool-25, Bus-0, Occup 1.00	0.51	8%	0.4	6.0
HOV 2	GP-75, Carpool-25, Bus-0, Occup 1.10	0.49	8%	0.4	5.4
HOV 3	GP-75, Carpool-25, Bus-0, Occup 1.25	0.47	7%	0.3	4.8
HOV 4	GP-50, Carpool-50, Bus-0, Occup 1.00	0.35	5%	0.2	4.5
HOV 5	GP-50, Carpool-50, Bus-0, Occup 1.10	0.34	5%	0.2	4.2
HOV 6	GP-50, Carpool-50, Bus-0, Occup 1.25	0.32	5%	0.2	3.8
Bus 1	GP-75, Carpool-0, Bus-25, Occup 1.00	0.49	8%	0.4	5.6
Bus 2	GP-75, Carpool-0, Bus-25, Occup 1.10	0.48	8%	0.3	5.1
Bus 3	GP-75, Carpool-0, Bus-25, Occup 1.25	0.46	7%	0.3	4.5
Bus 4	GP-50, Carpool-0, Bus-50, Occup 1.00	0.33	5%	0.2	3.7
Bus 5	GP-50, Carpool-0, Bus-50, Occup 1.10	0.32	5%	0.2	3.4
Bus 6	GP-50, Carpool-0, Bus-50, Occup 1.25	0.30	5%	0.2	3.0

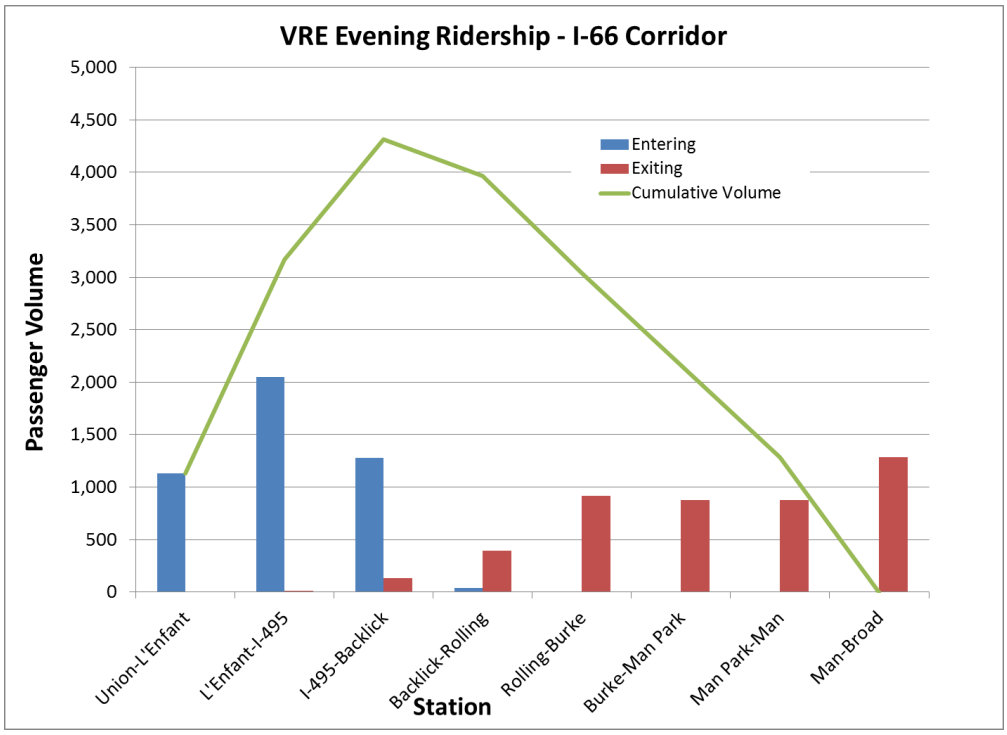
Appendix A. 15-Minute Volumes by Entrance and Exit

Appendix A illustrates entering and exiting passenger volumes at VRE stations along the corridors for the morning and evening peak periods (3,4). The cumulative passenger volumes for each corridor are also shown.






VRE Morning Ridership - I-66 Corridor
Passenger Volume
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Entering
Exiting
Cumulative Volume
Broad-Man
Man-Man Park
Man Park-Burke
Burke-Rolling
Rolling-Backlick
Backlick-I-495
I-495-L'Enfant
L'Enfant-Union
Station


VRE Evening Ridership - I-66 Corridor
Passenger Volume
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Entering
Exiting
Cumulative Volume
Union-L'Enfant
L'Enfant-I-495
I-495-Backlick
Backlick-Rolling
Rolling-Burke
Burke-Man Park
Man Park-Man
Man-Broad
Station

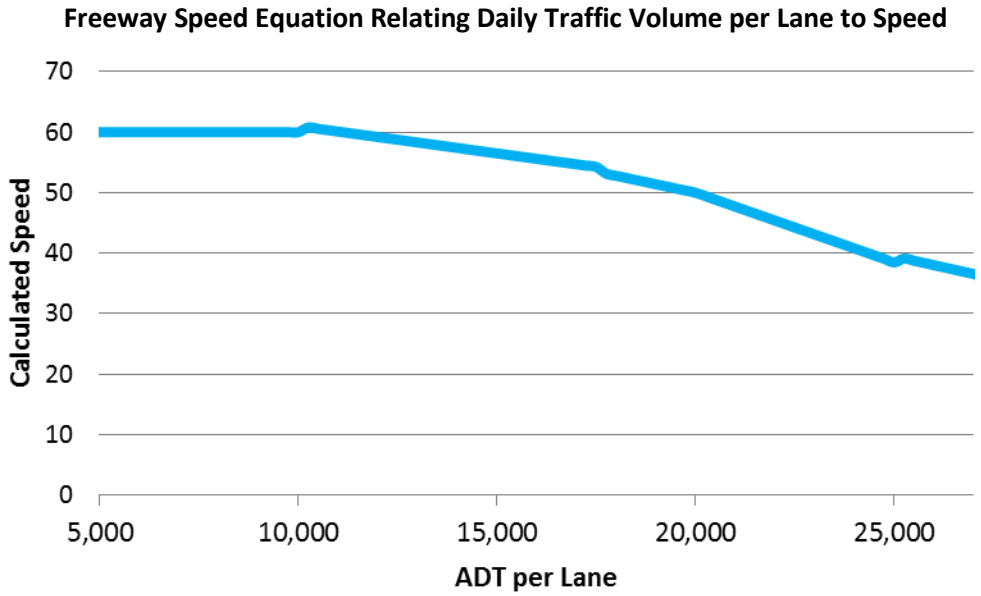
Appendix B. Traffic Density and Speed Relationship

The equations shown in the following table and graph are used in two separate calculations in the methodology. The first use is to determine the amount of speed improvement or degradation that occurs when vehicles are added onto the roadway or removed from the roadway depending on the scenario. As vehicles are added to the roadway the traffic density at a given location increases and speeds drop a certain amount of miles per hour due to the increase. This speed drop (expressed in percentage terms) was applied to the INRIX measured speeds and the change in the amount of delay between the base condition and the new condition determined.

The second way these equations are used is to determine the amount of additional capacity that would be needed or gained using the scenario conditions. If, for example, vehicles were being added to the roadway, the traffic density would increase and the amount of lane-miles that would be needed to match the increased vehicle travel could be determined.

Freeway Congestion Level	Daily Traffic Volume Per Lane	Speed Estimate Equation	
		Peak Direction	Off-Peak Direction
Uncongested	Under 10,000	60	60
Medium	10,001–17,500	70−(0.9*ADT/Lane)	67−(0.6*ADT/Lane)
Heavy	17,501–20,000	78−(1.4*ADT/Lane)	71−(0.85*ADT/Lane)
Severe	20,001–25,000	96−(2.3*ADT/Lane)	88−(1.7*ADT/Lane)
Extreme	Over 25,000	76−(1.46*ADT/Lane) Lowest is 35 mph	85.7−(1.6*ADT/Lane) Lowest is 40 mph

Source: Reference 9



Source: Reference 9

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