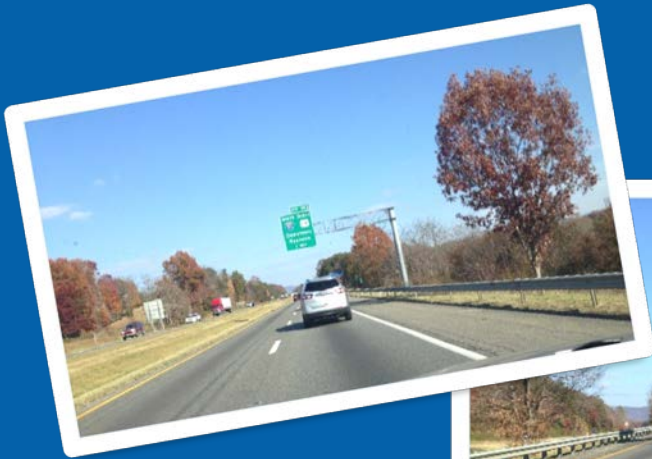

FINAL

I-81/I-581 Auxiliary Lane Transportation Study

Roanoke County, Virginia
VDOT, Salem District

JULY 2016

Prepared by

Kimley»Horn

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STARS
STRATEGICALLY TARGETED AND AFFORDABLE ROADWAY SOLUTIONS

Final Report

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
DS	design speed
EA	Environmental Assessment
EIS	Environmental Impact Statement
FEIS	Final Environmental Impact Statement
FHWA	Federal Highway Administration
GEH	traffic statistic for calibration (named after developer, Geoffrey E. Havers)
HCM	Highway Capacity Manual
HCS	Highway Capacity Software
HSC	Highway Safety Corridor
I-581	Interstate 581
I-81	Interstate 81
LOS	level of service
MOE	measure of effectiveness
MM	mile marker
MPH	miles per hour
NB	northbound
PHF	peak hour factor
ROD	Record of Decision
TMC	Traffic Message Channel
SB	southbound
SIU	Section of Independent Utility
VDOT	Virginia Department of Transportation
vph	vehicle per hour


SECTION 1

Introduction

The Salem District of the Virginia Department of Transportation (VDOT) identified the Interstate 81 (I-81)/Interstate 581 (I-581) corridor as an area prone to significant congestion due to high traffic volumes, including high-truck volume along northbound (NB) I-81 from Exit 141 to Exit 143.

The *I-81 Corridor Improvement Study, Tier I Final Environmental Impact Statement (FEIS)* that was completed in 2007 studied the entire 325 miles of I-81 corridor in Virginia for potential improvements including separation of trucks and passenger vehicles, managed lanes, as well as rail improvements. The Tier I Record of Decision (ROD) documents FHWA's decision to advance to Tier II a non-separated variable lane highway facility that involves construction of no more than two general purpose lanes in each direction, where needed, to address future traffic demands. Subsequently, The Tier I study divided I-81 in to eight segments for further detailed analysis which could be performed under Tier II studies. Also, Tier I ROD decision documents the immediate need for smaller, independent safety and operational improvements along I-81, along with the “Build” concept that was advanced into Tier II.

I-81 Corridor Improvement Study, Tier II Environmental Assessment (EA) for one the above segments is currently evaluating a 32 mile corridor that includes the project study limits. The specific purpose of the Tier II study is to address existing traffic volume and projected (2040) travel demand in order to improve the operating conditions by achieving acceptable levels of service along the I-81 segment including the study area. The traffic analysis performed for the Tier II EA confirmed the need to improve the traffic operations.

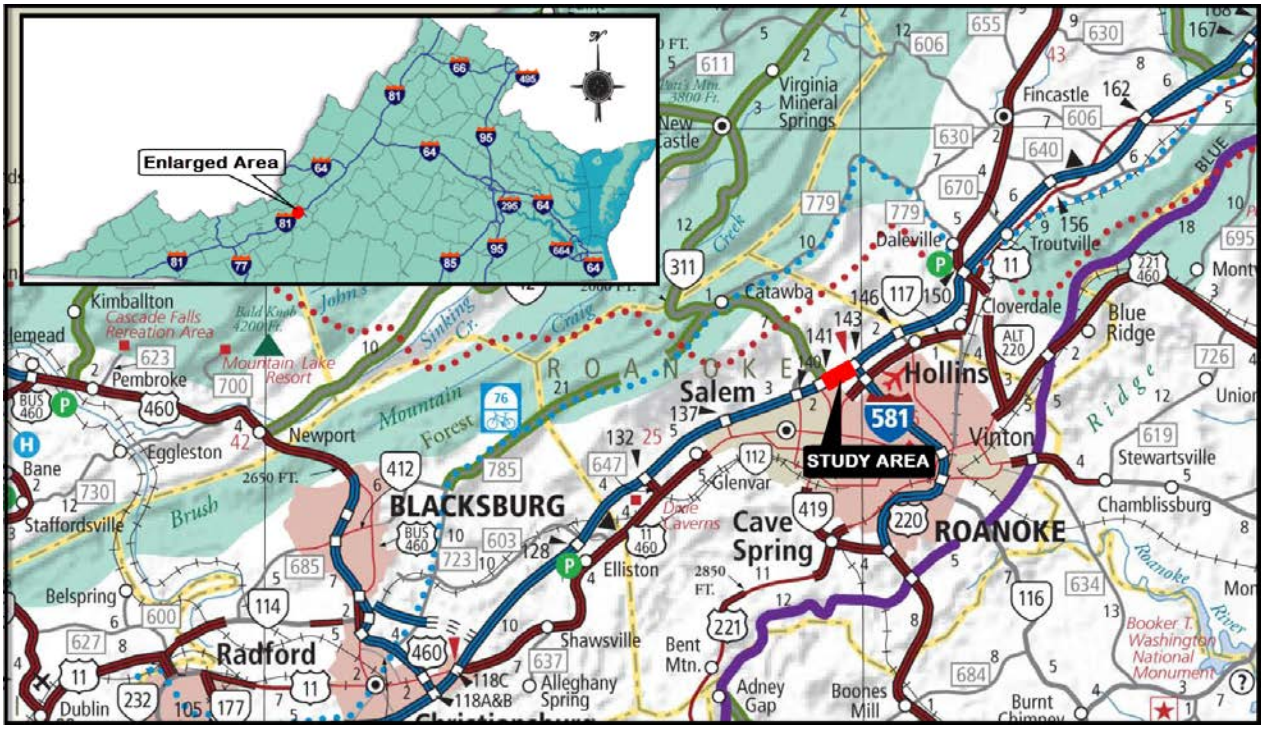
The proposed improvement project, to extend the auxiliary lane between Exit 141 and Exit 143, will provide a near-term mitigation to alleviate traffic congestion and improve safety in the study limits until a major improvement is defined, funded, and constructed. Preliminary design plans for auxiliary lane improvement are being completed concurrently with the traffic analysis for this study. The assumptions, methodology, results, and conclusions are summarized in this report.

Additionally, as part of the statewide prioritization process, a list of projects were identified to address safety and congestion relief along I-81 corridor. The prioritized list of projects were evaluated and scored, pursuant to Code of Virginia House Bill 2 (HB2), to determine the eligibility for funding by the Commonwealth Transportation Board (CTB) during fiscal year 2017-2022 Six-Year Improvement Program (SYIP). The proposed improvement project scored a statewide rank of 152 out of the total 287 eligible applications submitted during 2015 HB2 application screening process with eligibility under High Priority funding program. The one-page project and scoring summary generated by HB2 application tool is included in **Appendix A**.

1.1 Study Area

The study corridor is located in Roanoke County, Virginia. I-81 is oriented in a north-south direction through western Virginia from the Tennessee border to the West Virginia border. I-581 is oriented in a north-south direction from the City of Roanoke to I-81. The study segment along I-81 NB from Exit 141 to Exit 143 is approximately 1.54 miles long. **Figures 1-1 and 1-2** present the location map and study limits, respectively.

FIGURE 1-1: LOCATION MAP



Only I-81 NB was analyzed in this study. The ramps analyzed in the study segment include a merge-point on-ramp at Exit 141 and diverge-point off-ramp at Exit 143 to I-581.There are two interchanges within the study area. **Table 1-1** lists locations included within the scope of the study.

FIGURE 1-2: STUDY LIMITS

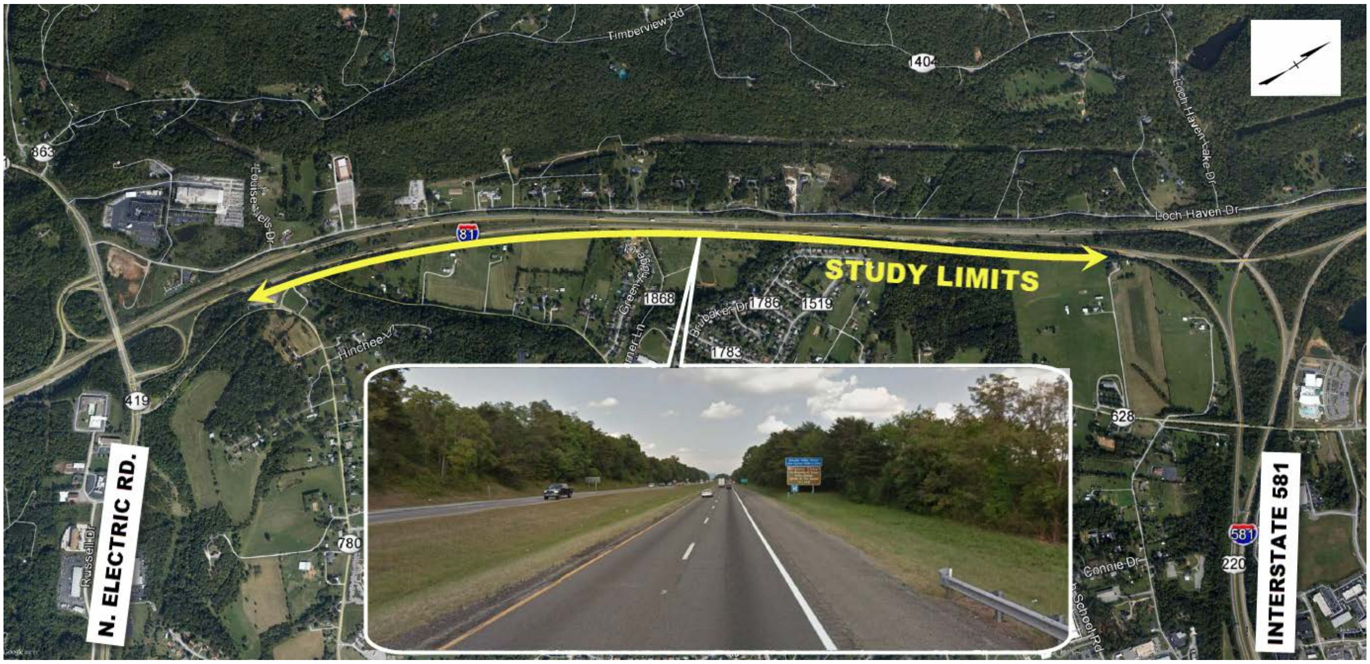


TABLE 1-1: STUDY INTERCHANGES

Study Interchanges	
Exit 141	Merge-point on-ramp along I-81 NB at Route 419/N. Electric Road
Exit 143	Diverge-point off-ramp along I-81 NB at I-581

1.2 Description of the Study Corridor

The study corridor encompasses a section of I-81 NB between Exit 141 (N. Electric Rd.) merge-point and Exit 143 (I-581) diverge-point. The *I-81 Corridor Improvement Study, Tier II EA* that is currently evaluating the 32-mile corridor along I-81 includes this segment of the project as one of the areas that exhibits higher volumes (daily and peak hour traffic) in comparison to all other segments of I-81 in the state of Virginia. As a result of 2003 Highway Safety Corridor program, part of the I-81 segment (from mile market 127 to mile marker 142) has been identified and designated as a "Highway Safety Corridor" due to higher than expected crash rates and crash severity, including injuries and fatalities. Also, the posted speed limit in this segment is restricted to 60 mph, although the majority of I-81 corridor in Virginia carries a higher posted speed limit of 70 mph.

The I-81 corridor segment in this region is functionally classified as "Urban Interstate" with rolling and mountainous terrain (Valley and Ridge), per the geological map of Virginia. The typical section of this segment consists of two 11-feet lanes with 10 feet of paved shoulder on the right and 3-4 feet of paved shoulder on the left. I-81 NB lanes in this segment are primarily separated from the I-81 southbound (SB) direction by a grass median of varying width with a minimum of 34 feet at its narrowest point. Inside and outside rumble strips are present in both directions through the segment. Guardrails provided along intermittent sections.


1.3 Other Studies and Projects

Given the economic importance of the region and interstate connections, multiple studies have been conducted along I-81 and at interchanges within and adjacent to the study limits. These include the following National Environmental Policy Act documents and planning studies:

- I-81 Corridor Improvement Study - Tier 1 Final Environmental Impact Statement (FEIS) – (2007) – 325 miles
- I-81 Corridor Improvement Study - Tier 2 EA - Draft (March 2016) - between Exit 118 and Exit 150
- Valley View Planning Study (June 2008) - Along I-581 from Hershberger Road and Valley View Boulevard
- Route 419 Corridor Plan (March 2010) - Between Route 311 and US 220

These references were reviewed by the study team to validate assumptions and supplement available data for this study.

SECTION 2

Data Collection and Inventory

The study team coordinated with the VDOT Salem District to obtain INRIX Data for speeds, as well as a 5-year history of crashes occurring within the study area. Other data were obtained through field visits and from adjacent studies (listed in Section 1.3). Additional details and supporting documentation can be found in **Appendix B**.

2.1 Traffic Volume Data

No new traffic data collection was conducted for this study. All of the traffic data used for the operational analysis were obtained from the *I-81 Corridor Improvement Study, Tier II EA*. This source was also used to determine truck percentages. A summary of AM and PM peak hour volumes for the year 2013 are provided in **Table 2-1**. Excerpts from the *I-81 Corridor Improvement Study, Tier II EA* presenting the traffic volumes used in this study are included in **Appendix B.**

TABLE 2-1: COUNT LOCATIONS AND 2013 PEAK HOUR TRAFFIC VOLUMES

Roadway Segment	2013 AM Peak Hour	2013 PM Peak Hour
I-81 NB, west of on-ramp at N. Electric Road	1,710	2,260
On-ramp at N. Electric Road	425	525
I-81 NB, east of on-ramp at N. Electric Road	2,135	2,785
Off-ramp at I-581	1,235	1,285
I-81 NB, east of off-ramp at I-581	900	1,500

Additional information/assumptions obtained from the *I-81 Corridor Improvement Study, Tier II EA* are listed as follows:

- Peak Hour Factor – 0.94
- Terrain/Grades – Rolling
- Heavy Vehicles – 16% (for both AM and PM peak hours)

2.2 Speed Data

Using the INRIX database, speeds derived from vehicle probe samples were available for Traffic Message Channel (TMC) segments located throughout the study area. The INRIX speed data were used to calibrate the existing (2013) weekday AM and PM CORSIM models. VDOT provided the INRIX data for November 2012 for the same days when Tier II EA traffic counts were conducted. INRIX speeds for typical day (Tuesday, Wednesday and Thursday) were used. From an analysis of traffic speeds from INRIX, it was found that most vehicles operate at approximately 65 mph, indicating a free-flow traffic condition during the peak hours in the study corridor. Detailed travel speeds for all TMCs during weekday peak hours are included in **Appendix B**.

2.3 Crash Data

Five years of crash data from January 1, 2011 through December 31, 2015, from mile marker 141.8 to 143.8 were used by VDOT to analyze crash trends along the study corridor. During those five years, there were 76 crashes documented along I-81 NB within the study limits. Out of the total 76 crashes along the study corridor, four crashes were recorded on the N. Electric Road on-ramp and one crash along I-581 off-ramp, the remaining crashes were in the travel lanes of I-81 NB. A detailed review of the raw crash data is summarized in Section 3.

Attribute data recorded with each crash included: crash document number, crash date, crash time, severity level, crash type, weather condition, work zone identifier, jurisdiction, number of involved vehicles, lighting condition, surface condition, relative roadway location, number of pedestrians involved, and latitude/longitude information.

The raw crash data is included in **Appendix B**.

SECTION 3

Safety Analysis

A safety analysis was conducted by first using historical data to identify crash “hot spots” and focusing particularly on the identified high-crash density locations. Based on the findings, appropriate recommendations were made for improving geometric deficiencies identified within the study corridor. Additional details and supporting documentation can be found in **Appendix C**.

3.1 Crash Data Analysis

VDOT Salem District has analyzed the raw data for the study period (January 1, 2011, through December 31, 2015) to identify the crash patterns based on attributes like crash type, crash severity, weather, time of the day, traffic peak period, and pavement condition. **Tables 3-1** and **3-2** present the overall crash summaries by type and severity.

TABLE 3-1: OVERALL CRASH SUMMARY – BY TYPE OF CRASH AND SEVERITY (2011-2015)

Year	Type of Collision											Severity				Total Number of Crashes
	Rear End	Angle	Fixed Object - Off Road	Fixed Object - In Road	Sideswipe - Opposite Direction	Sideswipe - Same Direction	Deer / Other Animal	Head On	Non-Collision	Other	Pedestrian	Fatal (K)	Severe Injury (A)	Minor/Possible Injury (B & C)	Property Damage Only (O)	
2011	4	0	3	0	0	1	2	0	1	0	0	0	0	1	10	11
2012	6	3	3	0	0	3	2	0	0	0	0	0	1	2	14	17
2013	6	0	6	1	0	0	4	0	0	0	0	0	1	6	10	17
2014	5	1	2	0	0	2	3	0	0	0	0	0	0	1	12	13
2015	9	1	3	0	0	3	0	0	1	1	0	0	0	4	14	18
SUB-TOTAL	30	5	17	1	0	9	11	0	2	1	0	0	2	14	60	**76**

TABLE 3-2: OVERALL CRASH SUMMARY – BY TRAFFIC PEAK PERIOD, LIGHT CONDITIONS, PAVEMENT, AND WEATHER (2011-2015)

Year	Peak Hour			Light Conditions			Pavement Condition			Weather Condition				
	AM (6-10 AM)	PM (3-7 PM)	Off Peak	Day	Dawn, Dusk	Dark	Dry	Wet	Misc	Clear, Cloudy	Fog	Rain, Mist, Sleet, Hail	Snow	Other
2011	3	3	5	6	2	3	9	2	0	8	0	3	0	0
2012	1	5	11	8	0	9	14	2	1	14	0	2	1	0
2013	2	6	9	9	1	7	12	5	0	13	0	3	1	0
2014	2	4	7	7	1	5	12	1	0	12	0	1	0	0
2015	4	7	7	16	0	2	13	5	0	14	0	4	0	0
SUB-TOTAL	12	25	39	46	4	26	60	15	1	61	0	13	2	0
TOTAL	76			76			76			76				

In addition to the tables presented above, **Figure 3-1** presents the crash summaries (in percentages) in a pie-chart format. Based on the information presented in **Tables 3-1** and **3-2** and **Figure 3-1,** rear-end crashes make up the majority (39%) of the total crashes, which indicate speed differentials along the highway. Also, 22% of the crashes were recorded to be fixed-object, off-road crashes. No fatalities were recorded during the study period. Seventy nine percent of the crashes were property damage only.

Table 3-3 presents the crash rate comparison by severity along the study segment, throughout the Salem District and statewide. Based on the comparison, the overall crash rate within the study area during the study period is recorded to be higher than the Salem District average crash rate for 2014, but lower than the statewide average crash rate for interstates in 2014.

TABLE 3-3: CRASH RATE COMPARISON – BY SEVERITY (2011-2015)

CRASH RATE COMPARISON	Fatal Crash Rate	Injury Crash Rate	Overall Crash Rate[*1]
Study Area (2011-2015)[*2]	0.00	17.80	58.82
Salem District Interstates (2014)[*3,4]	0.11	18.40	49.31
Statewide Interstates (2014)[*3,4]	0.35	30.24	71.80

Notes:
1. Crash rates are expressed in crashes per 100 million vehicle-miles traveled.
2. Study area crash rates are along I-81NB only.
3. Salem District & Statewide crash rates are obtained from 2014 Summary of Crash data published by VDOT Traffic Engineering Division.
4. Crash rates presented in the table for Salem District and Statewide are for Interstate system (on mainline only). These crash rates are not broken down by direction of travel on Interstate.

3.2 Safety Hot Spots

Crash activity by mile segments of roadway (or crash density) along the study corridor between 2011 and 2015 are represented as crash histograms in **Figures 3-2** and **3-3** along with study corridor (and milepost) information based on crash type and crash severity.

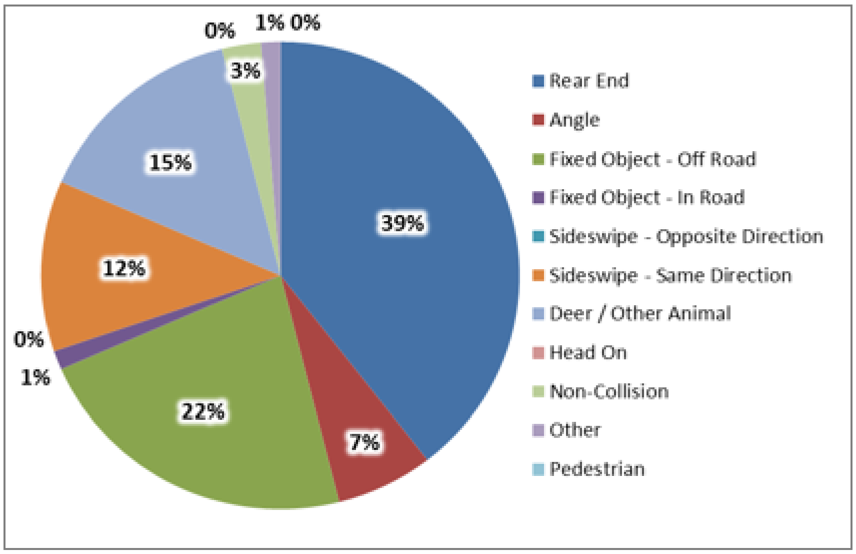
The following three "hot spots" were identified along I-81 NB:

- Hot Spot #1 – Milepost 141.8 to 142.0 (near Exit 141)
- Hot Spot #2 – Milepost 143.0 to 143.1
- Hot Spot #3 – Milepost 143.5 to 143.9 (near Exit 143)

Along I-81 NB, two out of the three "hot spots," (#1 and #3) are located near exit ramps.

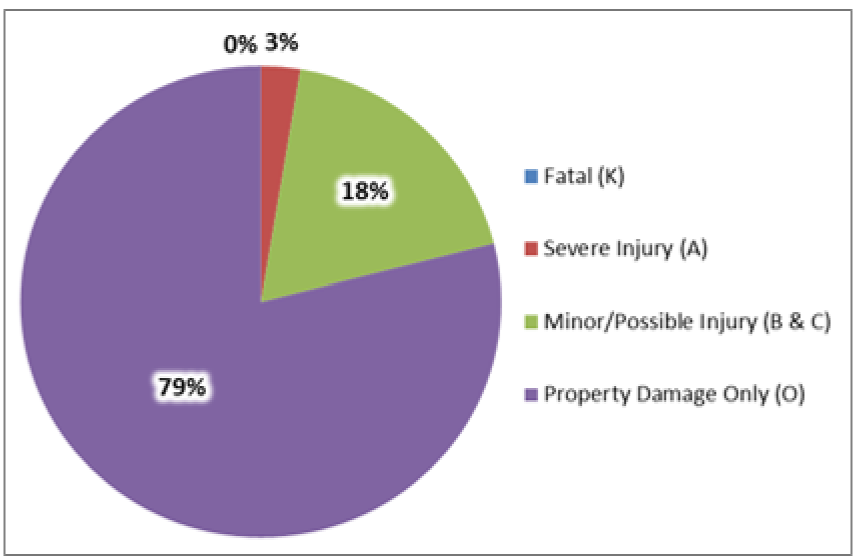
All relevant crash information from VDOT is included in **Appendix C.**

FIGURE 3-1: CORRIDOR CRASHES BY TYPE, SEVERITY, TIME OF DAY, WEATHER, LIGHT CONDITION, PAVEMENT CONDITION, AND VEHICLE TYPE



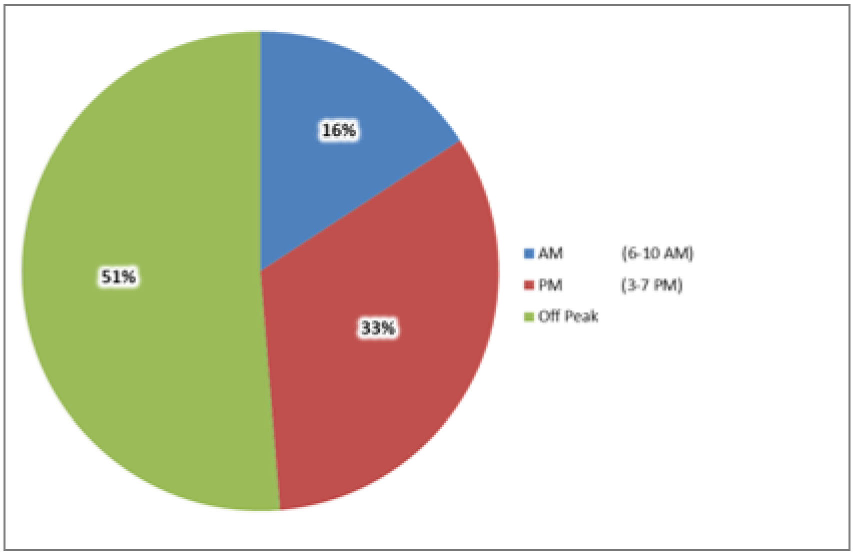
Crashes by Type

- The predominant crash type was Rear End (30 total crashes or 39%)
- The second most frequent crash type was Fixed Object - Off Road (17 total crashes or 22%)
- Deer/Other Animal (11 total crashes or 15%)
- Sideswipe - Same Direction (9 total crashes or 12%)



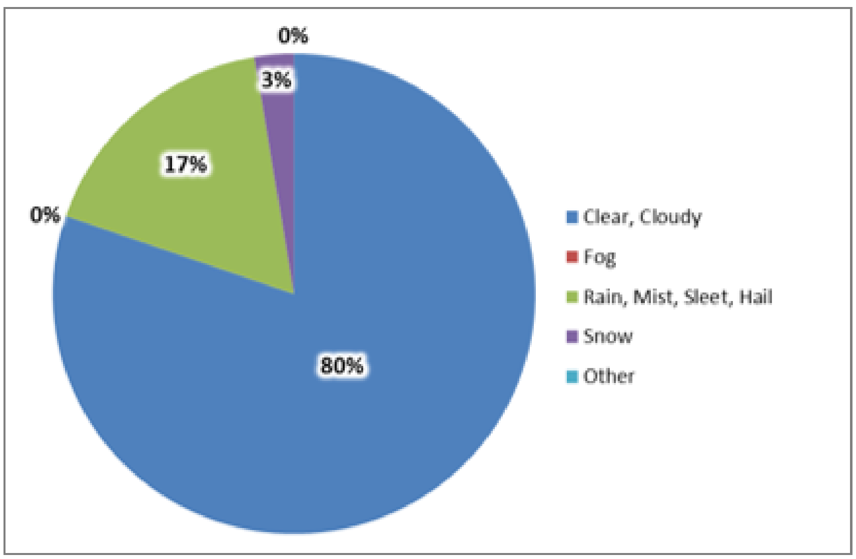
Crashes by Severity

- Zero Fatal Crashes (0%)
- 2 Crashes (3%) resulted in severe injury
- 14 Crashes (18%) resulted in Minor/Possible injury
- 60 Crashes (79%) resulted in Property Damage Only (No Injury)



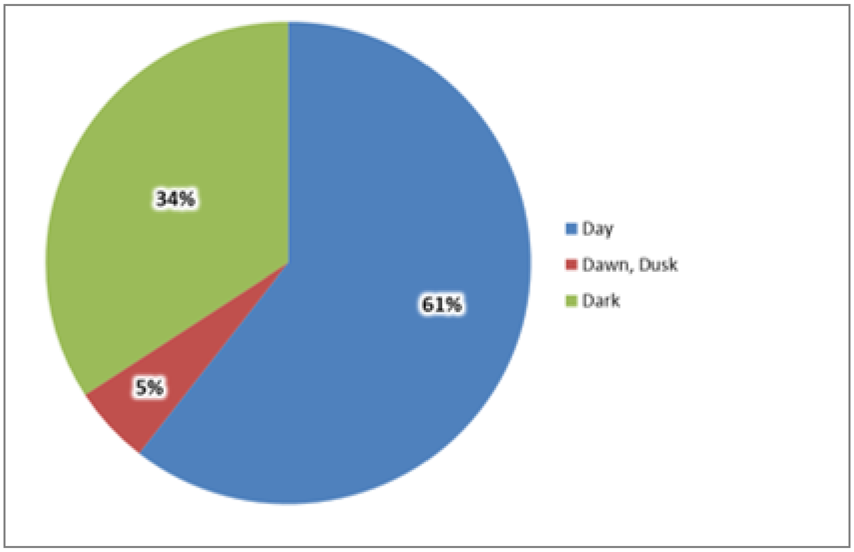
Crashes by Time of Day

- The most frequent crash time (39 total crashes or 51%) occurred during Off Peak hours
- Second most frequent crash time (25 total crashes or 45%) occurred during PM Peak Hours (3-7 PM)



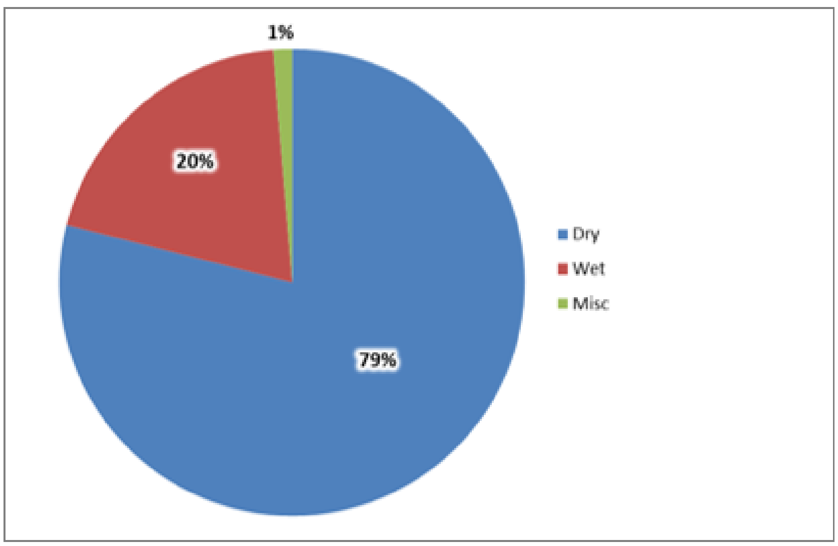
Crashes by Weather

- The majority of crashes (80%) occurred under clear/cloudy weather conditions
- Weather conditions in the "Other" category include Severe Crosswinds and Blowing sand, soil, dirt, or snow



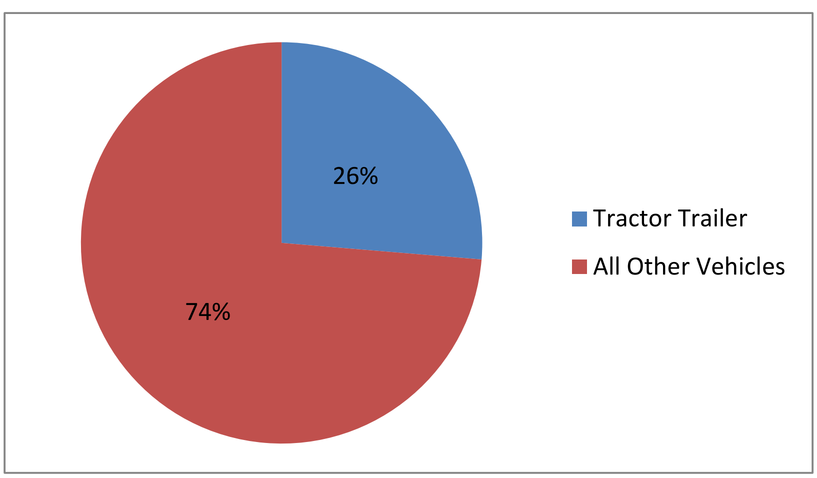
Crashes by Lighting

- Over half of the crashes (61%) occurred during the day
- 34% of crashes occurred in dark conditions



Crashes by Pavement Condition

- The majority of crashes (60 total crashes or 79%) occurred under dry roadway surface conditions
- Surface conditions in the "Misc." category include Icy and Slush



Crashes by Vehicle Type

- 26% of crashes involved tractor trailer vehicles
- Vehicle type for tractor trailer category includes single unit trucks (2-axle and 3-axle) and truck tractor

FIGURE 3-2: STUDY AREA CRASH LOCATIONS – BY TYPE OF CRASH (2011-2015)

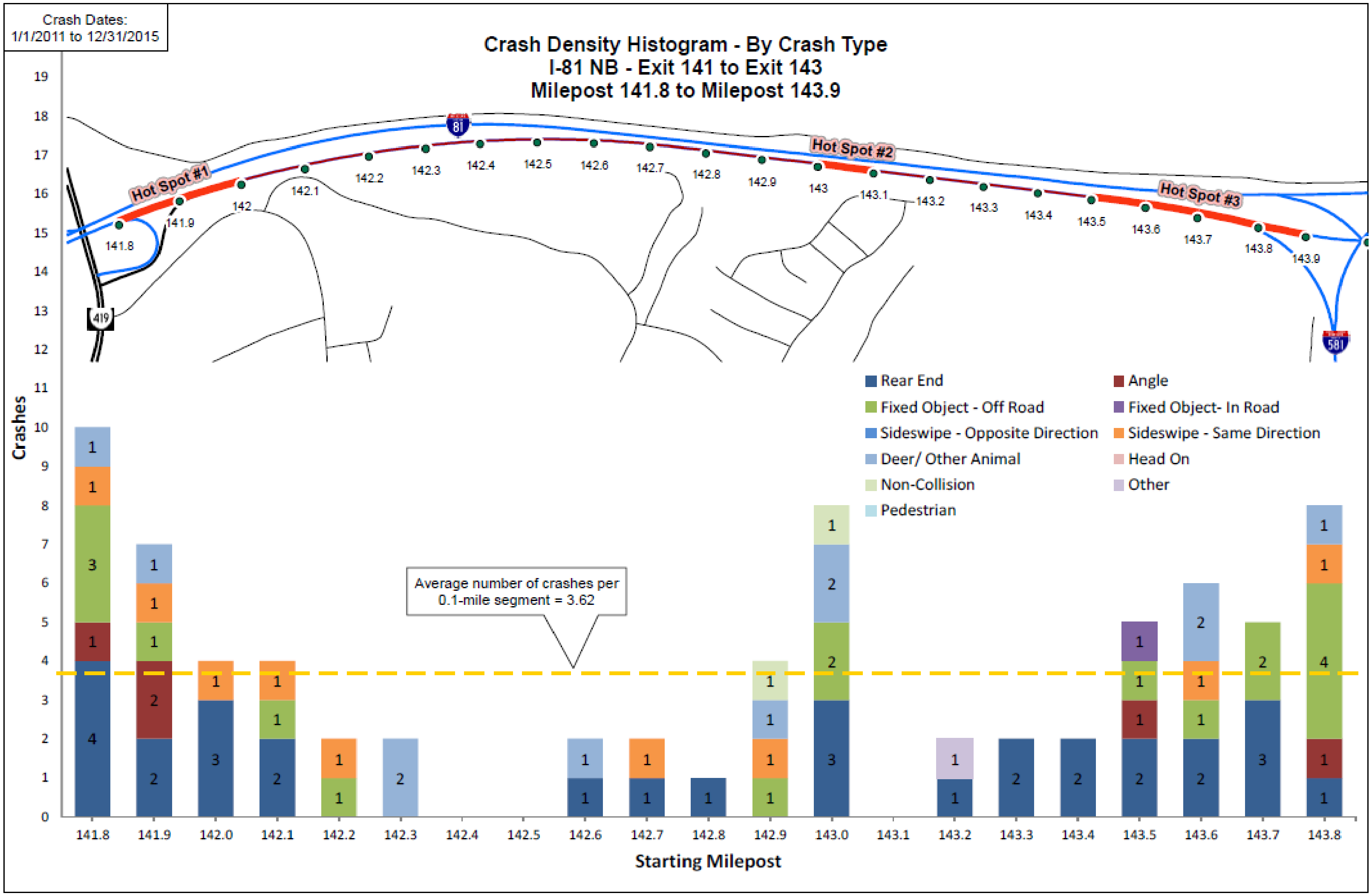
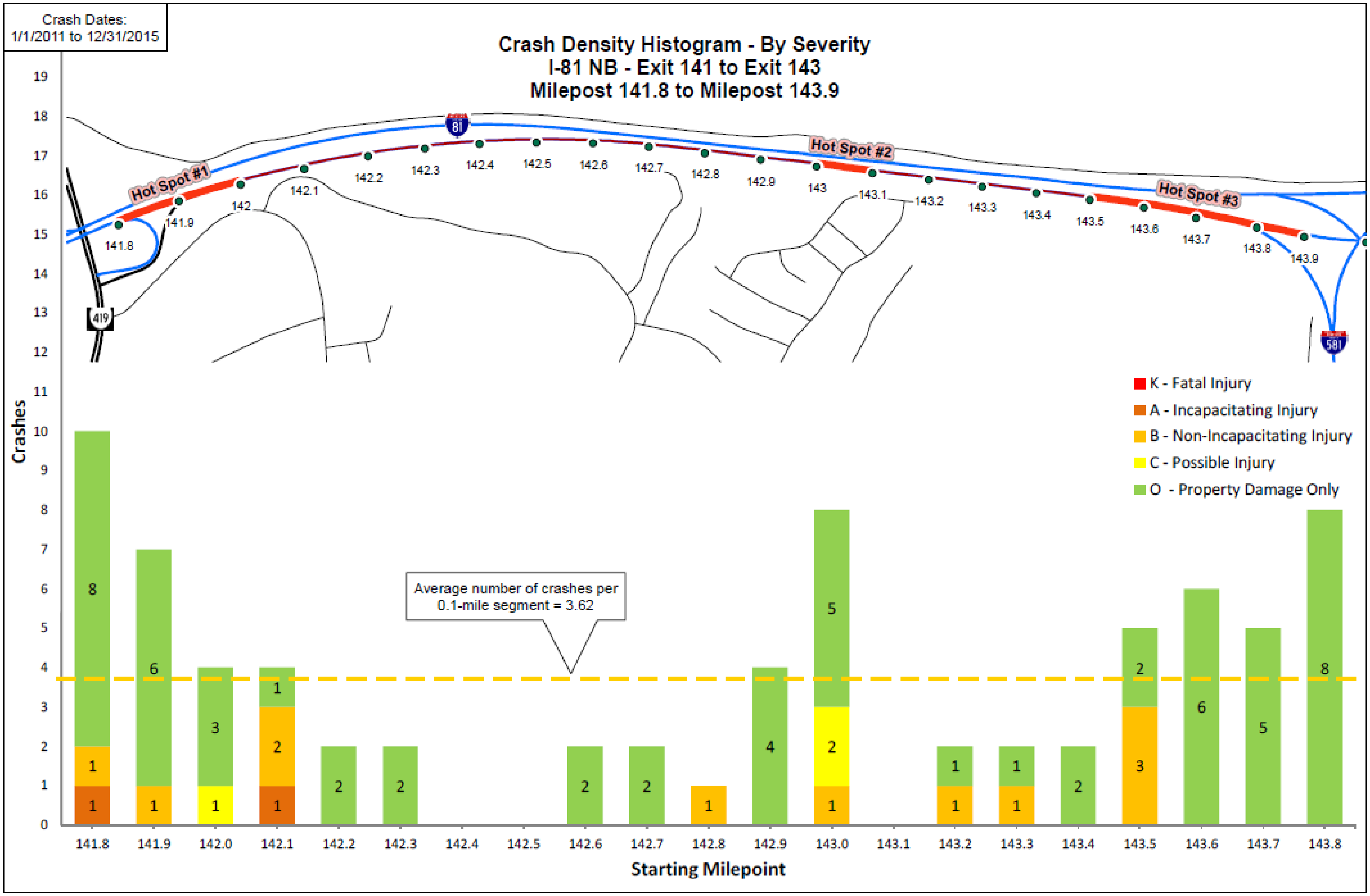


FIGURE 3-3: STUDY AREA CRASH LOCATIONS – BY SEVERITY (2011-2015)



3.3 Existing Geometric Deficiencies

Existing geometric conditions in the study area were assessed to identify areas that do not meet current geometric standards. The standards used for this assessment were:

- *Roadway Design Manual*, (VDOT, 2016)
- *A Policy on Geometric Design of Highways and Streets, 6th Edition (*American Association of State Highway and Transportation Officials [AASHTO], 2011) - Referred to as "2011 AASHTO Green Book" from here-on.
- *A policy on Design Standards Interstate System, American Association of State Highway and Transportation Officials, 2005.*

3.3.1 Design Speed and Posted Speed Limits

Based on the functional classification, land use type, and density, I-81 is classified as "Urban Interstate" within the project corridor. For an "Urban Interstate" with a relatively straight geometry and well-spaced interchange locations, 70 mph design speed (DS) is highly desirable. However, the I-81 NB corridor in the study area carries a posted speed limit of 60 mph. A design speed of 65 mph is assumed for the study area based on the anticipated operating speed and posted speed limit. **Figures 3-4** and **3-5** present I-81 Highway Safety Corridor limits and the posted speed limit sign along I-81 NB.

FIGURE 3-4: I-81 HIGHWAY SAFETY CORRIDOR LIMITS

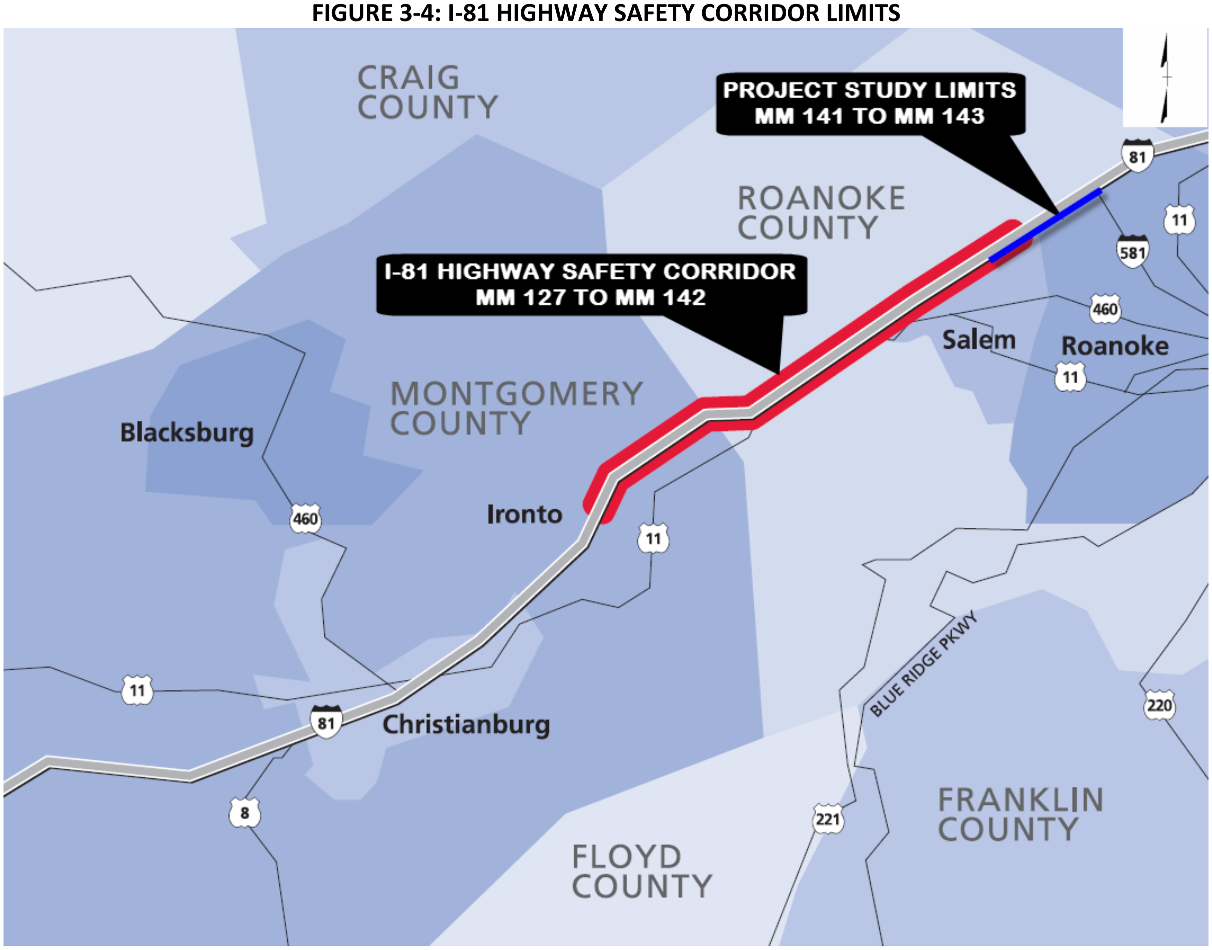


FIGURE 3-5: I-81 NB POSTED SPEED LIMIT

3.3.2 Interchange, Weave Spacing, and Acceleration/Deceleration Lane Length

The study area falls between the N. Electric Rd (Route 419) interchange on the south and I-581 interchange on the north, separated by approximately two miles, which is more than the recommended one-mile spacing between the interchanges in urban areas per the *2011 AASHTO Green Book* guidelines. These guidelines de-emphasize the measurement between the adjacent interchanges and instead recommends focus on design, operational, safety, and signing considerations.

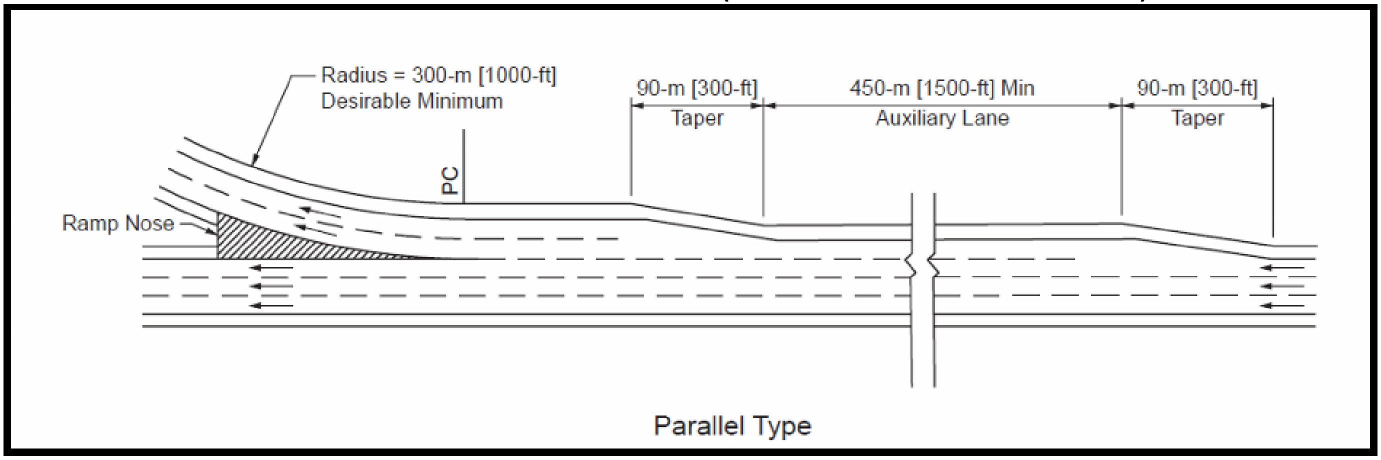
Per the 2011 AASHTO Green Book, a typical design of a parallel-type entrance ramp should have a curve with a radius of 1,000 feet or more and a length of at least 200 feet in advance of the added lane. A short radius curve at the entrance leads motorists to drive directly onto the freeway without using the acceleration lane, which results in undesirable merging operations. An acceleration lane length of at least 1,200 feet plus the taper is desirable whenever the ramp and freeway traffic volumes are approximately equal the design capacity of the merging area.

Ramp entering from the N. Electric Rd interchange (approximately mile marker 141) on the I-81 NB mainline has a posted speed limit of 30 mph. Based on the existing ramp geometry and posted speed limit, a design speed of 35 mph is assumed for the entrance ramp. I-81 NB lanes in this segment have a posted speed limit of 60 mph and hence a design speed of 65 mph is assumed at the merging point. The existing ramp entrance curve has a radius of 392 feet with a total of approximately 1,050 feet of acceleration length and approximately 280 feet of merging taper. This meets the recommended minimum acceleration length of 1,000 feet (for 35 mph design speed on-ramp to 65 mph design speed on mainline) for flat grades of two percent or less.

The ramp departing from I-81 NB mainline connects to I-581 SB with a posted speed limit of 55 mph. Based on the posted speed limit, a design speed of 60 mph is assumed reasonable. The exit curve has a radius of 1,145 feet which currently meets 55 mph design speed with a super-elevation rate of eight percent, per the 2011 AASHTO Green Book.

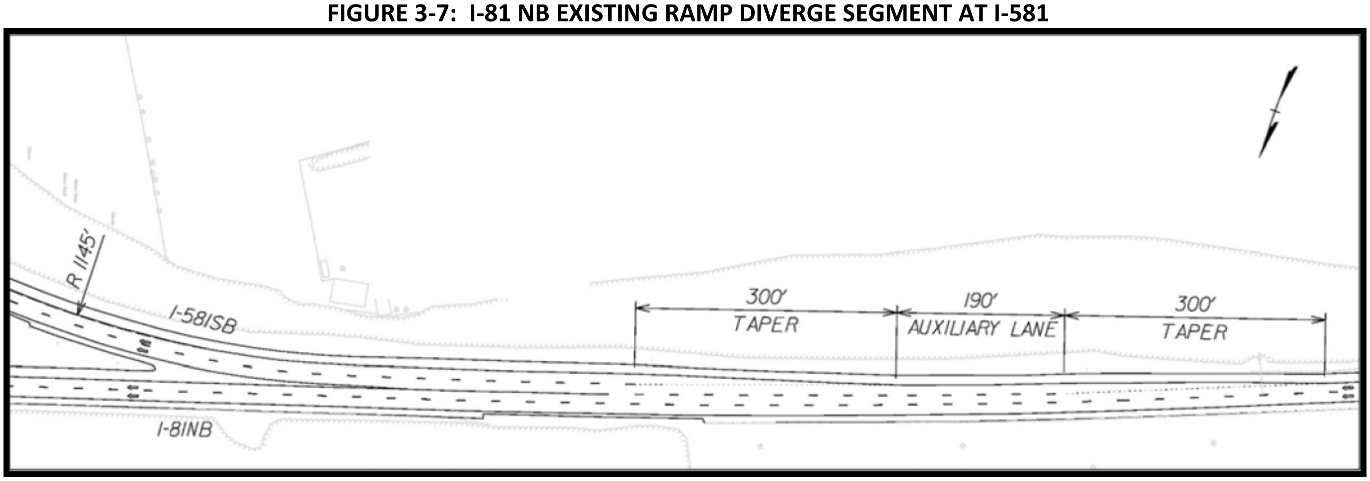
Per the 2011 AASHTO Green Book guidelines, an auxiliary lane of 1,500 feet upstream from the exit is recommended in order to develop the full capacity of a two-lane exit. Parallel-type of two-lane exits offers lane changing opportunities to operate efficiently over a substantial length of the highway. In addition, the guidelines recommend that the total length from the beginning of the first taper to the point where the ramp departs from the right-most through lane of the freeway should range from 2,500 feet for turning volumes of 1,500 vph or less upward to 3,500 feet for turning volumes of 3,000 vph. **Figures 3-6** and **3-7** present two-lane parallel exit ramp geometric guidance as per the 2011 AASHTO Green Book and contrasting field measurements at the diverge-point at I-581, along I-81 NB, respectively.

FIGURE 3-6: TWO LANE PARALLEL EXIT RAMP (SOURCE: 2011 AASHTO GREEN BOOK)



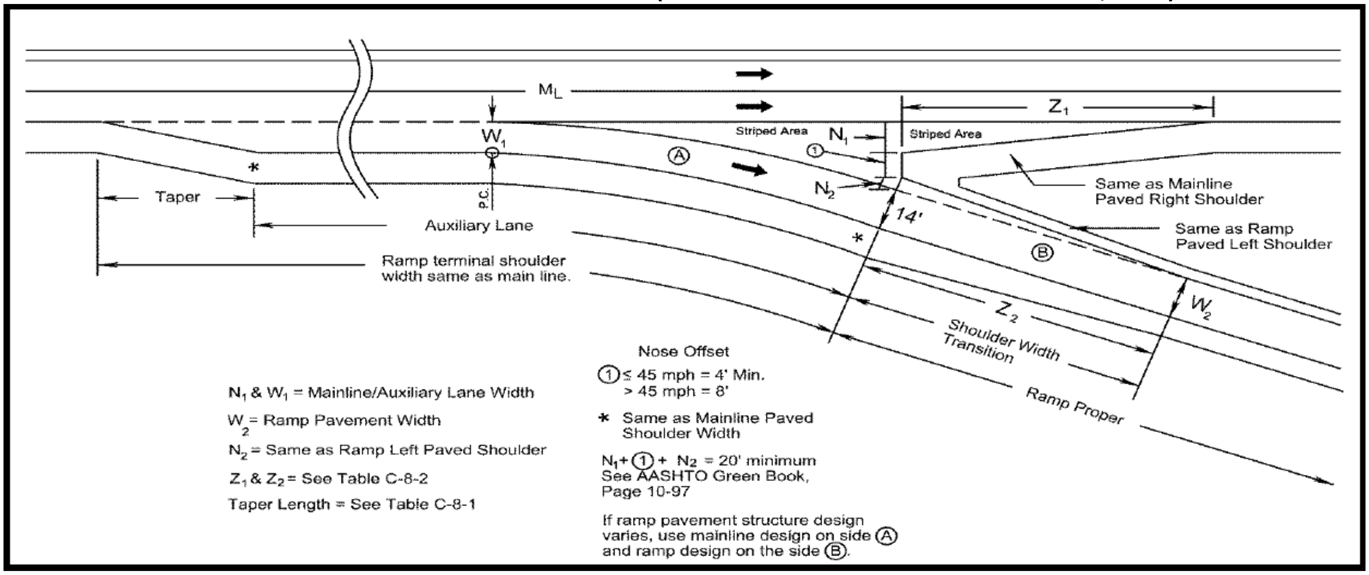
The existing ramp condition analysis revealed a substandard auxiliary lane length of 190 feet exists compared to the 1,500 feet minimum recommendation. The total length of the exit from the beginning of taper to diverge-point measures to be approximately 1,100 feet compared to 2,500 feet minimum recommendation for turning volumes less than 1,500 vph.

FIGURE 3-7: I-81 NB EXISTING RAMP DIVERGE SEGMENT AT I-581



Geometric layout of the gore area is an important part of the exit ramp terminal design. Exit ramps tend to have higher crash rates compared to entrance ramp terminals. The existing gore area at this diverge segment does not currently accommodate recovery area for an errant vehicle. It does not have striping or rumble strips for additional warning or delineation of the gore area, an important feature since this is a high-speed facility that connects system-to-system interchanges. **Figure 3-8** presents the layout of the ramp gore for the exit ramp, per *VDOT Road Design Manual*.

FIGURE 3-8: RAMP GORE FOR EXIT RAMP (SOURCE: VDOT ROAD DESIGN MANUAL, 2016)



3.3.3 Lane and Shoulder Width

As-built plans indicate two 12-foot lanes with a 3-foot paved shoulder on the left and a 10-foot paved shoulder on the right for I-81 NB mainline. Aerial survey information received indicate two 11-foot lanes (for the majority of the project varying between 11 and 11.5 feet) and a 3-4 foot paved shoulder width on the left and a 10-12 foot paved shoulder on the right. This may be attributed to a potential shift in pavement markings or accuracy of the survey data. The existing sub-standard lane width of approximately 11 feet combined with high-truck traffic in this segment has the potential to adversely affect the traffic merge and diverge operations and impacting highway capacity.

Adequate shoulder widths are needed to accommodate stopped vehicles outside the travel way. According to **Appendix A** of the *VDOT Road Design Manual*, a minimum of 4 feet of paved shoulder on the left and a 12 feet paved shoulder on the right should be provided when the mainline is two lanes in each direction. Truck traffic comprises almost one-fifth of the total traffic volume within the study area. The ability to move disabled vehicles (especially a large truck trailer) off the travel lanes can prevent a lane from being closed, which can cause severe congestion and safety problems on these facilities.

A summary of existing lane and paved shoulder widths are presented in **Table 3-4** below.

TABLE 3-4: EXISTING LANE AND SHOULDER WIDTH BASED ON SURVEY INFORMATION

Lane and Project Width	Percentage of Total Project Length
Left Shoulder Width (>4')	32%
Left Shoulder Width (>3' <4')	64%
Left Shoulder Width (<3')	4%
Right Shoulder Width (>12')	25%
Right Shoulder Width (>10' <12')	70%
Right Shoulder Width (<10')	5%
Lane Width (>11' <=11.5')	93%

3.3.4 Summary of Geometric Deficiencies

Overall review of the geometry in the study area indicates several deficiencies associated with mainline and ramp geometric elements that do not meet current AASHTO and VDOT standards. Many of these geometric deficiencies may have isolated impacts, but the effects could compound and impact a broader area when combined with other geometric deficiencies. Substandard lane widths compounded with a substandard diverge segment could lead to increased crash rates (sideswipe and rear-end), reduced free-flow speeds, and off-tracking to adjacent lane or shoulder.

SECTION 4

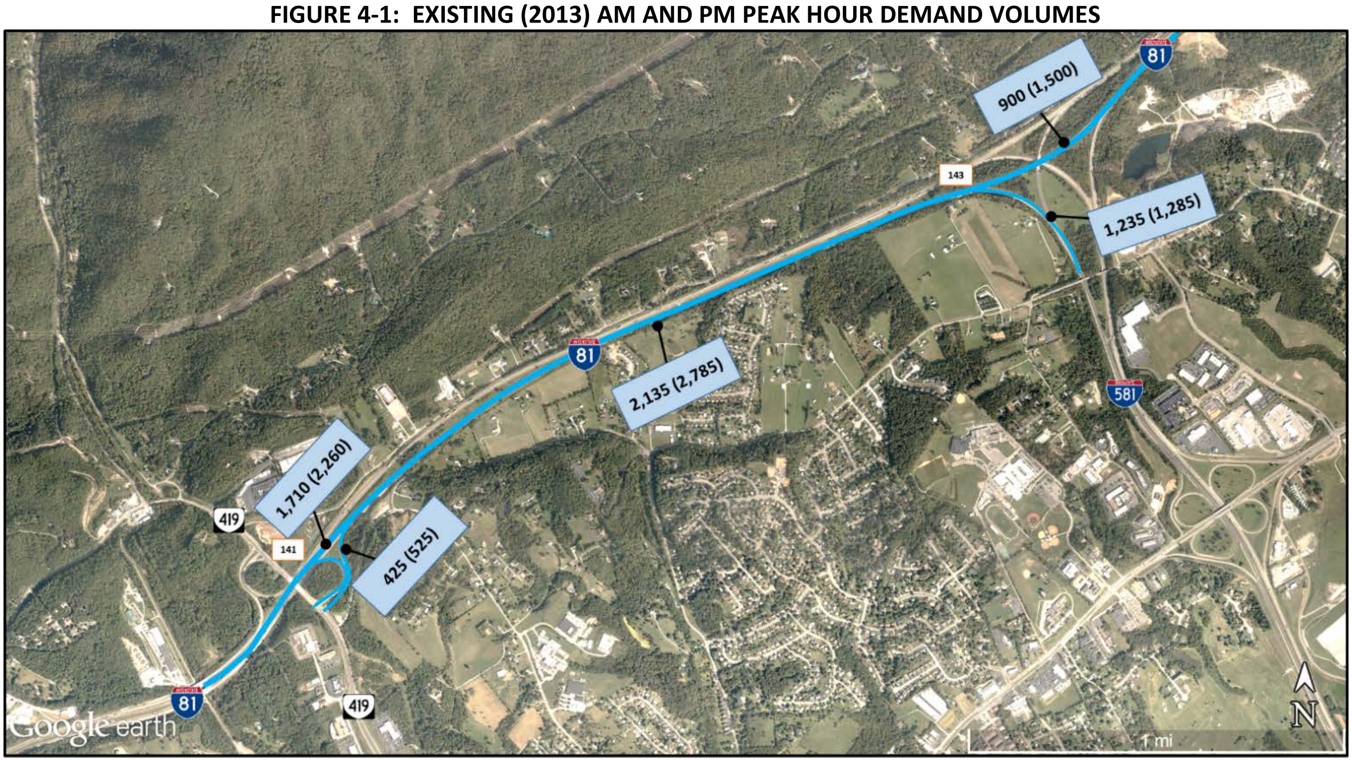
Existing Conditions - Traffic Analysis

2013 was established as the existing analysis year for baseline conditions based on the *I-81 Corridor Improvement Study, Tier II EA*. No new traffic counts were performed, and all the relevant traffic volumes were collected from the *I-81 Corridor Improvement Study, Tier II EA*. Figure 4-1 presents the 2013 existing AM and PM peak hour volumes. INRIX speed data was provided by VDOT. The 2013 existing conditions traffic analysis was conducted using the deterministic *2010 Highway Capacity Manual* (HCM)-based analyses and also supplemented using CORSIM, version 6.3 microsimulation. Supporting documents are included in **Appendix D**.

Traffic operational characteristics were identified by analyzing roadway capacity and traffic operations for the freeway mainline and merge/diverge areas within the study corridor. Highway Capacity Software (HCS) 2010 version 6.1, which is based on *2010 HCM* procedures, was used to assess freeway and ramp operations and to develop operating travel speeds along the study corridor. This software provides a macroscopic view of traffic operations and employs the *2010 HCM* methodologies.

In recognizing the limitations of HCS procedures in oversaturated highway systems in urban areas, additional microsimulation analyses were performed. To address the operational effects upstream and downstream of the study area, CORSIM software was used to provide this microscopic level of traffic operations. CORSIM simulates traffic operations on freeway segments and provides traffic operational data such as density and travel speeds on freeway networks.

FIGURE 4-1: EXISTING (2013) AM AND PM PEAK HOUR DEMAND VOLUMES



AM (PM) – Daily Peak Hour Volume (vph)   xxx Exit Number

4.1 Methodology

Level of Service (LOS), as defined in the HCM, is a qualitative measure describing the operational conditions within a traffic stream and their perception by motorists. The LOS of a roadway or intersection will fall into one of six categories, LOS A through LOS F, with 'A' representing optimum conditions and 'F' representing the worst. Tier II EA study defines acceptable Level of service for the mainline operations on freeway facilities in rural areas with rolling terrain as LOS B, and in urban areas as LOS C. Also it clarifies that the Level of Service standard thresholds derived from 2011 AASHTO Green Book (referenced in the Code of Federal Regulations that provides LOS standards for highways on the National Highway System including I-81 corridor) are intended as guidance only and failure to achieve the threshold does not constitute a non-standard design decision. Tier II EA traffic operational analysis was performed using the above level of service standard in order to compare the alternatives for existing, future No Build, and future Build conditions. For the purpose of this study, LOS C is used as the applicable standard for the study segment (urban freeway) to be consistent with Tier II EA traffic analysis.

4.1.1 Deterministic Highway Capacity Analysis Methodology

The *2010 HCM* defines vehicle density and speed as the measures of effectiveness (MOE) to assess the Level of Service (LOS) of freeway segments. **Table 4-1** lists the ranges for density in passenger cars per mile per lane and corresponding LOS for freeway segments based on *2010 HCM* criteria.

TABLE 4-1: HCM FREEWAY SEGMENT LEVEL OF SERVICE THRESHOLDS

LOS	Freeway Facility LOS Criteria **Density (pc/mi/ln)**		
	Basic Freeway Segments	**Freeway Weaving Segments**	**Freeway Merge and Diverge Segments**
A	≤11	≤10	≤10
B	>11-18	>10-20	>10-20
C	>18-26	>20-28	>20-28
D	>26-35	>28-35	>28-35
E	>35-45	>35	>35
F	>45 demand exceeds capacity	Demand exceeds capacity	Demand exceeds capacity

Source: HCM, 2010 Edition
****pc/mi/ln = passenger cars per mile per lane***

Levels of Congestion
Light to Moderate Traffic *Heavy Traffic*
High Congestion *Severe Congestion*

4.1.2 CORSIM Microsimulation Methodology

CORSIM was used as a primary tool for microsimulation. CORSIM model outputs are reported in terms of vehicles at individual link level for the entire corridor. These were converted to equivalent passenger cars to assess the LOS of freeway segments based on HCM methodology. It should be noted that this study was scoped prior to the implementation of VDOT's Traffic Operations and Safety Analysis Manual, as such this manual was not used as a reference.

In this study, the link-level CORSIM MOEs were grouped by freeway segment types according to the HCM, which classifies freeway links as basic, merge, diverge, or weave segments. However, as mentioned in the calibration section, speeds were aggregated to correspond with equivalent INRIX TMC segments. The following MOEs from CORSIM were used to evaluate the operational conditions of the freeway segments:

- Vehicle throughput (vehicle/hour)
- Vehicle density (vehicle/lane/mile)
- Vehicle speeds (mile/hour)

CORSIM model outputs are reported in terms of vehicles (different from equivalent passenger cars in the HCM) at individual link level for the entire corridor. Due to the difference in density units, each of the HCM-based LOS grade is assigned a qualitative level of traffic congestion for reporting purposes, as listed below:

- HCM densities in the range of LOS A, B, C is equivalent to "Light to Moderate Traffic"
- HCM densities in the range of LOS D is equivalent to "Heavy Traffic"
- HCM densities in the range of LOS E is equivalent to "High Congestion"
- HCM densities in the range of LOS F is equivalent to "Severe Congestion"

It is important to note that given the different detail associated with both traffic analysis methodologies, there is a potential for some inconsistency of results between the HCM analysis and the CORSIM traffic simulation analysis. This is because traffic simulation is able to account upstream and downstream conditions at any roadway segment. These differences are likely to occur where there is congestion and queuing.

4.2 Traffic Simulation Model Calibration

The 2013 existing operational conditions along I-81 NB were evaluated using the microscopic traffic simulation software, CORSIM, version 6.3. The methodology used to calibrate the CORSIM model for this study generally followed the guidelines presented in the Federal Highway Administration (FHWA) publication, *Traffic Analysis Toolbox Volume IV: Guidelines for Applying CORSIM Microsimulation Modeling Software*.

Two MOEs were used in the calibration process:

- Traffic volumes on each freeway link
- Average running speeds

As mentioned previously no additional data collection was done as part of this study. It was agreed that INRIX speeds will be used as one of the thresholds to calibrate the models.

Based on an example of calibration thresholds presented in the *Traffic Analysis Toolbox Volume IV*, the target thresholds for freeway analysis are listed in **Table 4-2**.

TABLE 4-2: MODEL CALIBRATION THRESHOLDS

MOE Criteria	Calibration Acceptable Targets
Hourly Flows, Model versus Observed	
Individual link flow rates (700 to 2,700 vehicles/hour)	Within 15% of field flow rates for at least 85% of all links
Sum of all link flows	Within 5% of sum of all link counts
Average Running Speeds, Model versus Observed	
Average running speeds	Within 15% from the INRIX speeds for at least 85% of all links
GEH Statistic*	
GEH Statistic for individual link flows	GEH < 5 for 85% cases
GEH Statistic for sum of all link flows	GEH < 4 for sum of all link counts

GEH Statistic is a formula used in traffic engineering to compare two sets of traffic volumes, named after the inventor, Geoffrey E. Havers,


The GEH statistics computed as shown below.

$$GEH = \sqrt{\frac{(E-V)^2}{(E+V)/2}}$$

where: E = model estimated volume   V = field count

Two CORSIM models of the study area were developed: 1) AM peak hour, and 2) PM peak hour. The basic CORSIM input variables included:

- Geometric inputs: roadway lane configuration, acceleration/deceleration lanes and grades.
- Traffic volumes: freeway entry volumes, ramp diverge/merge volumes, and percentage of truck volumes at freeway entry links.
- Speed data: interstate links.

There are two types of calibration adjustment parameters: global parameters and link-level parameters. Adjusting global parameters affects all links in the model. Engineering judgment must be exercised in selecting the global parameters. In general, the CORSIM models replicated observed traffic conditions under default global parameters. Reaction distance was changed from 1500 ft. to 3500 ft. for the diverge and merge segments to match the lane positioning behaviour and the signing observed in the field. No further adjustments were made to the CORSIM models.

After the models were developed and refined, CORSIM simulation was run for ten iterations with different random number seeds to capture average network simulation performance. **Table 4-3** shows the results for the AM and PM peak hour existing conditions.

TABLE 4-3: CORSIM ANALYSIS FOR EXISTING YEAR 2013 (AM AND PM PEAK HOURS)

Location	Field Volumes	Simulated Volumes	GEH	Volume Differential	INRIX Speed (mph)	Simulated Speed (mph)	Speed Differential
AM Peak Hour							
I-81 NB Merge segment between N. Electric Rd. (Exit 141) On-Ramp and Exit 143 Off-Ramp	2,135	2,131	< 1	0%	62.0	60.3	3%
I-81 NB Basic segment between N Electric Rd (Exit 141) On-Ramp and Exit 143 Off-Ramp	2,135	2,131	< 1	0%	62.0	56.6	9%
I-81 NB Basic segment between Exit 143 Off-Ramp and Exit 143 On-Ramp	900	899	< 1	0%	63.0	59.3	6%
PM Peak Hour							
I-81 NB Merge segment between N Electric Rd (Exit 141) On-Ramp and Exit 143 Off-Ramp	2,785	2,779	< 1	0%	62.0	57.6	7%
I-81 NB Basic segment between N Electric Rd (Exit 141) On-Ramp and Exit 143 Off-Ramp	2,785	2,779	< 1	0%	62.0	53.2	14%
I-81 NB Basic segment between Exit 143 Off-Ramp and Exit 143 On-Ramp	1,500	1,501	< 1	0%	63.0	56.6	10%

Note: The freeway segments used for calibration process are reflective of the INRIX TMC segments

Calibration is done so CORSIM models replicate field conditions, within an acceptable range. **Table 4-4** below shows the calibration results with respect to the criteria set forth in **Table 4-2**. The results indicate that the model sufficiently replicates results that meet the threshold levels for calibration. The simulated volumes on all links in both AM and PM simulations were within five percent of input volumes and simulated speeds on all links were within 15 percent of INRIX speeds for respective links.

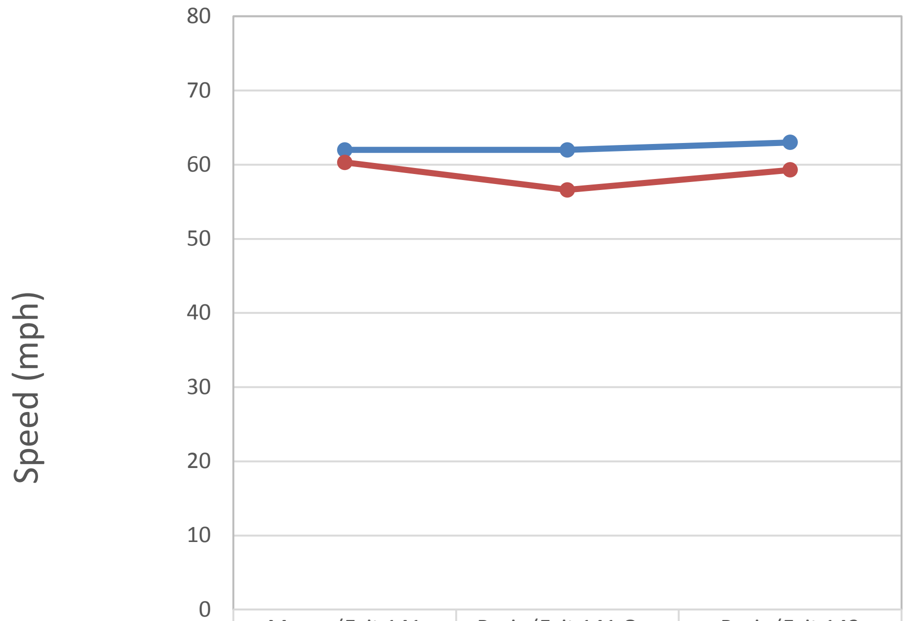
TABLE 4-4: EXISTING CONDITIONS CALIBRATION RESULTS

MOE Criteria	Calibration Results	
	AM Peak	PM Peak
Hourly Flows, Model versus Observed		
Individual link flows (700 to 2,700 vehicles/hour)	Within 5% of field flow for 100% of cases	Within 5% of field flow for 100% of cases
Sum of all link flows	1.0%	1.0%
Average Running Speeds, Model versus Observed		
Average running speeds	Within 15% of the INRIX speeds for 100% of all links	Within 15% of the INRIX speeds for 100% of all links
GEH Statistic*		
GEH Statistic for individual link flows	GEH < 1 for 100% cases	GEH < 1 for 100% cases
GEH Statistic for sum of all link flows	< 1	< 1

Figures 4-2 and **4-3** provide comparisons between INRIX speeds and simulated speeds from CORSIM at the INRIX TMC segment level. It should be noted that instead of the ramp diverge segment, the downstream segment, I-81 NB basic segment between Exit 143 Off-Ramp and Exit 143 On-Ramp, was used to calibrate the model. INRIX data is a spot average speed and does not accurately capture the slowing of vehicles at the ramp influence area. For that reason, the downstream segment was used as one of the TMCs.

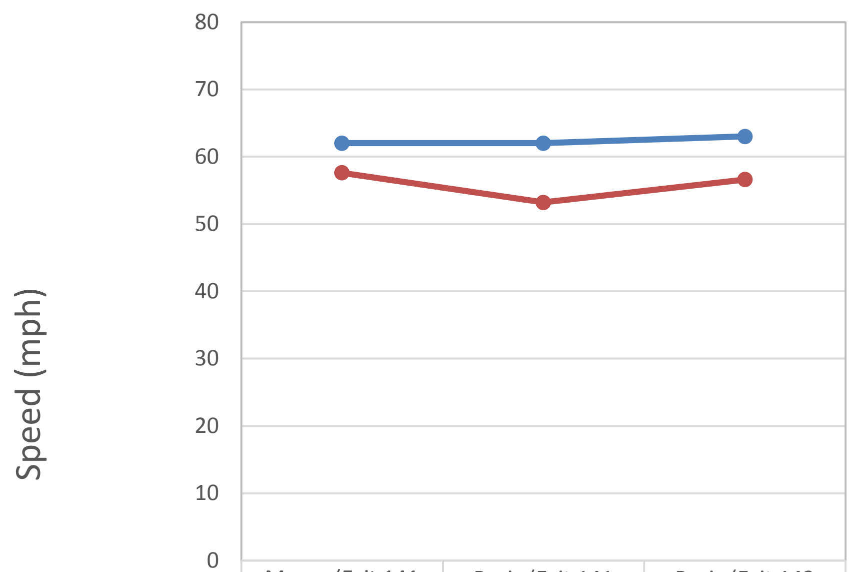
As shown in the speed comparison figures, the CORSIM model replicated average vehicle speeds which closely matched INRIX speed data.


FIGURE 4-2: AM PEAK I-81 NB TRAVEL SPEED COMPARISON



	Merge (Exit 141 On-Ramp and Exit 143 Off-Ramp)	Basic (Exit 141 On-Ramp and Exit 143 Off-Ramp)	Basic (Exit 143 Off-Ramp and Exit 143 On-Ramp)
INRIX Speed (mph)	62	62	63
CORSIM Speed (mph)	60	57	59

FIGURE 4-3: EXISTING - PM PEAK I-81 NB TRAVEL SPEED COMPARISON



	Merge (Exit 141 On-Ramp and Exit 143 Off-Ramp)	Basic (Exit 141 On-Ramp and Exit 143 Off-Ramp)	Basic (Exit 143 Off-Ramp and Exit 143 On-Ramp)
INRIX Speed (mph)	62	62	63
CORSIM Speed (mph)	58	53	57

4.3 Highway Capacity Analysis and Results

Highway Capacity Software (HCS 2010), version 6.1, HCS was used to determine the LOS information of the study segments, along with the MOEs, speed, and density for the existing conditions. The results of the HCS analysis for the existing year 2013 during AM and PM peak hours are summarized in **Table 4-5**.

TABLE 4-5: HCS ANALYSIS FOR EXISTING YEAR 2013 (AM AND PM PEAK HOURS)

Location	Speed (mph)	Density (pc/mi/ln)	LOS
AM Peak Hour			
Merge from N Electric Rd On-Ramp	58.0	20.6	C
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	65.0	21.7	C
Diverge to I-581 southbound (Exit 143) Off-Ramp	54.3	10.9	B
PM Peak Hour			
Merge from N Electric Rd On-Ramp	56.3	27.2	C
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	62.3	29.5	D
Diverge to I-581 southbound (Exit 143) Off-Ramp	54.2	18.3	B

Based on the results in **Table 4-5**, all three study segments operate at acceptable LOS C or better, except for the basic segment between Exit 141 and Exit 143 during PM peak hour that operates at LOS D.

4.4 CORSIM Analysis and Results

Table 4-6 summarizes the CORSIM outputs - throughputs, speeds and densities for the existing year 2013 AM and PM peak hour for each freeway segment within the study corridor. **Figures 4-4** and **4-5** graphically depict existing condition operations during AM and PM peak hours along the study corridor. CORSIM reports densities in veh/mi/ln. Based on the vehicle densities, operations under study corridor are light to moderate condition in both AM and PM peak hour with the exception of the basic segment between Electric Rd (Exit 141) and I-581 southbound (Exit 143) which operated under heavy traffic condition.

TABLE 4-6: CORSIM ANALYSIS FOR 2013 (AM AND PM PEAK HOURS)

Location	Demand	Throughput Volumes	CORSIM Speed (mph)	Density (veh/ln/mi)
AM Peak Hour				
Merge from N. Electric Rd. On-Ramp	2,135	2,131	60.3	13.6
Basic between N. Electric Rd. (Exit 141) and I-581 SB (Exit 143)	2,135	2,131	56.6	18.9
Diverge to I-581 SB (Exit 143) Off-Ramp	2,135	2,131	52.5	15.3
PM Peak Hour				
Merge from N. Electric Rd. On-Ramp	2,785	2,779	57.6	18.5
Basic between N. Electric Rd. (Exit 141) and I-581 SB (Exit 143)	2,785	2,779	53.2	26.2
Diverge to I-581 SB (Exit 143) Off-Ramp	2,785	2,779	50.5	20.6

FIGURE 4-4: EXISTING (2013) AM PEAK HOUR FREEWAY SEGMENTS DENSITY– HCS VS. CORSIM

Legend
- Light to Moderate Traffic
- Heavy Traffic
- High Congestion
- Severe Congestion

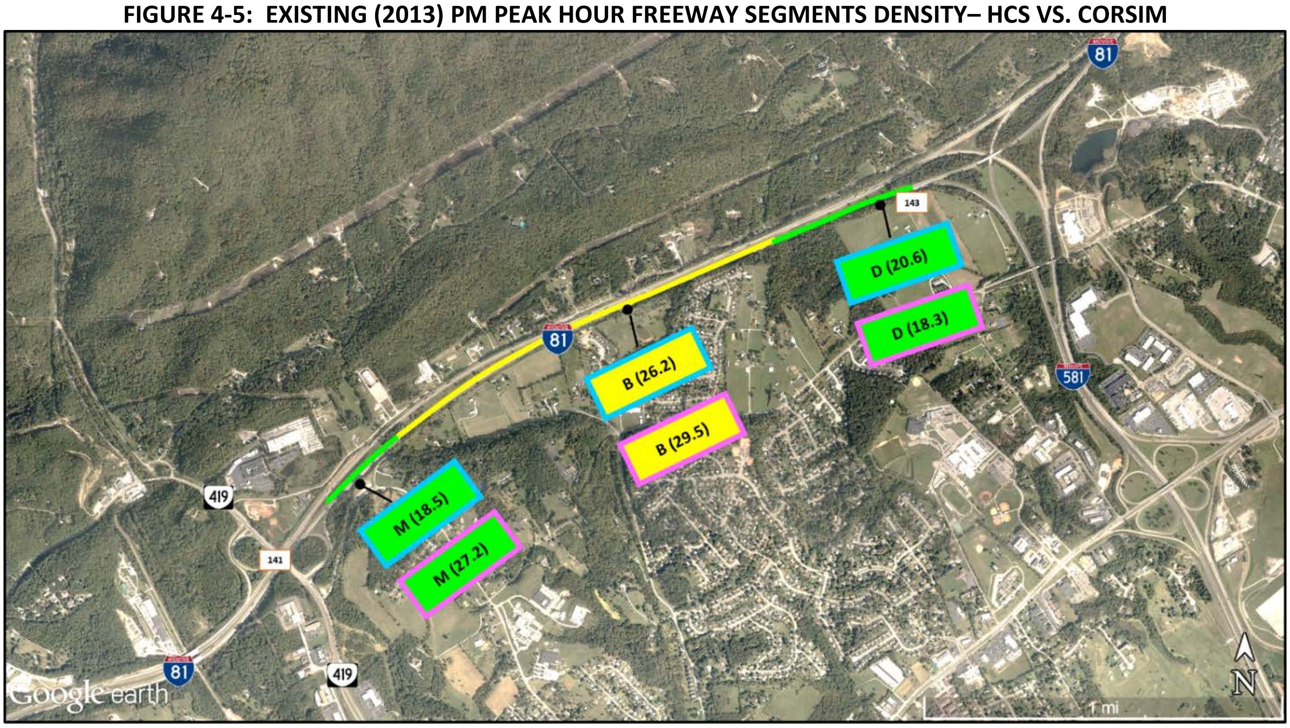
Segment Type
B – Basic
M – Merge
D - Diverge

xxx Exit Number

CORSIM - Density (veh/mi/ln) HCM

Note: Freeway segment color coding is based on CORSIM outputs

FIGURE 4-5: EXISTING (2013) PM PEAK HOUR FREEWAY SEGMENTS DENSITY– HCS VS. CORSIM



Legend
- Light to Moderate Traffic
- Heavy Traffic
- High Congestion
- Severe Congestion

Segment Type
B – Basic
M – Merge
D - Diverge

xxx Exit Number

CORSIM - Density (veh/mi/ln) HCM - Density (pc/mi/ln)

Note: Freeway segment color coding is based on CORSIM outputs

SECTION 5

Future Traffic

5.1 Traffic Growth Rate Assumptions

No new traffic forecasting or modeling was performed as part of this study. The *I-81 Corridor Improvement Study, Tier II EA* was used as the primary source to identify the growth rate to be used for this study to estimate the future traffic volumes. However, the other planning studies in the vicinity of the study area, as mentioned in Section 1.3, were also considered in this process. A growth rate memorandum was developed and presented to VDOT to finalize the assumptions. A growth rate of 2.1 percent per year was used from the *I-81 Corridor Improvement Study, Tier II EA*. Growth was assumed to be linear and did not reflect the effects of compounding. The growth rate memorandum is included in **Appendix E.**

SECTION 6

No-Build Analysis

6.1 2018 and 2040 No-Build Analysis

No-Build conditions were evaluated in HCS and CORSIM using existing geometry and calibrated CORSIM model with estimated 2018 and 2040 traffic volumes by applying a linear growth rate of 2.1%. For this project, it is assumed that year 2018 is the opening year and year 2040 is the design year. The estimated 2018 and 2040 traffic volumes are the same for No-Build and Build conditions. The AM and PM peak hour volumes for 2018 and 2040 are shown in **Figure 6-1** and **Figure 6-2**, respectively. **Appendix F** includes HCS reports and raw CORSIM output.

FIGURE 6-1: 2018 NO-BUILD / BUILD AM AND PM PEAK HOUR DEMAND VOLUMES

AM (PM) – Daily Peak Hour Volume (vph)

xxx Exit Number

HCS version 6.1 was used to determine the LOS information of the study segments, along with the MOEs, speed and density for both 2018 and 2040 No-Build conditions. The results of the HCS analysis for the No-Build conditions during AM and PM peak hours are summarized in **Tables 6-1** and **6-2**, respectively. Based on the results in **Tables 6-1** and **6-2**, for the year 2018, all three study segments operate at acceptable LOS C or better, except for the basic segment between Exit 141 and Exit 143 during PM peak hour that operates at LOS D. However, the operations worsen during 2040 for both AM and PM peak hours when compared to existing and 2018 No-Build conditions. During the PM peak hour, all three study segments would operate at LOS F under 2040 conditions.

FIGURE 6-2: 2040 NO-BUILD / BUILD AM AND PM PEAK HOUR DEMAND VOLUMES

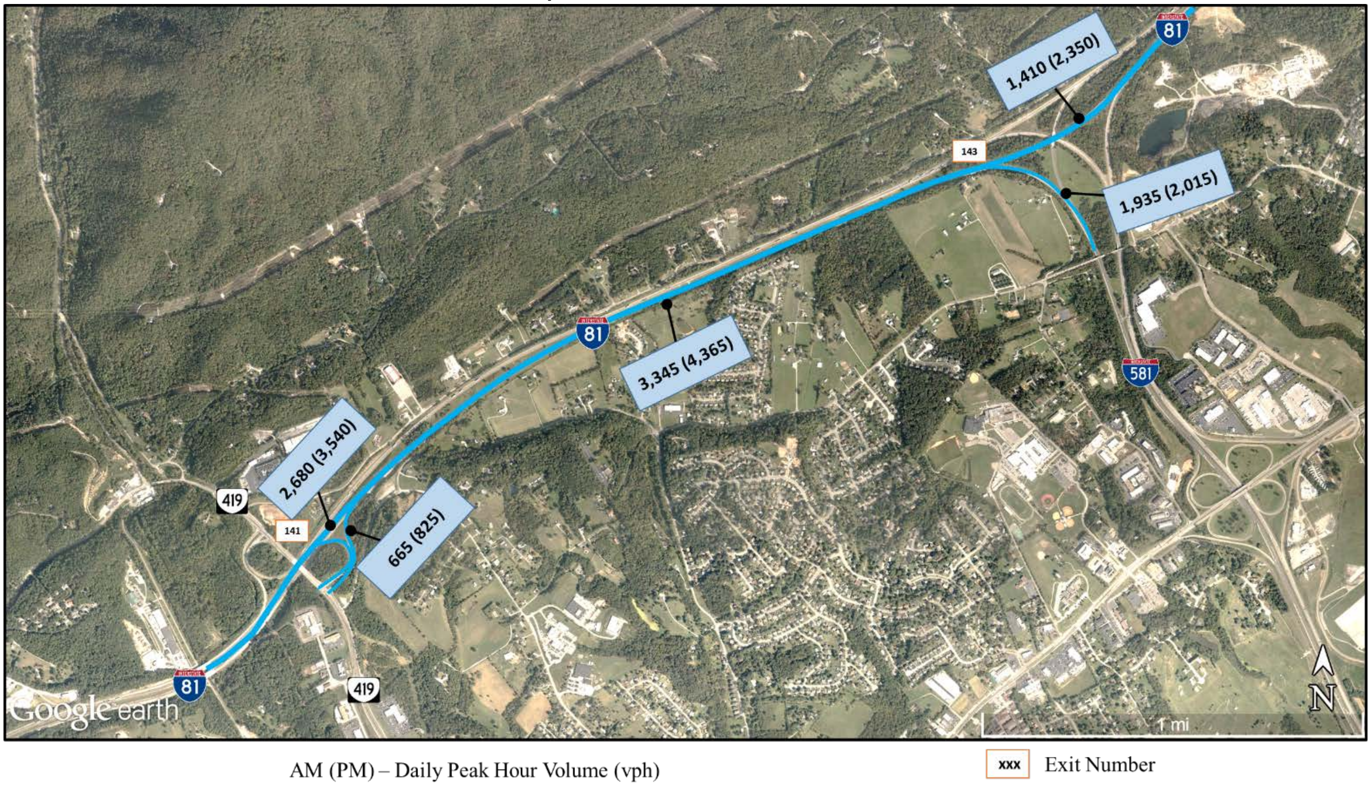


TABLE 6-1: HCS ANALYSIS FOR 2018 NO-BUILD (AM AND PM PEAK HOURS)

Location	HCM Speed (mph)	HCM Density (pc/mi/ln)	LOS
AM Peak Hour			
Merge from N Electric Rd On-Ramp	57.0	22.9	C
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	64.7	24.1	C
Diverge to I-581 southbound (Exit 143) Off-Ramp	54.1	13.5	B
PM Peak Hour			
Merge from N Electric Rd On-Ramp	57.0	30.2	D
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	59.4	34.1	D
Diverge to I-581 southbound (Exit 143) Off-Ramp	54.0	21.6	C

TABLE 6-2: HCS ANALYSIS FOR 2040 NO-BUILD (AM AND PM PEAK HOURS)

Location	HCM Speed (mph)	HCM Density (pc/mi/ln)	LOS
AM Peak Hour			
Merge from N Electric Rd On-Ramp	52.0	32.9	D
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	55.8	39.5	E
Diverge to I-581 southbound (Exit 143) Off-Ramp	52.8	24.7	C
PM Peak Hour			
Merge from N Electric Rd On-Ramp	31.0	41.4	F
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	34.0	84.7	F
Diverge to I-581 southbound (Exit 143) Off-Ramp	52.7	36.2	F

In addition to the HCS analysis, CORSIM analysis was performed for both the 2018 and 2040 No-Build conditions. **Tables 6-3 and 6-4** summarize the results of the CORSIM analysis for AM and PM peak hour for 2018 No-Build and 2040 No-Build conditions, respectively. The calibrated existing conditions CORSIM models served as a base for developing the No-Build CORSIM models.

In 2018, the results indicate that, compared to the existing conditions, densities slightly increase but are still within the same operating threshold.

In 2040, as seen in **Table 6-4**, the operations significantly worsen for both the peak hours. In the AM peak hour the basic segment between N Electric Road and I-581 southbound off-ramp operates under high congestion and the diverge segment operates under heavy traffic condition. The operating speeds along the corridor are between 40 and 55 mph in the AM peak hour.

In the PM peak hour, the merge segment from N. Electric Rd. On-Ramp and the basic segment between N. Electric Rd. and I-581 SB deteriorate significantly. These segments operates under severe congestion. The operating speeds also drop to below 40 mph in most of the segments along the corridor in the PM peak hour.

TABLE 6-3: CORSIM ANALYSIS FOR 2018 NO-BUILD (AM AND PM PEAK HOURS)

Location	Demand	Throughput Volumes	Speed (mph)	Density (veh/ln/mi)
AM PEAK HOUR				
Merge from N. Electric Rd. On-Ramp	2,360	2,354	59.4	15.3
Basic between N. Electric Rd. (Exit 141) and I-581 SB (Exit 143)	2,360	2,354	55.9	21.5
Diverge to I-581 SB (Exit 143) Off-Ramp	2,360	2,354	51.8	17.3
PM PEAK HOUR				
Merge from N. Electric Rd. On-Ramp	3,075	3,062	55.6	21.2
Basic between N. Electric Rd. (Exit 141) and I-581 SB (Exit 143)	3,075	3,062	50.9	30.2
Diverge to I-581 (Exit 143) Off-Ramp	3,075	3,062	48.0	24.0

TABLE 6-4: CORSIM ANALYSIS FOR 2040 NO-BUILD (AM AND PM PEAK HOURS)

Location	Demand	Throughput Volumes	Speed (mph)	Density (veh/ln/mi)
AM PEAK HOUR				
Merge from N. Electric Rd. On-Ramp	3,345	3,332	53.3	24.1
Basic between N. Electric Rd. (Exit 141) and I-581 SB (Exit 143)	3,345	3,332	47.4	35.7
Diverge to I-581 SB (Exit 143) Off-Ramp	3,345	3,332	43.0	29.1
PM PEAK HOUR				
Merge from N. Electric Rd. On-Ramp	4,365	3,860	19.2	77.6
Basic between N. Electric Rd. (Exit 141) and I-581 SB (Exit 143)	4,365	3,860	37.7	52.3
Diverge to I-581 SB (Exit 143) Off-Ramp	4,365	3,860	41.6	34.8

Figures 6-3 and **6-4** graphically present density results along the study corridor for 2018 No-Build AM and PM peak hour conditions from both HCS and CORSIM analysis. Similarly, **Figures 6-5** and **6-6** present density results for 2040 No-Build conditions.

FIGURE 6-3: 2018 NO-BUILD AM PEAK HOUR FREEWAY SEGMENT DENSITY – HCS VS. CORSIM

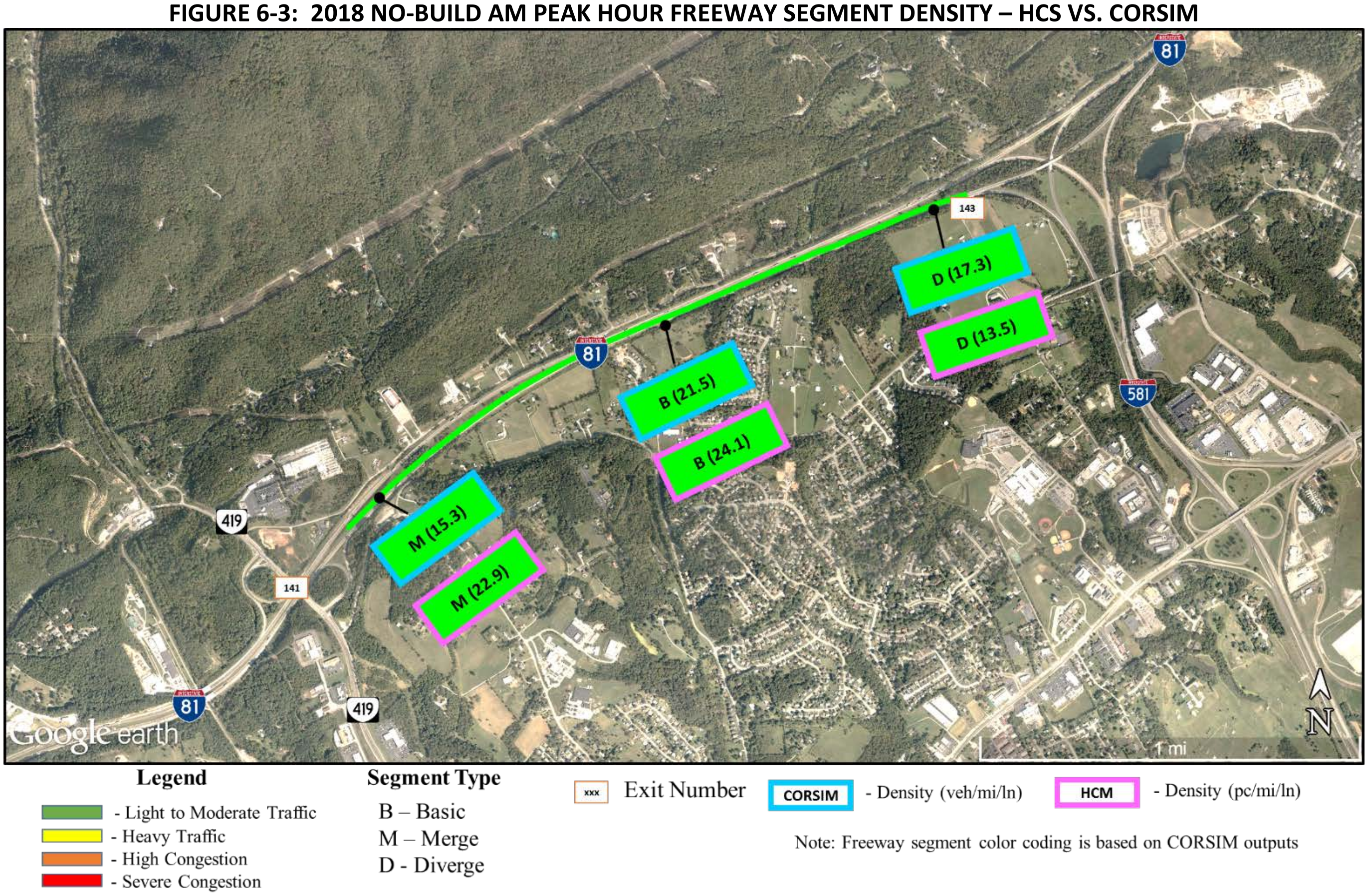


FIGURE 6-4: 2018 NO-BUILD PM PEAK HOUR FREEWAY SEGMENT DENSITY – HCS VS. CORSIM

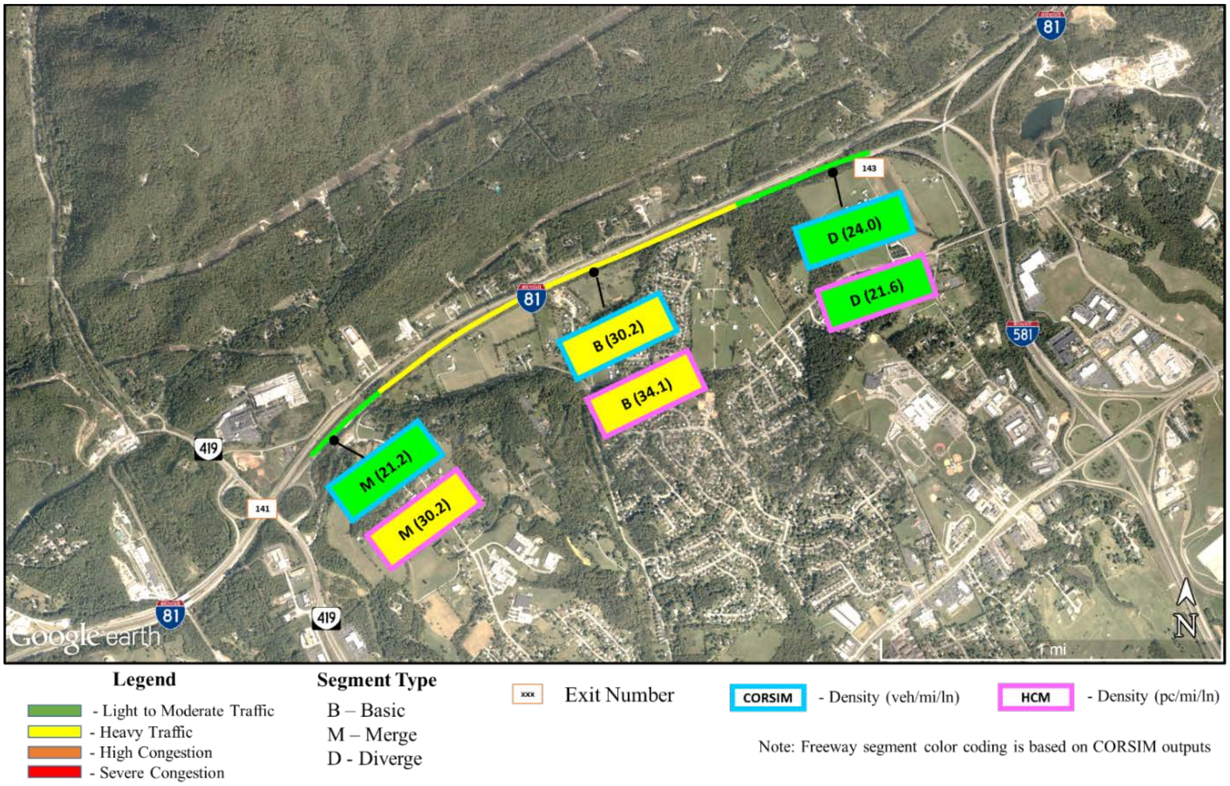


FIGURE 6-5: 2040 NO-BUILD AM PEAK HOUR FREEWAY SEGMENT DENSITY – HCS VS. CORSIM

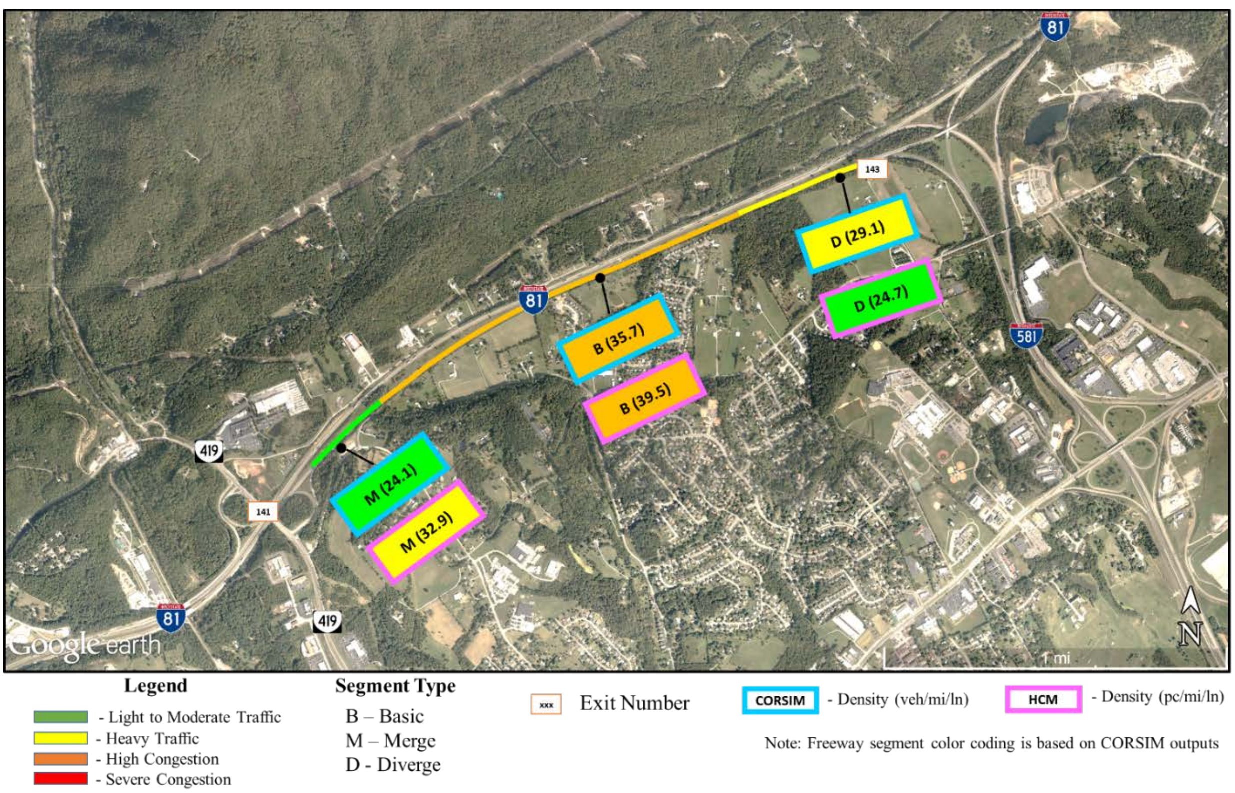
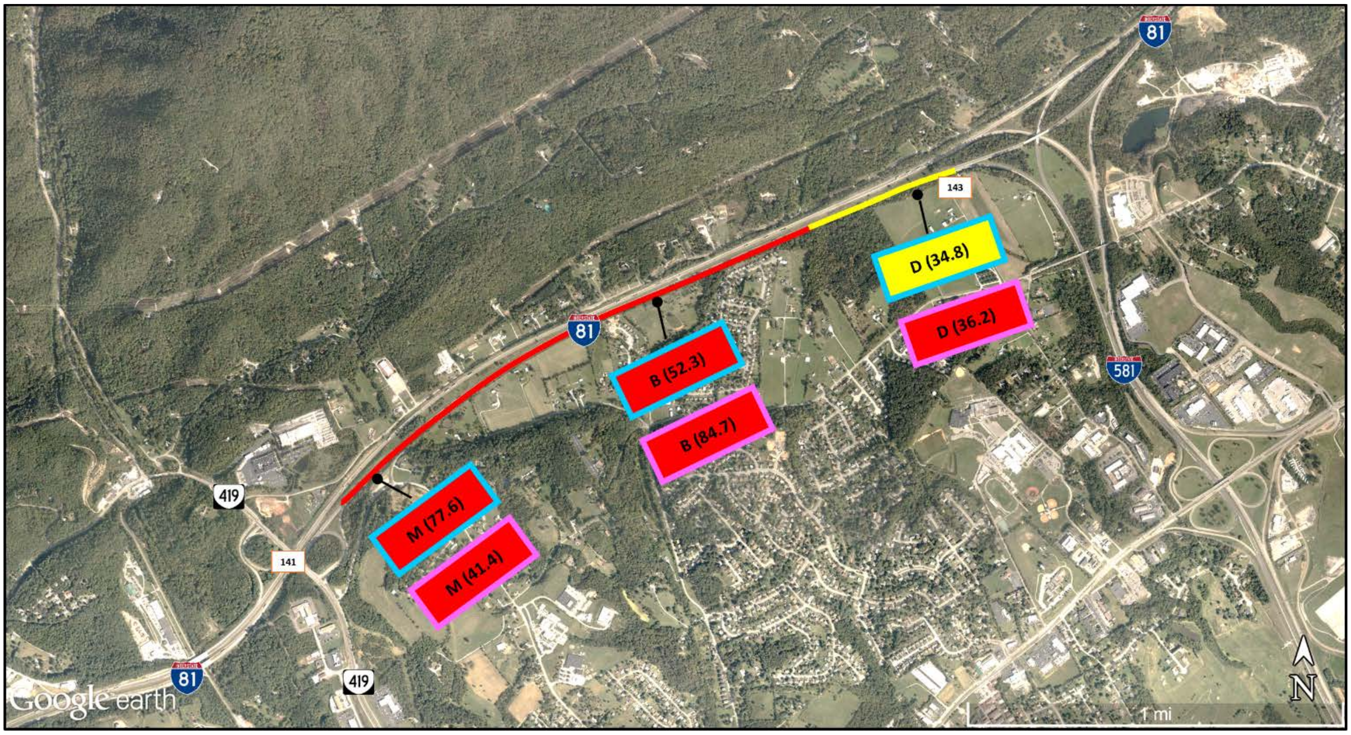


FIGURE 6-6: 2040 NO-BUILD PM PEAK HOUR FREEWAY SEGMENT DENSITY – HCS VS. CORSIM



Legend

- Light to Moderate Traffic
- Heavy Traffic
- High Congestion
- Severe Congestion

Segment Type

B – Basic
M – Merge
D - Diverge

xxx Exit Number

CORSIM - Density (veh/mi/ln)

HCM - Density (pc/mi/ln)

Note: Freeway segment color coding is based on CORSIM outputs

SECTION 7

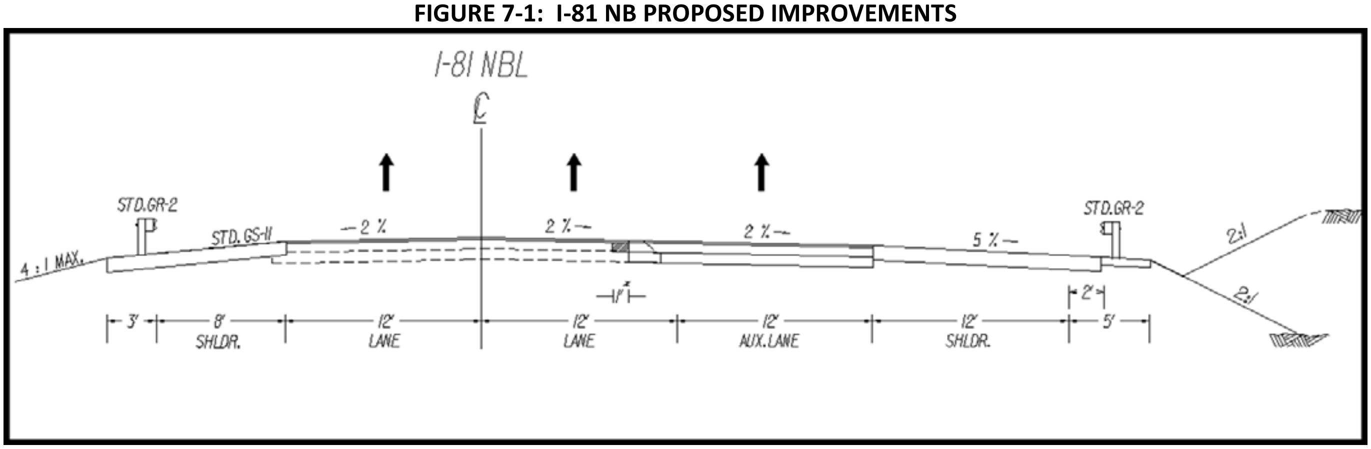
Auxiliary Lane Conceptual Design

7.1 Conceptual Design Development

The study area currently experiences significant northbound traffic congestion from Exit 141 to Exit 143 due to high-traffic volumes including a high percentage of truck traffic. The *I-81 Corridor Improvement Study, Tier I* study and subsequent Tier II study evaluated several alternatives to provide long term capacity improvements to I-81 corridor in order to address existing and future traffic demands by achieving acceptable levels of service. The Tier II study results and recommendations, which includes extended corridor foot-print along I-81 with major investment improvements, are being completed by others and is still pending. A near-term mitigation is being proposed to alleviate the traffic congestion until a major improvement is defined, funded, and constructed.

The proposed improvement, to alleviate congestion and improve safety, consists of the construction of a 12-foot auxiliary lane between the merge-point of the Exit 141 on-ramp and the diverge-point of the Exit 143 exit ramp along I-81 NB. No other alternatives were analyzed as part of this study. Preliminary engineering work is currently underway to study the impacts of widening on the adjacent parcels, construction of sound walls, retaining walls, drainage features including storm water management facilities, signing, and maintenance of traffic. In addition, several existing substandard geometry elements that were previously identified will be corrected including lane width, shoulder width, and exit gore improvements. A planning level cost estimate will be developed as part of the preliminary design efforts to define budget and schedule for the project.

FIGURE 7-1: I-81 NB PROPOSED IMPROVEMENTS



7.2 Signage Layout and Placement

Currently, the interchange signing for the movement from I-81 NB to I-581 SB consist of a cantilever structure identifying Exit 143 approximately one mile downstream (to the north), and then another cantilever structure located at the beginning of the exit lane taper identifying the beginning of Exit 143 with a directional arrow at 45 degrees. Both cantilever structures include route shields for I-581 and Route 220, as well as one or two destinations. The first sign identifies the destination as Downtown Roanoke, and the second sign identifies the destinations as Roanoke and Airport. Freeway guide sign layouts are included in **Appendix G.**

The proposed interchange signing, which considers the auxiliary lane between Route 419 and I-581, follows the guidance in the 2009 *Manual on Uniform Traffic Control Devices* using diagrammatic guide signs for a two-lane exit to the right with an option lane. A series of three overhead signs fully spanning I-81 NB are proposed, resulting in the removal of all existing cantilever structures. The first sign shown in Figure 7-2 will be a single panel structure located approximately one mile upstream from the gore of the exit ramp. The sign panel will include a diagram of the interchange exit showing that the left lane must continue north on I-81 towards Winchester, the right lane must exit to I-581 towards Roanoke, and the center lane has the option to go to either I-581 or I-81. The sign message will also include the physical distance of one mile to the exit ramp.

FIGURE 7-2: I-81/I-581 PROPOSED INTERCHANGE SIGN #1

Figure 7-3 displays the second sign in the series, and will be the same as the first sign, but will not include the physical distance to the exit ramp. The sign will be located between signs one and three of the interchange. Additional engineering is required to determine the exact location based on sight distance to the theoretical gore.

FIGURE 7-3: I-81/I-581 PROPOSED INTERCHANGE SIGN #2

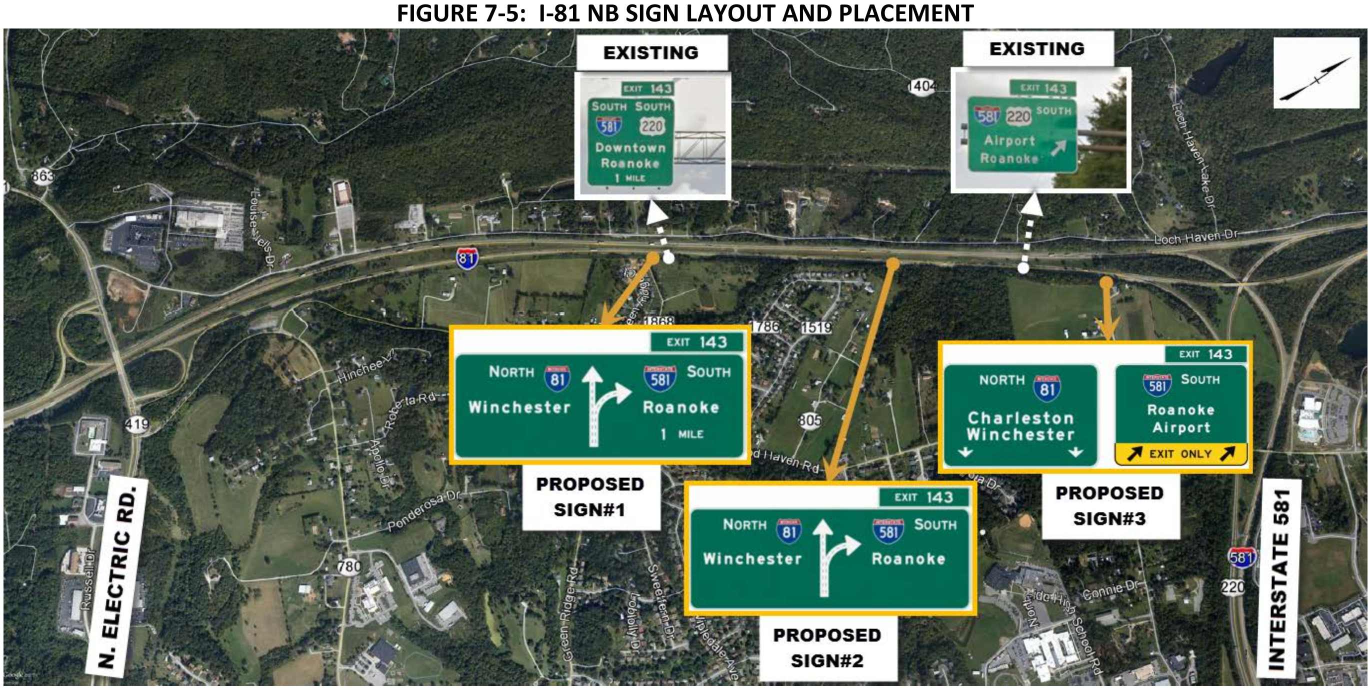
Figure 7-4 displays the final sign in the series, and will include two separate sign panels located on a single overhead structure placed so the sign spans both sides of the physical gore at the exit ramp. The sign on the left will be placed over the mainline lines with a down arrow pointing to each lane and the sign shall include an I-81 route shield and the destinations Winchester and Charleston. The second sign will be placed over the two exit lanes with a right-cocked arrow over each lane and include yellow “exit only” language. Above the exit only portion of the sign, the sign shall include a shield for I-581 and the destination of Roanoke.

FIGURE 7-4: I-81/I-581 PROPOSED INTERCHANGE SIGN #3

The proposed signs only include one destination for each movement on the diagrammatic and no more than two destinations per sign. This is the reason that Charleston was eliminated on the first two signs of the sequence. The word "Downtown" was also dropped to maintain consistency between all signs in the sequence. Finally, the Route 220 shield was dropped so only one route destination was shown for each movement.

Figure 7-5 displays the location of all signs in sequence at the approximate locations along the corridor. Sign 1 is placed approximately one mile in advance of the exit, Sign 3 is placed are the physical gore of the exit, and Sign 2 is shown approximately half way between Sign 1 and Sign 3, where the ultimate location will be based on sight distance to the exit.

FIGURE 7-5: I-81 NB SIGN LAYOUT AND PLACEMENT



SECTION 8

Build Analysis

As discussed in Section 7, a near term mitigation is being proposed to alleviate the traffic congestion until a major improvement is defined, funded, and constructed. The proposed improvement involves the construction of a 12-foot auxiliary lane between the merge-point of the Exit 141 on-ramp and the diverge-point of the Exit 143 exit ramp along I-81 NB. The forecasted 2018 and 2040 traffic volumes are the same for No-Build and Build conditions.

HCS version 6.1 was used to determine the LOS information of the study segments, along with the MOEs, speed and density for both 2018 and 2040 Build conditions. Due to the addition of the proposed auxiliary lane, the merge, basic, and diverge segments in the No-Build scenario will be replaced by a potential weave segment. The HCM 2010 *Chapter 12 Freeway Weaving Segments* outlines a revised recommendation of measuring the weaving distance which is based on volumes and weaving lanes within the segment. The weaving distance is the maximum length at which the capacity of the analyzed segment is equal to basic segment capacity. In other words, it's the maximum length within which the effects of weaving are experienced. If this measured weaving distance is more than the physical distance (typically gore to gore), then the segment operates as a weaving segment. If it is less, then the physical distance is long enough for the weaving effects to dissipate and segment operates as a basic segment. The study team applied the steps outlined in *Chapter 12 of HCM 2010* and based on the volumes and weaving number of lanes, the maximum weaving distance is estimated to be 3,518 feet. With the proposed auxiliary lane, the physical distance between the ramp gores is 9,820 feet. Since the physical distance is higher than the maximum weaving distance, in the Build scenarios, the segment is analyzed as only one basic freeway segment between Exit 141 merge-point to Exit 143 diverge-point. The results of the HCS analysis for the Build conditions during AM and PM peak hours are summarized in **Tables 8-1** and **8-2,** respectively. Based on the results in **Table 8-1**, for the year 2018, the basic segment would operate at an acceptable LOS C or better. However, as shown in **Table 8-2**, the operations worsen during 2040 PM peak hour; the study segment would operate at LOS D. **Appendix H** includes HCS reports.

TABLE 8-1: HCS ANALYSIS FOR 2018 – BUILD (AM AND PM PEAK HOURS)

Location	HCM Speed (mph)	HCM Density (pc/mi/ln)	LOS
AM Peak Hour			
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	65.0	16.0	B
PM Peak Hour			
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	65.0	20.8	C

TABLE 8-2: HCS ANALYSIS FOR 2040 – BUILD (AM AND PM PEAK HOURS)

Location	HCM Speed (mph)	HCM Density (pc/mi/ln)	LOS
AM Peak Hour			
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	64.9	22.7	C
PM Peak Hour			
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	61.2	31.4	D

In addition to the HCS analysis, CORSIM analysis was performed for both the 2018 and 2040 Build conditions. **Tables 8-3** and **8-4** summarize the results of the CORSIM analysis for AM and PM peak hours for the 2018 and 2040 Build conditions, respectively. Build conditions CORSIM models were developed using the No-Build conditions models for the AM and PM peak hours and were used to evaluate the impacts to the corridor as a result of the auxiliary lane improvements.

As mentioned above, the proposed auxiliary lane improvement eliminates the merge and diverge segments. As shown in **Table 8-3**, the basic freeway segment along I-81 NB between N. Electric Rd. and I-581 SB off-ramp now operates under light to moderate traffic condition in both 2018 AM and PM peak hours. The operating speeds are close to free-flow conditions in both AM and PM peak hours in 2018.

In 2040, the basic segment operates under light to moderate traffic in the AM peak hour, and in the PM peak hour, it operates under heavy traffic condition. The operating speed in the AM peak hour is close to free-flow conditions while in the PM it drops slightly below 55 mph.

The results from HCS and CORSIM analysis are very similar for all the study segments during the Build conditions for both AM and PM peak hours.

TABLE 8-3: CORSIM ANALYSIS FOR 2018 - BUILD (AM AND PM PEAK HOURS)

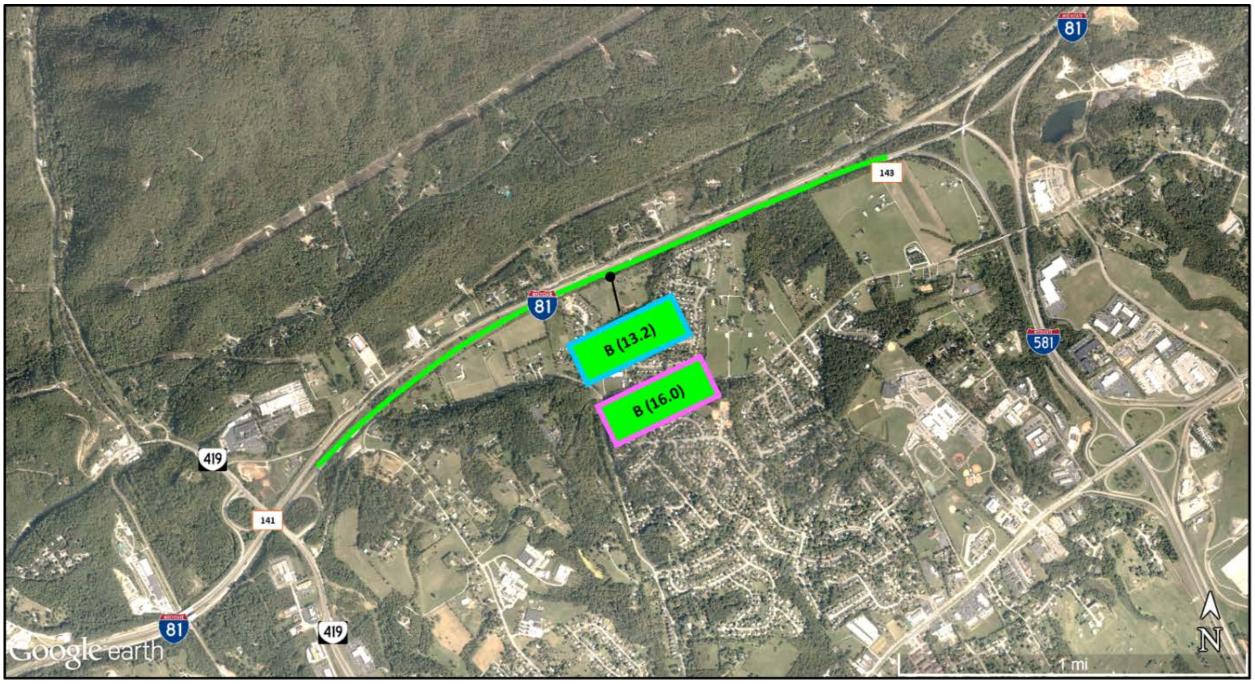
Location	Demand	Throughput Volumes	CORSIM Speed (mph)	Density (veh/ln/mi)
AM PEAK HOUR				
Basic between N. Electric Rd. (Exit 141) and I-581 SB (Exit 143)	2,360	2,353	59.6	13.2
PM PEAK HOUR				
Basic between N. Electric Rd. (Exit 141) and I-581 SB (Exit 143)	3,075	3,069	57.9	17.7

TABLE 8-4: CORSIM ANALYSIS FOR 2040 – BUILD (AM AND PM PEAK HOURS)

Location	Demand	Throughput Volumes	CORSIM Speed (mph)	Density (veh/ln/mi)
AM PEAK HOUR				
Basic between N. Electric Rd. (Exit 141) and I-581 SB (Exit 143)	3,345	3,328	57.2	19.4
PM PEAK HOUR				
Basic between N. Electric Rd. (Exit 141) and I-581 SB (Exit 143)	4,365	4,351	53.9	27.0

The analysis shows that the proposed auxiliary lane is expected to improve LOS. The segments which were operating at a LOS F in the 2040 No-Build scenario will operate at a LOS D or better in the 2018 and 2040 Build scenarios.

FIGURE 8-1: 2018 BUILD AM PEAK HOUR FREEWAY SEGMENT DENSITY – HCS VS. CORSIM



Legend
- Light to Moderate Traffic
- Heavy Traffic
- High Congestion
- Severe Congestion

Segment Type
B – Basic
M – Merge
D - Diverge

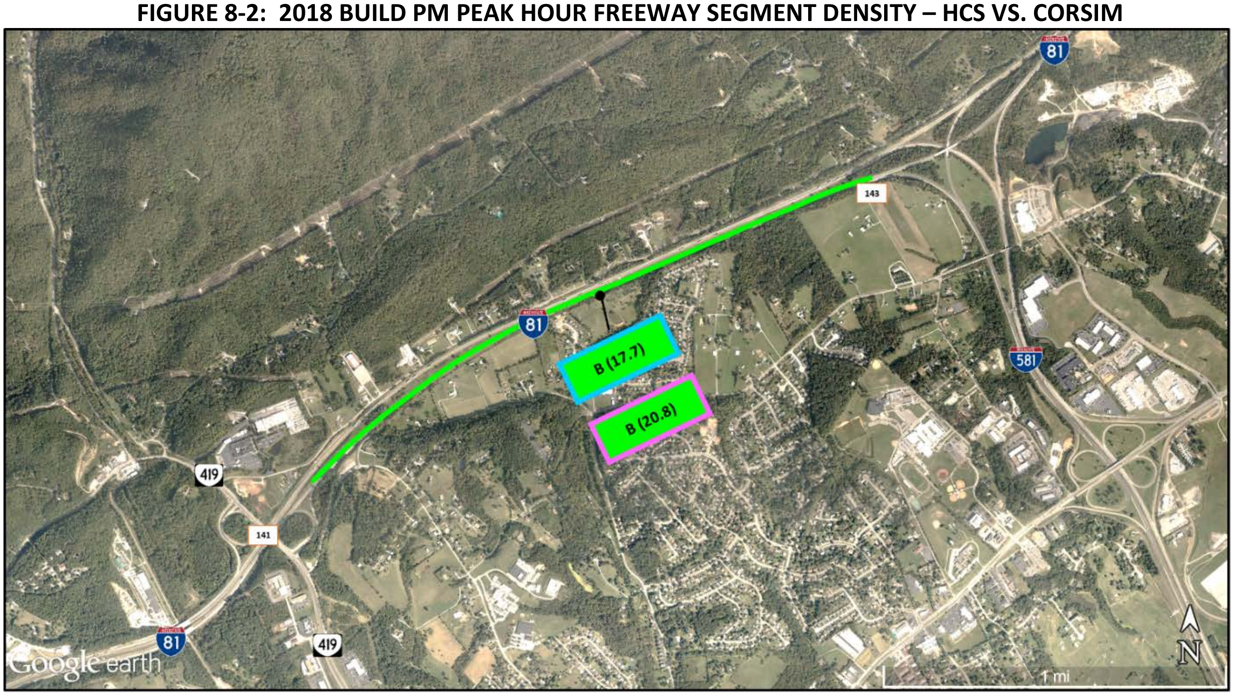
xxx Exit Number

CORSIM - Density (veh/mi/ln)

HCM - Density (pc/mi/ln)

Note: Freeway segment color coding is based on CORSIM outputs

FIGURE 8-2: 2018 BUILD PM PEAK HOUR FREEWAY SEGMENT DENSITY – HCS VS. CORSIM



Legend
- Light to Moderate Traffic
- Heavy Traffic
- High Congestion
- Severe Congestion

Segment Type
B – Basic
M – Merge
D - Diverge

xxx Exit Number

CORSIM - Density (veh/mi/ln)

HCM - Density (pc/mi/ln)

Note: Freeway segment color coding is based on CORSIM outputs

FIGURE 8-3: 2040 BUILD AM PEAK HOUR FREEWAY SEGMENT DENSITY – HCS VS. CORSIM

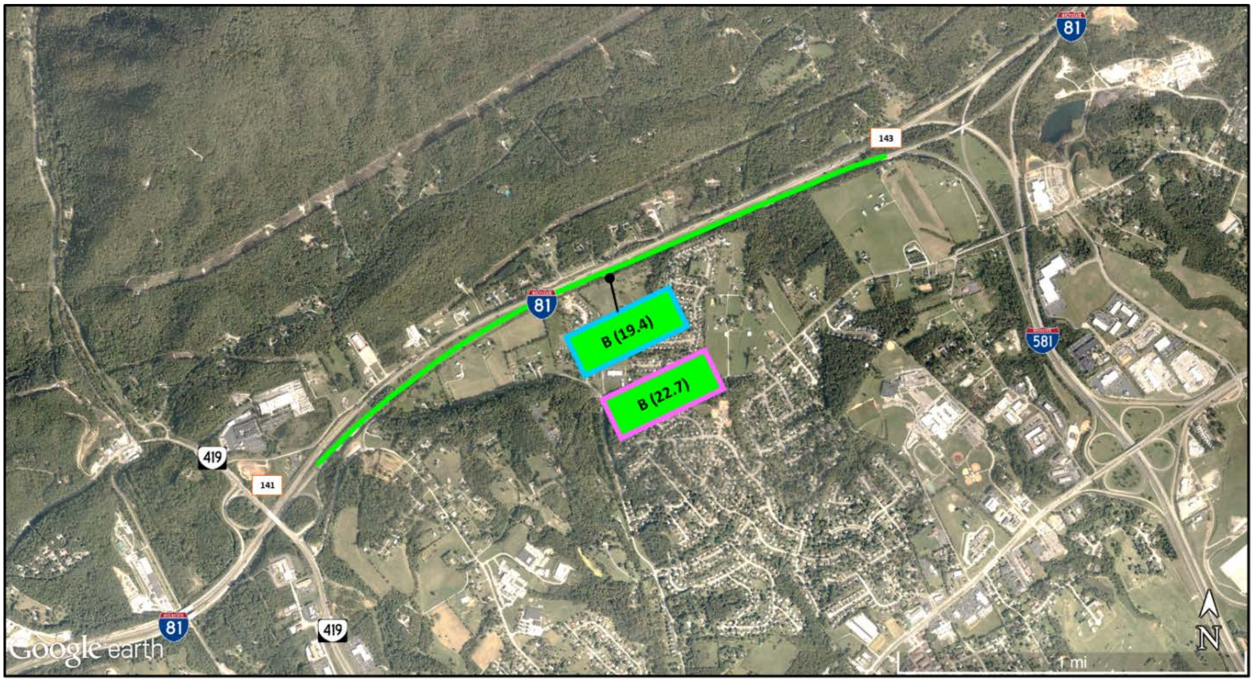
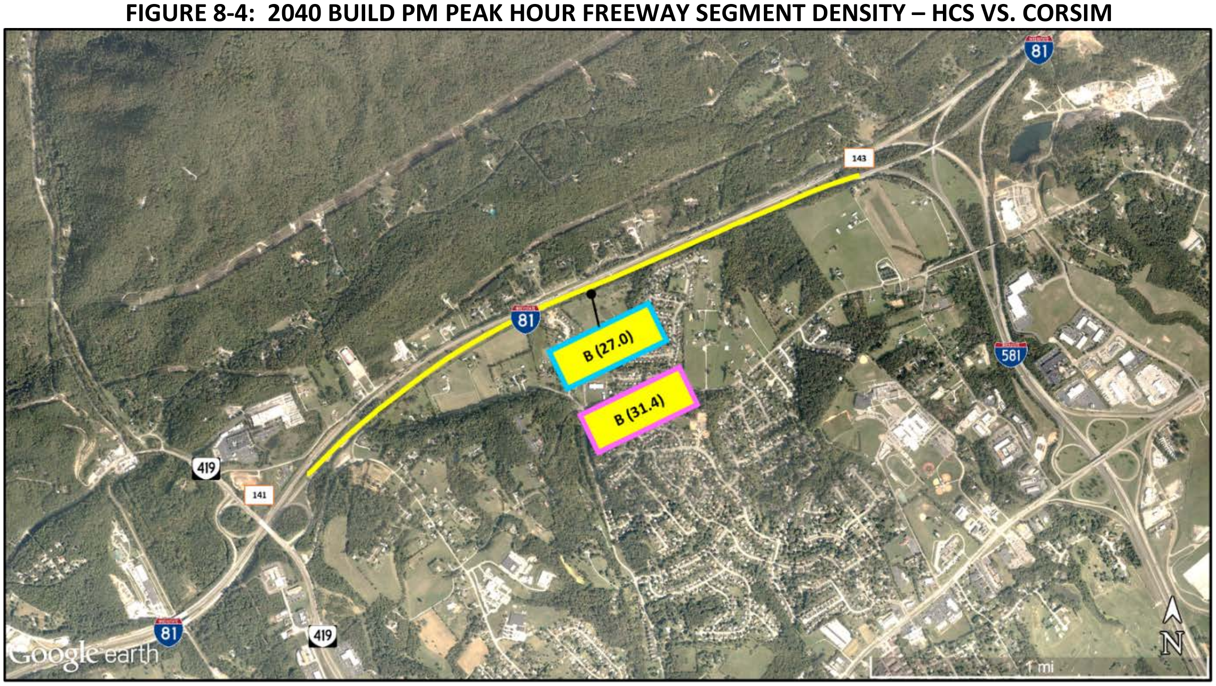


FIGURE 8-4: 2040 BUILD PM PEAK HOUR FREEWAY SEGMENT DENSITY – HCS VS. CORSIM



SECTION 9

Conclusions

The *I-81 Corridor Improvement Study, Tier II EA* study evaluated two alternatives for the build condition traffic analysis that involves construction of no more than two general purpose lanes in each direction. The 2040 Build condition operational analysis results, conducted as part of that study, indicate that two additional lanes are needed for both NB & SB directions to fully meet the AASHTO level of service guidance criteria for the entire 32 mile corridor. Similarly, addition of one lane in each direction indicated that the current project segment (between Exit 141 and Exit 143), in addition to five other traffic analysis segments, do not meet the level of service guidance criteria. The study results and recommendations, which includes a broad range of alternatives and major investment improvements, are being completed by others and is still pending.

In recognition of the above, a localized improvement to add a 12 feet auxiliary lane within the study limits was proposed to alleviate the traffic congestion until a major improvement is defined, funded, and constructed. This will provide additional capacity within the study limits to allow for safer merge movements between the exits. This improvement is considered a near-term mitigation, and not a long-term capacity improvement. Diverge segment at Exit 143 is proposed to be a major diverge with the middle lane being shared by mainline through and off ramp volumes. This proposed change will improve both the flow of traffic and safety as it reduces weaving conflict since the mainline volume does not have to weave with on-ramp volume to exit at I-581. An operational analysis was performed for existing conditions (2013), opening year conditions (2018), design year conditions (2040). The analysis also included 2018 and 2040 No-Build conditions, in order to set a baseline against which the effectiveness of the proposed improvements could be measured. The analysis compared average weekday AM and PM peak hour traffic conditions. In most cases, modest to significant improvements in operational performance could be seen (using measures such as level of service, speed, and density). **Table 9-1** shows the summary of the HCS and CORSIM analysis.

In addition to the operational analysis, VDOT performed a crash data analysis for the study area using the five most recent years of crash reports and data from January 1, 2011 through December 31, 2015, from mile marker 141.8 to 143.8. Crash rate results indicate that the overall crash rate within the study area is recorded to be higher than the Salem district average crash rate for 2014, and lower than the statewide average for the interstates in the same year. For a 5-year time period there were a total of 76 crashes, out of which 60 crashes were property damage only and no fatal crashes. Based on the FHWA Crash Modification Factor (CMF) clearinghouse, the installation of an continuous auxiliary lane between an entrance ramp and an exit ramp results in a 21 percent reduction in total crashes, i.e. 0.79 crash reduction factor. It is anticipated that implementation of this project type will reduce the total crashes over a 5-year time period by approximately 16 crashes.

Although this project will not solve all the recurring capacity issues along this stretch of the corridor, based on the analysis, the addition of the auxiliary lane as proposed in this study is recommended to serve as a near-term mitigation measure.

TABLE 9-1: SUMMARY OF RESULTS OF HCS AND CORSIM ANALYSIS FOR EXISTING, NO-BUILD AND BUILD CONDITIONS (AM AND PM PEAK HOURS)

Location	HCS Results			CORSIM Results	
	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (veh/ln/mi)
2013 Existing					
AM Peak Hour					
Merge from N Electric Rd On-Ramp	58.0	20.6	C	60.3	13.6
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	65.0	21.7	C	56.6	18.9
Diverge to I-581 southbound (Exit 143) Off-Ramp	54.3	10.9	B	52.5	15.3
PM Peak Hour					
Merge from N Electric Rd On-Ramp	56.3	27.2	C	57.6	18.5
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	62.3	29.5	D	53.2	26.2
Diverge to I-581 southbound (Exit 143) Off-Ramp	54.2	18.3	B	50.5	20.6
2018 No-Build					
AM Peak Hour					
Merge from N Electric Rd On-Ramp	57.0	22.9	C	59.4	15.3
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	64.7	24.1	C	55.9	21.5
Diverge to I-581 southbound (Exit 143) Off-Ramp	54.1	13.5	B	51.8	17.3
PM Peak Hour					
Merge from N Electric Rd On-Ramp	57.0	30.2	D	55.6	21.2
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	59.4	34.1	D	50.9	30.2
Diverge to I-581 southbound (Exit 143) Off-Ramp	54.0	21.6	C	48.0	24.0
2040 No-Build					
AM Peak Hour					
Merge from N Electric Rd On-Ramp	52.0	32.9	D	53.3	24.1
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	55.8	39.5	E	47.4	35.7
Diverge to I-581 southbound (Exit 143) Off-Ramp	52.8	24.7	C	43.0	29.1
PM Peak Hour					
Merge from N Electric Rd On-Ramp	31.0	41.4	F	31.0	77.6
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	34.0	84.7	F	34.0	52.3

Location	HCS Results			CORSIM Results	
	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (veh/ln/mi)
Diverge to I-581 southbound (Exit 143) Off-Ramp	52.7	36.2	F	52.7	34.8
2018 Build					
AM Peak Hour					
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	65.0	16.0	B	59.6	13.2
PM Peak Hour					
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	65.0	20.8	C	57.9	17.7
2040 Build					
AM Peak Hour					
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	64.9	22.7	C	57.2	19.4
PM Peak Hour					
Basic between N Electric Rd (Exit 141) and I-581 southbound (Exit 143)	61.2	31.4	D	53.9	27.0