APPENDIX C

Traffic and Transportation Report

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Route 1

Multimodal Alternatives Analysis

ROUTE 1 MULTIMODAL ALTERNATIVES ANALYSIS

TRAFFIC AND TRANSPORTATION REPORT

May 2014

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1.0 Introduction

This report provides an overview of the key transportation analyses conducted for the Route 1 Multimodal Alternatives Analysis. The report describes the technical methodologies and presents results of the vehicular lane and traffic analysis, as well as the ridership projections for the proposed transit alternatives. The technical findings presented support the evaluation of alternatives and will inform the technical recommendation of a multimodal alternative for implementation. Detailed appendices provide thorough documentation of the assumptions and processes applied in the analysis.

The report is organized into four key sections:

Section 2: General Corridor Travel Patterns
Section two describes the current travel patterns for the corridor. It provides information on where people travel to and the mode they choose to get there.

Section 3: Traffic Analysis: No Build Lane Analysis
Section three presents the vehicular lane analysis and is organized into two subsections. It confirms that six general purpose travel lanes along the majority of the corridor would support the projected increase of traffic volume in 2035; this recommendation is referred to as the "No Build" alternative, as it includes projects listed in the regional Constrained Long Range Plan (2013) and assumes improvements identified in the VDOT Centerline Study (1998). A six general purpose lane configuration is consistent with the Fairfax County Comprehensive Plan. **Figure 1-1** shows the proposed cross-section.

Figure 1-1: No Build Lane Configuration

Section 4: Traffic Analysis: Alternative Vehicular Lane Analysis
Section four compares the effects of four different transit alternatives on auto and transit operations. It describes the other vehicular lane configurations and summarizes the performance measure results.

Section 5: Projected Ridership of Transit Alternatives
Section five relates to ridership forecasting for the proposed transit alternatives and is organized into three sections. It discusses the operating and forecasting assumptions related to the transit alternatives, describes the methodological process, and presents the ridership results for both the initial and refined transit alternatives.

The project team notes that several ongoing studies and plans are geared toward understanding the impacts on the corridor traffic network and selecting projects that address those impacts:

- VDOT project selection process
- Fairfax and Prince William County implementation of DRPT Transit Design Guidelines
- Fairfax Countywide Transit Network Study
- MWCOG Constrained Long Range Plan

The project team discussed the forecasting approach with Fairfax County staff, who is conducting a concurrent Countywide Transit Network Study. The approach and key inputs were also coordinated with VDOT staff. The forecasts consider interactions among regional facilities and services, such as VRE and the greater I-95 transportation corridor.

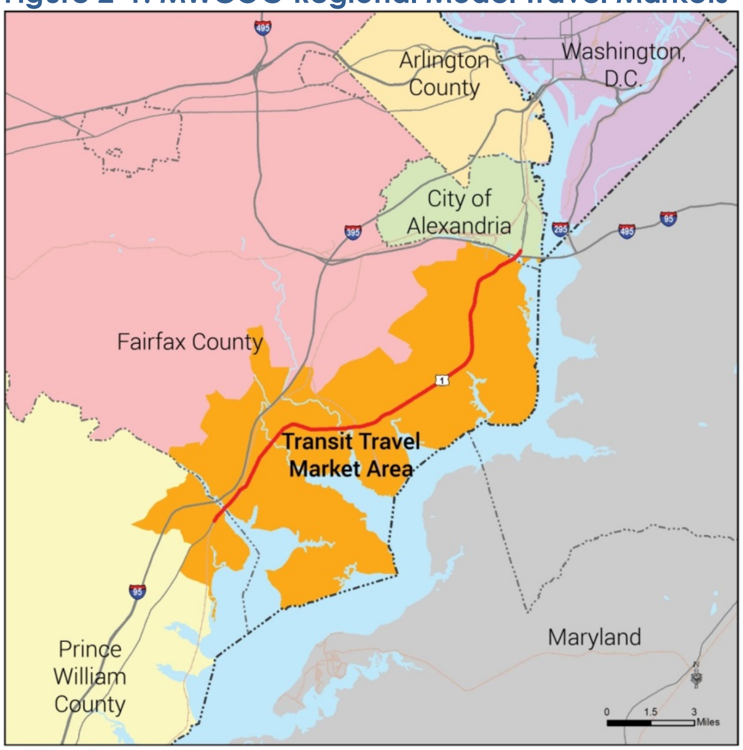
2.0 General Corridor Travel Patterns

Within the study area in Prince William and Fairfax counties, U.S. Route 1 (Route 1) serves local, regional, and longer-distance travel. Any assessment of transportation in the Route 1 corridor must consider the regional context as well as localized travel patterns.

2.1 Travel Origins and Destinations

The project team identified the trips to and from the Route 1 corridor using the Metropolitan Washington Council of Governments (MWCOG Version 2.2) regional travel demand model, refined for the Route 1 corridor. **Figure 2-1** shows the travel markets which were defined to study the trip patterns from the MWCOG regional model. The Route 1 corridor was defined by grouping all MWCOG TAZs within a half-mile buffer around Route 1 from the Huntington Metrorail station to the Woodbridge VRE station.

Figure 2-1: MWCOG Regional Model Travel Markets



In general, the largest shares of corridor travel, 34 percent of average weekday and 31 percent of peak period trips, are trips that begin and end in the corridor. The next largest share of travel are to and from other areas within Fairfax County, and account for 24 percent of both average weekday and peak period trips.

The typical average weekday and peak period (AM and PM peak) travel patterns to/from and within the Route 1 corridor are summarized in **Table 2-1** and **Table 2-2** below. Although there are relatively fewer total trips between the study corridor and the regional core in Washington DC and Arlington/Alexandria, those trips have the highest transit share; 29 percent of the daily trips and 39 percent of the peak period trips between Route 1 corridor and D.C are being currently made by transit. Of people who live within the corridor, the majority of corridor transit users (52 percent) are commuting to Washington D.C., using Metrorail, and 86 percent of corridor transit users are traveling to either Arlington/Alexandria or Downtown. Of people traveling by transit to destinations within the corridor; 64 percent of transit commuters to the corridor use the bus mode exclusively, and most transit trips begin and end in the corridor.

Table 2-1: Average Weekday (Auto and Transit) To, From, and Within Route 1 Corridor

Route 1 From/To	Total Trips		
	Total	% of Total	Transit Share
DC	52,000	6%	29%
Arlington/Alexandria	116,000	13%	6%
Within Rt.1 Corridor	310,000	34%	1%
Fairfax Other	216,000	24%	0%
Prince William Other	124,000	13%	0%
Other Areas	95,000	10%	2%
Total	**913,000**	**100%**	**3%**

Source: MWCOG/WMATA Version 2.2 Year 2010 model and Regional On-Board Transit Survey Data

Table 2-2: AM and PM Peak Period (Auto and Transit) To, From, and Within Route 1 Corridor

Route 1 From/To	Total Trips		
	Total	% of Total	Transit Share
DC	28,000	7%	39%
Arlington/Alexandria	54,000	13%	9%
Within Rt.1 Corridor	127,000	31%	1%
Fairfax Other	95,000	24%	0%
Prince William Other	55,000	14%	0%
Other Areas	46,000	11%	2%
Total	**404,000**	**100%**	**4%**

Source: MWCOG/WMATA Version 2.2 Year 2010 model and Regional On-Board Transit Survey Data

3.0 No Build Lane Configuration Analysis

The purpose of this analysis was to confirm whether a consistent, six-lane cross section along the majority of the corridor (No Build lane configuration alternative) could adequately support the future traffic volumes in 2035 (See **Figure 3-1**). The No Build alternative assumes widening Route 1 from Annapolis Way to Mount Vernon Memorial Highway from two-lanes to three-lanes, as identified in the 1998 VDOT Centerline Study (See **Figure 3-2**). A significant portion of the recommendation is either under construction or is a committed project in the National Capital Region's Financially Constrained Long Range Plan (CLRP 2013).

Figure 3-1: No Build Lane Configuration

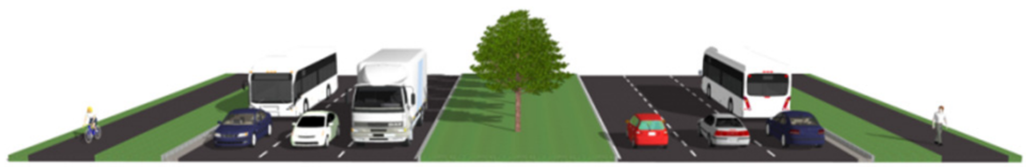
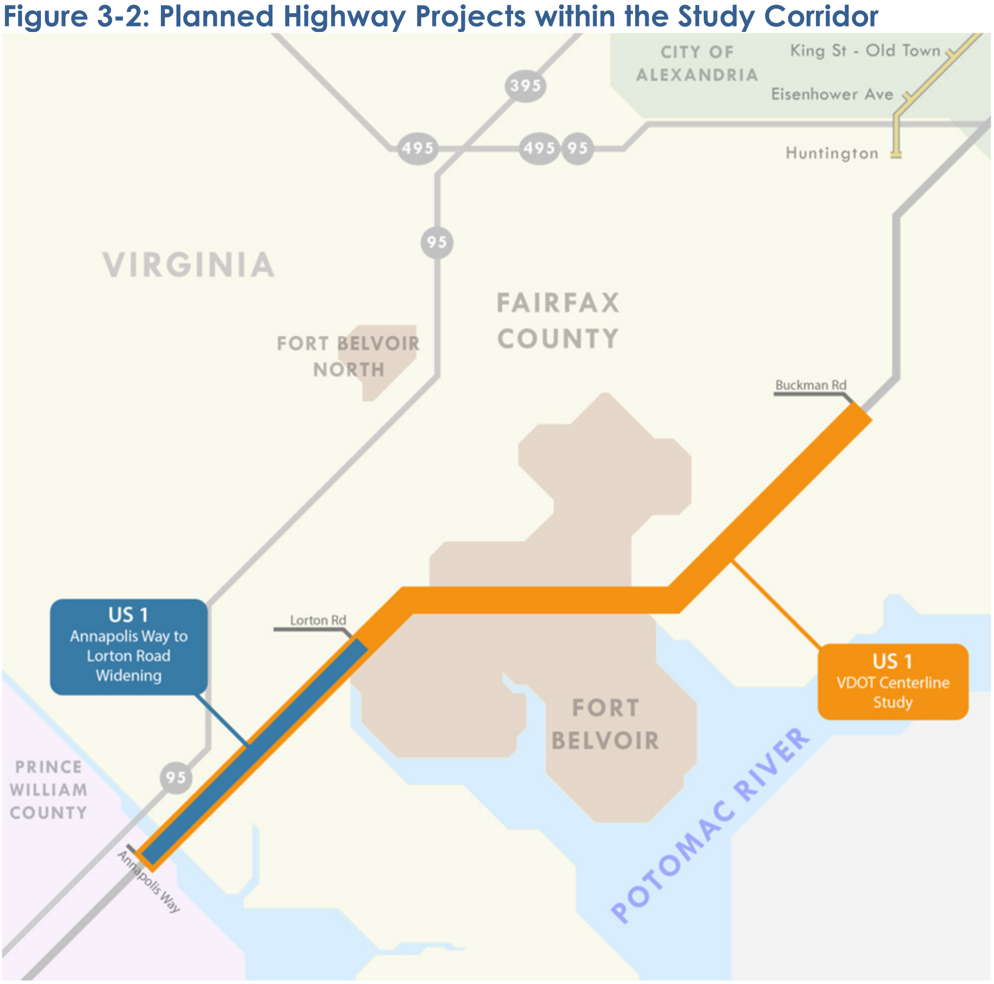


Figure 3-2: Planned Highway Projects within the Study Corridor



The No Build alternative is compared to the existing Lane configuration, which varies from four to six lanes along the corridor. The current lane configuration is shown in **Attachment A**.

To confirm the No Build alternative, the project team took a two-step approach:

1. Analyzed No Build traffic conditions in 2035 under two traffic growth scenarios.
2. Analyzed traffic impacts in 2035 for varied lane configurations to confirm whether the No Build could best accommodate future vehicular demand while minimizing impacts on right-of-way and improving pedestrian safety and accommodation.

The following sections describe the methodology and findings for each approach.

3.1 2035 No Build traffic conditions (two traffic growth scenarios)

This section presents the results of the 2035 No Build condition. The purpose of the analysis was to understand traffic conditions along the entire corridor by developing growth scenarios and applying the future volumes to analyze intersection performance.

For purposes of this analysis, the project team developed and tested two growth scenarios: moderate growth rates, where historical growth rates were blended with MWCOG projections; and high growth rates, based directly on MWCOG projections. For both growth rate scenarios, intersection level of service (LOS) and volume to capacity (v/c) ratio in the morning and evening peak hour were analyzed for each study intersection using SYNCHRO. Study intersections include all signalized intersections along the 15-mile project corridor and comprise of 40 intersections in total. **Attachment A** shows all of the study intersections.

3.1.1 Development of Growth Scenarios

In coordination with VDOT staff, the project team studied historical growth in Annual Average Daily Traffic (AADT) along the corridor, and reviewed growth projections based on MWCOG Version 2.2 Model with Land Use Round 8.2 projections. Between 2001 and 2012 traffic volumes grew at a rate of between negative one percent and positive one percent per year, depending upon the location along the corridor. By contrast, MWCOG projections for future traffic volumes show greater rates of growth—between one and two percent each year. Given the large difference between the historical growth rates and the MWCOG growth rate, the project team developed two growth rate scenarios to apply to the No Build alternative:

1. Moderate Growth Rate: Considers both historical and MWCOG growth rates, ranging from 0.75-1.3 percent annually
2. High Growth Rate: MWCOG output growth rate, which varies from 1.0 to 2.0 percent annually

Attachment B provides detailed information on the development and detailed definition of the two growth rate scenarios. Section 3.1.2 describes the results on both the intersection LOS and V/C ratio.

3.1.2 Intersection Performance with 2035 Traffic Projections

Using SYNCHRO traffic analysis software, the team analyzed future traffic conditions at intersections along the entire length of the corridor. For both growth rate scenarios, intersection LOS and V/C ratio in the morning and evening peak hour were analyzed.

Table 3-1 provides a summary of LOS and intersection V/C for the 40 study intersections under the moderate growth rate and high growth rate scenarios in 2035. For comparison purposes, the existing 2035 lane configuration results were also included.

Under the moderate growth rate scenario, results show that with the consistent six-lane cross-section, three intersections in the morning peak and four intersections in the evening peak hour operate with LOS E or worse. Only one intersection in the morning peak hour operates with LOS F. Under the high growth rate scenario, with the consistent 6-lane cross-section, four intersections in the morning peak and ten intersections in the evening peak hour operate with LOS E or worse. One intersection in the morning peak and three intersections in the evening peak operate with LOS F. Detailed traffic analysis which includes intersection LOS and v/c ratios for all study intersections is provided in **Attachment C**.

Table 3-1: Intersection Level of Service and Volume to Capacity Summary for 2035 Growth Scenarios (No Build alternative)

Measure	Existing Lane Configuration (2035)		No Build Moderate Growth (2035)		No Build High Growth (2035)	
	AM	PM	AM	PM	AM	PM
# of intersections with LOS E or worse	3	3	3	4	4	10
# of intersections with volume/capacity > 0.95	5	4	4	7	7	17

*Note: LOS analysis included no additional traffic operations improvements

3.2 2035 Traffic Impacts 2035 for Alternative Lane Configurations

The second step to confirm the No Build alternative was to compare it against other vehicular lane configurations to understand the tradeoffs between accommodating future vehicular demand, and minimizing right-of-way and improving pedestrian safety and accommodation. Two additional roadway configurations were developed and performance results were compared to the existing roadway configuration and the No Build alternative, including:

1. Expanded Lane: Adds an additional lane to the existing configuration, making the majority of the corridor four general purpose lanes in each direction
2. Converted lanes: Repurposes one existing travel lane per direction to serve as a managed lane for transit and potentially other high occupancy vehicles

All four vehicular lane alternatives analyzed are described and shown in Section 3.2.2.

3.2.1 Methodology

To evaluate the performance of intersections under the different general purpose lane alternatives, the project team considered intersection LOS, V/C, and pedestrian crossing time as performance measures.

Intersection level of service and volume to capacity ratio were obtained using SYNCHRO's Highway Capacity Manual (HCM) signalized intersection capacity analysis module. Pedestrian crossing times were calculated based on the crossing distances and signal delays at the intersections. It is assumed that under the additional (expanded) lane scenario, cycle lengths would be higher to accommodate longer pedestrian crossing times (i.e., longer pedestrian clearance intervals). MUTCD's recommended pedestrian travel speed of 3 ½ feet per second (3.5 ft/s) was used to determine pedestrian clearance intervals.

Alternatives were evaluated utilizing the moderate growth rate scenario and tested at 12 intersections along two segments; five intersections along Route 1 near Fort Belvoir and seven intersections at Hybla Valley (See **Figures 3-3** and **3-4**). The two segments were selected based on:

- High variability in LOS and V/C ratios in the No Build analysis
- Variability of general purpose lanes under existing conditions (4 lane vs. 6 lane operation)
- Location of the transition from BRT to Metro Rail for the Hybrid Alternative (Hybla Valley)

The selection was not based on the areas that have the worst traffic performance. Rather the selection was conducted such that the performance of the intersections can be generalized or extrapolated from the selected intersections to the entire corridor.

Given the relationship between population growth and growth in traffic over the past several years, and the range of intersection performance levels associated with the two growth scenarios, the project team recommended applying the moderate growth scenario for subsequent traffic analysis.

Figure 3-3: Analyzed Intersections, Route 1- Hybla Valley Segment

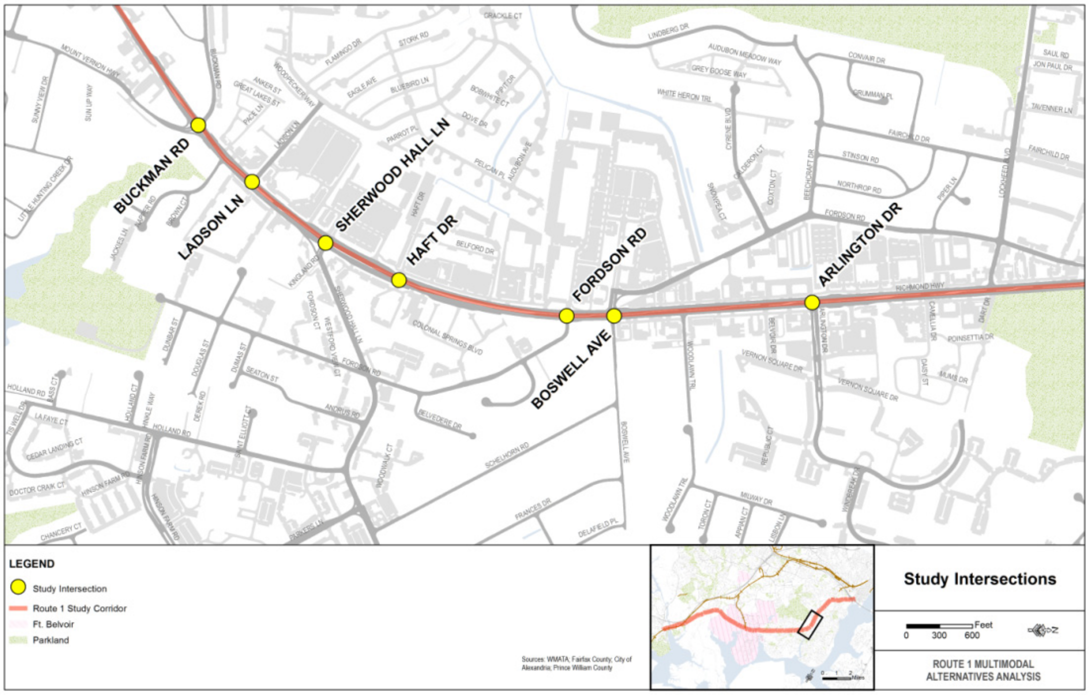
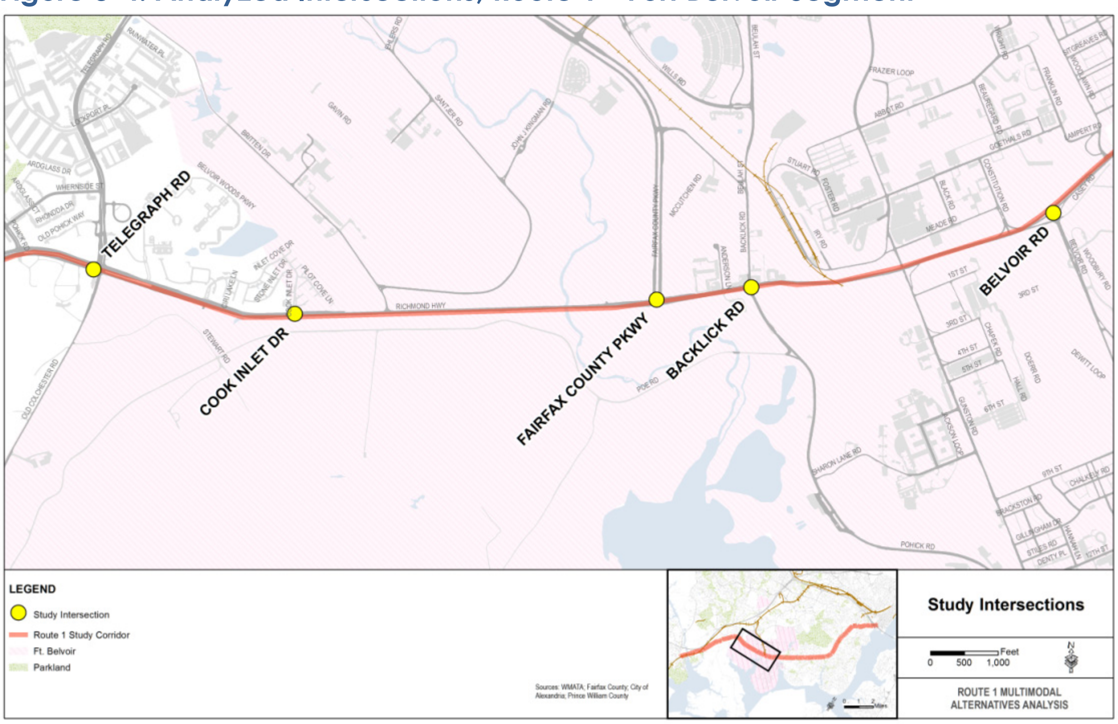


Figure 3-4: Analyzed Intersections, Route 1- Fort Belvoir Segment

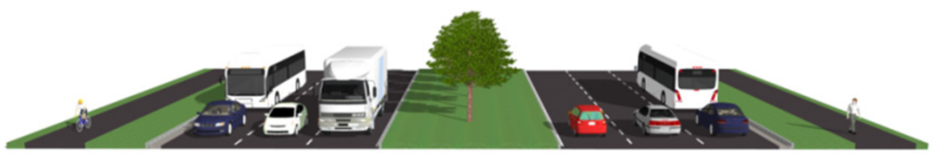


3.2.2 Vehicular Roadway Alternatives

Two lane configurations were analyzed in addition to the No Build alternative and the Existing Lane configuration, including "expanded lanes" and "converted lanes." The lane configuration alternatives are described below:

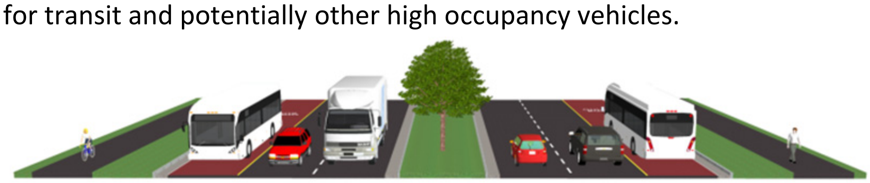
1. **Existing Lanes:** Retains the varied cross section as presently built. In general, there are two travel lanes in each direction in the southern segment, and three travel lanes in each direction in most of the northern segment. **Attachment A** shows the existing lane configuration.

2. **No Build** (also referred to as "consistent lanes"): Consists of planned improvements identified in the VDOT Centerline Study (1998) and the highway improvements included in the adopted CLRP 2013. The No Build assumes a consistent three-lane per direction (6-lane total) configuration for the majority of the subject segment with the exception of the northernmost portion which would retain its existing four-lanes per direction.



3. **Expanded Lanes:** Adds an additional lane, making the majority of the corridor a four lane per direction configuration (although some areas are expanded from two to three lanes).This alternative is also the widest cross-section.

4. **Converted Lanes**: Repurposes one existing travel lane per direction to serve as a managed lane for transit and potentially other high occupancy vehicles.



3.2.3 Performance of Roadway Alternatives

Table 3-2 shows intersection LOS and **Table 3-3** displays intersection volume to capacity ratios for Hybla Valley and Fort Belvoir segments under different roadway alternatives in 2035.

Results indicate that in the morning peak hour, consistent travel lane alternative or the No Build (3 travel lanes in each direction) yields similar intersection level of service and volume to capacity results as compared with the expanded lanes alternative. In the evening peak hour, the expanded lanes alternative performs better than the consistent number of lanes alternative, resulting in improved intersection level of service and lower volume to capacity ratio; however, it is also important to note that none of the selected intersections within Hybla Valley and Fort Belvoir segments operates with LOS F under the No Build, or consistent lanes alternative.

Table 3-2: Intersection Level of Service (Hybla Valley and Fort Belvoir Route 1 segments) 2035

Intersection	Existing Lane Configuration		No Build (Consistent Lanes)		Expanded Lanes		Converted Lane	
	LOS AM	LOS PM	LOS AM	LOS PM	LOS AM	LOS PM	LOS AM	LOS PM
Hybla Valley								
Arlington Dr	B	C	B	C	B	C	D	E
Boswell Ave	C	D	C	D	C	D	D	F
Fordson Rd/Shopping Cen.	B	D	B	D	B	D	B	F
Haft Dr	A	B	A	B	A	B	A	D
Sherwood Hall Lane	C	E	C	E	C	D	D	F
Ladson Ln	A	C	A	C	A	B	C	F
Buckman Rd/Mt Vernon	E	E	E	E	E	D	F	F
Fort Belvoir								
Belvoir Rd	C	D	B	C	B	C	C	D
Backlick Rd	E	F	D	E	D	D	E	F
Fairfax County Pkwy	C	F	C	D	C	C	C	F
Cook Intel Dr	D	E	A	A	A	A	D	E
Telegraph Rd	D	D	D	D	D	D	F	F
Total								
# of Intersections with LOS E or worse	**2**	**5**	**1**	**3**	**1**	**0**	**3**	**10**

Table 3-3: Volume to Capacity Ratios (Hybla Valley and Fort Belvoir Route 1 segments) - 2035

Intersection	Existing Lane Configuration		No Build (Consistent Lanes)		Additional Lane		Converted Lane	
	LOS AM	LOS PM	LOS AM	LOS PM	LOS AM	LOS PM	LOS AM	LOS PM
Hybla Valley								
Arlington Dr	0.67	0.90	0.67	0.90	0.67	0.88	0.89	1.02
Boswell Ave	0.76	0.94	0.76	0.94	0.65	0.84	0.97	1.17
Fordson Rd/Shopping Cent	0.64	0.92	0.64	0.92	0.62	0.85	0.85	1.15
Haft Dr	0.51	0.78	0.51	0.78	0.41	0.76	0.72	0.98
Sherwood Hall Lane	0.79	1.00	0.79	1.00	0.76	0.89	0.98	1.22
Ladson Ln	0.68	0.84	0.68	0.84	0.55	0.80	0.96	1.19
Buckman Rd/Mt Vernon	1.06	0.99	1.06	0.99	0.98	0.94	1.22	1.20
Fort Belvoir								
Belvoir Rd	0.83	0.94	0.80	0.73	0.80	0.66	0.83	0.94
Backlick Rd	1.17	1.29	1.16	1.04	1.14	0.92	1.17	1.29
Fairfax County Pkwy	0.74	1.22	0.70	0.96	0.70	0.84	0.74	1.22
Cook Intel Dr	1.08	1.13	0.75	0.79	0.60	0.64	1.08	1.13
Telegraph Rd	0.88	1.11	0.88	1.11	0.79	0.94	1.15	1.42
Total Intersection volume/capacity > 0.95	**3**	**6**	**2**	**5**	**2**	**0**	**7**	**11**

3.2.4 Pedestrian Crossing Time

Table 3-4 provides average pedestrian crossing times based on the signal delay and crossing distances for the Hybla Valley and Fort Belvoir intersections. The No Build alternative offers better pedestrian conditions compared to expanded lanes; shorter crossing time and crossing distance will potentially improve pedestrian compliance (preventing pedestrians from jay-walking) and improve pedestrian access to transit. However, the National Cooperative Highway Research Program Report 562[1] stated that above a delay of about 30 seconds, pedestrians are more likely to accept shorter gaps in traffic through which to cross. Even though the NCHRP Report mainly addresses pedestrian crossings at unsignalized intersections, long red duration (wait cycles) for pedestrians as a result of long cycle lengths along Route 1 may cause pedestrian compliance issues for all roadway alternatives.

[1] *National Cooperative Highway Research Program Report 562*: "Improving Pedestrian Safety at Unsignalized Crossings", Washington, D.C., 2006

Table 3-4: Average Pedestrian Crossing Time (seconds)

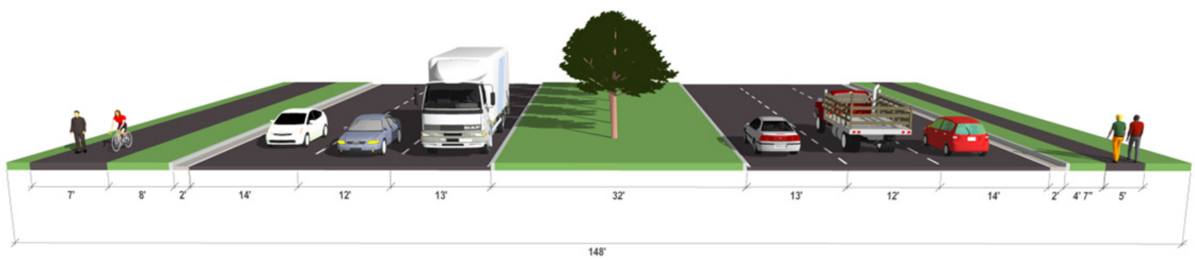
Segment	Existing (2 Lane)	No Build	Additional lane	Converted lane
Hybla Valley	95	100	110	94
Fort Belvoir	89	105	115	94

3.2.5 Conclusions

After evaluating existing travel patterns and future growth projections, and taking into account the desire to concurrently minimize pedestrian crossing distance in order to support access to and use of transit, the project team confirmed the No Build (consistent lanes) alternative as the recommendation. This alternative accommodates current and forecasted demand while enabling a transit-supportive environment.

The consistent number of lanes alternative is also supported in the Fairfax County Comprehensive Plan (as depicted in **Figure 3-5**).

Figure 3-5: Fairfax County Comprehensive Plan Recommended Section



The project team also examined the effects of shorter cycle length and reduced speeds on Route 1 travel time and network delay with implementation of the No Build alternative. The results of this analysis are provided **Attachment D**.

The next step in the traffic analysis was to simulate the No Build alternative with four different transit modes to understand the potential impacts on traffic. The results are discussed in the next section of the report.

4.0 Performance Results of No Build alternative with transit alternatives

This section presents the vehicular and transit performance results of the four multimodal alternatives under detailed evaluation. The No Build lane configuration, combined with the refined transit alternatives and the preferred bicycle and pedestrian alternative (10-foot multiuse path along the entire corridor) make up the four multimodal alternatives that are analyzed in detail and could be recommended for implementation. The four multimodal alternatives are defined below and described in further detail in the *Evaluation of Alternatives Report* (June 2014).

1. Alternative 1- Bus Rapid Transit – curb running
2. Alternative 2- Bus Rapid Transit- median running
3. Alternative 3- Light Rail Transit – median running
4. Alternative 4- Hybrid- Yellow line extension to Hybla Valley with supporting Bus Rapid Transit (median) to Woodbridge

4.1 Methodology

The analysis of the four refined Multimodal alternatives was based on 2035 projected traffic volumes using the moderate growth rate (described in 3.1.1). Performance measures were obtained through VISSIM traffic analysis. VISSIM is a microscopic traffic simulation software with the ability to simulate multi-modal traffic flows (e.g., pedestrians, bicycles, vehicles, and transit) through a network of street segments and intersections. VISSIM is a very effective tool in simulating transit behavior within the context of vehicular traffic. It is able to model different transit routes, various transit vehicle types (e.g., BRT or LRT), schedules, stops, dwell times of passengers, as well as transit preferential treatments.

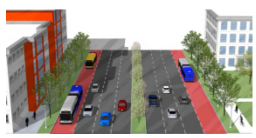
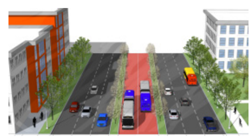
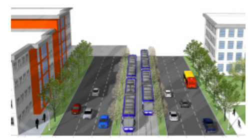
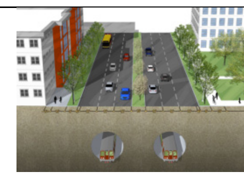
Key outputs of this analysis include performance measures for interdependent vehicular traffic flow and transit operations:

- Total Auto Network Delay (vehicle.hr/hr)
- Peak Direction Corridor Auto Travel Time (min/vehicle)
- Peak Direction Corridor Transit Travel Time (min/transit-vehicle)

4.1.1 Key Transit Inputs

Detailed characteristics of the transit elements of the multimodal alternatives are described in Section 5.0. Key features of transit operations relevant to the traffic analysis are shown in **Table 4-1** below and used as inputs to the VISSIM model.

Table 4-1: Key Transit Characteristics

	Alt 1- Bus Rapid Transit - Curb	Alt 2 - Bus Rapid Transit - Median	Alt 3 - Light Rail Transit	Alt 4 - Metrorail/Bus Rapid Transit Hybrid
Peak service headway	6 min	6 min	6 min	6 min
Principal Transit Operating Environment	Curb Running Bus Only Lane	Median Running Bus Only Lane	Median Running Transit Only Lane	Median Running Bus Only Lane + Exclusive Right-of-Way (Underground)
				
Local Bus Operating Environment	Curb Running Bus Only Lane	Mixed Traffic	Mixed Traffic	Mixed Traffic
Fare Collection Method	Off-Board	Off-Board	Off-Board	Off-Board
Preferential Treatments	TSP for Peak Direction, (queue jump for mixed traffic section)	TSP for Peak Direction	TSP for Peak Direction	TSP for Peak Direction

4.1.2 Key Traffic Analysis Assumptions

The following assumptions were made during the development and analysis of VISSIM model:

- The average free-flow traffic speeds were 45 mph for the Hybla Valley segment analysis and 45 mph for the Fort Belvoir segment analysis (posted speeds).
- For the median running BRT (Alternative 2) and LRT (Alternative 3) alternatives, it is assumed that left turn phases on Route 1 operate under protected only phasing in order to eliminate a potential conflict between left-turning vehicles and transit, and improve safety. Moreover, local buses operate in mixed traffic under these two alternatives.
- For the curb running BRT alternative (Alternative 1), it is assumed that local buses also operate on the curb running bus-only lanes to take advantage of bus lanes. Furthermore, right-turning vehicles can enter the bus-only lanes to make right turns at intersections.

- Transit Signal Priority (TSP) is provided only for the transit vehicles traveling in the peak direction (e.g., TSP for northbound direction in the morning peak). No TSP was given for non-peak direction in order to limit the impact on non-transit traffic. Green extension and red truncation (also known as early green) were applied as TSP tactics. 10 seconds of green extension and red truncation (10 seconds truncation for each conflicting phase) were considered in the analysis.
- Transit performance measures for the No Build, such as travel time savings, were obtained based on the operation of Richmond Highway Express (REX) service.
- Transit travel time measure includes only in vehicle travel time and does not consider the delay due to transfers (e.g., transfer delay from BRT to Metrorail in the Hybrid Alternative).

The results of VISSIM findings for the two segments are provided in the following two sections.

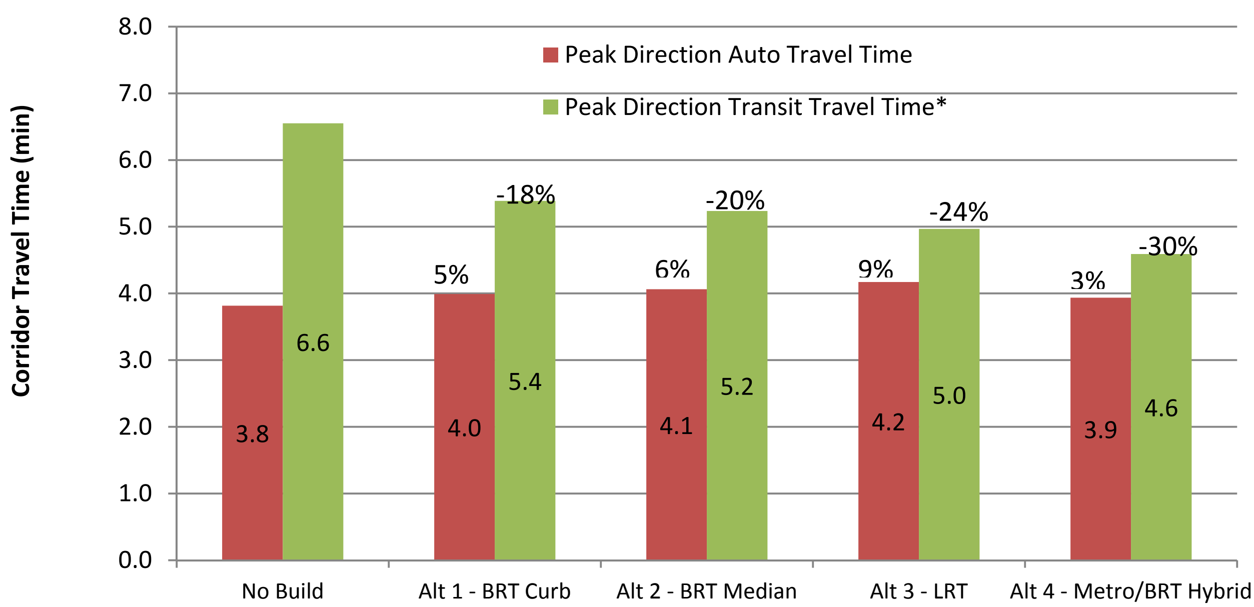
4.2 Travel Time Savings

Transit and automobile travel times were calculated for seven intersections within the two segments along the corridor: Hybla Valley and Fort Belvoir. The travel time data presented in this section are reported in two forms: absolute travel time and the percent difference. The differences in absolute travel time among the alternatives are minor due to the short study segment lengths. The percentage differences reflect the absolute differences extrapolated to the entire corridor.

4.2.1 Hybla Valley Study Segment

For the Hybla Valley segment (see **Figure 3-2** for reference), simulation results showed that all alternatives result in significant peak direction transit travel time savings, as compared with the existing conditions. Alternative 4 (Hybrid Metrorail and median running BRT) yielded the largest travel time saving (30 percent). Median running LRT (Alternative 3) and BRT (Alternative 2) reduced transit travel time by 24 percent and 20 percent, respectively. Curb running BRT resulted in the least travel time savings (about 18 percent), which can be explained by the right turning vehicles that also use bus-only lanes as well as the interaction between local buses and BRT. **Figure 4-1** shows the peak travel time results for automobiles and transit.

Figure 4-1: Peak Direction Travel Time – Hybla Valley



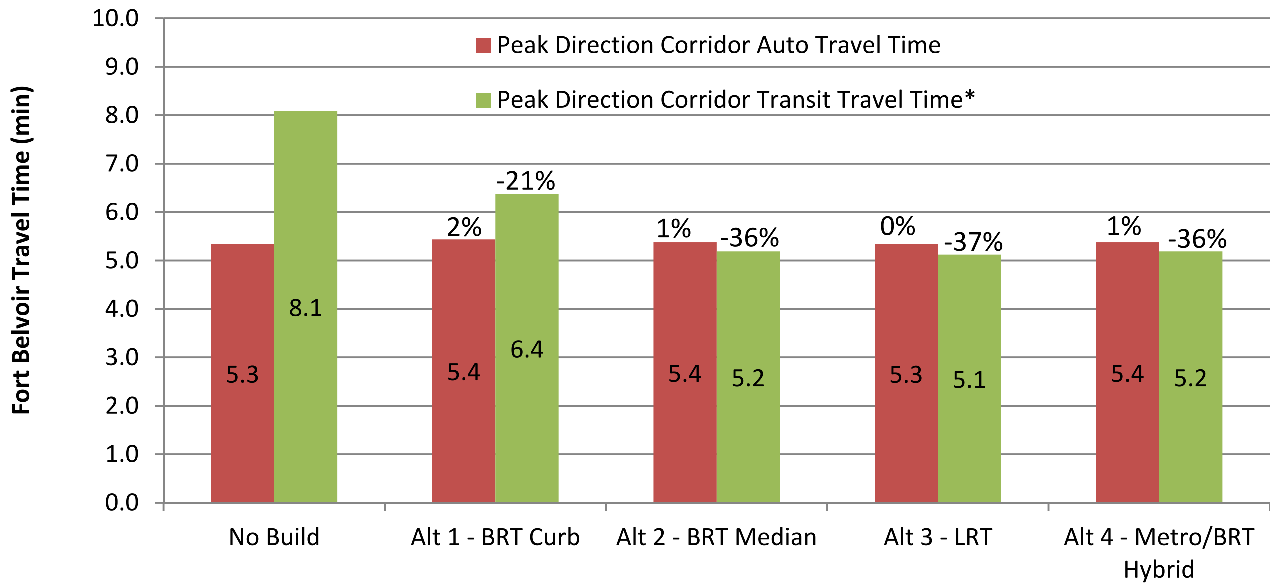
4.2.2 Fort Belvoir Study Segment

For the Fort Belvoir segment (see **Figure 3-3**), the VISSIM analysis findings show less impact on transit and auto travel time than along the Hybla Valley segment. The transit alternatives operate slightly differently through Fort Belvoir than through Hybla Valley:

- Alternative 4, BRT operates in the median through Fort Belvoir, similar to Alternative 2.
- Alternative 1 transitions from curb bus-only lanes to median bus-only lane (east of Telegraph Road intersection) through a special bus-only signal in order to permit buses to make all movements free of conflicting traffic movements. These signals are only activated when an approaching bus is detected.

Alternatives 2, 3, and 4, which operate in the dedicated median would reduce transit travel time and very marginally increase auto travel times. Results showed that the curb running BRT alternative reduced transit travel time by more than 20 percent compared to current REX travel times. All other transit alternatives resulted in travel time reduction of more than 35 percent. **Figure 4-2** shows the peak travel time results.

Figure 4-2: Peak Direction Travel Time



4.2.3 Corridor-wide findings

Because the VISSIM analysis only looked at two short segments, the travel time savings between the transit alternatives are relatively small (e.g., only 0.2 minutes difference between curb running BRT and median BRT). However, the travel time savings are more substantial when segment findings are extrapolated to the entire corridor. Extrapolation of VISSIM findings, for example, indicated approximately six minutes reduction in corridor travel time (between Mt Vernon Highway and Huntington Station) with curb running BRT and nine minutes reduction with median running BRT, as compared to REX operation. **Tables 4-2** and **4-3** summarize the impacts on auto travel time and transit travel time savings for each segment and extrapolated to the corridor.

Table 4-2: Corridor Peak Direction Auto Travel Time (Increase over Existing)

	Alternative 1: BRT- Curb	Alternative 2: BRT Median	Alternative 3: LRT	Alternative 4: Metro-BRT Hybrid
Hybla Valley Segment	5%	6%	9%	3%
Fort Belvoir	2%	1%	0%	1%
Corridor Peak Direction Travel Time Increase (Estimate)	1.0 min	0.7 min.	1.0 min.	0.3 min.

Table 4-3: Transit Travel Time Savings

	Alternative 1: BRT- Curb	Alternative 2: BRT Median	Alternative 3: LRT	Alternative 4: Metro-BRT Hybrid
Hybla Valley Segment	-18%	-20%	-24%	-30%
Fort Belvoir	-21%	-36%	-37%	-36%
Corridor Peak Direction Travel Time Savings (Estimate)	6 min	8.7 min	9.4 min	10.2 min

4.3 Auto Network Delay

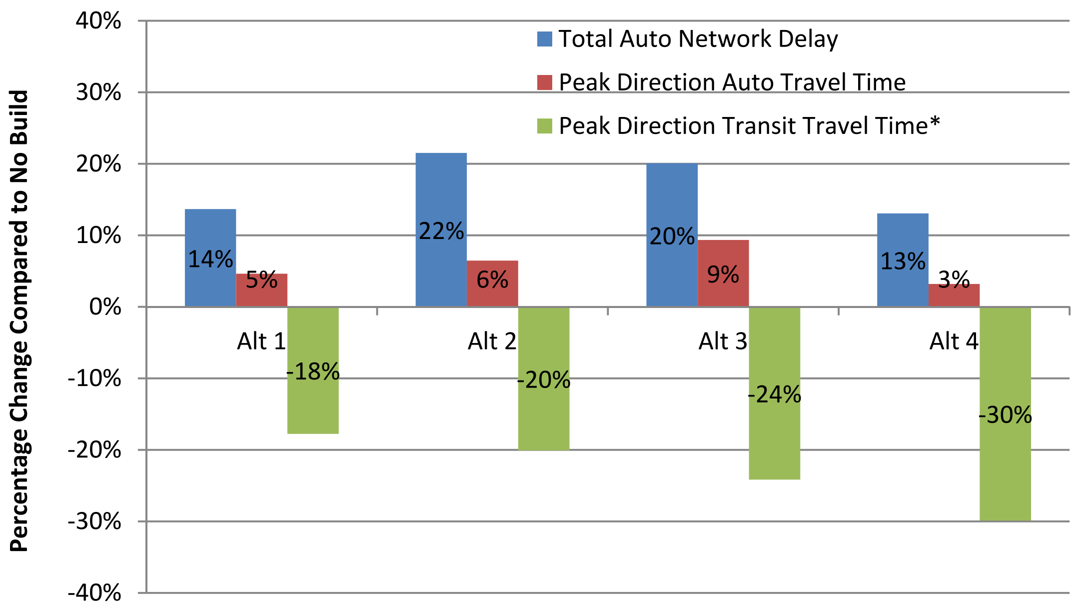
This section summarizes the impact on auto network delay. Auto network delay represents the impact on the surrounding roadway network, not just the Route 1 corridor. Results also indicated that transit alternatives caused considerable amount of auto network delay in the corridor.

4.3.1 Hybla Valley

For Alternatives 2 and 3, auto network delay increased by 22 percent and 20 percent, respectively. The increase in auto delay is primarily attributed to the application of TSP, causing impacts on non-transit traffic, and the elimination of permissive left turn phases (only protected left turn is allowed under median running transit only lanes to improve safety).

For Alternatives 1 and 4, the impacts on auto network delay are relatively lower than Alternatives 2 and 3, with delays of about 14 percent and 13 percent, respectively. The reason for lower impact on auto is due to the fact that curb running BRT (Alternative 1) does not require restriction of permissive left turns (does not conflict with the left-turn phases) and the Metrorail portion of the hybrid alternative (Alternative 4) has no impact on general traffic as it runs underground. **Figure 4-3** shows the results.

Figure 4-3: Auto Network Delay vs. Transit Travel Time



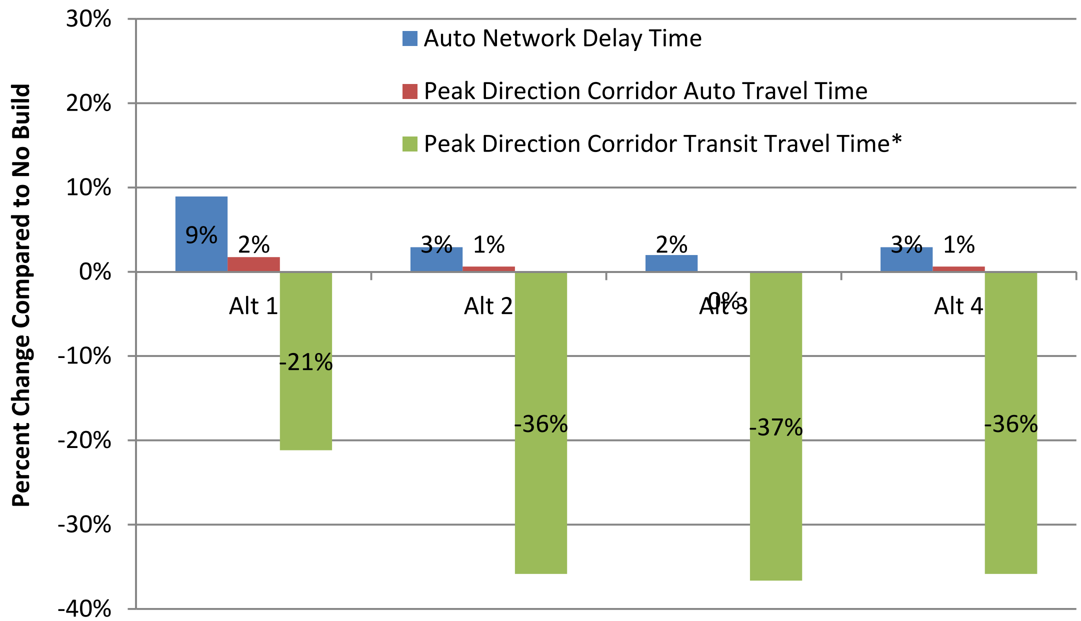
*Negative values indicate a reduction in transit travel time compared to the No-Build scenario

4.3.2 Fort Belvoir Segment

The impact on auto network delay was lower in the Fort Belvoir segment than in the Hybla Valley segment. Relatively lower increases in auto delay can be attributed to the long green intervals for Route 1 phases (therefore also long green intervals for transit alternatives) and better signal progression at Fort Belvoir intersections, which in turn eliminate the need for TSP and limit the impact on general traffic.

Alternative 1 increased auto network delay by 9 percent, while all other transit alternatives caused an increase of less than five percent delay. Higher auto delay under Alternative 1 is due in part to the special transit-only signal at Telegraph Road, which reduces intersection capacity when a bus is detected. **Figure 4-4** shows the auto network delay and transit travel time.

Figure 4-4: Auto Network Delay vs. Transit Travel Time



*Negative values indicate a reduction in transit travel time compared to the No-Build scenario

5.0 Transit ridership forecasts

Transit ridership forecasts were developed for a set of initial transit alternatives and a subsequent set of refined alternatives. Forecasts were prepared using a modeling tool and methodology used previously for an FTA-approved forecast. The goal of the ridership forecasting effort at this stage of project planning is to facilitate the comparison among the range of transit alternatives and provide an initial assessment of how the alternatives perform with respect to FTA's New & Small Starts rating criteria. This section is organized into three sections: description of the forecasting tool, list of transit operating characteristics, and a summary of ridership forecasts for each alternative.

5.1 Forecasting Tool

The FTA requires that project sponsors seeking Capital Investment Program (New Starts/Small Starts) funding to rigorously develop travel demand forecasting model tools used to evaluate fixed guideway transit investments. The forecasting approach which was applied represents an adaptation of the forecasting methods used and applied for the Columbia Pike Transit Initiative. As part of its review of the Columbia Pike Transit Initiative, FTA approved this variant of the MWCOG model for the purposes of New and Small Starts evaluation.

For the purpose of enhancing this variant of the MWCOG model, the project team implemented a number of refinements to enhance the forecasting capabilities in the Route 1 corridor. This work included:

- Updates to the transportation analysis zone (TAZ) structure
- Updates to the transportation network for both the highway and transit system
- Refinements to ensure that the model replicates observed transit customer behavior in the Route 1 corridor, including access mode, time of day distribution, route selection, low income/transit dependents, and mode selection (bus, Metrorail and bus-to-Metrorail)

A complete list of model enhancements made for the Route 1 corridor is included in the Travel Demand Forecasting Methodology report, **Attachment E**.

The resulting Route 1 forecasting model has a number of methodological advantages over the current MWCOG model and the current WMATA Regional Transit System Plan model as it pertains to transit forecasting:

- It does not need to rely on large transit submode-specific constants in the mode choice model to describe sub-transit mode preferences.
- The MWCOG home-based-work (HBW) trip distribution model is replaced with a hybrid data/modeled process that better reflects observed travel behavior. This process uses the MWCOG "trip ends" (trip generation), while replacing the home-to-work travel patterns (trip distribution) with real, observed data.

The 2035 No-Build alternative reflects committed highway and transit projects as reflected in the MWCOG Constrained Long Range Plan for 2030. The committed projects that are directly relevant to the Route 1 corridor include:

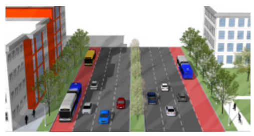
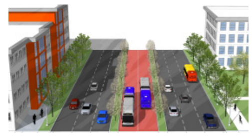
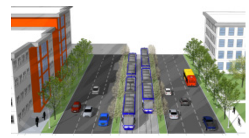
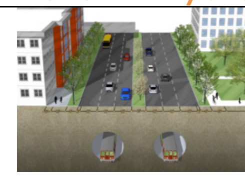
- Travel lane expansions along Route 1 between Woodbridge and Mt. Vernon Highway,
- HOV and HOT lanes along I-95, and
- Improvements to bus stops and bus stop intersections along Route 1.

5.2 Transit Operating Characteristics

This section summarizes the service plans and operating characteristics of the four refined transit alternatives. The operating characteristics of transit play a major role in the performance of transit systems (e.g., travel time and reliability). For example, high frequency transit service operating with off-board fare collection and transit signal priority (TSP) increases the relative attractiveness of transit by improving transit speed and reliability, which in turn results in higher ridership.

Service headway (or frequency) and transit travel time are the two key model parameters that typically affect ridership forecasting. In order to make a fair comparison among the alternatives, the same service headway was assumed for each of the transit alternatives. **Table 5-1** shows transit operating characteristics for different transit alternatives for the Route 1 corridor. Detailed information on the assumptions is provided in **Attachment F**.

Figure 5-1: Transit Operating Characteristics

	Alternative 1: BRT- Curb	Alternative 2: BRT Median	Alternative 3: LRT	Alternative 4: Metro-BRT Hybrid
				
Weekday peak service headway	6 min	6 min	6 min	6 min
Weekday off-peak service headway	12 min	12 min	12 min	12 min
Weekend service headway	20 min	20 min	20 min	20 min
Vehicle Capacity	90 pax/bus	90 pax/bus	160 pax/car – Single car train	120 pax/car – 8 car train
Operating Environment	Mixed Traffic + Curb Running Bus Only Lane	Median Running Bus Only Lane	Median Running Transit Only Lane	Median Running Bus Only Lane + Exclusive Right-of-Way (Underground)
Local Bus Service	Mixed Traffic + Curb Running Bus Only Lane	Mixed Traffic	Mixed Traffic	Mixed Traffic
Fare Collection Method	Off-Board	Off-Board	Off-Board	Off-Board
Preferential Treatments	Queue Jump (for Mixed Traffic Section) and TSP for Peak Direction	TSP for Peak Direction	TSP for Peak Direction	TSP for Peak Direction

5.3 Transit Travel Time Estimation

This section discusses the methodology for estimating the transit travel times along the corridor to develop ridership forecasts. Travel time for the four refined transit alternatives were estimated for the peak periods using an analytical approach and spreadsheet calculations. The estimated travel times were then used in the travel demand forecasting model to develop ridership.

Travel time components for the transit alternatives include in-motion travel time, transit stop dwell time, and traffic signal delay. Travel time components are below and details are described in **Attachment G.**

In-motion travel time is calculated based on the assumed free-flow travel time using a maximum defined speed (free flow speed) for each alternative. For the transit alternatives operating in exclusive bus lane (i.e., curb running BRT, median running BRT and LRT), 45 mph was assumed as the maximum speed. For BRT in mixed traffic and Metrorail, 35 mph and 55 mph were assumed, respectively.

Transit stop dwell time includes passenger boarding and alighting times at each stop as well as the delay that occurs due to acceleration and deceleration. Based on the ridership forecasts obtained from the initial screening alternatives, dwell time was assumed as 25 seconds at stops with high ridership and 15 seconds at stops with moderate ridership. Note that these relatively short dwell times were used assuming the availability of off-board fare collection, level boarding platforms, and boarding through multiple doors.

Traffic signal delay estimation assumed uniform, deterministic arrivals at intersections, using the well-known cumulative arrivals and departures concept (based on the duration of red and green signal and the arrival volumes, Highway Capacity Manual 2000). Delay savings associated with TSP and queue jump lanes were estimated using results of past research.

5.4 Summary of Ridership Forecast Results

Ridership forecasts were prepared at two stages in the development of alternatives: initial and refined alternatives. These ridership forecasts were prepared using MWCOG year 2035 Round 8.2 (Scenario 1) land use forecasts. Additional forecasts were also developed for refined alternatives using enhanced land use growth scenarios, Scenario 2 and Scenario 3.

5.4.1 Initial Transit Alternatives

The first stage forecasts related to the initial transit alternatives, which assumed a transit mode and alignment for the full 15-mile study corridor. The descriptions of the alternatives are provided in the *Evaluation of Alternatives Report* (June 2014). These forecasts were developed with high-level transit operating assumptions, to provide screening of initial alternatives. **Table 5-1** summarizes the average weekday project ridership forecasts for these initial alternatives. The forecasts reflect the range of transit service characteristics and amenities associated with different modes.

Table 5-1: Project Ridership Forecasts for the Initial Multimodal Transit Alternatives

Land Use Scenario	Average Weekday Ridership (2035)			
	Enhanced Bus	Bus Rapid Transit	Light Rail Transit	Metrorail
Scenario 1	9,500	16,600	18,400	38,500

5.4.2 Refined Transit Alternatives

The second set of forecasts is for the refined, multimodal transit alternatives. The refined alternatives represent a narrower range of travel times and transit amenities. The key transit operating assumptions are detailed above in Section 5 of this report. **Table 5-2** summarizes the ridership results of the four refined alternatives.

Table 5-2: Project Ridership Forecasts for the Refined Multimodal Alternatives

Land Use Scenario	Average Weekday Ridership (2035)			
	Alternative 1: BRT- Curb	Alternative 2: BRT - Median	Alternative 3: LRT	Alternative 4: Metro-BRT Hybrid
Scenario 1	15,200	16,600	18,400	26,500 (10,600 BRT; 22,900 Metro)

The detailed ridership forecasts for all modes and key statistical measures are shown in **Attachment F**.

5.4.3 Enhanced Land Use Scenarios

The enhanced land use scenarios were modeled to identify the market potential with additional land use intensity, along Route 1 corridor, over the MWCOG (Scenario 1) 2035 forecasts. The ridership forecasts were developed for two enhanced land use scenarios: Scenario 2 and Scenario 3. The Scenario 2 assumes 15-25 percent growth above the MWCOG forecasts whereas Scenario 3 assumes very high growth, upwards of 150 percent along the Route 1 corridor. The detailed descriptions of the land use scenarios are provided in the Land Use and Economics Report (May 2014). Ridership forecasts were prepared for each of the refined alternatives with Scenario 2 land use, and for Alternative 4- Metro-BRT Hybrid with Scenario 3 land use.

Table 5-3 summarizes ridership results for the Scenario 2 and Scenario 3 land use. As shown in the table the Scenario 2 ridership changes are consistent with the assumed land use growth in the Route 1 corridor. For the local travel oriented BRT and LRT alternatives there is a higher increase (17-18%) compared to the more urban core travel oriented Metrorail /BRT (10%) alternative.

For Scenario 3 ridership forecasts were prepared for the Metrorail/BRT alternative assuming significant (over 150%) growth in the land use in the Route 1 corridor. As shown in the table, ridership forecasts for the project increase by about 40 percent compared to Scenario 1.

Table 5-3: Project Ridership Forecasts for the Enhanced Land Use Scenarios

Land Use Scenario	Average Weekday Ridership (2035)			
	Alternative 1: BRT- Curb	Alternative 2: BRT Median	Alternative 3: LRT	Alternative 4: Metro-BRT Hybrid
Scenario 2	17,900	19,500	21,500	28,900 (11,800 BRT; 24,400 Metro)
Percent Change from Scenario 1	*18%*	*17%*	*17%*	*10% (11% BRT; 7% Metro)*
Scenario 3	n/a	n/a	n/a	36,800 (13,000 BRT; 31,000 Metro)
Percent Change from Scenario 1	*n/a*	*n/a*	*n/a*	*39% (23% BRT; 35% Metro)*

Note: Table 5-3 does not include a Park & Ride facility at the Hybla Valley Metrorail station. AECOM also ran these alternatives with a PNR facility at Hybla Valley (1,500 spaces) and each scenario generated approximately 3,500 additional trips (Scenarios 1, 2 and 3).

5.5 Ridership Forecasting Next steps

The analyses Next steps related to ridership forecasting for subsequent studies, including NEPA documentation for the Route 1 Multimodal Project, would be to upgrade the version MWCOG mode 2.3 to satisfy FTA requirements. This work would involve upgrading to the Version 2.3 platform, then splitting TAZs to represent the grain of analysis required for walk and transit trips. The model constants that reflect the range of mode preference would need to be refined to match FTA expectations.

The current forecasts are generally being developed from the transit perspective, but the study recommendations will document general system deficiencies from the multimodal and highway perspectives. With land use changes, recommendations will address general anticipated impacts on the roadway network and outline potential mitigation approaches.

Attachment A: Current and Proposed Lane Configuration and Study Intersections

Figure A-1: Existing and Proposed Lane Configuration

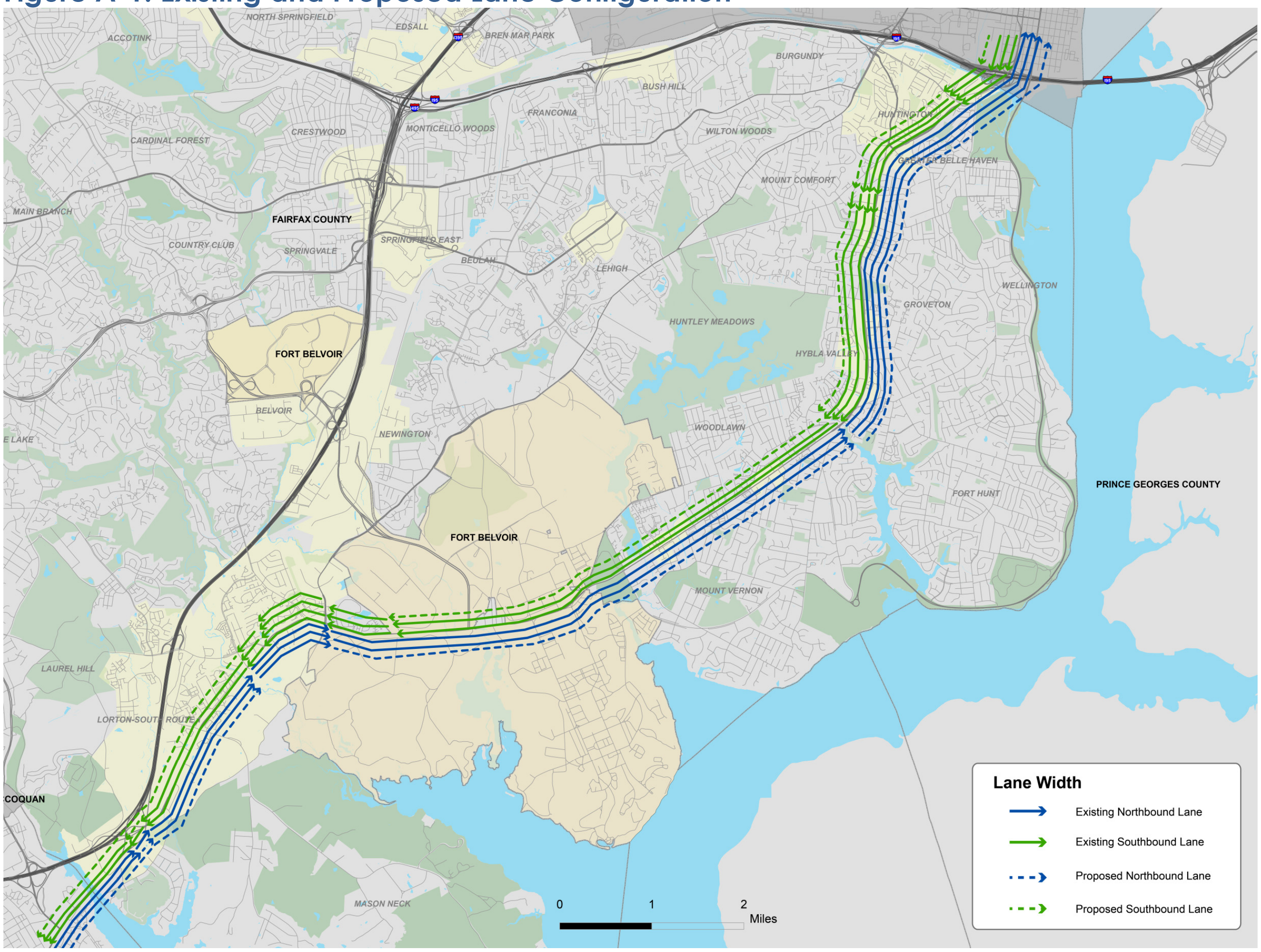
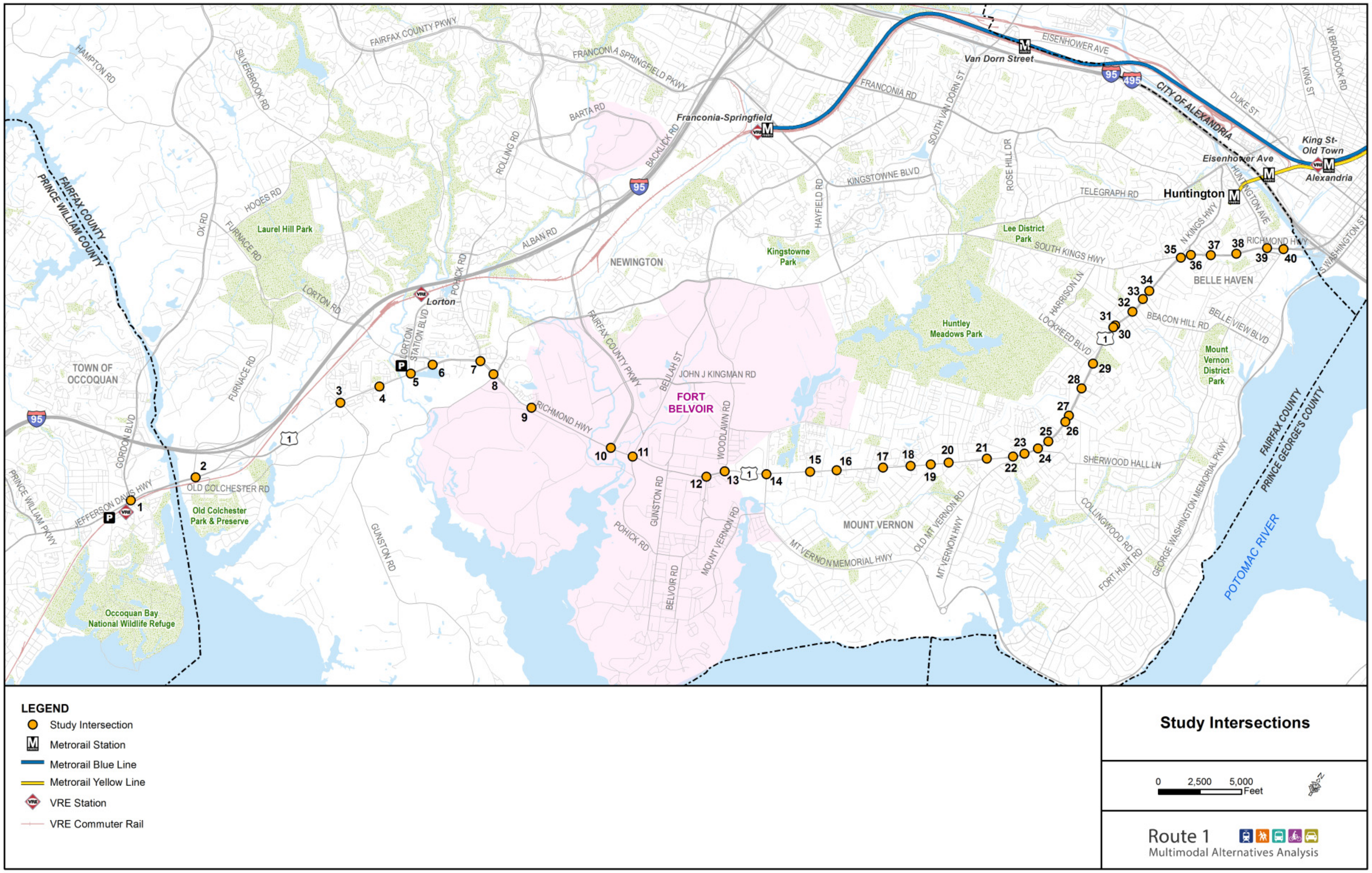


Figure A-2: Study Intersections



Attachment B: Traffic Growth Rate Development Methodology

Methodology

The project team considered historical growth rates in Annual Average Daily Traffic (AADT) and growth rates obtained from Metropolitan Washington Council of Governments (MWCOG) Version 2.2 with Land Use Round 8.2 model. For purposes of this analysis, the project team developed and tested two growth scenarios: moderate growth rates, where historical growth rates were blended with MWCOG projections; and high growth rates, based directly on MWCOG projections. For both growth rate scenarios, intersection LOS and volume to capacity (v/c) ratio in the morning and evening peak hour were analyzed for each study intersection using SYNCHRO. Study intersections include all signalized intersections along the 15-mile project corridor comprise of 40 intersections in total.

Historic Growth Rates

To understand the historic growth pattern along the corridor, AADT volumes between 2001 and 2012 were analyzed. **Figure B-1** displays the annual percentage growth rates. Positive values indicate an increase in volume from 2001 to 2012. Results indicate that, except for Segment 3 (Gunston Road to Woodlawn Road), traffic volumes along the corridor stayed relatively constant or decreased between the years 2001 and 2012.

Table B-1 shows recent corridor demographic growth trends. In general, traffic growth rates have been less than population and employment growth rates in the corridor.

Table B-1: Combined Population and Employment Growth, 2000 to 2010

	North Area	South Area
Census 2000	89,214	27,806
Census 2010	98,852	41,152
Percent Growth	**10.8%**	**48.0%**
Annual Percent Growth	**1.0%**	**4.0%**

Figure B-1: Annual Percentage Growth Rates based on Historical Traffic Data (2001 - 2012)

MWCOG Growth Rates

Table B-2 provides annual percentage growth rates based on the MWCOG model 2010 and 2035 outputs. MWCOG model results show approximately one to two percent annual growth rate along the corridor, where the rates are typically higher in the off-peak direction (i.e., southbound in the morning peak and northbound in the evening peak). This could be attributed to the increase in reverse commuting trips (i.e., non-peak direction trips), particularly due to employment growth in the Fort Belvoir area. MWCOG forecasts indicate that population along the corridor will grow by about 32 percent and employment will grow by about 38 percent, which approximately results in 1.2 percent annual growth along the corridor.

Table B-1 – Annual Percentage Growth Rates based on MWCOG 2010 and 2035 Models

	Annual Growth Rate (%)									
	Gunston Road to Armistead		Telegraph Road and Fairfax County Parkway		Frye to Mt Vernon Highway		S Kings Hwy to Fairhaven		Fairhaven to Huntington	
	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB
AM	2.31	1.02	2.24	1.44	1.36	1.39	0.91	0.01	1.48	0.50
PM	1.20	1.45	1.59	1.86	1.94	1.74	1.44	0.83	0.95	1.18

Findings: Proposed Growth Rates

The project team identified two growth rates to apply: “moderate” and “high” growth rate to analyze the Consistent Lane (No Build Alternative).

Given the results of the MWCOG model outputs, reverse commute impacts, and historic growth rates, the project team developed a “moderate” growth scenario to evaluate the 2035 traffic conditions. Additionally, to test the robustness of the intersections, the project team also analyzed with a “high growth” rate scenario, in which the growth rates were based on MWCOG model outputs.

Moderate Growth Rate: This scenario considered both historical and MWCOG growth rates to develop annual percentage growth rates. **Figure B-2** shows segment growth rates under the moderate growth scenario.

High Growth Rate: In general, this scenario used MWCOG model outputs. It should be noted that the maximum growth rate along the segments was limited to two percent (based on engineering judgment). Therefore, in areas where MWCOG model indicated more than two percent growth (e.g., Segment 1, morning peak in the southbound direction, see **Table B-1**), a two percent growth rate was proposed. **Figure B-3** shows segment growth rates under the high growth scenario.

Figure B-2: Annual Percentage Growth Rates by Segment – Moderate Growth Rate

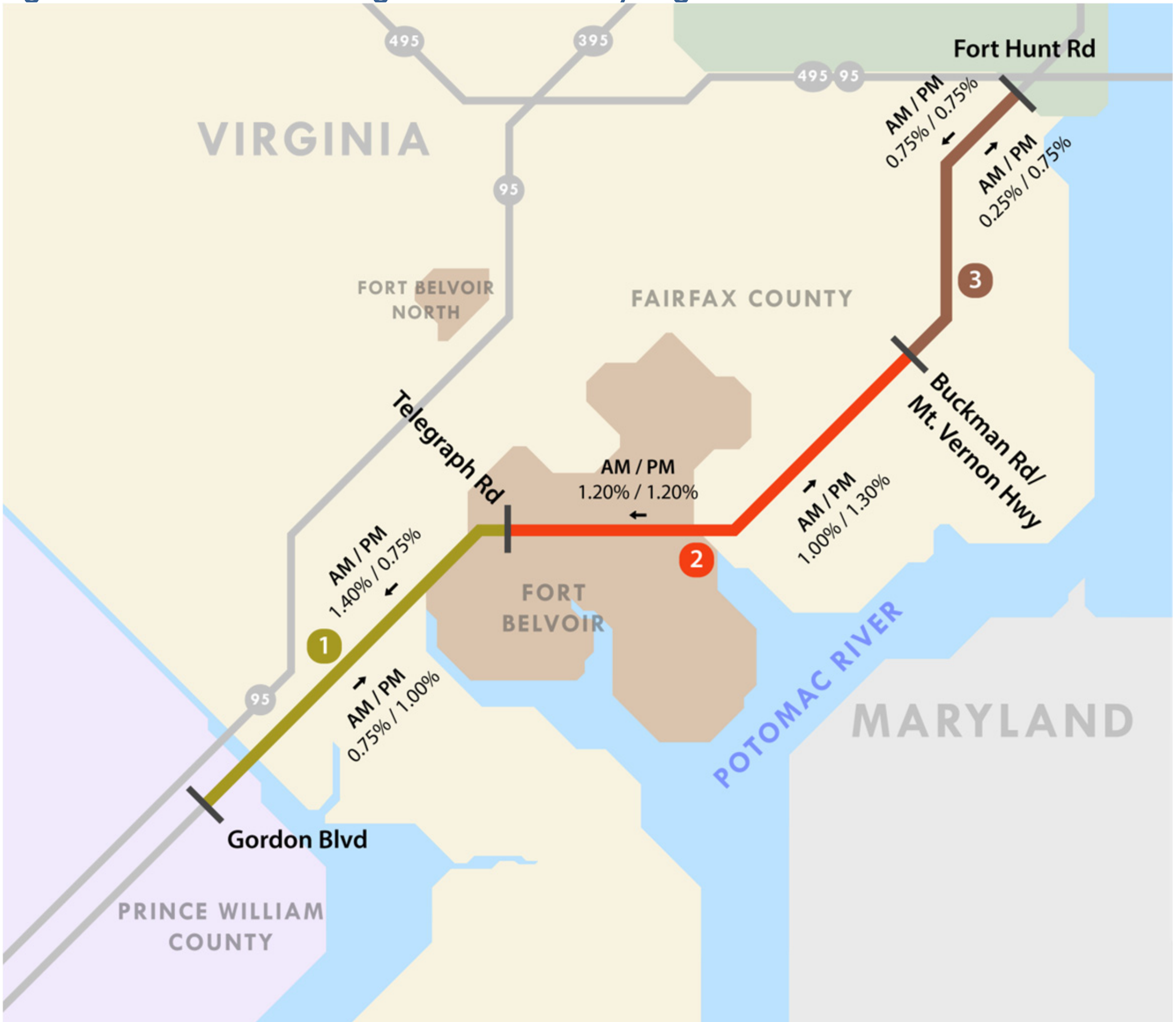


Figure B-3: Annual Percentage Growth Rates by Segment - High Growth Rate Scenario

Attachment C: Intersection Performance Results

Intersection LOS and v/c ratio under the moderate growth rate and high growth rate scenario were evaluated. For comparison purposes, existing intersection LOS results were also included.

LOS is based on the average vehicle delay per vehicle for the traffic movements in the intersection. **Table C-1** defines signalized intersection LOS based on observed delay per vehicle.

Table C-1: Relationship between Average Vehicle Delay and LOS for Signalized Intersections

Delay Per Vehicle (seconds)	Level of Service (LOS)
≤ 10	A
> 10 - 20	B
> 20 - 35	C
> 35 - 55	D
> 55 - 80	E
> 80	F

Source: Highway Capacity Manual

Under the moderate growth scenario, results show that with the consistent 6-lane cross-section, none of the intersections operate with LOS F in the evening peak and only one operates with LOS F in the morning peak. Three intersections in the morning peak and four intersections in the evening peak operate with LOS E or worse.

Under the high growth rate scenario, with the consistent 6-lane cross-section, only one intersection in the morning peak and three intersections in the evening peak operate with LOS F. Four intersections in the morning peak and ten intersections in the evening peak hour operate with LOS E or worse. **Table C-2 and Table C-3** provide intersection LOS and v/c ratio under the moderate and high growth rate scenarios, respectively. For comparison purposes, existing and No Build moderate growth intersection LOS results are also included

Table C-2: Intersection LOS and v/c ratios- Moderate Growth Scenario (2035)

Intersection	Existing		Consistent Lanes – Moderate Growth			
	LOS AM	LOS PM	LOS AM	v/c - AM	LOS PM	v/c - PM
Ft Hunt Rd	F	D	F	1.16	D	0.86
Huntington Ave	C	D	C	0.69	D	0.69
Holiday Inn Ent	B	B	B	0.61	B	0.55
Quander Rd	B	B	B	0.79	B	0.67
N Kings Hwy	B	C	B	0.74	D	0.77
S King Hwy	D	D	D	0.92	E	0.95
Southgate Dr	A	B	B	0.70	B	0.65

Intersection	Existing		Consistent Lanes – Moderate Growth			
	LOS AM	LOS PM	LOS AM	v/c - AM	LOS PM	v/c - PM
Beacon Hill Rd	C	D	C	0.89	D	0.88
Memorial St	B	C	B	0.80	C	0.97
Collard St	A	A	A	0.77	A	0.67
Popkins Lane	B	B	B	0.77	B	0.82
Lockheed Blvd/Dart Dr	C	D	D	0.81	D	0.93
Arlington Dr*	B	C	B	0.67	C	0.90
Boswell Ave*	C	D	C	0.76	D	0.94
Fordson Rd/Shopping Center*	B	C	B	0.64	D	0.92
Haft Dr*	A	B	A	0.51	B	0.78
Sherwood Hall Lane*	C	D	C	0.79	E	1.00
Ladson Ln*	A	B	A	0.68	C	0.84
Buckman Rd/Mt Vernon*	F	D	E	1.06	E	0.99
Janna Lee Ave	A	B	A	0.52	B	0.57
Russell Rd	C	B	C	0.75	B	0.85
Mohawk Ln	A	B	A	0.52	B	0.68
Buckman Rd/Radford Ave	B	B	B	0.49	B	0.64
Frye Rd	B	B	B	0.59	B	0.66
Lukens Ln	B	B	B	0.51	B	0.70
Cooper Rd	B	B	C	0.66	B	0.63
Mt Vernon Memorial Hwy	E	E	D	0.90	D	0.92
Woodlawn Rd	A	A	A	0.59	A	0.52
Belvoir Rd*	B	C	B	0.80	C	0.73
Backlick Rd*	D	E	D	1.16	E	1.04
Fairfax County Pkwy*	D	E	C	0.70	D	0.96
Cook Intel Dr*	B	A	A	0.75	A	0.79
Telegraph Rd*	D	D	D	0.88	D	1.11
Pohick Rd	C	B	C	0.94	C	0.91
Lorton Rd	C	B	D	0.90	C	0.92
Armistead Rd	B	C	C	0.82	C	0.86
Dutchman Drive	A	B	A	0.64	A	0.64
Gunston Rd	D	C	D	0.87	C	0.97
Furnace Rd	C	D	C	0.74	D	0.74
Gordon Blvd	D	B	E	1.03	C	0.95

Table C-3: 2035 No Build Intersection LOS & v/c Ratios under High Growth Rate Scenario

Intersection	Existing		Moderate Growth		High Growth			
	LOS AM	LOS PM	LOS AM	LOS PM	LOS AM	v/c - AM	LOS PM	v/c – PM
Ft Hunt Rd	F	D	F	D	F	1.16	F	0.93
Huntington Ave	C	D	C	D	C	0.70	D	0.75
Holiday Inn Ent	B	B	B	B	B	0.62	C	0.60
Quander Rd	B	B	B	B	B	0.83	B	0.74
N Kings Hwy	B	C	B	D	B	0.74	D	0.84
S King Hwy	D	D	D	E	D	0.94	F	1.04

Intersection	Existing		Moderate Growth		High Growth			
	LOS AM	LOS PM	LOS AM	LOS PM	LOS AM	v/c - AM	LOS PM	v/c – PM
Southgate Dr	A	B	B	B	B	0.70	B	0.71
Beacon Hill Rd	C	D	C	D	C	0.92	E	0.96
Memorial St	B	C	B	C	B	0.81	D	1.08
Collard St	A	A	A	A	A	0.77	A	0.74
Popkins Lane	B	B	B	B	B	0.78	B	0.88
Lockheed Blvd/Dart Dr	C	D	D	D	D	0.81	E	1.01
Arlington Dr*	B	C	B	C	C	0.69	C	0.88
Boswell Ave*	C	D	C	D	C	0.79	D	1.01
Fordson Rd/Shopping Center*	B	C	B	D	B	0.69	D	0.99
Haft Dr*	A	B	A	B	A	0.51	B	0.81
Sherwood Hall Lane*	C	D	C	E	D	0.82	E	1.08
Ladson Ln*	A	B	A	C	A	0.68	D	0.93
Buckman Rd/Mt Vernon*	F	D	E	E	E	1.11	E	1.09
Janna Lee Ave	A	B	A	B	A	0.57	B	0.64
Russell Rd	C	B	C	B	D	0.83	C	0.96
Mohawk Ln	A	B	A	B	A	0.57	C	0.77
Buckman Rd/Radford Ave	B	B	B	B	B	0.57	B	0.72
Frye Rd	B	B	B	B	B	0.66	B	0.78
Lukens Ln	B	B	B	B	B	0.59	C	0.81
Cooper Rd	B	B	C	B	D	0.75	B	0.71
Mt Vernon Memorial Hwy	E	E	D	D	D	1.00	E	1.03
Woodlawn Rd	A	A	A	A	A	0.67	A	0.58
Belvoir Rd*	B	C	B	C	C	0.90	D	0.82
Backlick Rd*	D	E	D	E	D	1.08	F	1.16
Fairfax County Pkwy*	D	E	C	D	C	0.75	E	1.07
Cook Intel Dr*	B	A	A	A	A	0.82	A	0.89
Telegraph Rd*	D	D	D	D	D	0.96	E	1.23
Pohick Rd	C	B	C	C	C	0.99	D	1.00
Lorton Rd	C	B	D	C	D	0.95	D	1.02
Armistead Rd	B	C	C	C	D	0.87	D	0.95
Dutchman Drive	A	B	A	A	A	0.68	A	0.71
Gunston Rd	D	C	D	C	E	0.94	D	1.00
Furnace Rd	C	D	C	D	C	0.79	D	0.82
Gordon Blvd	E	B	E	C	E	1.09	D	0.97

Attachment D: Shorter Cycle Length and Reduced Speed Limit Test

The objective of this exercise is to test Route 1 intersections with shorter cycle lengths and lowered speed limit to evaluate the impact on automobiles and transit, as well as pedestrians. In order to perform the analysis, Hybla Valley intersections (the same seven signalized intersections considered for the roadway and transit alternatives) in the morning peak hour will be tested. VISSIM will be used in the analysis of intersections.

Traffic signal cycle lengths may have a considerable impact on the quality of access for bicycles and pedestrians since long cycle lengths can make crossing a street frustrating, discouraging walking and turning streets into barriers for non-motorized users. This in turn impacts the operation of public transit as bicycles and in particular pedestrians are the primary users of transit. Moreover, transit vehicles typically are not able to follow signal coordination (also known as "green wave") provided for arterial traffic as they make stops to serve passengers. Therefore longer cycle lengths also tend to increase transit delay.

Webster's well-known optimal cycle length concept indicates that longer cycle lengths increase capacity and as a result, there is often a tendency for traffic engineers to use longer cycle lengths during periods of high demand. However, recent research also showed that during periods of high demand and oversaturation, using a shorter cycle length resulted in slightly increased throughput[2].

Similarly, reducing speed limits will potentially improve traffic safety by reducing the number of crashes, promoting walking and cycling. Furthermore, the secondary benefits of lowered speed limits include reduced fuel costs, and reduction in vehicle emissions and noise. However, there are also concerns regarding mobility due to the impact on travel time.

Results show that reduced speed and cycle lengths would lead to incremental increases in travel time but overall improvements in network delay.

Hybla Valley VISSIM Analysis

Intersections in Hybla Valley under the existing conditions operate with 180 seconds cycle length in the morning peak hour and the posted speed limit is 45 mph. In order to evaluate the impact of shorter cycle length and reduced speed limit for multimodal road users, cycle length was reduced to 120 seconds and 35 mph was used as the posted speed limit for the vehicular traffic. Only the median running BRT alternative (i.e., Alternative 2) was considered in the analysis. Note that the maximum speed limit defined for BRT (45 mph) was kept unchanged in the evaluation.

[2] Denney, R.W., E. Curtis, and L. Head. "Long Green Times and Cycles at Congested Traffic Signals." Transportation Research Record No. 2128, pp. 1-10, 2009.

Table D-1 presents VISSIM findings under the No Build (consistent 6-lane with REX service), median running BRT (Alternative 2), and median running BRT with 120 seconds cycle length and 35 mph speed limit.

Table D-1: Evaluation of Performance Measures with Shorter Cycle Length and Reduced Speed Limit for Hybla Valley Intersections

		No Build[1]	Median Running BRT: C = 180 s, Posted Speed Limit = 45 mph	Median Running BRT (Alt 2): C = 120 s, Posted Speed Limit = 35mph
Network Level Performance Measures	Total Auto Network Delay Time (veh.hr/hr)	192	234 (22%[2])	220 (14%)
	Average Auto Network Speed (mph)	21.6	19.7 (-9%)	17.8 (-18%)
	Total Auto Network Travel Time (veh.hr/hr)	389	433 (11%)	480 (23%)
	Average Pedestrian Signal Delay[3] (s)	74	74 (0%)	50 (-33%)
Segment Level Performance Measures	Segment Auto Travel Time - Northbound (min)	3.8	4.1 (6%)	5.2 (37%)
	Segment Auto Travel Time - Southbound (min)	3.5	4.2 (19%)	4.8 (37%)
	Segment Transit Travel Time - Northbound (min)	6.6	5.2 (-20%)	5.8 (-12%)
	Segment Transit Travel Time - Southbound (min)	6.6	6.0 (-8%)	5.1 (-22%)

1: No Build measures were obtained based on the consistent six travel lane alternative and the operation of REX Service
2: Values in parentheses indicate percentage change compared to No Build
3: Average pedestrian signal delay was obtained using Highway Capacity Manual [HCM].

Results show that compared to median running BRT with 180 second cycle length scenario, the reduction of cycle length decreased total auto network delay from 234 to 220 vehicle hours during the morning peak hour. This reduction can be explained by better allocation of green time, that is, better serving cross street traffic as a result of shorter red time, which in turn results in shorter delay. Note that delay is not affected by the change in free-flow speed as free-flow conditions are considered as the baseline in the delay calculation. Average pedestrian signal delay was also reduced from 74 seconds to 50 seconds due to shorter waiting times, corresponding to a 33 percent reduction.

Peak direction auto travel time along the analysis segment, however, increased from 4.1 minutes to 5.2 minutes with the decrease in cycle length and free-flow speed. This increase can be explained in two ways: (1) The 180 second cycle length provides very generous green time for Route 1 at the cost of high cross street and pedestrian delay. Reduction of cycle length results in relatively shorter green times for Route 1 and causes longer corridor travel time. (2) Reduction of posted speed limit from 45 mph to 35 mph increases travel time along certain segments which allow vehicles to reach the posted speed limit (typically segments with large intersection spacing and good signal coordination).

Results also indicate that reducing the cycle length increased the average peak direction transit travel time (from 5.2 mins to 5.8 mins) as a result of shorter green times for Route 1 (similar to the impact on auto travel time). However, it is worth noting that shorter cycle length improved corridor level transit travel time in the non-peak direction (6.0 vs. 5.1 minutes), where TSP was not applied. With shorter cycles, when a transit vehicle stops at a red signal (which happens more frequently in the non-peak direction due to the lack of TSP), the wait time until the green signal is also shorter, resulting in shorter non-peak direction transit travel time.

Attachment E: Detailed Transit Demand Forecasting Methodology

This attachment describes the travel demand forecasting approach to be used to evaluate the Route 1 multimodal alternatives. This technical memorandum will describe our rationale for selecting the appropriate forecasting methodology, our step-by-step approach for enhancing it to ensure a robust evaluation of the alternatives, the required inputs and the key resulting outputs to be used in this analysis.

Process

During the early stage of the alternatives analysis, demand forecasts were used to screen alternatives. Subsequently, forecasts were refined to support detailed evaluation and selection of a preferred alternative.

Overview

As defined in our scope of work, AECOM developed Federal Transit Administration (FTA) compliant travel demand forecasts to support the evaluation of a series of multimodal alternatives for the Route 1 corridor between Prince William and Fairfax Counties. The FTA-compliant requirement for the forecasting procedures is a very important factor in selecting the proper forecasting tool to evaluate Route 1 corridor improvements. It is anticipated that the resulting recommended transit alternative for the Route 1 corridor would be a refined and advanced as a potential New/Small Starts submittal to FTA.

FTA requires project sponsors seeking New/Small Starts funding to develop rigorous travel demand forecasting model tools to evaluate fixed guideway transit investments. Of particular emphasis the forecasting models must be able to:

- Replicate the total travel market in the project corridor
- Understand the existing propensity to use transit in the corridor
- Understand the existing automobile and transit travel times and service frequency
- Generate realistic estimates of future year automobile and transit travel times
- Understand the existing transit markets, by key segmentation group:
    - Trip Purpose (Home-to-Work, Home-to-Other, Non-Home Based)
    - Income/Auto Ownership
    - Relative attractiveness by key attraction market (travel to DC, versus City of Alexandria, versus local transit on Route 1)
    - Transit sub-mode (bus, express bus, VRE and Metrorail)
    - Mode of access (walk, drop-off, park-and-ride)
- Properly reflect transit sub-mode choice without the use of large or illogical transit sub-mode specific constants in the mode choice model.

The last bullet listed above is one of the most important elements in FTA reviews of travel demand forecasting procedures. Transit sub-mode specific constants are travel time advantages given to fixed guideway transit service to reflect the “unmeasured attributes” that accompany fixed guideway services (versus local bus). These unobserved attributes generally include elements of the travel experience such as:

- Enhanced ride quality
- Enhanced visibility
- Increased reliability
- Enhanced stations
- Passenger information systems

These constants are expressed in an equivalent amount of travel time benefits for the fixed guideway alternative. While FTA generally allows for the use of transit mode-specific constants, they require that their maximum magnitude be in the range of 15-20 minute advantage for fixed guideway transit, versus local bus.

Forecasting Tool

When attempting to identify the most appropriate forecasting tool to conduct the Route 1 analysis, AECOM reviewed both the recently released MWCOG forecasting model and the current version of the WMATA Regional Transit System Plan (RTSP) forecasting model to determine how FTA compliant both forecasting tools are. Both forecasting tools use the current MWCOG Version 2.3 platform (3722 traffic analysis zones) and both also rely on the use of transit sub-mode specific constants with magnitudes outside of the FTA expected range.

AECOM evaluated the magnitude of the constants in both forecasting models and found that Metrorail had transit sub-mode biases in the range of 30-75 minutes for home-based work travel. In application, this means that a Metrorail alternative will be 30-75 minutes faster than bus, before considering the actual travel times and costs offered by each line-haul mode. FTA generally allows transit sub-mode biases of up-to 15-20 minutes for premium transit (versus the 30-75 minutes in MWCOG and RTSP models). The magnitude of these constants means that the model will likely over-simulate response to a Metrorail alternative. At a minimum, both of these current forecasting tools would need a substantial restructuring and recalibration of the mode choice models and likely also require adjustment to the trip distribution processes to replicate observed behavior in a FTA compliant fashion.

Rather than venturing into an extensive model calibration exercise, which is time consuming and expensive, AECOM did a review of prior applicable forecasting methodologies. Like the Route 1 corridor, the Columbia Pike corridor is located within the area covered by the MWCOG transportation model. It was determined that the Columbia Pike forecasting model, which employs the WMATA Transit Post-Processor (using the MWCOG model Version 2.2) was the preferred way to proceed.

In 2010 AECOM, with WMATA, Arlington County, and Fairfax County, engaged the Federal Transit Administration (FTA) on the travel demand forecasting methodology to support the Columbia Pike Streetcar Environmental Assessment (EA). Through a series of meetings with FTA technical staff, the project obtained FTA acceptance of using a variant of the older MWCOG 2.2 forecasting model to identify the ridership impacts associated with Columbia Pike. Ultimately the version of the model that was applied was the original version of the Regional Transit System Plan (RTSP) model, with further enhancements in the Columbia Pike project corridor.

This forecasting model has a number of methodological advantages for performing FTA New Starts/Small Starts project evaluations over the current MWCOG model and the current RTSP model as it pertains to transit forecasting:

- It has no transit sub-mode specific constants in the mode choice model to describe sub-transit mode preferences. Instead, it relies on IVTT discounts, which were discussed and vetted by FTA to differentiate higher quality transit services (Metrorail) versus local bus services. By not having transit sub-mode constants, this allows for a mode neutral evaluation of a variety of transit modes in the Route 1 corridor and facilitates an easier review by FTA technical staff.

- The MWCOG home-based-work (HBW) trip distribution model is replaced with a hybrid data/modeled process. Rather than using the MWCOG gravity model to represent trip distribution, AECOM has embedded a process that 1) starts with MWCOG trip ends (productions and attractions) and 2) FRATAR factors the Year 2000 US Census CTPP Journey-to-Work Trip Tables to those trip ends. In essence, this preserves the MWCOG trip generation process while replacing the modeled trip distribution with real, measured Census-based surveyed trip patterns.

  Our experience is that traditional trip distribution models generally do a poor job of representing realistic home-to-work, origin-destination travel patterns for a metropolitan area. This is due to the fact that trip distribution models use only travel time as the explanatory value for where people live and work. Other variables such as housing stock, price of housing, quality of schools, and income of jobs are all very important variables that in reality drive residential location choice to which gravity models cannot consider. Obtaining realistic origin-to-destination trip patterns is essential to transit planning, as transit requires both trip ends (home and work) to be accessible to the transit system. We've employed this approach in a number of large metropolitan areas including Chicago, New York and Los Angeles and have significantly improved the performance of the HBW models.

- The proposed forecasting approach includes detailed micro-coding of transit fixed guideway stations and stops. As part of this micro-coding approach, the forecasting tool provides additional detail between the interface of kiss-and-ride, park-and-ride, and bus transfer locations at fixed guideway stations.

To confirm that this forecasting model provides a realistic understanding of transit demand from the Route 1 corridor, AECOM reviewed the transit validation statistics from the base year 2010 forecasting model (see **Table E-1**).

Table E-1: DRAFT EARLY LOOK VALIDATION AS OF OCTOBER 9, 2013

Comparison of Average Weekday Transit Boardings:
Forecasting Model vs. Observed by Operator

Bus Ridership		Columbia Pike
Route	Observed (2008)*	Model
REX	3,400	1,331
F151	1,480	2,916
F152	1,555	290
F161	665	791
F162	585	678
F171	3,575	1,741
Total	**11,260**	**7,747**
Major Routes on Route 1	8,455	5,988
*Fairfax County Transit development Plan Report		
REX Boardings from WMATA 2008 Survey		
Metro Ridership		Columbia Pike
Station	Observed (2008)	Model
Huntington	8,863	10,177
Franconia	10,335	10,623
	19,198	**20,800**
VRE		Columbia Pike
Station	Observed (2012)	Model
WoodBridge	663	1,379
Lorton	617	271
	1,279	**1,650**

As the table shows, the forecasting model without any adjustment in the Route 1 corridor reflects existing transit markets in the corridor (replicates overall Metrorail and VRE ridership, and understates bus ridership). This fidelity to existing conditions, combined with its enhanced FTA compatibility make it an ideal platform to evaluate Route 1 alternatives.

As described below, the project team undertook a robust improvement program for this tool for the purpose of evaluating Route 1 alternatives.

Step 1: Define the Traffic Analysis Zone System

Working with Fairfax County land use and transportation divisions, AECOM defined an enhanced Traffic Analysis Zone (TAZ) system for the Route 1 corridor. The existing Columbia Pike forecasting model uses a relatively course zone system in the Route 1 corridor and needed to be substantially improved for the purpose of representing activity centers in the corridor. This step was coordinated with Fairfax County to ensure that we adequately represent both current and key planned/proposed development to properly represent automobile and transit attributes. Together AECOM and Fairfax County added approximately 70 zones in the Route 1 corridor in Fairfax County to isolate current/future activity centers. As a result of changing the TAZ system in the project corridor, a number of mechanical changes to the forecasting model were necessary to accommodate the increased zonal resolution. The following 3 steps discuss these enhancements.

Step 2: Implement MWCOG Round 8.2 Land Use Forecasts for Enhanced TAZ System

FTA requires that project sponsors use the regionally adopted land use forecasts when evaluating New/Small Starts projects. In this step, the MWCOG Round 8.2 land use forecasts were incorporated into the new TAZ system. This required two elements:

1. Start with the “native” MWCOG Round 8.2 Land Use forecast
2. Allocate the land use variables (such as population, households and employment) to the “split” zones based on current and future development.

An important component of this work was to maintain the MWCOG original TAZ level forecasts contained with the Round 8.2 land use forecasts. This work was performed for current conditions (2014/2015) and a 20-year horizon (2035). Fairfax County staff assisted with allocations from MWCOG TAZ’s to the Route 1 model sub-TAZ’s defined in Step 1 above.

Step 3: Enhance the Transportation Network

An important step with the Route 1 analysis was to enhance the underlying transit system in the Route 1 corridor. With the additional TAZs defined in Step 1, AECOM embedded a series of measures to ensure that 1) the transportation network provides enough resolution to adequately represent accessibility to the highway and transit networks, 2) the current highway speeds represent realistic observed speeds for peak period and off-peak service, 3) transit services correctly represent alignments with stops and park-and-ride locations.

Step 4: Recalibrate the Base Year Model

With the enhanced TAZs, enhanced land use inputs, and the enhanced transportation network, AECOM recalibrated the model to represent current travel behavior in the corridor. Emphasis was placed on:

- Representing roadway volumes on Route 1
- Representing realistic highway travel times on Route 1
- Representing transit utilization in the corridor by:
    - Trip Purpose
    - Transit Sub-Mode (Metrorail, VRE, commuter bus, bus, bus-to-Metrorail)
    - Access Mode (walk, park and ride and kiss and ride)
    - Income level
    - Time of day (peak vs. off-peak)
- Representing transit utilization by route
- Representing demand for parking at park-and-ride facilities

The end product of this step was an enhanced travel demand forecasting methodology that replicates observed travel behavior from the corridor with a high degree of accuracy.

Step 5: Develop 2035 No-Build Forecasts

Following the recalibration of the base year model, AECOM ran no-build forecasts for the 2035 horizon year. The No-Build alternative contains all regional projects from MWCOG's Constrained Long Range Plan (CLRP). The purpose of the no-build alternative is to understand:

- How land use changes impact total trip making in the Route 1 corridor.
- How the highway network performance is impacted by the additional growth programmed for the Route 1 corridor.
- How the programmed transportation investments and growth impact total transit utilization and modal share.
- Can the growth in land use be accommodated where transit system constraints might exist in the horizon year in the corridor (for example parking at VRE and Metrorail stations in the corridor)?
- Can regional and corridor growth in land use be accommodated where transit system constraints might exist in the future (Metrorail line haul volumes crossing the Potomac River absent investment)?

One of the most important elements from the 2035 forecasts is to understand how forecasted growth would affect the performance of the highway system in the project corridor. This is especially important for automobile travel times along Route 1. In general, regional forecasting tools such as the MWCOG model overstate the impacts of congestion. That is because the MWCOG model uses static time-of-day procedures and has no ability to shift trip making from congested to non-congested time periods. In capacity constrained networks (Washington DC is one) typically several phenomena occur (which the MWCOG process can't represent):

- Peak spreading (shifting to less congested portions of the peak period)
- Peak to off-peak shifts (shifting to off-peak)
- Trips not occurring at all

On completion of the 2015 and 2035 No-Build forecasts AECOM assessed the resulting future year highway speeds from the MWCOG model to ensure the modeled degradation is realistic on Route 1. The highway travel times play a crucial role in the quality of the resulting forecasts; they establish:

- Highway network performance/customer travel times in the corridor
- Transit travel times for service operating in mixed traffic
- The degree to which fixed guideway will improve mobility in the corridor

AECOM's travel forecasting group and traffic engineering group worked extensively on the quality of the resulting automobile travel times along Route 1.

Step 6: Develop 2015/2035 Build Alternative Forecasts

Upon completion of the 2015 2035 No-Build forecasts, AECOM evaluated the build alternatives for 2015 and 2035. As part of this exercise, the AECOM team developed operating plans for the transportation alternatives (see **Attachment F**).

Alternatives were developed and evaluated in two phases.

First, four *Initial* transit build alternatives were evaluated. For the purpose of seeding the analysis, these runs provided an order of magnitude market assessment for a variety of transit mode technologies. These include:

- Metrorail extension to Woodbridge. This service would provide a Yellow Line one-seat ride between Woodbridge to Downtown Washington DC.
- New LRT between Woodbridge and Huntington.
- New BRT between Woodbridge and Huntington. The BRT would operate in a dedicated running way and would provide a significant travel time advantage over the current local bus operation.
- New enhanced bus between Woodbridge and Huntington. Here the bus option would operate in mixed traffic and would offer limited improvements versus local bus.

Second, four *Refined* transit build alternatives were evaluated:

- Alternative 1: Bus Rapid Transit- Curb
- Alternative 2: Bus Rapid Transit- Median
- Alternative 3: Light Rail Transit
- Alternative 4: Metrorail/ Bus Rapid Transit Hybrid

Step 7: Enhanced Land Use Scenarios

In Step 7, AECOM developed forecasts for two enhanced land use scenarios, defined as Scenario Two and Scenario Three as part of the land use analysis task of this alternatives analysis. FTA requires that the land use forecasts used to support a New Starts/Small Starts application use fixed land use assumptions (i.e. no change in development with the build alternative). The enhanced land use scenarios anticipate the potential that a major transit investment would serve as a catalyst for more rapid population and employment growth in the corridor, and provide a sensitivity test to ensure that the alternatives provides sufficient capacity to handle projected loadings if growth levels exceed those projected in the MWCOG forecast for 2035.

As noted above, the base land use assumption ("Scenario One") is tied to the 2035 MWCOG (version 8.2) projections for the ½ mile radius around each proposed station location. 2035 TAZ data were used to analyze the population and employment currently projected for the station locations. Scenario One represents "current trends for growth" under the 2035 population and employment projections, with assumed concentration of population and employment developed in close collaboration with Fairfax County and Prince William County planning staff.

The Scenario Two land use analysis reflects a "reasonable increment of growth" above the 2035 MWCOG projections. The "reasonable increment of growth" is assumed to result from:

(1) New development that can be attributed to a high quality transit investment, and
(2) New development that can be attributed to a change in County policies that promotes transit-oriented development.

The growth increment for each station area has been estimated to range from 15 to 25 percent, depending on the station location, and input provided by Fairfax and Prince William County staff members. The percentages are further informed by national experience with transit-oriented development and associated policies. For this scenario, population and employment is concentrated within the half-mile station core, at greater densities than Scenario One.

Ridership forecasts were generated for each of the four alternatives under Scenario Two.

Scenario Three: The Scenario Three land use analysis reflects the amount of population and employment needed to achieve development densities typically associated with Metrorail stations. Population and employment is concentrated within the half-mile core, but may also be distributed locally as needed to achieve the requisite high activity density for Metrorail.

Ridership forecasts were generated only for the Metrorail alternative under Scenario Three.

Attachment F: Transit Operations Assumptions

This attachment details the key assumptions and metrics related to operations of the transit alternatives. These assumptions informed the definition of initial and refined alternatives, and provide the basis for comparison and evaluation of the refined alternatives.

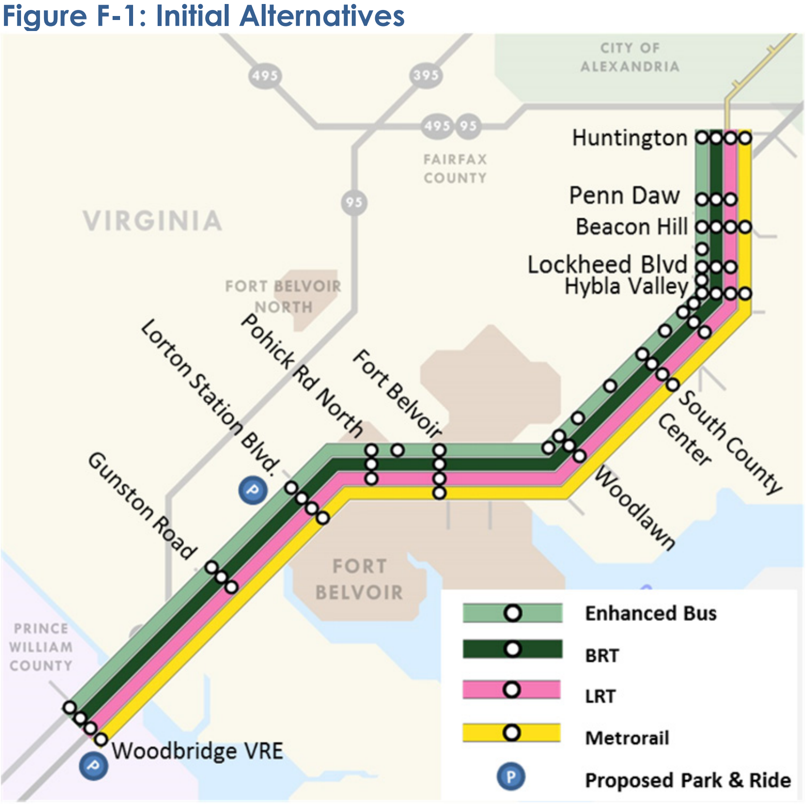
Alternatives

Operating requirements (service hours, number of vehicles, etc.) and the operations and maintenance (O&M) costs estimates were developed for the four initial alternatives and the four refined alternatives advancing from the initial screening of alternatives. The initial alternatives include:

1. Enhanced Bus
2. BRT Alternative
3. LRT Alternative
4. Metrorail Alternative

Figure F-1 shows the initial alternatives.

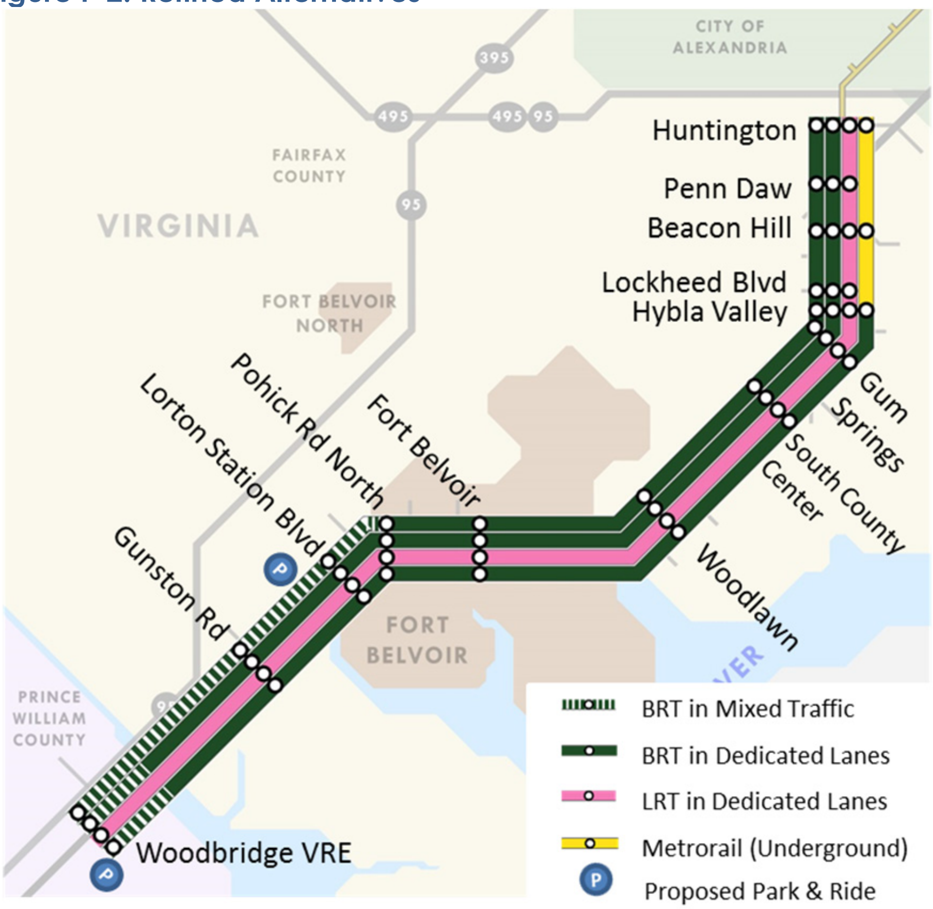
Figure F-1: Initial Alternatives



The four refined alternatives are listed below and shown in **Figure F-2**:

1. Curb-running BRT Alternative
2. Median-running BRT Alternative
3. Median-running LRT Alternative
4. Metrorail and median-running BRT Alternative

Figure F-2: Refined Alternatives



In addition, service plans and operating requirements were defined for a Fort Belvoir shuttle timed to interface with alternatives serving the Richmond Highway Corridor.

Operating Plans

The operating requirements for each alternative reflect the following service plan assumptions. The service span Monday-Thursday is from 05:00 to 00:00 and includes 205 operating days annually. The service span on Friday is from 05:00 to 03:00 and includes 52 operating days annually. The service span on Saturday is from 07:00 to 03:00 and includes 52 operating days annually. The service span on Sunday is from 07:00 to 00:00 and includes 56 operating days annually, including holidays.

The weekday AM peak period is defined from 05:00-09:30 and the weekday PM peak period is defined from 15:30-19:00, an effective peak service span of 8 hours. During the morning and afternoon peak periods, to reflect the need for additional peak directional capacity (vehicles) based on peak hourly load, additional vehicles are placed into service for 1 hour in the AM and 1 hour in the PM peaks. The weekday peak headways are a vehicle every 6 minutes and every 12 minutes in the off-peak. Saturday and Sunday headways are a vehicle every 20 minutes.

The cost per trip (cost per boarding) is calculated based on the annual operating costs divided by the annualized demand.

The shuttle service plan for Fort Belvoir assumes the following. A weekday service span from 05:00-00:00 and includes 254 annual operating days. The weekday peak periods are 05:00-09:30 and 15:30-19:00, a daily effective peak service span of 8 hours. The weekday peak headways equate to a vehicle operating every 6-minutes. The weekday off-peak headways equate to a vehicle operating every 15-minutes. No service will be operated on weekends. The shuttle will run a 13-mile round trip of bidirectional service with an effective cycle time of 58 minutes during the peak periods and 52 minutes in the off-peak.

Operations and Maintenance Costs

The operating requirements and cost basis for the alternatives build upon the following assumptions. The vehicle operating capacities by mode are:

- Enhanced Bus and BRT assume a 60 foot articulated vehicle with a capacity of 90 persons;
- LRT assumes a 2-car train with capacity of 160 persons per car;
- Metrorail assumes an 8-car train with a capacity of 120 persons per car.

Peak load demand estimates were used to assure the estimated demand requires 80% of scheduled service capacity. This planning target is intended to assure that the operating plans provide sufficient capacity relative to forecast demand and anticipated variability in the peak hour demand. Vehicle requirements are calculated to serve the larger of either the service policy service requirements (the amount of service required to meet service span and peak and off-peak headways) or estimated demand (the capacity required to serve 1.25% of estimated demand).

To accommodate directional demand peaking (to make sure adequate capacity is scheduled in the peak hour travel direction) additional peak directional service was added to the peak morning and evening hours. The same was applied to off-peak service if additional capacity was required to serve estimated demand. The additional peak directional service for BRT was calculated only for northern segment of the corridor where the peak hourly load is experienced. Operationally this reflects the use of trippers and/or turn-back service above the policy service headways for the entire corridor.

Metrorail costs are based on the difference between operations (train-miles) from Mount Vernon Square to Huntington compared to service from Mount Vernon Square to Woodbridge (Initial Alternatives) or Hybla Valley (Refined Alternatives). This approach recognizes that changes to the Metrorail operating plan affect operations for the entire length of Yellow Line service.

The Refined Alternatives were defined based on modeled demand and an established cost basis for each mode. Demand is identified as average daily trips, peak hour directional load, and off peak demand. In **Table F-1** is the peak hour directional demand and off-peak hourly demand.

Table F-1: Peak Hour Directional Demand and Off-peak Hourly Demand

Modal Alternative	Peak Hour Demand	Off-Peak Demand
Enhanced Bus	1049	490
BRT	1180	510
LRT	1364	613
Metrorail+BRT	3465	1242

The cost basis for BRT and Metrorail were defined using existing WMATA cost information from the WMATA 2015 Budget. The bus based services, enhanced bus, Fort Belvoir Shuttle, and BRT, use the Virginia Regional Bus cost per vehicle revenue hour as the basis for cost estimation. In the case of BRT, an additional 21% of the Virginia Regional Bus cost basis was added to reflect the additional non-labor component often associated with BRT services.

The cost basis for LRT is defined in terms of per revenue train-hour using a set of peer transit agencies as reported by the National Transit Database (2012). The peer costs were also factored to reflect the WMATA cost structure. The Metrorail cost basis is the per car-mile cost reported in the WMATA 2015 Budget, adjusted to a cost per 8-car train in terms of train-miles. **Table F-2** summarizes the unit cost assumptions.

Table F-1: Unit Cost by Alternative

Modal Alternative	Unit Cost
Enhanced Bus	$156.65 vehicle rev-hour
BRT	$189.55 vehicle rev-hour
LRT	$346.28 train-hour
Metrorail+BRT	$67.08 8-car train-mile

The operating run times (cycle times) by alternative and mode include station dwell times and layover time (calculated as 10% of the round trip running time). Off peak cycle times are 10% less than peak cycle times for all modes but Metrorail. Speeds by alternative and mode were provided by AECOM based on modeled travel speeds including acceleration and deceleration rates, station dwell times, and traffic controls.

Performance metrics were calculated for each alternative and mode as a basis for comparison and for the purpose of evaluation and screening. As the alternatives were developed a policy service plan (headways and service span) based operating requirements are compared to demand based operating requirements to allow an evaluation of modal alternatives in terms of service hours and costs relative to demand and capacity. Peak and off-peak vehicle requirements are included as a metric. Annual revenue hours of service, annual train-miles for Metrorail, and annual O&M costs based on policy service plan and demand based service plan. In addition, the cost per trip (boarding) is a standard industry metric, and lower cost per trip indicates more efficient system performance.

Peak demand capacity over peak policy capacity is included, a score over 1 means demand requires additional capacity and a score under 1 means service policy capacity is greater than what is required to serve demand. Finally, available peak capacity, the inverse of the previous metric, is provided, a score over 1 means the service operated is in excess of what demand requires.

Table F-3 below presents the summary findings for the Initial Alternatives screened. **Table F-4** reports the summary of findings for the screening and evaluation of alternatives

Table F-3: Initial Alternatives Performance Metrics

Alternative Summary	Peak Vehicles Policy Service	Annual Rev-Hours Policy Service	Annual O&M Costs Policy Service	Daily Demand	Peak Vehicles Demand Based	Weekday Off-Peak Vehicles	Annual Rev-Hours Demand Based	Annual O&M Costs Demand Based	Cost / Trip	Peak Demand/Policy Capacity	Available Peak Capacity
Metrorail (Alt 4)	8	37,339	$74,065,828	48,999	8	10	37,339	$74,065,828	$ 5.04	0.88	1.14
BRT (Alt 2)	14	57,633	$10,924,133	16,397	19	9	61,231	$11,606,122	$ 2.36	1.21	0.82
LRT (Alt 3)	14	54,650	$18,924,373	18,228	14	6	54,650	$18,924,373	$ 3.46	0.43	2.33
Enhanced Bus (Alt 1)	13	55,577	$8,706,137	9,505	13	7	55,577	$8,706,137	$ 3.05	0.69	1.44
Ft. Belvior Shuttle	10	31,868	$4,992,122								

Table F-4: Refined Alternatives Performance Metrics

Alternative Summary	Peak Vehicles Policy Service	Annual Rev-Hours Policy Service	Annual O&M Costs Policy Service	Daily Demand	Peak Vehicles Demand Based	Weekday Off-Peak Vehicles	Annual Rev-Hours Demand Based	Annual O&M Costs Demand Based	Cost / Trip	Peak Demand/Policy Capacity	Available Peak Capacity
Metro + BRT (Alt 4)	13	52,770	$26,431,926	33,473	15	6	53,622	$26,626,780	$ 2.65	1.00	1.00
BRT (Alt 2)	14	57,633	$10,924,133	16,397	19	9	61,231	$11,606,122	$ 2.36	1.21	0.82
LRT (Alt 3)	14	54,650	$18,924,373	18,436	14	6	54,650	$18,924,373	$ 3.42	0.43	2.33
BRT + Enhanced Bus (Alt 1)	15	61,681	$10,769,691	15,179	20	7	65,279	$11,447,826	$ 2.51	1.00	1.00
Ft. Belvior Shuttle	10	31,868	$4,992,122								

Attachment G: Transit Travel Time Methodology

This attachment summarizes the methodology and key assumptions in estimating travel times for transit service for the Route 1 Multimodal Alternatives Analysis. Transit travel times were estimated and applied in two basic iterations. First, as input to ridership forecasting for the initial set of transit alternatives, in which the estimates were general, based on average speeds for the transit modes in current application on other projects. In the second iteration the project team applied more detailed assumptions regarding free-flow travel time, vehicle performance, boarding/alighting times, and traffic signal delays. The resulting refined travel time estimates were applied to the ridership forecasts and detailed comparison of the multimodal transportation alternatives.

In-Motion Travel Time

In-motion travel time is calculated based on the assumed free-flow travel time using a maximum defined speed (free flow speed) for each alternative. For the transit alternatives operating in exclusive bus lane (i.e., curb running BRT, median running BRT and LRT), 45 mph was assumed as the maximum speed. For the enhanced bus and Metrorail, 35 mph and 55 mph were assumed, respectively.

Transit Stop Dwell Time

Transit stop dwell time includes passenger boarding and alighting times at each stop as well as the delay that occurs due to acceleration and deceleration. Based on the ridership forecasts obtained from the initial screening alternatives, dwell time was assumed as 25 seconds at stops with high ridership and 15 seconds at stops with moderate ridership. Note that relatively lower dwell times were used due to the availability of off-board fare collection, level boarding platform, and boarding through multiple doors. Acceleration and deceleration delay due to stops were calculated using the following equation:

$$d_{accel} = \frac{V_{max}}{2a} \qquad d_{decel} = \frac{V_{max}}{2d} \qquad (1)$$

where d_{accel} and d_{decel} are the acceleration and deceleration delays (second), V_{max} is the maximum defined speed (mph), and a and d are the acceleration and deceleration rates (miles per hour per second, mphps), respectively. **Table G-1** provides the acceleration and deceleration rates used for each transit alternative.

Table G-1: Assumed Acceleration and Deceleration Rates for Transit Alternatives

	Acceleration Rate (mphps)	Deceleration Rate (mphps)
BRT*	2.0	2.0
LRT	2.2	2.5
Metrorail	2.8	2.8

*Same acceleration and deceleration rates were assumed for Alternative 1 (Enhanced Bus + Curb Running BRT)

Traffic Signal Delays

Traffic signal delay estimation assumed uniform, deterministic arrivals at intersections. Using the well-known cumulative arrivals and departures concept (based on the duration of red and green signal and the arrival volumes, Highway Capacity Manual 2000), uniform delay was calculated for the transit alternatives using the following equation:

$$d = \frac{0.5 * r^2}{C} * \left[\frac{1}{1 - v/s}\right] \qquad (2)$$

- Where d is the signal delay, r is the effective red time, C is the cycle length, v is the arrival volume, and is the saturation flow rate. Note that the arrival volume was considered as zero for median-running BRT and LRT service.
- The formula given above assumes uniform arrivals (random arrivals), which typically occurs at isolated intersections without signal coordination. However, along Route 1, intersections are coordinated, which may result in transit vehicles arriving during green signal, particularly when there is no transit stop upstream of an intersection, resulting in lower transit delays. In order to take into account signal coordination benefits, delay calculated using equation (2) was reduced by 67 percent at intersections where there is no upstream transit stop (i.e., the probability of a transit vehicle stopping at an intersection is 33 percent or a transit vehicles stops at a red signal once in every three intersections). The 67 percent reduction factor was assumed based on the quality of signal progression observed in the field and in the simulation and engineering judgment). However, when there is an upstream stop at an intersection, it is assumed that transit arrivals are random due to the dwell time at the stop and signal delay calculated using equation (2).

Transit Preferential Treatment Savings

Delay savings associated with TSP and queue jump lane were estimated using the results of past research. For example, Zlatkovic et al.[3] evaluated the individual and combined effects of queue jump

[3] Zlatkovic M., Stevanovic A., and Reza Z., "Effects of Queue Jumpers and Transit Signal Priority on Bus Rapid Transit", presented at the 92nd Transportation Research Board Annual Meeting, Washington D.C., 2013

lanes and TSP on performance of a BRT system in West Valley City, Utah. Altun and Furth [4] developed a deterministic model for isolated intersections to estimate TSP delay savings, which uses the fundamentals of traffic flow theory at signalized intersections. The current VISSIM analysis was also performed to validate and supplement the application of these findings to the Route 1 study.

The total savings as a result of preferential treatments were then subtracted from the signal delay. Note that the probability of stopping (0.33) as described above, was used in estimating preferential treatment savings with signal coordination. For example, if the total savings due to preferential treatments were estimated as 10 seconds, signal delay was reduced by 3.3 seconds at an intersection when there is no upstream stop to take into account signal coordination benefits.

[4] Altun, S. Z. and P. G. Furth, "Scheduling Buses to Take Advantage of Transit Signal Priority", Transportation Research Record: No. 2111, Washington D.C., 2009, pp.50-59