TRAFFIC STUDY FOR
ROUTE 28 (CATLETT ROAD) IMPROVEMENTS

Fauquier County, Virginia

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EXECUTIVE SUMMARY

This report presents results of a traffic and safety study conducted for the Route 28 (Catlett Road) improvement project between US 29 and US 17 in Fauquier County, Virginia. The intent of the project is to provide safety and operational improvements along the corridor and intersections by constructing dedicated left and right turn lanes and realigning the roadway to standardize horizontal and vertical curves. The planned improvements include the following:

- Construct westbound dual left turn lanes and a through lane to replace the shared through/left lane at the intersection of Route 28 and US 29.
- Convert the existing eastbound single left turn lane at the intersection of Route 28 and US 17 to a dual left turn lane.
- Construct dedicated left and right turn lanes at the intersection of Route 28 at Schoolhouse Road.
- Convert access to Lucky Hill Road to right-in/right-out only and construct an acceleration lane on eastbound Route 28 for northbound right turning vehicles.
- Provide storage lengths for the dedicated left and right turn lanes on Route 28 based on the queuing analysis for the future conditions.

The project extends from US 29 (James Madison Highway) to the west and US 17 (Marsh Road) to the east. Within these limits, the corridor includes the following eight study intersections:

1. Route 28 at US 29 (James Madison Highway) - signalized
2. Route 28 at Lucky Hill Road
3. Route 28 at Whipkey Drive
4. Route 28 at Southcoate Village Drive
5. Route 28 at Edgewood Drive
6. Route 28 at Schoolhouse Road
7. Route 28 at Oak Shade Road
8. Route 28 at US 17 (Marsh Road) - signalized

Only the intersections at both ends of the projects are signalized. All other intersections are controlled by stop signs on the side streets.

The project is expected to be advertised in 2018 and completed in 2020. The design year is 2043, or 25 years past the advertisement date. Capacity and queuing analyses were conducted for baseline conditions (2014), build out year conditions (2020), and design year conditions (2043). The results are summarized below.

2014 Existing (Baseline) Conditions

A safety analysis was conducted based on the three-year crash history (June, 2011 to May, 2014). A total of 53 crashes were reported in this period, with 38 injuries and no fatalities. Rear end crashes are the most prevalent along the study corridor, with a higher frequency at or adjacent to the following intersections:

1. Route 28 at US 29
2. Route 28 at US 17
3. Route 28 at Schoolhouse Road

The proposed roadway improvements are expected to improve safety by reducing congestion. In addition, some relatively short-term, lower cost safety improvements that involve signing and pavement marking upgrades are proposed at horizontal curves along Route 28.

The capacity analyses show that currently the unsignalized intersections along the corridor operate at acceptable levels of service (LOS) D or better, but the two signalized intersections on either end of the project operate with multiple movements at LOS E or F. The westbound approach on the Route 28 at US 29 intersection operates at LOS F in the PM peak period with long queues. Multiple movements at the Route 28 at US 17 operates at LOS E or F in both AM and PM peak periods.

2020 Build Out Year

With the proposed roadway improvements at build out, the benefits in traffic operation are as follows:

- With the construction of dual left turn lanes at Route 28 and US 29, all movements improve to D or better, and westbound queues are significantly reduced.
- With the construction of dual left turn lanes at Route 28 and US 17 intersection and signal timings optimization, the intersection operation improves with an eastbound and westbound through traffic delay reduction of 0.5 - 1 min/veh. However, the intersection still operates at a poor service level of LOS E in the PM peak period.

2043 Design Year

Even with the proposed improvements, both signalized intersections are expected to operate with overall service levels of E or F. These two intersections would require major geometric redesign to provide enough capacity for the expected future traffic volumes. The individual turning movements with poor service levels of E or F in 2043 are listed as follows:

- Route 28 at US 29:
    - AM Peak - Eastbound approach operates at LOS E.
    - PM Peak - Several individual turning movements operate at LOS E or F.
- Route 28 at Southcoate Village Drive: southbound approach operates at LOS E in the PM Peak.
- Route 28 at Schoolhouse Road: northbound approach operates at LOS E in the PM Peak.
- Route 28 at Oak Shade Road: southbound approach operates at LOS F in the AM and PM Peak.
- Route 28 at US 17: several movements operate at LOS E or F in both the AM and PM peak periods.

A queuing analysis was performed for 2043 traffic conditions to determine the required storage and taper lengths at each intersection. All turn lanes were designed to accommodate the expected queue lengths in the design year.

Turn lane warrants were evaluated for the intersection of Route 28 at Schoolhouse Road. All other intersections already provide dedicated turn lanes. As a result, dedicated left and right turn lanes are warranted at this intersection for both 2020 build out and 2043 design year traffic conditions.

The arterial level of service analysis indicates that two-lane Route 28 has an adequate capacity to operate at LOS D or better for the existing and future traffic conditions, however improvements are needed at the signalized intersections on both ends of the corridor.

Summary

The capacity and queuing analyses results for the build out year (2020) and design year (2043) conditions show that the proposed improvements considerably improve traffic operations along Route 28. Without the project improvements, several movements at the study intersections are expected to operate with excessive delays and long queues.

For 2043 no build conditions, the westbound approach at the intersection of Route 28 and US 29 operates with 10 min/veh of delay, and at the intersection of Route 28 and US 17, the eastbound left turn operates with 4 min/veh of delay. While these two intersections are still expected to operate at LOS E or F even with the proposed improvements, the delays are significantly reduced. Major geometric redesign outside the scope of this roadway project, such as an interchange, would be required to bring the service levels to acceptable service levels of D or better.

INTRODUCTION

This traffic engineering study analyzes traffic operations for approximately two miles of Route 28 (Catlett Road) between US 29/15 (James Madison Highway) and US 17 (Marsh Road) in Fauquier County, Virginia. Although Route 28 is categorized as a north-south roadway, it 28 is referred as east-west for the purpose of this report, and all references to direction are consistent with this assumption. The proposed roadway improvements include the following:

- Construct westbound dual left turn lanes and a through lane to replace the shared through/left lane at the intersection of Route 28 and US 29.
- Convert the existing eastbound single left turn lane at the intersection of Route 28 and US 17 to a dual left turn lane.
- Construct dedicated left and right turn lanes at the intersection of Route 28 at Schoolhouse Road.
- Convert access to Lucky Hill Road to right-in/right-out only and construct an acceleration lane on eastbound Route 28 for northbound right turning vehicles.
- Provide storage lengths for the dedicated left and right turn lanes on Route 28 based on the queuing analysis for the future conditions.

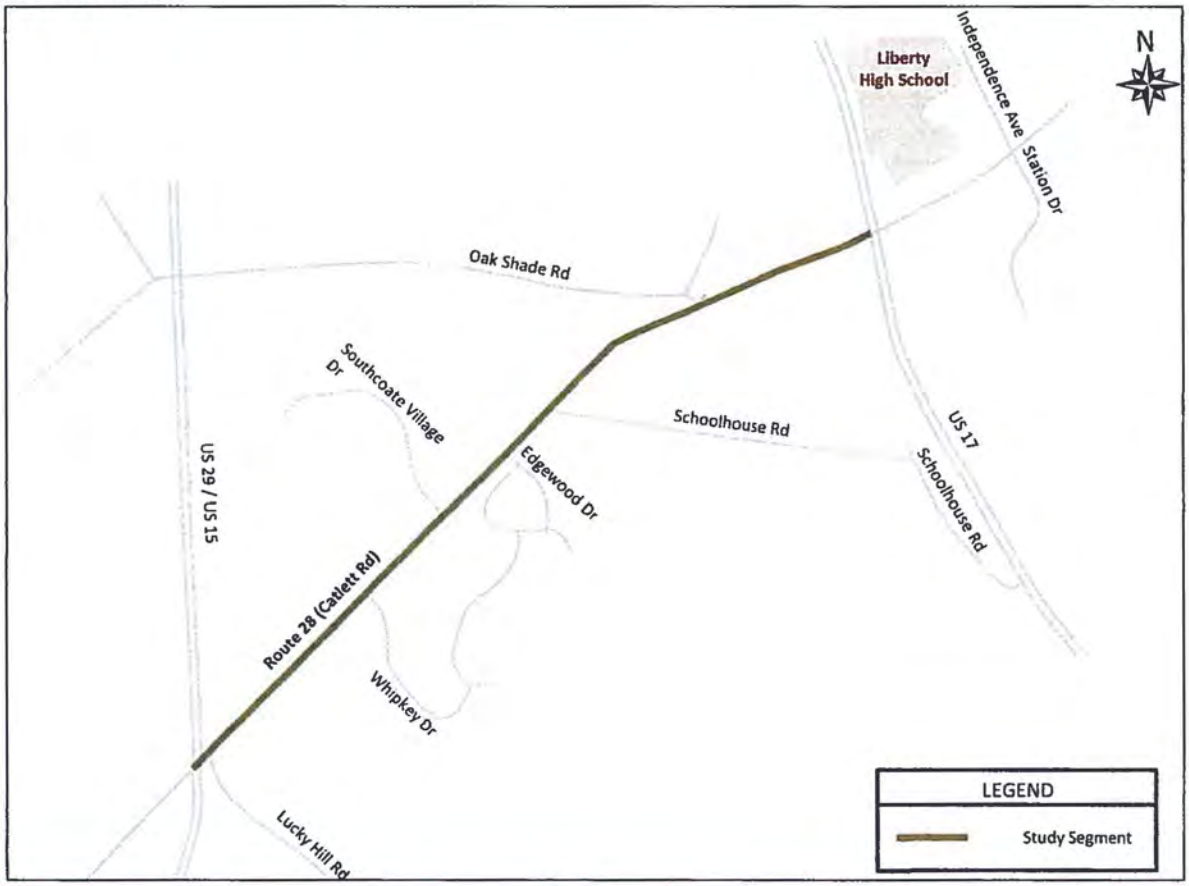
The project advertisement date is 2018 and construction is expected to be completed in 2020. The project design year is 2043, or 25 years beyond the advertisement date. This design year based on 25 years instead of 22 years allows for some flexibility should the project not be advertised by 2018. Capacity and queuing analyses were conducted for the existing baseline conditions (2014), build out year conditions (2020) and design year conditions (2043).

The scope of this study includes the following tasks:

- Collect AM and PM peak period existing year (2014) turning movement counts at the eight study intersections.
- Collect 24-hour counts at 4 locations along Route 28.
- Conduct field inventory for the existing roadway geometry.
- Develop future traffic projections for the build out year (2020) and design year (2043).
- Conduct capacity analyses using Synchro 8.0 for the existing, build out, and design years.
- Analyze three-year crash history data.
- Evaluate turn lane warrants for the Route 28 at Schoolhouse Road intersection.
- Calculate left and right turn lane storage length requirements based on queuing analysis results.
- Complete traffic study documenting data collection, analyses, methodology, conclusions, and recommendations.

This report provides a discussion of the existing conditions, evaluation of the study intersections for the build out and design year conditions, conclusions, and recommendations. Figure 1 presents the study location and the adjacent roadway network.

Figure 1: Site Location



EXISTING YEAR (2014) CONDITIONS

Roadway Inventory

The study network consists of eight (8) intersections surrounded by predominantly residential land usage. The characteristics of these roadways are described below. All Average Annual Daily Traffic (AADT) volumes stated in this section are published by VDOT for 2013.

Route 28 (Catlett Road) is a two-lane, undivided roadway within the study limits. It runs primarily northeast to southwest, from Route 7 in Loudoun County to James Madison Highway (US 29) in Fauquier County. Within the study limits, the land use along Route 28 is primarily residential, with a few commercial developments at the US 17 intersection. The AADT is 9,200 vehicles per day (vpd) in this area, and the posted speed limit is 45 mph.

US 29/US 15 (James Madison Highway) is a four-lane, divided roadway that runs north to south between Route 7 to the north and Jefferson Davis Highway (Route 1) to the south. US 29 intersects Route 28 at a signalized, four-way intersection at the west end of the project. The AADT is 29,000 vpd south of Route 28 and 23,000 vpd north of Route 28, with a posted speed limit of 60 mph.

Lucky Hill Road is a two-lane local road that terminates at an unsignalized T-intersection with Route 28. Lucky Hill Road extends through mostly undeveloped land consisting of a few residential houses and farming plots. It terminates to the south at Remington Road, approximately one mile from Route 28, and the AADT is 640 vpd. The speed limit is not posted along Lucky Hill Road.

Whipkey Drive is a two-lane local road that intersects Route 28 at an unsignalized T-intersection. It provides access to a residential development and terminates at Falling Creek Drive, approximately 0.5 miles south of Route 28. There is no AADT listed for Whipkey Drive, and the posted speed limit is 25 mph.

Southcoate Village Drive is a two-lane local road that intersects Route 28 at an unsignalized T-intersection. It provides access to a single-family housing development and ends as a cul-de-sac slightly less than a mile north of Route 28. There is no AADT listed for Southcoate Village Drive. The posted speed limit is 25 mph.

Edgewood Drive is a two-lane local road that intersects Route 28 at an unsignalized T-intersection. It provides access to a residential development. Edgewood Drive is a short residential street that terminates at Maplewood Drive, 0.25 miles east of Route 28. The AADT is 770 vpd and the posted speed limit is 25 mph.

Schoolhouse Road is a two-lane local road that intersects Route 28 at an unsignalized T-intersection. It provides access to several residential and a few commercial developments. It terminates at Remington Road about 1.2 miles south of Route 28. The AADT along Schoolhouse Road is 1,900 vpd, and the posted speed limit is 40 mph.

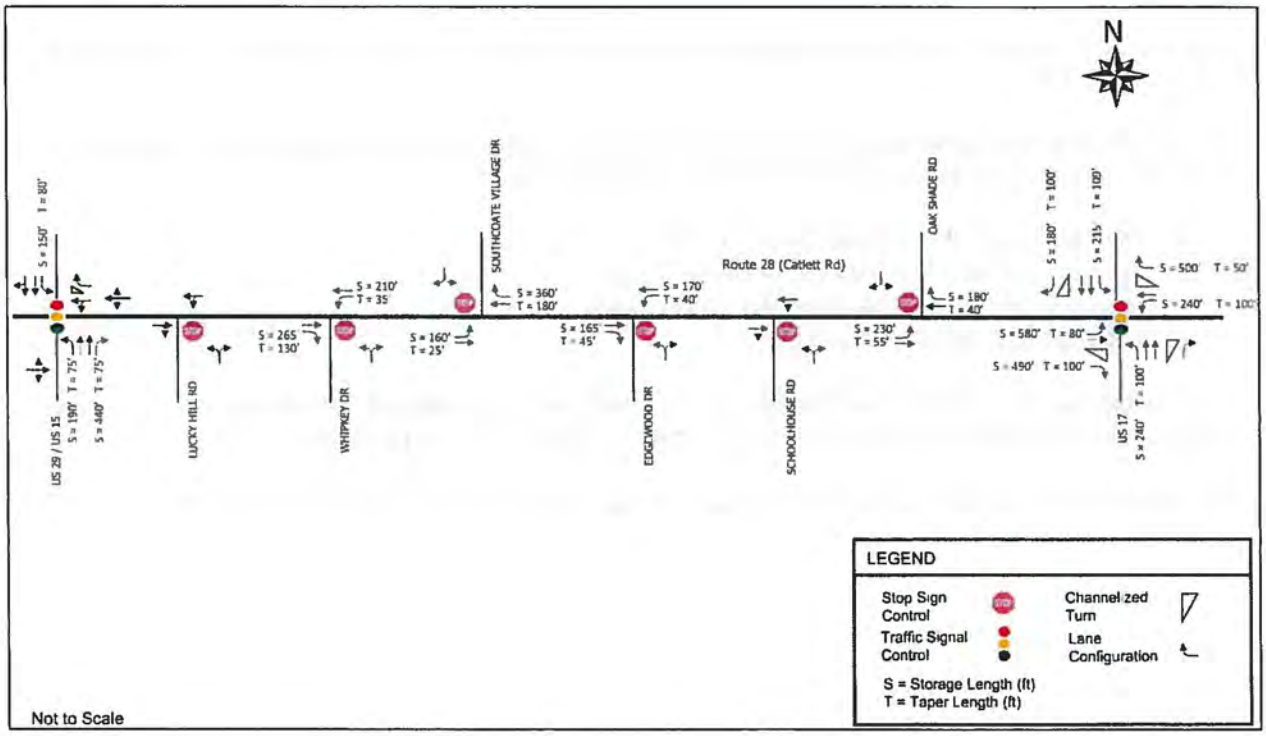
Oak Shade Road is a two-lane local road that intersects with Route 28 at an unsignalized T-intersection. It provides access to a large residential neighborhood and terminates at US 29 about 1.5 miles north of Route 28. The AADT along Oak Shade Road is 2,400 vpd, and the posted speed limit is 25 mph.

US 17 (Marsh Road) is a four-lane, divided road that runs primarily north to south from US 29 to the north in Fauquier County and Warrenton Road to the south in Falmouth County. US 17 intersects Route

28 at a signalized intersection. Within the study limits, the land use along US 17 is a mix of residential, commercial, and institutional developments. The AADT is 19,000 vpd north of Route 28 and 21,000 vpd south of Route 28. The posted speed limit in the study area is 45 mph.

The study intersections and their existing lane configurations and traffic control are depicted in Figure 2.

Figure 2: Existing Lane Configuration



Existing Year (2014) Traffic Volume

Peak period turning movement counts were collected during the week of December 1, 2014, from 6:00-9:00 AM and 4:00-7:00 PM at the following intersections:

1. Route 28 at US 29/US 15
2. Route 28 at Lucky Hill Road
3. Route 28 at Whipkey Drive
4. Route 28 at Southcoate Village Drive
5. Route 28 at Edgewood Drive
6. Route 28 at Schoolhouse Road
7. Route 28 at Oak Shade Road
8. Route 28 at Marsh Road

The turning movement counts indicate that the AM peak hour begins at 7:00 AM, and the PM peak hour begins at 5:00 PM.

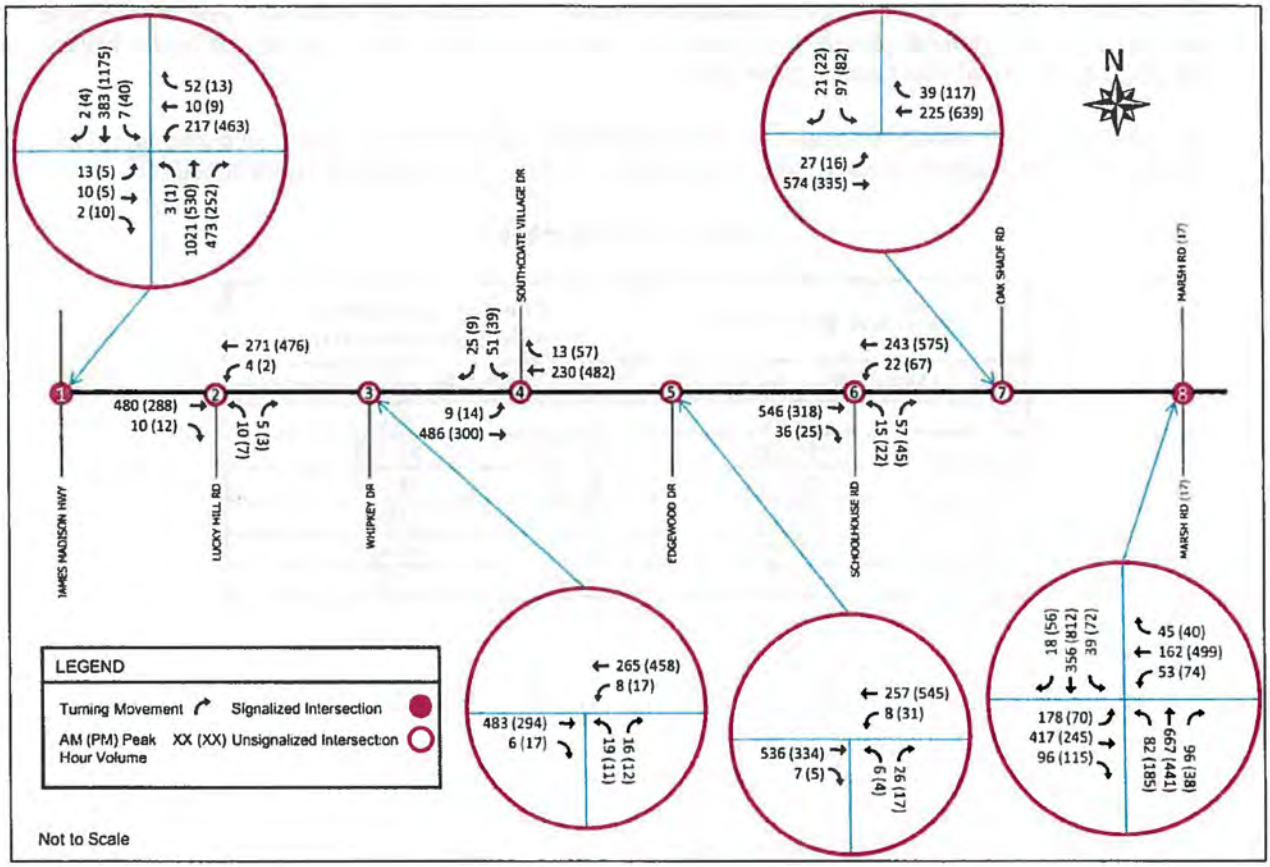
In addition to the turning movement counts, twenty-four hour (24-hour) traffic volume data was collected in December 2014 at the following four different locations on Route 28:

- Between Lucky Hill Road and Whipkey Drive
- Between Whipkey Drive and Schoolhouse Road
- Between Schoolhouse Road and Oak Shade Road
- Between Oak Shade Road and US 17

The turning movement counts were reviewed for consistency and balanced for continuity in this report where required. The resulting 2014 existing peak hour volumes are shown in Figure 3.

The supporting turning movement count data and 24-hour volumes are provided in Appendix A.

Figure 3: 2014 Existing Peak Hour Volumes



Traffic Analysis Methodology

Capacity analyses of the study intersections for both existing and future conditions were completed using the microscopic analysis and optimization software program, *Synchro 8.0*.

Operating conditions at intersections were evaluated in terms of levels of service (LOS) thresholds defined in the *2000 Highway Capacity Manual* (HCM 2000). Since HCM 2010 methodology has several limitations which are not uniformly incorporated in Synchro 8 at this time, the VDOT Traffic Operation Analysis Tool Guidebook Version 1.1 advises using HCM 2000 methodology for intersection analysis. Levels of service (LOS) for intersections are presented in terms of average control delay per vehicle.

Levels of service A through D are considered acceptable peak hour operations in urban conditions. Levels of service E and F are considered unacceptable peak hour conditions. However, low-volume side approaches at unsignalized intersections frequently experience low levels of service, since the highest priority is given to mainline through movements.

The average control delay per vehicle for signalized intersections is estimated for each lane group and aggregated for each approach and for the intersection as a whole. The criteria are listed in Table 1.

Table 1: LOS Thresholds

Signalized Intersections		**Two-Way and All-Way Stop-Controlled Intersections**	
LOS	Control Delay Per Vehicle (s)	LOS	Control Delay Per Vehicle (s)
A	≤ 10	A	0-10
B	>10 - 20	B	>10-15
C	>20 - 35	C	>15-25
D	>35-55	D	>25-35
E	>55-80	E	>35-50
F	>80	F	>50

Capacity Analysis – Existing Year (2014) Traffic Conditions

Existing traffic conditions were analyzed based on signal timings provided by VDOT for the signalized intersections on both ends of the project. Results for the overall study intersections, along with individual turning movements and lane groups are presented in Table 2.

Table 2: LOS Results – Existing Year (2014) Conditions

Existing Year Conditions				2014 AM		2014 PM	
Intersection	Type of Control	Movement		LOS	Delay (sec/veh)	LOS	Delay (sec/veh)
Route 29 and Route 28	Signalized	EB	LTR	D	53.7	D	53.9
			EB Overall	D	53.7	D	53.9
		WB	LTR	D	43.0	F	122.3
			WB Overall	D	43.0	F	122.3
		NB	L	B	17.2	C	22.5
			T	C	29.3	C	25.2
			R	C	21.0	C	22.4
			NB Overall	C	26.7	C	24.3
		SB	L	B	19.3	B	16.6
			TR	B	19.3	C	31.7
			SB Overall	B	19.3	C	31.2
		Intersection Overall		**C**	**27.9**	**D**	**47.7**
Lucky Hill Road and Route 28	Unsignalized	NB	LR	C	17.8	C	15.0
			NB Overall	C	17.8	C	15.0
		EB	TR	A	0.0	A	0.0
			EB Overall	A	0.0	A	0.0
		WB	LT	A	0.2	A	0.1
			WB Overall	A	0.2	A	0.1
		Intersection Overall		**A**	**0.4**	**A**	**0.4**
Whipkey Drive and Route 28	Unsignalized	NB	LR	C	16.2	B	13.9
			NB Overall	C	16.2	B	13.9
		EB	T	A	0.0	A	0.0
			R	A	0.0	A	0.0
			EB Overall	A	0.0	A	0.0
		WB	L	A	9.1	A	8.0
			T	A	0.0	A	0.0
			WB Overall	A	0.3	A	0.3
		Intersection Overall		**A**	**0.8**	**A**	**0.8**

Table 2: LOS Results – Existing Year (2014) Conditions (Cont'd.)

Existing Year Conditions				2014 AM		2014 PM	
Intersection	Type of Control	Movement		LOS	Delay (sec/veh)	LOS	Delay (sec/veh)
Southcoate Village Drive and Route 28	Unsignalized	SB	LR	C	17.9	C	18.4
			SB Overall	C	17.9	C	18.4
		EB	L	A	8.1	A	8.7
			T	A	0.0	A	0.0
			EB Overall	A	0.1	A	0.4
		WB	T	A	0.0	A	0.0
			R	A	0.0	A	0.0
			WB Overall	A	0.0	A	0.0
		Intersection Overall		**A**	**2.0**	**A**	**1.4**
Edgewood Drive and Route 28	Unsignalized	NB	LR	C	15.3	B	12.3
			NB Overall	C	15.3	B	12.3
		EB	T	A	0.0	A	0.0
			R	A	0.0	A	0.0
			EB Overall	A	0.0	A	0.0
		WB	L	A	9.0	A	8.1
			T	A	0.0	A	0.0
			WB Overall	A	0.3	A	0.4
		Intersection Overall		**A**	**0.8**	**A**	**0.7**
Schoolhouse Road and Route 29	Unsignalized	NB	LR	C	17.8	C	17.0
			NB Overall	C	17.8	C	17.0
		EB	TR	A	0.0	A	0.0
			EB Overall	A	0.0	A	0.0
		WB	LT	A	1.0	A	1.6
			WB Overall	A	1.0	A	1.6
		Intersection Overall		**A**	**1.7**	**A**	**2.3**
Oak Shade Road and Route 28	Unsignalized	SB	LR	D	33.3	D	34.5
			SB Overall	D	33.3	D	34.5
		EB	L	A	8.1	A	9.6
			T	A	0.0	A	0.0
			EB Overall	A	0.4	A	0.4
		WB	T	A	0.0	A	0.0
			R	A	0.0	A	0.0
			WB Overall	A	0.0	A	0.0
		Intersection Overall		**A**	**4.3**	**A**	**3.5**

Table 2: LOS Results – Existing Year (2014) Conditions (Cont'd.)

Existing Year Conditions				2014 AM		2014 PM	
Intersection	Type of Control	Movement		LOS	Delay (sec/veh)	LOS	Delay (sec/veh)
US 17 and Route 28	Signalized	EB	L	E	66.2	E	77.3
			T	F	121.4	D	43.8
			R	C	33.6	D	37.3
			EB Overall	F	95.0	D	47.5
		WB	L	E	61.6	E	66.6
			T	D	49.7	F	113.0
			R	D	42	D	35.6
			WB Overall	D	50.8	F	102.3
		NB	L	E	67.0	E	57.9
			T	C	20.4	A	7.8
			R	C	23.4	C	24.2
			NB Overall	C	25.3	C	22.7
		SB	L	E	55.3	E	61.7
			T	C	30.2	D	44.6
			R	C	25.1	C	28.7
			SB Overall	C	32.4	D	45.0
		Intersection Overall		D	52.3	D	53.3

The results show that all intersections operate at acceptable overall service levels of D or better during both AM and PM peak hours. However, there are some individual movements that operate at LOS E or F at the two signalized intersections of Route 28 with US 29 and Route 28 with US 17. The following movements operate at LOS E or worse.

Route 28 at US 17

- AM Peak: eastbound left turn operates at LOS E, and through movements operate at LOS F with over 2 min/veh of delay.
- AM Peak: westbound, northbound and southbound left turns operate at LOS E. The overall intersection operates at LOS D.
- PM Peak: all left turns operate at LOS E. The westbound through movement operates at LOS F with 2 min/veh of delay. The overall intersection operates at LOS D.

Route 28 at US 29

- PM Peak: westbound approach operates at LOS F with over 2 min/veh of delay. The overall intersection operates at LOS D.

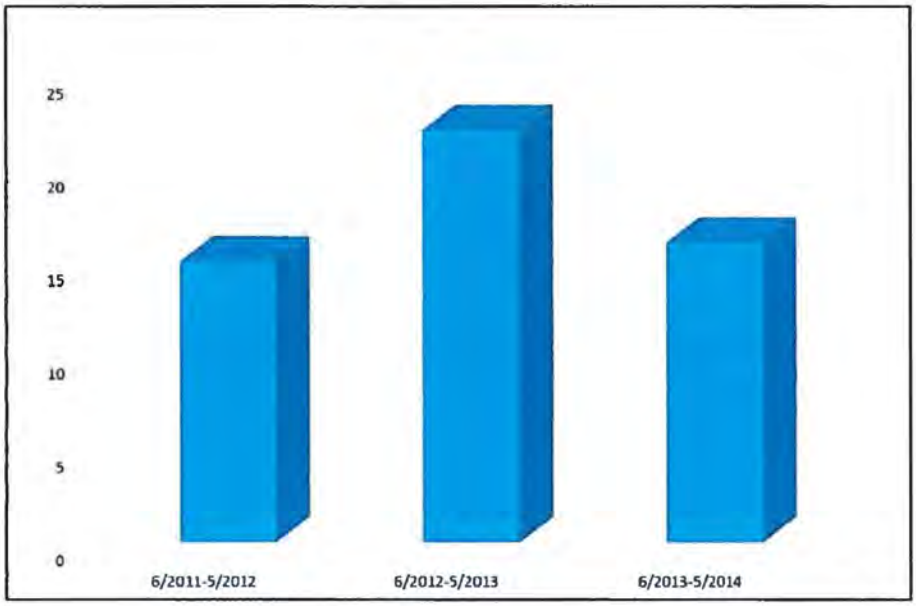
The accompanying Synchro reports are provided in Appendix B.

Crash Analysis

Three years of crash history data were analyzed for the segment of Route 28 between US 29 and US 17, from June 1, 2011, to May 31, 2014. The crash data was provided by VDOT and included date, time, location, direction, type, and severity.

Figure 4 summarizes the total number of crashes by year.

Figure 4: Annual Crash Totals on Route 28



A total of 53 crashes occurred on Route 28 in the three-year period, with an average of 17 crashes per year. The number of crashes was highest in the second year and lowest in the first year examined.

Table 3 presents a comparison of crash, injury, and fatality rates on Route 28 with the average statewide and districtwide rates for similar facilities.

Table 3: Route 28 Yearly Crashes

	Crash Rate	Injury Rate	Fatality Rate
	(per 100 Million Veh Miles Traveled)		
Rte 28 between US 15 and US 29	237.3	170.2	0
Statewide Rates	122.51	68.74	1.94
Districtwide Rates	125.62	66.36	1.43

The comparison shows that the crash and injury rates on Route 28 are about twice the statewide and districtwide rates for primary roads. This indicates that for the existing roadway and geometric conditions, the study segment of Route 28 is a critical crash location as compared to other roads with a similar functional classification within the state and district.

Table 4 presents a summary of crashes by location, type, severity and other factors.

Table 4: Crash Summary By Location

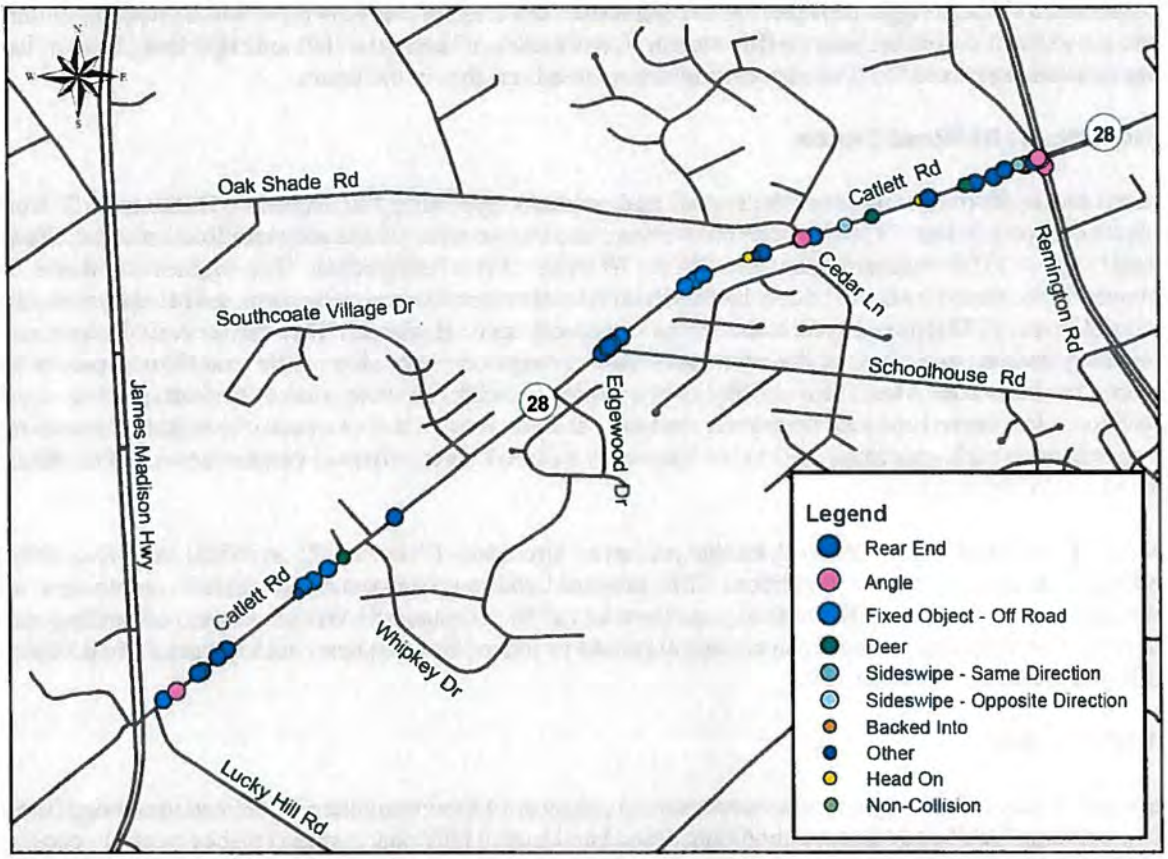
	Crash Type											Crash Severity			Time of Day				Lighting				Surface Condition	
Location	Rear End	Angle	Head On	Sideswipe - Same Direction	Sideswipe - Opposite Direction	Non-Collision	Fixed Object - Off Road	Deer	Backed Into	Other	Total	Property Damage Crash	Injury Crash	Fatality	AM Peak	Midday	PM Peak	Off Peak	Darkness	Dawn	Daylight	Dusk	Dry	Wet
Intersection of US 29 and Route 28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Segment Between US 29 and Lucky Hill Road	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Intersection of Lucky Hill Road and Route 28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Segment between Lucky Hill Road and Whipkey	4	1	0	0	0	0	4	2	0	1	12	7	5	0	1	2	5	4	5	0	7	0	10	2
Intersection of Whipkey and Route 28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Segment between Whipkey and Southcoate Village Drive	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	1	0	1	0
Intersection of Southcoate Village Drive and Route 28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Segment between Southcoate Village Drive and Edgewood Drive	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Intersection of Edgewood Drive and Route 28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Segment between Edgewood Drive and Schoolhouse Road	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Intersection of Schoolhouse Road and Route 28 (Catlett Road)	5	1	0	1	0	1	3	0	0	0	11	4	7	0	2	4	4	1	1	1	9	0	7	4
Segment between Schoolhouse Road and Oak Shade Road	1	0	1	0	1	0	4	0	0	1	8	1	7	0	1	0	3	4	4	0	4	0	7	1
Intersection of Oak Shade Road and Route 28	0	3	0	0	0	0	0	0	0	0	3	1	2	0	1	0	2	0	0	0	2	1	2	1
Segment between Oak Shade Road and US 17	4	1	1	1	1	0	1	2	0	0	11	7	4	0	7	1	2	1	3	0	8	0	10	1
Intersection of US 17 and Route 28	3	3	0	0	0	0	0	0	1	0	7	6	1	0	1	3	2	1	2	0	4	1	7	0
Total	18	9	2	2	2	1	12	4	1	2	53	27	26	0	13	10	19	11	15	1	35	2	44	9
	53											53			53				53				53	

Notable results are summarized below.

- Predominant crash types:
  - 18 of 53 (34%) were rear-ends
  - 12 of 53 (23%) were fixed object off-road crashes
  - 9 of 53 (17%) were angle crashes
  - 4 of 53 (7%) were deer-related
- Property damage vs. injury crashes:
  - 27 of 52 (51%) were property damage crashes
  - 26 of 53 (49%) were injury crashes involving 38 injuries
- There were no fatal crashes during the three-year study period.
- Crashes segregated by time of day:
  - 32 of 53 (60%) occurred during the AM and PM peak periods
  - 21 of 53 (40%) occurred during the midday or off-peak period
- Crashes by lighting condition:
  - 35 of 53 (66%) occurred during daylight
  - 18 (34%) occurred after dark or at dawn/dusk
- Crashes by surface condition:
  - The majority, 44 of 53 (83%), occurred with dry pavement surface conditions
  - 9 of 53 (17%) occurred under wet surface conditions.

Figure 5 shows the location of crashes on Route 28 by type.

Figure 5: Crash Map by Type



Rear-End Crashes

Rear-end crashes are the most prevailing type along this segment. Figure 1 shows that the concentration of rear-end crashes (11 out of 18, or 61%) is at or adjacent to the signalized intersections on both ends of the project: Route 28 at US 29 and Route 28 at US 17. The crash data indicates that 9 of 11 (82%) rear-end crashes at these intersections occurred during the AM or PM peak periods when traffic congestion is high at both intersections. This is typical at signalized intersections when vehicles are in "stop-and-go" traffic conditions. Construction of additional left turn lanes on the eastbound approach at the Route 28 and US 17 intersection, as well as the westbound approach at the intersection of Route 28 and US 29 will help mitigate traffic congestion by adding capacity that is expected to reduce the frequency of rear-end crashes during peak hours.

In addition, five out of 18 (28%) rear-end crashes occurred at the intersection of Route 28 and Schoolhouse Road. At unsignalized intersections like this, rear-end crashes are common where there are no dedicated left and right turn lanes to accommodate vehicles that are slowing down or stopping to turn and move them out of the main traffic stream. Construction of dedicated left and right turn lanes at this intersection is expected to eliminate or minimize rear-end crashes in the future.

Fixed Object Off-Road Crashes

Fixed object off-road crashes are the second most common type along this segment. Of the total 12 fixed object off-road crashes, 7 (58%) occurred between the intersections of Schoolhouse Road and Oak Shade Road, and 4 (33%) occurred just west of the Whipkey Drive intersection. The segment of Route 28 between Oak Shade Road and Schoolhouse Road has a horizontal curve alignment, and at approximately 0.5 miles east of Whipkey Drive, Route 28 has a vertical curve alignment. There are several obstructions, including mature tree lines, utility poles, and roadway signs on both sides of the road that appear to be within the clear zone. Also, there is little, if any, shoulder width on either side of the road near the crash locations. The curved roadway alignment, minimal shoulder width, and presence of roadside obstructions in combination with speeding lead to the frequency of fixed object off-road crashes between Oak Shade Road and Whipkey Drive.

Most of the fixed object off-road crashes occurred after dark (8 out of 12, or 67%), and five (42%) occurred under wet surface conditions. The proposed roadway improvements include construction of shoulders on both sides of the roadway, realignment of the substandard vertical curves, and milling and paving. These roadway improvements are expected to reduce the frequency and impact of fixed object off-road crashes in the study area.

Angle Crashes

Six out of nine (67%) angle crashes occurred at or adjacent to the unsignalized intersections along Route 28, including Oak Shade Road, Schoolhouse Road and Lucky Hill Road. Angle crashes typically occur at unsignalized intersections when drivers turning into or out of the side streets either misjudge available gaps in the opposing traffic stream, misjudge the speed of oncoming traffic, or have limited sight distance.

The two intersections at Oak Shade Road and Schoolhouse Road are located within one mile of the Route 28 and US 17 intersection. There are no "side street ahead" warning signs on westbound Route 28 in advance of these intersections to notify drivers of the presence of turning traffic. In addition, the intersection sight distance for the vehicles turning from Schoolhouse Road may be restricted due to the horizontal curve just east of the intersection.

To mitigate angle crashes at the intersections of Route 28 and Schoolhouse Road and Route 28 and Oak Shade Road, "side street ahead" (W2-7R) warning signs it is recommended on westbound Route 28 in

advance of these intersections. The proposed roadway improvements include relocating Lucky Hill Road and converting its access to a right-in/right-out only, and this is expected to eliminate angle crashes involving westbound left turning vehicles at this intersection.

Other Crashes

There were four deer-related crashes on Route 28, two of which occurred between the intersections of US 17 and Oak Shade Road. The other two crashes occurred adjacent to the Whipkey Drive intersection. Currently, there are no "deer crossing" warning signs on Route 28. Once the roadway improvements on Route 28 are completed, it is recommended to install "deer crossing" (W11-3) warning signs in advance of the crash locations to alert drivers to deer activity along the segment.

The crash database is presented in Appendix C.

FUTURE CONDITIONS – BUILD OUT YEAR (2020)

Traffic Projections – Build Out Year (2020)

Whether roadway improvements on Route 28 are constructed or not, traffic volumes are expected to increase between today and future build-out (2020) and design years (2043). The projected traffic volumes for these future conditions are calculated by combining the background traffic with new site-generated trips for local development. Background volumes are determined by increasing the existing year (2014) volumes by an annual compounded traffic growth rate of one percent (1%), as approved by VDOT. It is assumed that the background traffic projection encompasses regional traffic growth, as well as new trips generated by local development activity not specifically considered in this study.

New site-generated trips were prepared for the following developments that are planned or proposed for construction in the vicinity of the study area:

1. Mintbrook – A mixed-use development planned in the northwest quadrant of the Route 28 at US 17 intersection.

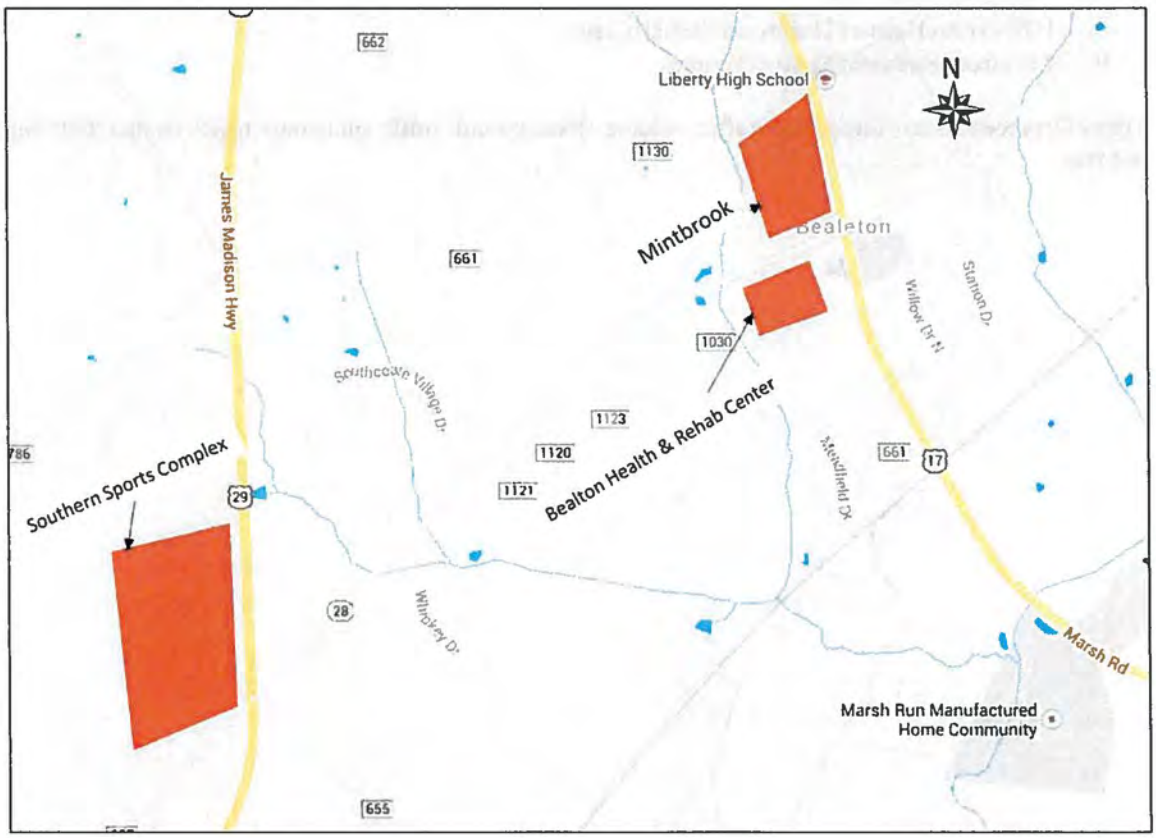
2. Bealeton Health and Rehabilitation Center – A 120-bed nursing home proposed 1,000 feet west of the Route 28 and US 17 intersection.

3. Southern Sports Complex – A sports complex with recreation center and fields for different sporting activities to be located in the northwest quadrant of the Route 28 at US 29 intersection.

A technical memorandum detailing the traffic projections, trip generation and trip distribution from the proposed developments was prepared and submitted to VDOT in January, 2015. A copy of the technical memorandum is included for reference in Appendix D.

Figure 6 shows the location of the proposed and planned developments.

Figure 6: Location of Planned/Proposed Developments



The Mintbrook mixed-used development includes 100 age-restricted houses that are planned to be constructed by 2016. The Bealton Health and Rehabilitation Center was initially planned to be open in summer of 2014, but the construction of this facility has not yet begun. For the build out year (2020), it is assumed that the Mintbrook age-restricted houses and the Bealton Health and Rehabilitation Center will both be build out and open for public use by 2020.

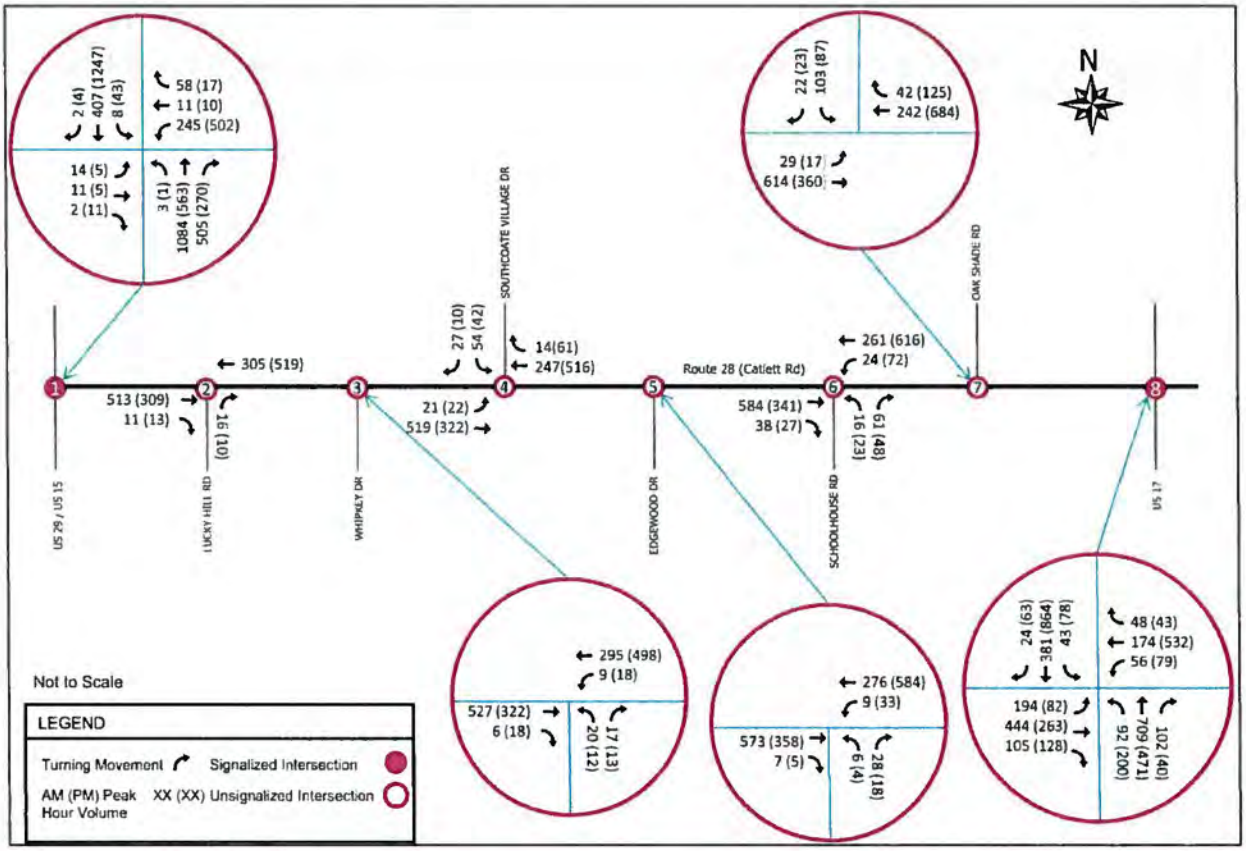
The age-restricted houses are expected to generate a total of 17 trips during the AM peak hour and 22 trips during the PM peak hour. The Bealton Health and Rehabilitation Center is expected to generate a total of 20 trips during the AM peak hour and 26 trips during the PM peak hour.

Based on the traffic impact study report prepared by Bowman Consulting for Mintbrook Senior Residencies, the following trip distribution was used for each development to access Route 28 based on the number and type of access points from the development and existing traffic patterns:

- 15% from Mintbrook
- 100% from Bealton Health and Rehab Center
- 15% from Southern Sports Complex

Figure 7 presents total forecasted traffic volumes (background traffic plus new trips) for the 2020 build out year.

Figure 7: Build Out Year (2020) Total Traffic Volumes



Traffic Projections – Design Year (2043)

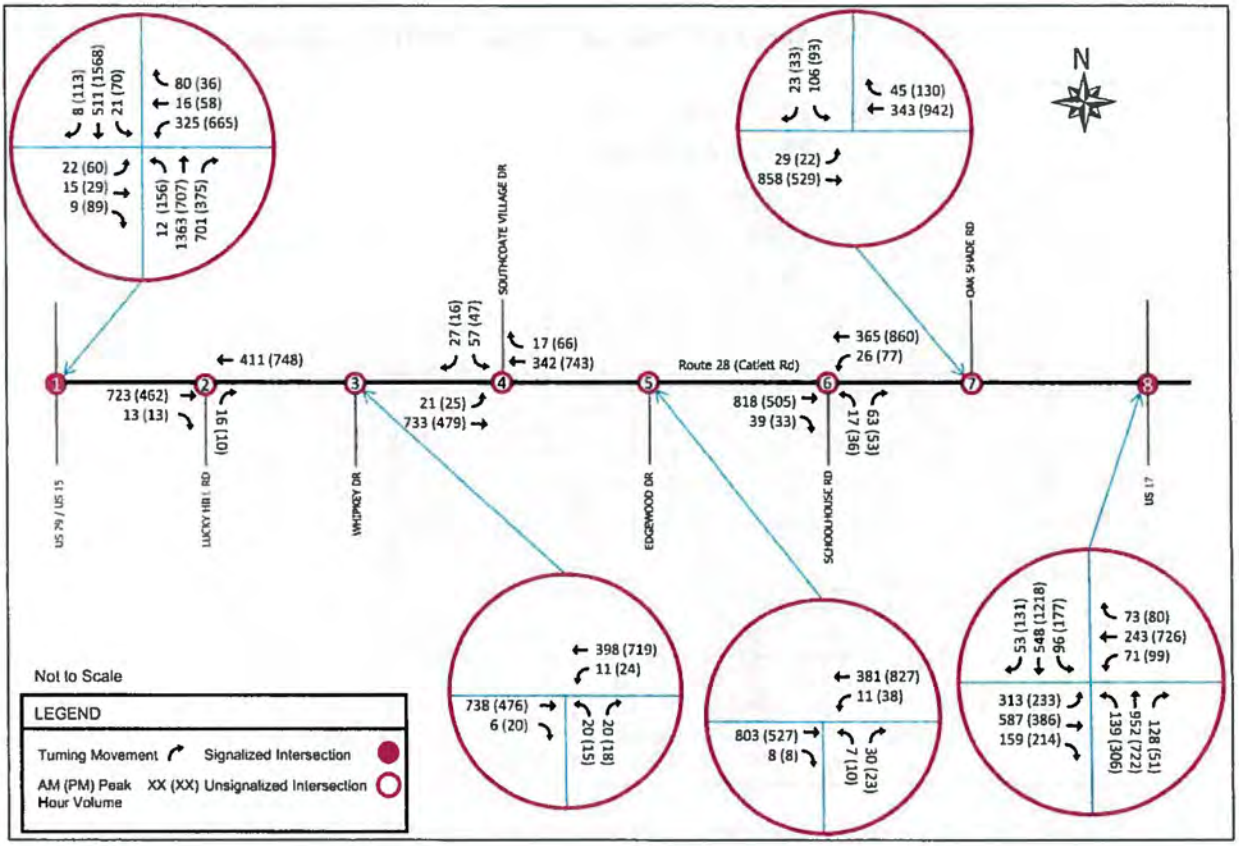
To project the background traffic volumes for the design year (2043), the build out year traffic volumes on Route 28, US 29/US 15, and US 17 were projected by a 1 percent annual growth rate over a twenty three years (2020 to 2043) period. The side street traffic was not projected (0 percent growth) past the build out year. It was assumed that due to the limited growth opportunity on the side streets traffic volumes would not be further increased beyond the build out year.

To calculate the total projected volumes for 2043, new trips generated by the Southern Sports Complex and fully constructed Mintbrook development and Bealton Rehabilitation were added to the background volumes.

Figure 8 presents the total forecasted traffic volumes (background traffic plus new trips) for the design year 2043.

Trip distribution to the study intersections from new developments for the build out year 2020 and design year 2043 are presented in Appendix D.

Figure 8: Design Year (2043) Total Traffic Volumes



Turn Lane Warrant Analysis – Route 28 at Schoolhouse Road

Currently, there are no dedicated left or right turn lanes at the intersection of Route 28 and Schoolhouse Road. Turn lane warrants were evaluated for the left and right turning movements from Route 28 onto Schoolhouse Road for future build out and design year traffic conditions. The warrants were analyzed based on the methodology provided in the VDOT Road Design Manual for a two-lane road with a 50 mph design speed.

Left turn lane warrants are evaluated for PM peak hour conditions when the westbound left turns are maximum. This warrant includes different graphs and curves based on the percentage of left turn volume compared to the volume for the entire approach. In this case, the left turn volume is about 10 percent of the entire westbound approach, so the 10 percent graph is employed. A graphical representation of the results for both build out and design years is presented in Figure 9.

Figure 9: Left Turn Lane Warrant – Future Traffic Conditions

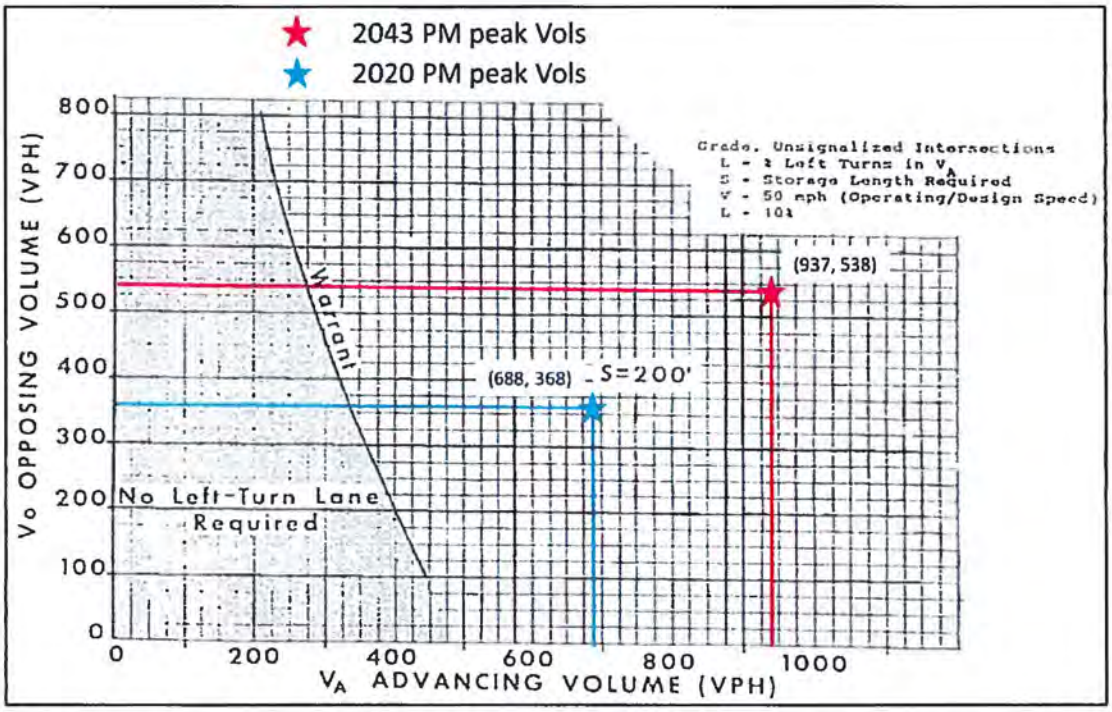
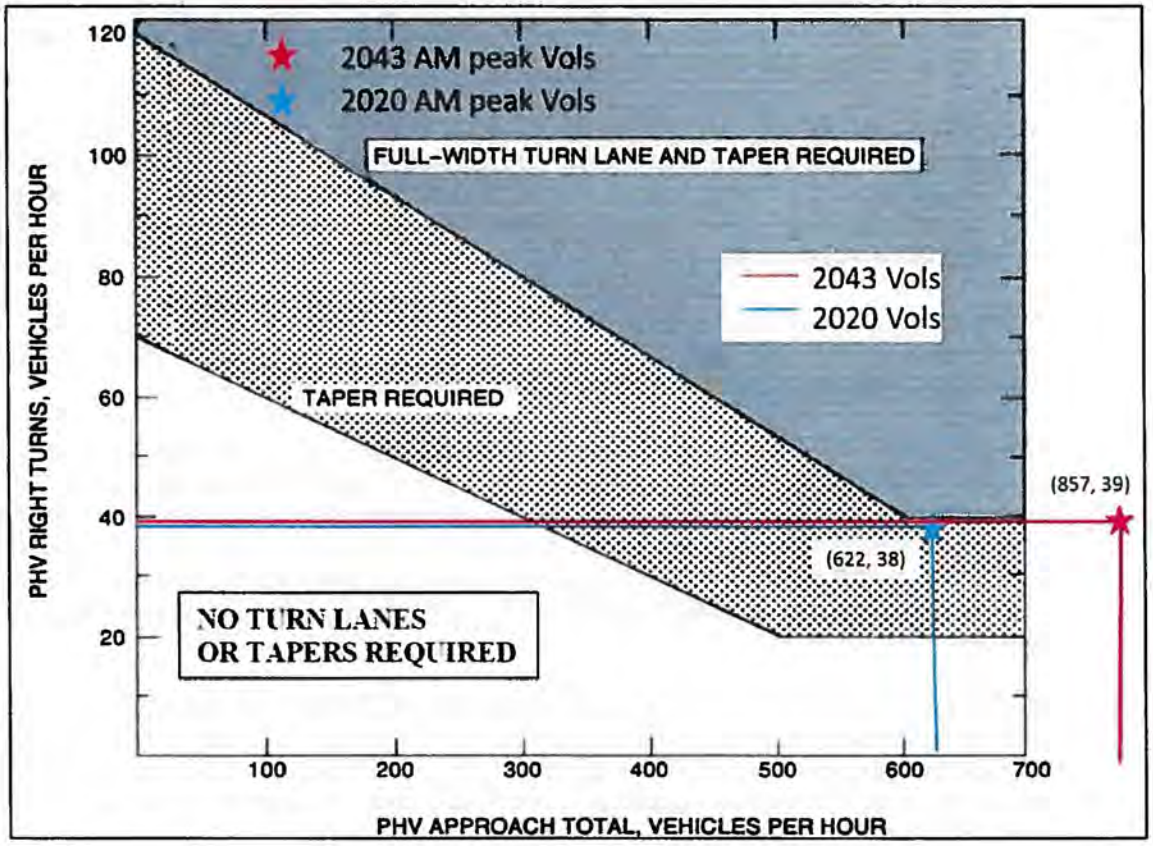


Figure 9 shows that a dedicated left turn lane is warranted for westbound left turns at the Route 28 and Schoolhouse Road intersection for both build out and design year traffic conditions.

Right turn lane warrants are evaluated for AM peak hour traffic conditions when the eastbound right turn from Route 28 onto Schoolhouse Road is maximum, at just under 40 vph for both build out and design years. A graphical representation of the warrants for both build out and design year traffic conditions is presented in Figure 10.

Figure 10: Right Turn Lane Warrant – 2020 Traffic Conditions



The right turn lane warrant threshold is 40 right turns per hour for approaches over 600 vph. The right turn volume is 38 vph in the 2020 build out year and 39 vph in the 2043 design year. Because these are just shy of the threshold, a full width eastbound right turn lane is recommended to provide safe and efficient traffic operation, instead of just providing a taper.

Proposed Improvements for Route 28

Based on a review of the projected traffic volumes, turn lane warrants, and safety analyses, construction of the following enhancements are proposed to be included in the Route 28 improvement project.

- *Dual westbound left turn lanes at the Route 28 and US 29 intersection.* The westbound approach currently has a shared through/left turn lane. However, the westbound left turn volumes are high in the PM peak hour, with 500 vph in the build out year and 665 vph in the 2043 design year. According to VDOT Road Design Manual specifications, it is desirable to construct dual left turn lanes if peak hour volume exceeds 300 vph.

- *Additional eastbound left turn lane at the Route 28 and US 17 intersection.* This approach currently has a single left turn lane. During the AM peak hour, eastbound left turns are high at this intersection, with 195 vph in the build out and 315 vph in the design year. The second left turn lane adds capacity to improve traffic flow through this congested intersection where Route 28 is considered the minor street.

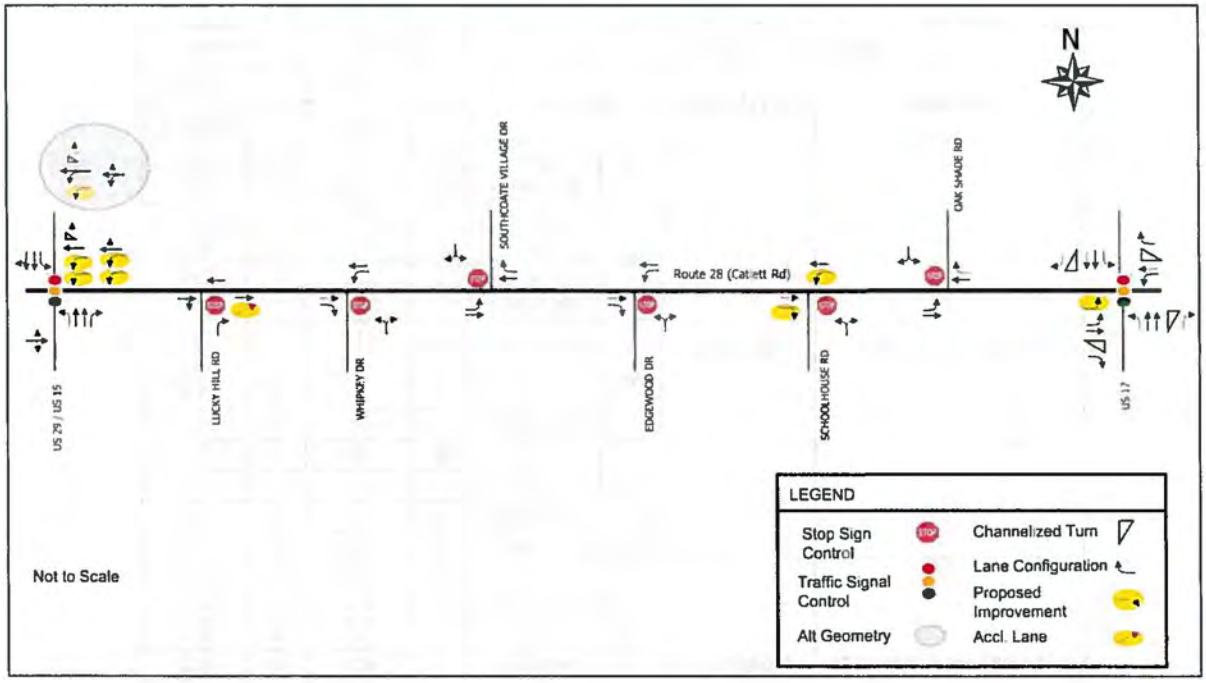
- *Dedicated left and right turn lanes on Route 28 at the Schoolhouse Road intersection.* Left turn lane warrants are met, and right turn volume of 39 vph is just one less than the right turn warrant threshold of 40 vph. Both left and right turn lanes are proposed on Route 28.

- *Change access to Luck Hill Road as a right in/right out only.* Lucky Hill Road currently intersects Route 28 at a full access T-intersection approximately 200 feet east of the US 29 intersection. This location does not meet VDOT's minimum spacing specifications of 470 feet between a signalized intersection and a full access entrance on a minor arterial with 45 mph speed limit. It is proposed to change access to Lucky Hill Road as a right-in/right out only and construct an acceleration lane on eastbound Route 28 for the northbound right turning vehicles from Lucky Hill Road.

  To improve safety and traffic operations on Route 28, Lucky Hill Road is to be relocated 160 feet east of its existing location and converted right-in/right-out access only. As a result, the intersection spacing between US 29 and Lucky Hill Road is extended to 360 feet, which meets the VDOT minimum spacing requirement of 250 feet between a signalized intersection and a right-in/right-out access on a minor arterial with 45 mph speed limit.

The future improvements on Route 28 are illustrated schematically in Figure 11.

Figure 11: Proposed Improvements on Route 28



CAPACITY AND QUEUING ANALYSIS REULTS

Capacity Analysis – Build Out Year (2020)

For 2020 build out conditions, the study network was analyzed for the increased capacity and improved geometry. Signal timings at the study intersections were optimized for the increased traffic volumes. VDOT typically retimes signalized intersections about every two years, so optimized timings for future conditions most accurately reflects the expected signal operation in 2020.

Results for the 2020 build out year are presented in Table 5.

Table 5: LOS Results – Build Out Year (2020) Conditions

Build Out Year Conditions				2020 AM		2020 PM	
Intersection	Type of Control	Movement		LOS	Delay (sec/veh)	LOS	Delay (sec/veh)
Route 29 and Route 28	Signalized	EB	LTR	D	42.8	D	52.1
			EB Overall	D	42.8	D	52.1
		WB	LTR				
			WBL	C	30.3	D	35.8
			WBTR	C	27.9	C	28.9
			WB Overall	C	29.8	D	35.5
		NB	L	B	14.0	C	20.3
			T	C	26.3	C	22.6
			R	A	8.4	A	7.6
			NB Overall	C	20.6	B	17.7
		SB	L	B	15.8	B	13.1
			TR	B	15.3	C	27.4
			SB Overall	B	15.3	C	26.9
		Intersection Overall		**C**	**21.1**	**C**	**25.9**
Lucky Hill Road and Route 28	Unsignalized	NB	R	B	12.6	B	10.8
			NB Overall	B	12.6	B	10.8
		EB	TR	A	0.0	A	0.0
			EB Overall	A	0.0	A	0.0
		WB	T	A	0.0	A	0.0
			WB Overall	A	0.0	A	0.0
		Intersection Overall		**A**	**0.2**	**A**	**0.1**
Whipkey Drive and Route 28	Unsignalized	NB	LR	C	15.9	B	14.2
			NB Overall	C	15.9	B	14.2
		EB	T	A	0.0	A	0.0
			R	A	0.0	A	0.0
			EB Overall	A	0.0	A	0.0
		WB	L	A	9.1	A	8.1
			T	A	0.0	A	0.0
			WB Overall	A	0.3	A	0.3
		Intersection Overall		**A**	**0.8**	**A**	**0.6**

Table 5: LOS Results – 2020 Build Out Conditions (Cont'd.)

Build out Year Conditions				2020 AM		2020 PM	
Intersection	Type of Control	Movement		LOS	Delay (sec/veh)	LOS	Delay (sec/veh)
Southcoate Village Drive and Route 28	Unsignalized	SB	LR	C	17.0	C	19.4
			SB Overall	C	17.0	C	19.4
		EB	L	A	8.1	A	8.9
			T	A	0.0	A	0.0
			EB Overall	A	0.3	A	0.6
		WB	T	A	0.0	A	0.0
			R	A	0.0	A	0.0
			WB Overall	A	0.0	A	0.0
		Intersection Overall		**A**	**1.8**	**A**	**1.2**
Edgewood Drive and Route 28	Unsignalized	NB	LR	B	14.2	B	12.8
			NB Overall	B	14.2	B	12.8
		EB	T	A	0.0	A	0.0
			R	A	0.0	A	0.0
			EB Overall	A	0.0	A	0.0
		WB	L	A	8.8	A	8.2
			T	A	0.0	A	0.0
			WB Overall	A	0.3	A	0.4
		Intersection Overall		**A**	**0.6**	**A**	**0.6**
Schoolhouse Road and Route 28	Unsignalized	NB	LR	C	15.9	C	17.2
			NB Overall	C	15.9	C	17.2
		EB	T	A	0.0	A	0.0
			R	A	0.0	A	0.0
			EB Overall	A	0.0	A	0.0
		WB	T	A	0.0	A	0.0
			L	A	9.0	A	8.3
			WB Overall	A	0.8	A	0.9
		Intersection Overall		**A**	**1.5**	**A**	**1.6**
Oak Shade Road and Route 28	Unsignalized	SB	LR	D	27.1	E	36.0
			SB Overall	D	27.1	E	36.0
		EB	L	A	8.0	A	9.8
			T	A	0.0	A	0.0
			EB Overall	A	0.4	A	0.4
		WB	T	A	0.0	A	0.0
			R	A	0.0	A	0.0
			WB Overall	A	0.0	A	0.0
		Intersection Overall		**A**	**3.4**	**A**	**3.2**

Table 5: LOS Results - 2020 Build Out Conditions (Cont'd.)

Build Out Year Conditions				2020 AM		2020 PM	
Intersection	Type of Control	Movement		LOS	Delay (sec/veh)	LOS	Delay (sec/veh)
US 17 and Route 28	Signalized	EB	L	E	64.8	E	66.3
			T	E	63.1	D	42.6
			R	D	35.8	D	36.4
			EB Overall	E	59.7	D	45.0
		WB	L	E	74.3	E	69.0
			T	D	43.5	E	77.5
			R	D	38.9	C	32.8
			WB Overall	D	48.9	E	73.5
		NB	L	E	65.8	E	66.4
			T	C	29.7	D	50.2
			R	D	39.8	C	29.0
			NB Overall	D	34.5	D	53.6
		SB	L	E	67.8	E	66.9
			T	C	34.3	E	70.8
			R	C	28.6	D	35.3
			SB Overall	D	37.2	E	68.3
		Intersection Overall		D	44.6	E	61.9

With an increase in capacity and optimized signal timings, traffic operations for the following movements improve for the build out year (2020) traffic conditions.

Route 28 at US 29

- With the construction of dual left turn lanes, the westbound approach improves from LOS F to D in the PM peak hour with a reduction in delay of 1.5 min/veh.
- The overall intersection improves from LOS D to C in the PM peak hour with a reduction in delay of 22 sec/veh.

Route 28 at US 17

- With an additional capacity on the eastbound approach and optimized signal timings, the eastbound through movement improves from LOS F to LOS E in the AM peak hour with a reduction in delay of 1 min/veh.
- The overall intersection level of service improves from LOS E to D in the PM peak hour.

Although the proposed improvements significantly reduce delay for the eastbound approach, the overall intersection still operates at LOS E in the PM peak period, and several individual movements operate at LOS E in both peak periods. This is because all approaches at the Route 28 and US 17 intersection experience high traffic volumes that are at or exceeding the capacity limit. Major geometric redesign such

as an interchange would be required to provide the capacity needed for the expected future traffic volumes.

Queuing Analysis – Build Out Year (2020)

For signalized intersections, the 95th percentile queue length is a measure of the maximum distance vehicles will stack behind the stop line during a traffic signal cycle. For an unsignalized intersection, the 95th percentile queue length is a measure of the maximum distance vehicles will stack behind the stop line while waiting for adequate gaps in the conflicting traffic.

Table 6 presents queue lengths from SimTraffic analyses for left and right turning movements. The greater of the two queues calculated for either the AM or PM peak period are reported so that the roadway can be designed for worst case conditions.

According to the AASHTO (2011) specification, a full turn lane length consists of the following three components:

- Storage Length, based on the 95th percentile queue length.
- Deceleration Length: according to AASHTO specifications for a 50 mph design roadway, a deceleration length of 425 feet is required.
- Taper Length: according to AASHTO specifications, a taper length of 180 feet is required for a rural high speed roadway.

AASHTO guidance also states that it is desirable to provide a turn lane length as a sum of storage, deceleration, and taper lengths; however, if not practical, taper length can be a part of deceleration length.

Table 6 provides the required total turn lane lengths for all dedicated left and right turn lanes at the study intersections, where taper length is considered part of the full deceleration length.

Synchro reports for capacity and queuing results for 2020 traffic conditions are included in Appendix E.

Table 6: Required Turn Lane Lengths – 2020 Build Out Conditions

2020 - Left Turn Storage Length (Rte 28 is considered running EB/WB)								
Intersection	Greater of AM or PM 95th%-tile Queue (ft)						Total Turn Lane Length (ft) (Including Taper length as a part of the deceleration length)	
	Storage Length (ft)		Deceleration Length (ft)		Taper (ft)			
	EB	WB	EB	WB	EB	WB	EB	WB
Rte 28 @ US 29/ James Madison Highway		195		425		180		620
Rte 28 @ Lucky Hill Road								
Rte 28 @ Whipkey Drive		20		425		180		445
Rte 28 @ Southcoate Village Drive	25		425		180		450	
Rte 28 @ Edgewood Drive		30		425		180		455
Rte 28 @ Schoolhouse Road		45		425		180		470
Rte 28 @ Oak Shade Road	30		425		180		455	
Rte 28 @ US 17/ Marsh Road	170		425		180	180	595	

2043 - Right Turn Storage Length								
Intersection	Greater of AM or PM 95th%-tile Queue (ft)						Total Turn Lane Length (ft) (Including Taper length as a part of the deceleration length)	
	Storage Length (ft)		Deceleration Length (ft)		Taper (ft)			
	EB	WB	EB	WB	EB	WB	EB	WB
Rte 28 @ US 29/ James Madison Highway								
Rte 28 @ Lucky Hill Road								
Rte 28 @ Whipkey Drive	0		425		180		425	
Rte 28 @ Southcoate Village Drive		0		425		180		425
Rte 28 @ Edgewood Drive	0		425		180		425	
Rte 28 @ Schoolhouse Road	0		425		180		425	
Rte 28 @ Oak Shade Road		5		425		180		430
Rte 28 @ US 17/ Marsh Road	65		425		180		490	

For dual left turn lanes, the length indicated applies to each lane.

Capacity Analysis – Design Year (2043)

Traffic operation were analyzed for the design year with the proposed geometric improvements and optimized signal timings. The results are presented in Table 7.

Table 7: LOS Results – Design Year (2043) Conditions

Design Year Conditions				2043 AM		2043 PM	
Intersection	Type of Control	Movement		LOS	Delay (sec/veh)	LOS	Delay (sec/veh)
Route 29 and Route 28	Signalized	EB	LTR	E	63.4	F	248.7
			EB Overall	E	63.4	F	248.7
		WB	LTR				
			WBL	D	49.5	F	99.7
			WBTR	D	43.4	E	58.9
			WB Overall	D	48.1	F	94.7
		NB	L	B	14.2	F	94.8
			T	C	31.1	C	28.9
			R	A	9.5	A	9.0
			NB Overall	C	23.7	C	31.2
		SB	L	C	21.1	C	22.9
			TR	B	16.5	F	107.4
			SB Overall	B	16.7	F	104.0
		Intersection		**C**	**26.4**	**F**	**85.8**
Lucky Hill Road and Route 28	Unsignalized	NB	R	C	15.5	B	12.2
			NB Overall	C	15.5	B	12.2
		EB	TR	A	0.0	A	0.0
			EB Overall	A	0.0	A	0.0
		WB	T	A	0.0	A	0.0
			WB Overall	A	0.0	A	0.0
		Intersection		**A**	**0.2**	**A**	**0.1**
Whipkey Drive and Route 28	Unsignalized	NB	LR	C	22.5	C	20.8
			NB Overall	C	22.5	C	20.8
		EB	T	A	0.0	A	0.0
			R	A	0.0	A	0.0
			EB Overall	A	0.0	A	0.0
		WB	L	B	10.1	A	8.6
			T	A	0.0	A	0.0
			WB Overall	A	0.3	A	0.3
		Intersection		**A**	**0.8**	**A**	**0.7**
Southcoate Village Drive and Route 28	Unsignalized	SB	LR	D	27.2	E	36.7
			SB Overall	D	27.2	E	36.7
		EB	L	A	8.4	A	9.9
			T	A	0.0	A	0.0
			EB Overall	A	0.2	A	0.5
		WB	T	A	0.0	A	0.0
			R	A	0.0	A	0.0
			WB Overall	A	0.0	A	0.0
		Intersection		**A**	**2.1**	**A**	**1.9**

Table 7: LOS Results – Design Year (2043) Conditions

Design Year Conditions				2043 AM		2043 PM	
Intersection	Type of Control	Movement		LOS	Delay (sec/veh)	LOS	Delay (sec/veh)
Edgewood Drive and Route 28	Unsignalized	NB	LR	C	19.5	C	21.3
			NB Overall	C	19.5	C	21.3
		EB	T	A	0.0	A	0.0
			R	A	0.0	A	0.0
			EB Overall	A	0.0	A	0.0
		WB	L	A	9.8	A	8.8
			T	A	0.0	A	0.0
			WB Overall	A	0.3	A	0.4
		Intersection		**A**	**0.7**	**A**	**0.7**
Schoolhouse Road and Route 29	Unsignalized	NB	LR	C	23.9	E	41.1
			NB Overall	C	23.9	E	41.1
		EB	T	A	0.0	A	0.0
			R	A	0.0	A	0.0
			EB Overall	A	0.0	A	0.0
		WB	T	A	0.0	A	0.0
			L	B	10.1	A	9.0
			WB Overall	A	0.7	A	0.7
		Intersection		**A**	**1.6**	**A**	**2.8**
Oak Shade Road and Route 28	Unsignalized	SB	LR	F	73.2	F	174.1
			SB Overall	F	73.2	F	174.1
		EB	L	A	8.3	B	11.3
			T	A	0.0	A	0.0
			EB Overall	A	0.3	A	0.4
		WB	T	A	0.0	A	0.0
			R	A	0.0	A	0.0
			WB Overall	A	0.0	A	0.0
		Intersection		**A**	**6.9**	**B**	**12.7**
US 17 and Route 28	Signalized	EB	L	E	74.7	F	114.9
			T	E	77.0	E	60.7
			R	C	34.7	D	45.6
			EB Overall	E	70.0	E	72.0
		WB	L	F	116.5	F	113.9
			T	D	48.8	F	257.4
			R	D	41.7	D	44.7
			WB Overall	E	59.9	F	222.8
		NB	L	F	101.0	F	327.9
			T	D	44.7	E	55
			R	D	48.9	D	38.4
			NB Overall	D	51.6	F	132.6
		SB	L	F	123.1	F	112.5
			T	D	51.7	F	145.0
			R	D	38.4	D	41.0
			SB Overall	E	60.4	F	132.3
		Intersection		**E**	**60.2**	**F**	**139.4**

The unsignalized intersections all operate at acceptable overall service levels of D or better, with a couple of individual movements at LOS E or F. The signalized intersections operate at LOS E or F, except that Route 28 at US 29 operates at LOS C in the AM peak period. Both intersections have multiple movements with LOS E or worse.

Route 28 at US 29

- The eastbound approach operates at LOS E in the AM peak period and LOS F in the PM peak period.
- The westbound left turn operates at LOS F in the PM peak period with 1.7 min/veh of delay.
- The overall intersection operates at LOS F with 1.5 min/veh of delay.

Instead of a dual left turn lane, the westbound approach was analyzed with the alternative of a single dedicated left turn lane plus a shared left/through and a dedicated right turn lane as shown as an "alternative geometry" in Figure 11. This alternative was developed as a way to still provide two lanes for turning traffic with a smaller overall footprint since the westbound through volumes are relatively light. However, the results showed that the alternative geometry was insufficient, with the westbound left turn operating at LOS F and 2.75 min/veh of delay, which is 1.5 times higher than if dual left turn lanes are provided with a separate through lane.

Route 28 at Southcoate Village Drive

- The southbound Southcoate Village Drive stop-controlled approach operates at LOS E in the PM peak hour.

Route 28 at Schoolhouse Road

- The northbound Schoolhouse Road stop-controlled approach operates at LOS E in the PM peak hour.

Route 28 at Oak Shade Road

- The southbound Oak Shade Road stop-controlled approach operates at LOS F in the AM and PM peak hours.

Route 28 at US 17

- All left turns at this intersection operate at LOS E or worse during both peak periods. The eastbound left turn operates at LOS F in the PM peak hour.
- The overall intersection operates at LOS E in the AM and LOS F in the PM peak hour.

Even with the proposed improvements, both signalized intersections are expected to operate with overall service levels of E or F. These two intersections would require major geometric redesign to provide enough capacity for the expected future traffic volumes.

Capacity Analysis – No Build (2043) Conditions

Because the signalized intersections within the project limits are still expected to operate at LOS E or F in the design year, 2043 no build conditions are analyzed to compare delays and level of service in the future if the project is not constructed. The no build scenario analyzes existing lane configurations with 2043 traffic projections. Signal timings were optimized for the increased traffic volumes at both intersections.

Table 8 presents a comparison of level of service and delay for 2043 with and without the proposed project. The grey-shaded cells highlight where there is a significant difference in delay if the project is not constructed, even if the overall level of service with improvements is still considered failing at either LOS E or F.

Table 8: 2043 LOS Results – With and Without Proposed Improvements

				2043 Build				2043 No Build			
Design Year Conditions				2043 AM		2043 PM		2043 AM		2043 PM	
Intersection	Type of Control	Movement		LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)
Route 29 and Route 28	Signalized	EB	LTR	E	63.4	F	248.7	F	**110.8**	F	214.0
			EB Overall	E	63.4	F	248.7	F	**110.8**	F	214.0
		WB	L	D	49.5	F	99.7		-		-
			TR/LTR	D	43.4	E	58.9	E	73.1	F	**596.2**
			WB Overall	D	48.1	F	94.7	E	73.1	F	**596.2**
		NB	L	B	14.2	F	94.8	C	21.0	F	94.5
			T	C	31.1	C	28.9	D	52.9	C	29.6
			R	A	9.5	A	9.0	A	8.3	A	9.4
			NB Overall	C	23.7	C	31.2	D	37.7	C	31.7
		SB	L	C	21.1	C	22.9	C	31.8	C	23.4
			TR	B	16.5	F	107.4	C	24.8	F	113.4
			SB Overall	B	16.7	F	104.0	C	25.1	F	109.8
		Intersection Overall		**C**	**26.4**	**F**	**85.8**	**D**	41.2	**F**	**182.9**
US 17 and Route 28	Signalized	EB	L	E	74.7	F	114.9	F	82.8	F	**257.9**
			T	E	77	E	60.7	E	74.6	E	55.8
			R	C	34.7	D	45.6	C	32.7	D	43.0
			EB Overall	E	70	E	72	E	70.7	F	**109.0**
		WB	L	F	116.5	F	113.9	F	117.4	F	111.1
			T	D	48.8	F	257.4	E	63.8	F	269.2
			R	D	41.7	D	44.7	D	48.6	D	45.4
			WB Overall	E	59.9	F	222.8	E	70.7	F	232.1
		NB	L	F	101	F	327.7	F	102.1	F	278.0
			T	D	44.7	D	55	C	34	E	71.6
			R	D	48.9	D	38.4	B	18.6	D	41.3
			NB Overall	D	51.6	F	131.6	D	40.2	F	128.8
		SB	L	F	123.1	F	112.5	F	151	F	108.7
			T	D	51.7	F	145	D	50.1	F	191.4
			R	D	38.4	D	41	D	36.8	D	44.5
			SB Overall	E	60.4	F	132.3	E	62.9	F	169.2
		Intersection Overall		E	**60.2**	F	**139.4**	E	58	F	160.7

While the proposed project does not achieve intersection service levels of LOS D or better at these two intersections, it does provide significant improvements for some of the individual movements. A comparison of results with and without the improvements show that the project provides the following benefits:

Route 28 at US 29

- Westbound dual left turn lanes on Route 28 improve this movement from LOS E to D in the AM peak period.

- Without improvements, the westbound approach operates at LOS F in the PM peak period with approximately 10 min/veh of delay. This is reduced to 1.5 min/veh with dual left turn lanes.

Route 28 at US 17

- With the construction of an additional left turn lane, delays for the eastbound left turn reduce by approximately 2.5 min/veh during the PM peak hour.

Queuing Analysis – Design Year (2043)

The queuing analysis results for 2043 traffic conditions are shown in Table 9. This table presents queue lengths from SimTraffic 8 for the left and right turn movements. Worst case scenario with the longest length from either the AM or PM peak hour is reported.

Table 9: Required Turn Lane Lengths – 2043 Design Year Conditions

2043 - Left Turn Storage Length (Rte 28 is considered running EB/WB)								
Intersection	Greater of AM or PM 95th%-tile Queue (ft)						Total Turn Lane Length (ft)	
	Storage Length (ft)		Deceleration Length (ft)		Taper (ft)		(Including Taper length as a part of the deceleration length)	
	EB	WB	EB	WB	EB	WB	EB	WB
Rte 28 @ US 29/ James Madison Highway		210		425		180		635
Rte 28 @ Lucky Hill Road								
Rte 28 @ Whipkey Drive		30		425		180		455
Rte 28 @ Southcoate Village Drive	35		425		180		460	
Rte 28 @ Edgewood Drive		30		425		180		455
Rte 28 @ Schoolhouse Road		45		425		180		470
Rte 28 @ Oak Shade Road	30		425		180		455	
Rte 28 @ US 17/ Marsh Road	430		425		180	180	855	
2043 - Right Turn Storage Length								
Intersection	Greater of AM or PM 95th%-tile Queue (ft)						Total Turn Lane Length (ft)	
	Storage Length (ft)		Deceleration Length (ft)		Taper (ft)		(Including Taper length as a part of the deceleration length)	
	EB	WB	EB	WB	EB	WB	EB	WB
Rte 28 @ US 29/ James Madison Highway								
Rte 28 @ Lucky Hill Road								
Rte 28 @ Whipkey Drive	0		425		180		425	
Rte 28 @ Southcoate Village Drive		5		425		180		430
Rte 28 @ Edgewood Drive	0		425		180		425	
Rte 28 @ Schoolhouse Road	5		425		180		430	
Rte 28 @ Oak Shade Road		5		425		180		430
Rte 28 @ US 17/ Marsh Road	410		425		180		835	

For 2043 traffic conditions, the 95th percentile queue lengths for the westbound left turn at the Route 28 and US 29 interection, as well as all left and right turns at the unsignalized intersections are fairly similar to the 95th percentile queue lengths developed for the 2020 build out scenario.

Synchro reports for capacity and queuing results for 2043 traffic conditions are included in Appendix F.

Additional Mitigation Measures

Because the two signalized intersections of Route 28 with US 17 and US 29 and the stop-controlled approach at the Route 28 and Oak Shade Road still operate at LOS F in the design year with the proposed roadway improvements, additional improvements were examined to determine if acceptable services levels could be reached at LOS D or better, even if they are outside the project limits and scope.

In addition, the capacity of the Route 28 roadway segment between the signalized intersections was also evaluated to determine if a two-lane highway provides adequate capacity to operate at an acceptable level of service D or better for future traffic volumes, or if a four-lane highway section would be required instead.

Chapter 16 of Highway Capacity Manual (HCM 2010) provides a planning tool with thresholds for daily service volumes to assess the level of service provided by an urban street facility. This is based on a given posted speed limit, an hourly volume factor (K-factor), and a directional distribution factor (D-Factor). The daily service volume thresholds as defined in HCM Chapter 16 are presented in Table 10.

Table 10: Generalized Daily Service Volumes for Urban Street Facilities
(Reported in 1,000 vehicles/day)

K-Factor	D-Factor	Two-Lane Streets				Four-Lane Streets				Six-Lane Streets			
		LOS B	LOS C	LOS D	LOS E	LOS B	LOS C	LOS D	LOS E	LOS B	LOS C	LOS D	LOS E
Posted Speed = 30 mi/h													
0.09	0.55	NA	5.9	15.4	19.9	NA	11.3	31.4	37.9	NA	16.3	46.4	54.3
	0.60	NA	5.4	14.1	18.3	NA	10.3	28.8	34.8	NA	15.0	42.5	49.8
0.10	0.55	NA	5.3	13.8	17.9	NA	10.1	28.2	34.1	NA	14.7	41.8	48.9
	0.60	NA	4.8	12.7	16.4	NA	9.3	25.9	31.3	NA	13.5	38.3	44.8
0.11	0.55	NA	4.8	12.6	16.3	NA	9.2	25.7	31.0	NA	13.4	38.0	44.5
	0.60	NA	4.4	11.5	14.9	NA	8.4	23.5	28.4	NA	12.2	34.8	40.8
Posted Speed = 45 mi/h													
0.09	0.55	NA	10.3	18.6	19.9	NA	21.4	37.7	37.9	NA	31.9	54.0	54.3
	0.60	NA	9.4	17.1	18.3	NA	19.6	34.1	34.8	NA	29.2	49.5	49.8
0.10	0.55	NA	9.3	16.8	17.9	NA	19.3	33.5	34.1	NA	28.7	48.6	48.9
	0.60	NA	8.5	15.4	16.4	NA	17.7	30.7	31.3	NA	26.3	44.5	44.8
0.11	0.55	NA	8.4	15.3	16.3	NA	17.5	30.5	31.0	NA	26.1	44.2	44.4
	0.60	NA	7.7	14.0	14.9	NA	16.1	27.9	28.4	NA	23.9	40.5	40.7

The posted speed limit along Route 28 is 45 mph between US 29/US 15 and US 17. The K-factor is approximately 9 percent, and the D-factor is approximately 64 percent, as determined from the 24-hour traffic data collected on Route 28.

Based on HCM values for a two-lane urban street with a 45 mph posted speed limit, a 9 percent K-factor and a 60 percent D-factor, the daily service volume range is between 17,100 and 18,299 vehicles per day at LOS D. This means that a two-lane roadway can support up to 18,299 vehicles per day with an acceptable service level. For a four-lane urban street, the daily service volume range is between 34,100 and 34,799 vehicles per day at LOS D.

The 2043 Average Daily Traffic (ADT) volume on Route 28 is projected at 16,300 vehicles per day, which is ***below*** the range of daily service volumes defined for a two-lane section operating at LOS D. This comparison of projected traffic volumes with the daily service volume thresholds indicate that a two-lane highway is expected to be sufficient capacity for the Route 28 roadway segment between the signalized intersections at Route US 29 and at US 17.

The roadway capacity itself is sufficient, but the intersection capacity is not, as demonstrated by the two signalized intersections of Route 28 with US 29 and with US 17 that are shown to operate with excessive delays in design year conditions. At both intersections, all approaches involve high traffic volumes with significant turning movements that create high volume-to-capacity ratios, indicating conditions at or above the intersection capacity.

In addition to the signalized intersections, the southbound approach at the unsignalized intersection of Route 28 at Oak Shade Road is projected with high left turns (AM-106 vph, PM-93 vph). Because of the continuous movement of mainline traffic in both directions along Route 28, these left turns from the side street cannot find adequate gaps in the oncoming traffic stream and therefore experience excessive delays that are as high as three minutes per vehicle in the PM peak period.

To mitigate traffic congestion at the study intersections, various alternatives were evaluated for the PM peak hour traffic conditions, since it represents the worst case scenario when all movements at the study intersections operate with the highest traffic volumes. The overall intersection level of service (LOS) from each alternative is compared with no build conditions and with the improvements proposed as a part of the Route 28 project (referred to in this section as Alternative 1).

The intent of the alternatives is to determine how capacity can be increased enough to provide acceptable levels of service, without replacement of the intersection with an interchange. Available options are to add lanes or to employ unconventional intersection design strategies.

The alternatives examined on a conceptual level are as follows:

1. Alternative 1: Route 28 Widening Project, as proposed and shown previously in this report.
2. Alternative 2: Relatively minor capacity improvements, such as adding dual left turn lanes.
3. Alternative 3: Significant capacity improvements, with multiple additional turn lanes and through lanes, including improvements at US 17 as proposed in the Mintbrook Development traffic impact study report prepared by Gorove/Slade Associates in February, 2011.
4. Alternative 4: Unconventional Intersection Design

Table 11 presents a comparison of results for different alternatives for the three intersections discussed above with service failures:

1. Route 28 at US 17
2. Route 28 at US 29
3. Route 28 at Oak Shade Road

Each alternative, with specific improvements at each intersection, as well as the resulting impact on traffic operation is described in detail following the table.

Table 11: LOS Results – Alternative Improvements Comparison

				No-Build		Alt 1 (Imp on Rte 28 Only)		Alt 2		Alt 3		Alt 4	
Design Year Conditions				2043 PM		2043 PM		2043 PM		2043 PM		2043 PM	
Intersection	Type of Control	Movement		LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)
Rte 28 at US 17	Signalized	EB	L	F	257.9	F	114.9	F	89.3	F	93.8		
			T	E	55.8	E	60.7	D	52.1	E	60.4	D	46.2
			R	D	43.0	D	45.6	D	41.8	E	55.1	E	57.7
			EB Overall	F	109.0	E	72.0	E	59.8	E	68.3	D	52.4
		WB	L	F	111.1	F	113.9	F	137.4	F	92.5		
			T	F	269.2	F	257.4	F	222.5	F	91.7	D	45.5
			R	D	45.4	D	44.7	D	42.7	D	43.6	D	39.7
			WB Overall	F	232.1	F	222.8	F	197.2	F	87.5	D	44.4
		NB	L	F	278.0	F	327.9	F	173.3	F	119.7		
			T	E	71.6	E	55.0	D	49.7	D	36.5	C	30.9
			R	D	41.3	D	38.4	D	36.2	C	27.5	C	24.3
			NB Overall	F	128.8	F	132.6	F	84.1	E	59.7	C	29.9
		SB	L	F	108.7	F	112.5	F	99.2	F	88.9		
			T	F	191.4	F	145.0	F	127.4	E	63.8	D	42.1
			R	D	44.5	D	41.0	D	39.5	C	31.6	C	26.1
			SB Overall	F	169.2	F	132.3	F	116.6	E	63.9	D	38.5
		Intersection Overall		F	160.7	F	139.4	F	114.5	E	68.6	D	39.3
US 29 and Route 28	Signalized	EB	L	F	214.0	F	248.7	F	82.3	F	84.6	E	77.4
			T/LT	F	214.0			F	85.4	E	78	E	73.3
			R							E	76.1	E	74.0
			EB Overall	F	596.2	F	248.7	F	84.4	E	79.3	E	75.0
		WB	L	F	596.2	F	99.7	F	89.7	E	74.8	E	67.5
			T/TR	F	94.5	E	58.9	E	56.3	F	82	D	49.5
			R	C	29.6					D	49.3		
			WB Overall	A	9.4	F	94.7	F	85.6	E	75.9	E	65.3
		NB	L	C	31.7	F	94.8	F	86.8	F	107.8		
			T	C	23.4	C	28.9	C	28.3	C	25.6	C	23.5
			R	F	113.4	A	9	A	8.5	A	8.5	A	4.6
			NB Overall	F	109.8	C	31.2	C	29.7	C	30.8	B	17.1
		SB	L	F	182.9	C	22.9	C	22.4	B	18.7		
			T/TR	F	113.4	F	107.4	E	78.4	D	54.4	D	42.6
			R					B	19.5	B	16.9	B	13.9
			SB Overall	F	109.8	F	104.0	E	72.4	D	50.5	D	38.5
		Intersection Overall		F	182.9	F	85.8	E	62.0	D	50.5	D	38.2
Rte 28 at Oak Shade Rd	UnSignalized	EB	L	B	11.3	B	11.3	A	6.9	B	12.3		
			T/LT	A	0.0	A	0.0	A	7.9	B	12.3		
			R										
			EB Overall	A	0.4	A	0.4	A	7.9	B	12.3		
		WB	L										
			T/TR	A	0.0	A	0	C	20.5	F	73		
			R	A	0.0	A	0.0	A	6	F	73		
			WB Overall	A	0	A	0	B	18.7	F	73		
		NB	L										
			T										
			R										
			NB Overall										
		SB	LR	F	174.1	F	174.1	C	24.5	B	14.3		
			SB Overall	F	174.1	F	174.1	C	22.8	B	14.3		
		Intersection Overall		B	12.7	B	12.7	C	24.0	E	49.6		

The results are detailed further by intersection, with improvements specific to that alternative described along with the operational outcomes.

Intersection of Route 28 at US 17

Alternative 1:

- Construct eastbound dual left turn lanes.

As stated previously in this report, the improvements associated with the proposed Route 28 project result in an overall intersection LOS F and delay of 2.3 min/veh for design year conditions. While this is an improvement over no build conditions, it is still considered as an unacceptable service level. This is the baseline to which Alternatives 2 through 4 are compared.

Alternative 2:

- Construct dual left turn lanes on northbound and southbound US 17 instead of single left turn lanes.

With this increase in capacity, the overall intersection still operates at LOS F, with 1.9 min/veh of delay. However, the overall intersection delay is reduced by 0.45 min/veh as compared to Alternative 1 and 0.75 min/veh as compared to the no build conditions.

Alternative 3:

- Construct dual left turn lanes on northbound and southbound US 17 instead of single left turn lanes.
- Add one through lane on the eastbound and westbound approaches each on Route 28, so that Route 28 is widened to four lanes at the intersection.

These mitigation measures, except for an additional eastbound through lane, are proposed in the Mintbrook Development traffic impact study report prepared by Gorove/Slade Associates in February 18, 2011. With these improvements, the overall intersection level of service is improved from LOS F to E, and the delay is reduced by 1.2 min/veh as compared to Alternative 1 and 1.6 min/veh as compared to the no build conditions.

Alternative 4 (Median U-Turn; Unconventional Design):

This unconventional at-grade intersection design is also commonly known as a "Michigan Left." The primary objective of the median U-turn design is to remove all left turn traffic from the main intersection. In this configuration, all left turns are converted to right turns at the intersection and re-routed on the major highway using a median crossover. The main intersection is then reduced to only two signal phases, which reduces the overall lost time and increases the intersection capacity. The Michigan Left turn intersection design is shown in Figure 12.

In general, this design involves constructing uni-directional median crossovers on the major highway at a distance of 600 to 800 feet upstream and downstream of the main intersection. The median crossover openings are also signalized to accommodate the u-turn traffic, and these signals are also two-phased. Since the signalized intersection of US 17 at Village Center Drive is located approximately 1,100 feet south of Route 28 intersection, and the unsignalized intersection of US 17 at Independence Avenue is located approximately 2,500 feet north of Route 28, the left turns from the Route 28 and US 17 intersection would be re-routed at these locations instead of constructing new median crossover openings. While this loses the benefit of two-phase signals for the u-turn, it eliminates signals on the mainline and is more efficient for a corridor with existing signalized intersections.

This alternative includes the following improvements:

- Eliminate left turn lanes from all approaches at the Route 28 and US 17 intersection.
- Add a through lane on the westbound approach on Route 28.
- Construct dual southbound left turn lanes at the US 17 and Village Center Drive intersection.
- Construct dual northbound left turn lanes at Independence Avenue and signalize the intersection.

In the Mintbrook Development traffic impact study report, a full access driveway to the site is proposed on the west side of US 17 directly opposite Independence Avenue, and the intersection would be signalized along with construction of dual northbound left turn lanes and a dedicated left turn and a shared through/right turn lane at the site entrance.

With the improvements proposed in Alternative 4, the overall intersection of Route 28 and US 17 operates at LOS D with a 0.67 min/veh of delay. This is because the left turns are eliminated from all approaches, and the intersection operates with two signal phases only.

Comparison of Alternatives 1-4:

Comparing Alternatives 1 through 4 indicates that Alternative 4 is the preferred alternative for the Route 28 and US 17 intersection, because this is the only alternative that alleviates traffic congestion at the intersection while minimizing right of way acquisition on Route 28. Although an additional through lane is needed for the westbound approach to operate at LOS D, little additional right of way would be required, because the existing westbound left turn lane can be restriped to a through lane.

It appears that the local community and the County Board of Supervisors are opposed to widening Route 28. If this is the case, Alternative 4 can mitigate traffic congestion at the intersection without significantly widening Route 28. However, construction of a Median U-turn or Michigan Left Turn design does have a relatively low right of way impact on Route 28, but the drawbacks include the following:

- Requires a significant right-of-way acquisition for constructing additional left turn lanes at the upstream and downstream intersections on US 17
- Requires installation of a traffic signal at Independence Avenue
- Signal system must be coordinated with the adjacent intersections.
- Adds significant u-turn volumes to an arterial
- This design is not widely used in Virginia and is not intuitive to drivers unfamiliar with this strategy.

Other Unconventional Design Options:

Similar traffic operations can be achieved by a few other unconventional intersection designs where removing left turns from the intersection is the primary intent, including the "Single Quadrant Roadway," the "Jughandle," and the "Continuous Flow" intersection configurations.

1. The Single Quadrant Roadway intersection design involves removing left turns from the main intersection and re-routing them using a bypass road in one of the intersection quadrants, as shown in Figure 12.

2. The Jughandle intersection configuration involves removing left turns from the major road at the intersection and shifting them onto a ramp constructed either in advance of the intersection or just past the intersection that loops onto the side street. In this case, left turns from the mainline must go through the intersection, then loop around and go through the intersection again as a through movement on the side street. This configuration is shown in Figure 12.

3. The Continuous Flow Intersection (CFI) design involves eliminating all left turn conflicts from the main intersection. The Partial Continuous Flow Intersection treatment requires less footprint and involves eliminating the left turn conflicts for just the major road.

   In either case, the idea is that left turns cross the opposing through lanes at a new traffic signal several hundred feet upstream of the intersection, and then travel on a new service lanes that are parallel to the opposing through traffic lanes. This allows the traffic to execute a left turning movement simultaneously with the through traffic at the main intersection. Traffic signals at the left turn crossovers and main intersection operate in a coordinated mode. The CFI is displayed graphically in Figure 12.

Figure 12: Unconventional Intersection Configurations

Michigan Left Turn Intersection Design

Jughandle Intersection Design

Single Quadrant Intersection Design

Continuous Flow Intersection Design

Although both the Single Quadrant Roadway and Jughandle options can mitigate congestion at the intersection without widening Route 28, they require significant right-of-way in two quadrants adjacent to the intersection to construct loops or access/bypass roads. However, this intersection has limited right-of-way due to both existing and proposed developments in each quadrant. This makes the Single Quadrant Roadway and the Jughandle design treatments relatively less feasible than the Median U-Turn alternative.

Likewise, a full Continuous Flow intersection is not a preferred alternative, since it requires significant widening or right of way acquisition on Route 28 for the new parallel road and is expected to face opposition from the local community and Board of Supervisors. A Partial Continuous Flow intersection design would involve eliminating and re-routing northbound and southbound left turns from the main intersection by constructing parallel road on US 17. However, traffic operation for the eastbound and westbound approaches are not improved in this scenario without significant geometric improvements on Route 28.

While theoretically an unconventional at-grade intersection designs or an interchange mitigates traffic congestion at the main intersection, these designs require a significant right-of-way acquisition and installation of signals at new and/or existing intersections.

Intersection of Route 28 at US 29

Alternative 1:

- Construct dual westbound left turn lanes on Route 28.

As stated previously in this report, the improvements associated with the proposed Route 28 project result in an overall intersection LOS F and delay of 1.4 min/veh for design year conditions. While this is an improvement over no build conditions, it is still considered as an unacceptable service level.

Alternative 2:

- Construct a dedicated left turn lane on the Route 657 (Kings Hill Road) eastbound approach and restripe the existing shared left/through/right turn lane to a shared through/right turn lane.
- Construct a dedicated southbound right turn lane.

With the additional capacity, the overall intersection improves from LOS F to E with a reduction in delay of 0.4 min/veh when compared to Alternative 1 and 2 min/veh of delay when compared to no build conditions.

Alternative 3:

- Construct dedicated left and right turn lanes on the Route 657 eastbound approach and restripe the existing shared left/through/right turn lane to through lane only.
- Construct a dedicated southbound right turn lane.
- Construct a dedicated westbound right turn lane.
- Restripe the shared westbound through/right turn lane to a shared through/left turn lane so that the westbound approach on Route 28 has dual dedicated left turn lanes, a shared left turn and through lane and a dedicated right turn lane.

With these improvements, the overall intersection improves from LOS F to D. This would provide acceptable operating service levels.

Alternative 4:

This alternative is similar to the Median U-Turn design as proposed earlier for the US 17 intersection, except that it is a modified design where the left turn phase is eliminated from the mainline approaches only. This alternative involves the following improvements:

- Eliminate northbound and southbound left turn movements from US 29.
- Construct median crossover openings to the north and south of Route 28 and re-route northbound and southbound left turns through the median crossovers.
- Construct dedicated left turn lanes and install two-phase traffic signals at the median crossover openings.

With this improvement the overall intersection operates at LOS D with a reduction in delay of 0.8 min/veh as compared to Alternative 1 and 2.5 min/veh of delay as compared to the no build condition.

Comparing Alternatives 3 and 4 indicate that Alternative 3 is preferable, since Alternative 3 achieves the same LOS D with relatively less right-of-way acquisition as compared to Alternative 4. In addition, the Michigan left described in Alternative 4 is a treatment seldom seen outside Michigan and would create three signalized intersections in a row on US 29 to replace one signalized intersection. The three closely-spaced signals would also violate VDOT's access management standard for signalized intersection spacing on an arterial.

Intersection of Route 28 at Oak Shade Road

To mitigate traffic congestion on the southbound approach of the Route 28 and Oak Shade Road intersection, two improvement alternatives were examined:

- Alternative 1 or No Build
- Alternative 2 - Traffic signal
- Alternative 3 - Single lane roundabout

Alternative 1:

There are no additional improvements proposed at the Route 28 and Oak Shade Drive intersection as a part of the Route 28 improvement project, and there are few other options at this location. A four-way stop is not practical on Route 28, so that leaves either signalization or a roundabout.

Alternative 2:

With the installation of a traffic signal, all movements at the Route 28 and Oak Shade Drive intersection operate at LOS D or better. However, installation of a traffic signal requires that at least one signal warrant must be met. Signal warrant evaluation was not included in the scope of this traffic study, but it is possible that at least one warrant would be met for design year conditions while none would be met for build out year conditions. The intersection should be monitored and signal warrants evaluated in the future when traffic levels increase, at some point before the 2043 design year when traffic operations dictate.

Alternative 3:
For a single lane roundabout, the westbound Route 28 approach operates at LOS F due to high through volumes in the PM peak period that must yield to circulating traffic. This causes the westbound approach to operate with higher delays than either free flow conditions or with traffic signal control. Construction

of a roundabout also would likely require significant right-of-way acquisition to accommodate the larger geometric footprint.

Comparison of the results for the two alternatives indicates that installation of a traffic signal would be a preferable mitigation measure for the Oak Shade Road intersection, since all movements would operate at acceptable service levels of D or better. In addition, this alternative has a much smaller geometric footprint and is likely to require less right-of-way acquisition, if any.

Comparison of Alternatives

Alternative mitigation strategies were explored for intersection to see if acceptable service levels could be attained without replacing the at-grade signalized intersections with interchanges. Construction of grade separated interchanges would be expected to significantly reduce traffic congestion at both of these intersections, but the construction costs and right-of-way impacts of an interchange is well outside the scope and budget of this project.

Table 12 presents a qualitative comparison of the different improvement alternatives proposed in this report by intersection.

Table 12: Alternative Improvements Comparison

Scenarios	Route 28 at US 17	Route 28 at US 29	Route 28 at Oak Shade Rd
No Build	**No roadway improvements, signal timing optimized**	**No roadway improvements, signal timing optimized**	**No improvements**
- LOS (Delay)	F (2.7 min/veh)	F (3 min/veh)	SBL; F (3 min/veh); Overall Int; B (0.21 min/veh)
- ROW Acquisition	N/A	N/A)	N/A
- Imp. Duration	Short	Short	N/A
Alternative 1	**Dual EBL**	**Dual WBL**	**No improvements**
- LOS (Delay)	F (2.3 min/veh)	F (1.4 min/veh)	SBL; F (3 min/veh); Overall Int; B (0.21 min/veh)
- ROW Acquisition	Low	Low	N/A
- Imp. Duration	Intermediate	Intermediate	N/A
Alternative 2	**Dual EBL, NBL, SBL**	**Dual WBL, EBL and EBTR, SBR**	**Signalization**
- LOS (Delay)	F (1.9 min/veh)	E (1 min/veh))	SBL; C (0.4 min/veh); Overall Int; A (0.4 min/veh)
- ROW Acquisition	Moderate	Moderate	Low
- Imp. Duration	Intermediate	Intermediate	Intermediate
Alternative 3	**Dual EBL, NBL, SBL and Dual EBT, WBT**	**Dual WBL, WBLT, WBR; EBL, EBT, EBR; SBR**	**Roundabout**
- LOS/Delay	F (1.14 min/veh)	D (0.84 min/veh)	WBTR; E (1.2 min/veh); Overall Int; E (0.82 min/veh)
- ROW Acquisition	Significant	Significant	Significant
- Imp. Duration	Long	Long	Long
Alternative 4	**Direct Left Turns to adjacent Int.; Dual WBT; improvements at adjacent intersections**	**Direct Left Turns to adjacent median crossovers.; Dedicated EBL, EBT, EBR; Dual WBL; Dedicated SBR; improvements at adjacent median crossovers**	
- LOS (Delay)	D (0.7min/veh)	D (0.64/min)	
- ROW Acquisition	Significant on US 17	Significant	
- Imp. Duration	Long	Long	

Appendix G includes figures for additional improvements at each intersection and analysis output.

ARTERIAL LEVEL OF SERVICE ANALYSIS

An arterial analysis was conducted to determine if Route 28 is sufficient as a two-lane road for expected traffic volumes. According to HCM (2010) methodology, arterial levels of service are measured in terms of average travel speed. One of the inputs in travel speed is the running time required to travel *between* two signalized intersections. However, average speed includes the delay at the signalized intersections.

Average Speed = (Running Time + Signal Delay)/(Distance between the two intersections)

The arterial results are presented in Table 13 for existing and future traffic conditions, as well as improvement alternatives. Synchro reports for arterial LOS are included in Appendix H.

Table 13: Arterial Level of Service Results

Scenarios	Performance Measures	Rte 28 - EB		Rte 28 - WB	
		AM	PM	AM	PM
Existing	Running Time (min)	3.2	3.3	3.3	3.4
	Avg. Speed (mph)	25.6	34	32	24
	LOS	D	C	C	D
2020 Build Out	Running Time (min)	3.3	3.2	3.2	3.2
	Avg. Speed (mph)	30.3	33	37	32
	LOS	C	C	B	C
2043 No Build	Running Time (min)	3.1	3.3	3.1	3.2
	Avg. Speed (mph)	25.4	21.8	28	9.5
	LOS	D	D	C	F
2043 Alt 1	Running Time (min)	3.1	3.1	3.3	3.2
	Avg. Speed (mph)	27.2	20	36.2	20
	LOS	C	E	B	E
2043 Alt 2	Running Time (min)	-	3.1	-	3.2
	Avg. Speed (mph)	-	30	-	21
	LOS	-	C	-	E
2043 Alt 3	Running Time (min)	-	3.1	-	3.2
	Avg. Speed (mph)	-	27.2	-	24.8
	LOS	-	C	-	D
2043 Alt 4	Running Time (min)	-	3.1	-	3.1
	Avg. Speed (mph)	-	29	-	33
	LOS	-	C	-	C

The results show that for the 2043 no build conditions, average speeds on westbound Route 28 are less than 10 mph, or LOS F, in the PM peak hour. With proposed improvements at US 29 and US 17 intersections in Alternatives 1 and 2, average speeds on westbound Route 28 increase to 20 mph, and levels of service improve to LOS E as compared to the no build scenario. In Alternatives 3 and 4, average travel speeds on both eastbound and westbound Route 28 are 25 mph or higher, equating to LOS D or better in AM and PM peak periods.

The arterial analysis shows that running times, or the time required to traverse Route 28 between the US 29 and US 17 intersections, is about three (3) minutes for the existing and future traffic conditions with and without the improvements at the US 29 and US 17 intersections. Delays at the signals on both ends of the corridor are the limiting factor for traffic. This indicates that the two-lane Route 28 has adequate

capacity to operate at LOS D or better for existing and projected traffic volumes, and improvements are needed just at the signalized intersections.

CONCLUSIONS

Capacity analyses were conducted for the Route 28 improvement project for the existing year (2014), the build out year (2020), and the design year (2043) traffic conditions. Queuing was analyzed for build out and design year conditions. The report also examined safety by analyzing the crash history, and turn lane warrants were evaluated for the intersection of Route 28 and Schoolhouse Road for future build-out and design year scenarios.

Summary of Safety Analysis

Crash history data provided by VDOT for a three-year period (2012-2014) was analyzed to determine trends in crash types. A total of 53 crashes were reported along Route 28 involving 38 injuries. No fatalities occurred on Route 28 within the time period examined. Rear-end crashes were the most prevalent type, and they were clustered at the intersections of Route 28 with US 29, US 17, and Schoolhouse Road.

The crash and injury rates on Route 28 are about twice the statewide and districtwide rates for primary roads. This indicates that for the existing roadway and geometric conditions, the study segment of Route 28 is a critical crash location as compared to other roads with a similar functional classification within the state and district. Traffic congestion at the signalized intersections on both ends of the project, as well as horizontal and vertical curvature within the project limits are contributing factors to the crash rate. The proposed project is expected to improve both of these elements and reduce the crash and injury rates for the study area. Additional short-term, low cost improvements include signing and pavement marking upgrades at the horizontal curves.

Summary of Existing Year (2014) Results

All unsignalized intersections currently operate at acceptable levels of D or better, but several movements at the signalized intersection located on either end of the project operate at unacceptable levels of E or F during both peak periods. The following movements operate at LOS E or worse.

<u>Route 28 at US 17</u>

- AM Peak: eastbound left turn and through movements operate at LOS E or F with an average 1 to 2 min/veh of delay.
- AM Peak: All left turns operate at LOS E with an approximately 1 min/veh of delay.
- PM Peak: all left turns operate at LOS E or F. The westbound through movement operates at LOS F with over 2 min/veh of delay. The overall intersection operates at LOS D.

<u>Route 28 at US 29</u>

- PM Peak: westbound approach operates at LOS F with an over 2 min/veh of delay. The overall intersection operates at LOS D.

Summary of Build Out Year (2020) Results

Turn lane warrants at the intersection of Route 28 at Schoolhouse Road show that dedicated left and right turn lanes are warranted for both 2020 build out and 2043 design year traffic conditions. These lanes are included in the proposed roadway improvements for both scenarios.

With the proposed roadway improvements at build out, the benefits in traffic operation are as follows:

- With the construction of dual left turn lanes at Route 28 and US 29, all movements improve to D or better, and westbound queues are significantly reduced.

- With the construction of dual left turn lanes at Route 28 and US 17 and signal timing optimization, the intersection operation improves, with an eastbound and westbound through movements delay reduction of 0.5 to 1 min/veh in the AM peak period. However, the intersection still operates at a poor service level of LOS E in the PM peak period.

Summary of Design Year (2043) Results

Even with the proposed improvements, both signalized intersections are expected to operate with overall service levels of E or F. These two intersections would require major geometric redesign to provide enough capacity for the expected future traffic volumes. The individual turning movements with poor service levels of E or F in 2043 are listed as follows:

- Route 28 at US 29:
  - AM Peak - Eastbound approach operates at LOS E.
  - PM Peak - Several individual turning movements operate at LOS E or F.
- Route 28 at Southcoate Village Drive: southbound approach operates at LOS E in the PM Peak.
- Route 28 at Schoolhouse Road: northbound approach operates at LOS E in the PM Peak.
- Route 28 at Oak Shade Road: southbound approach operates at LOS F in the AM and PM Peak.
- Route 28 at US 17: several movements operate at LOS E or F in both the AM and PM peak periods.

A queuing analysis was performed for 2043 traffic conditions to determine the required storage and taper lengths at each intersection. All turn lanes were designed to accommodate the expected queue lengths in the design year.

Summary of No Build Comparison

Because the signalized intersections within the project limits are still expected to operate at LOS E or F in the design year, 2043 no build conditions were analyzed to compare delays and level of service in the future if the project is not constructed.

While the proposed project does not achieve intersection service levels of LOS D or better at these two intersections, it does provide significant improvements for some of the individual movements. A comparison of results with and without the project show that the project provides the following benefits:

<u>Route 28 at US 29</u>

- Westbound dual left turn lanes on Route 28 improves this movement from LOS E to D in the AM peak period.
- Without improvements, the westbound approach operates at LOS F in the PM peak period with approximately 10 min/veh of delay. This is reduced to 1.5 min/veh with the construction of dual left turn lanes.

<u>Route 28 at US 17</u>

- With the construction of an additional left turn lane, delays for the eastbound left turn reduce by approximately 2.5 min/veh during the PM peak hour.

Summary of Alternative Mitigation Strategies

Various alternatives were explored to determine if acceptable service levels could be attained by adding turning lanes, through lanes, or unconventional intersection configurations. Adding turn lanes at the signalized intersections could achieve LOS D instead of LOS F but would require additional right-of-way and improvements outside the scope of this project. In addition, signalizing the intersection of Route 28 at

Oak Shade Road improves the intersection to acceptable service levels. Traffic volumes at this intersection should be monitored and signal warrants evaluated when service levels decrease in the future.

Summary of Arterial Level of Service Analysis

The arterial analysis shows that running times, or the time required to traverse Route 28 between the US 29 and US 17 intersections is about 3 minutes, which equates to about 40 mph running speed for the existing and future traffic conditions. When signal delay is included, LOS decreases. This indicates that two-lanes on Route 28 provide adequate capacity to operate at an acceptable service levels of D or better for the existing as well as the projected traffic volumes.

However, when signal delay is included from the US 29 and US 17 intersections, the average travel speed on westbound Route 28 reduces to less than 10 mph for the future no build scenario. With the proposed intersection improvements at US 29 and US 17 as described in Alternatives 3 and 4, average travel speeds are 25 mph or higher, equating to LOS D or better.

Summary of Project Benefits

The capacity and queuing analyses results for the build out (2020) and design year (2043) conditions indicate that the proposed improvements result in a significant reduction in delays along Route 28 between US 29 and US 17 intersections for the future traffic volume conditions. To bring the signalized intersections at either end of the project, major geometric redesign such as unconventional at-grade intersection design or an interchange would be required to provide adequate capacity.

APPENDIX A – (2014) TURNING MOVEMENT AND 24-HOUR COUNTS