

February 10, 2023

Project# 25669.143

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Virginia Department of Transportation
2430 Pine Forest Drive
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From: Andrew Butsick, PE; Tiffany Lim

CC: Jeff Kuttesch, PE, PTOE

RE: Route 632 Safety Study – Goochland County

SAFETY ASSESSMENT

Kittelison and Associates, Inc. (Kittelison) prepared this memorandum to document the safety assessment performed on a 5.1-mile segment of Route 632 (Fairground Road) in Goochland County, Virginia. The study corridor extends from the intersection of Route 632/522 (Sandy Hook Road) on the western end to Route 632/ US 250 (Broad Street Road) on the eastern end. Due to upcoming construction of a roundabout at Route 632/522 (Sandy Hook Road), this intersection was excluded from the study. The goal of this study was to understand existing conditions and provide recommendations to improve road safety. **Figure 1** illustrates the study corridor.

Two priority intersections were identified and are listed below:

- Route 632 and US 250 (Broad Street Road)
- Route 632 and Route 634 (Maidens Road)

The first phase of this study included an existing conditions analysis which included:

- Summary of Existing Roadway Characteristics
- Year 2022 (Existing) Traffic Operations
- Year 2042 No-Build Traffic Operations
- Historical Safety Analysis

From the existing conditions, key challenges and opportunities were identified. Kittelison developed recommendations to address safety concerns at the two study intersections and along the corridor. This memorandum summarizes the proposed recommendations, including the following analyses and calculations that were considered:

- Screening analysis to evaluate alternative intersection configurations
- Operational Analysis
- Planning-Level Cost Estimates

Attachment A contains concept level diagrams of the final recommendations of this study and **Attachment B** contains planning level cost estimate for the recommendations.



Figure 1. Site Vicinity Map

Existing Roadway Conditions

The Route 632 study corridor was visited and inventoried in August 2022. At that time, information was collected regarding site conditions, adjacent land uses, existing transportation facilities, and traffic operations in the study area.

TRANSPORTATION INFRASTRUCTURE

Table 1 summarizes the primary transportation facilities along the study corridor. At a high level, the corridor is a two-lane undivided cross-section with a varying-width outside shoulder. Most of the corridor has less than a two-foot shoulder. Sections of the corridor with a steep recovery slope have existing guardrails.

Figure 2 illustrates a typical view of the section along the corridor. **Figure 3** displays a typical view of a section along the corridor with guardrails.

Table 1. Existing Transportation Facilities and Roadway Designations

Roadway	Classification ¹	Number of Lanes	Speed Limit (mph)	Median	Side-walks	Bicycle Lanes	On-Street Parking
Route 632 (Fairground Road) from US 522 to Route 634	Minor Arterial	2	45	No	No	No	No
Route 632 (Fairground Road) from Route 634 to US 250	Minor Arterial	2	55/45 ²	No	No	No	No
Route 634 (Maidens Road)	Minor Collector/Major Collector ³	2	40/45 ³	No	No	No	No
US 250 (Broad Street Road)	Minor Arterial	2	55	No	No	No	No

¹ Per VDOT 2014 Functional Classification Map

² Route 632 east of Route 634 has a posted speed limit of 55 mph for passenger vehicles and 45 mph for trucks.

³ Route 634 has different classifications and speed limits north of and south of Route 632. The classification and speed limit are displayed as north of Route 632/south of Route 632.



Figure 2. Typical undivided cross-section on Route 632



Figure 3. Typical undivided cross-section with guardrails on Route 632

Pedestrian and Bicycle Facilities

Current pedestrian and bicycle facilities are limited along the corridor, with no sidewalks or off-street bicycle facilities present.

Transit Facilities

No fixed-schedule transit service is provided within the immediate vicinity of the study corridor.

FIELD VISIT

A field visit was conducted along the study corridor to document existing roadway characteristics. The qualitative field review included an assessment of current:

- Roadway alignment and cross-sectional elements (e.g., sight distances, shoulders, cross/side slopes)
- Auxiliary lanes
- Intersections
- Signs and lighting
- Marking and delineation
- Barriers and clear zones
- Accommodations for non-motorized users
- Accommodations for older drivers
- Accommodations for heavy vehicles
- Pavement conditions
- Visual distractions
- Design consistency
- Weather (sunlight)
- Surrounding terrain

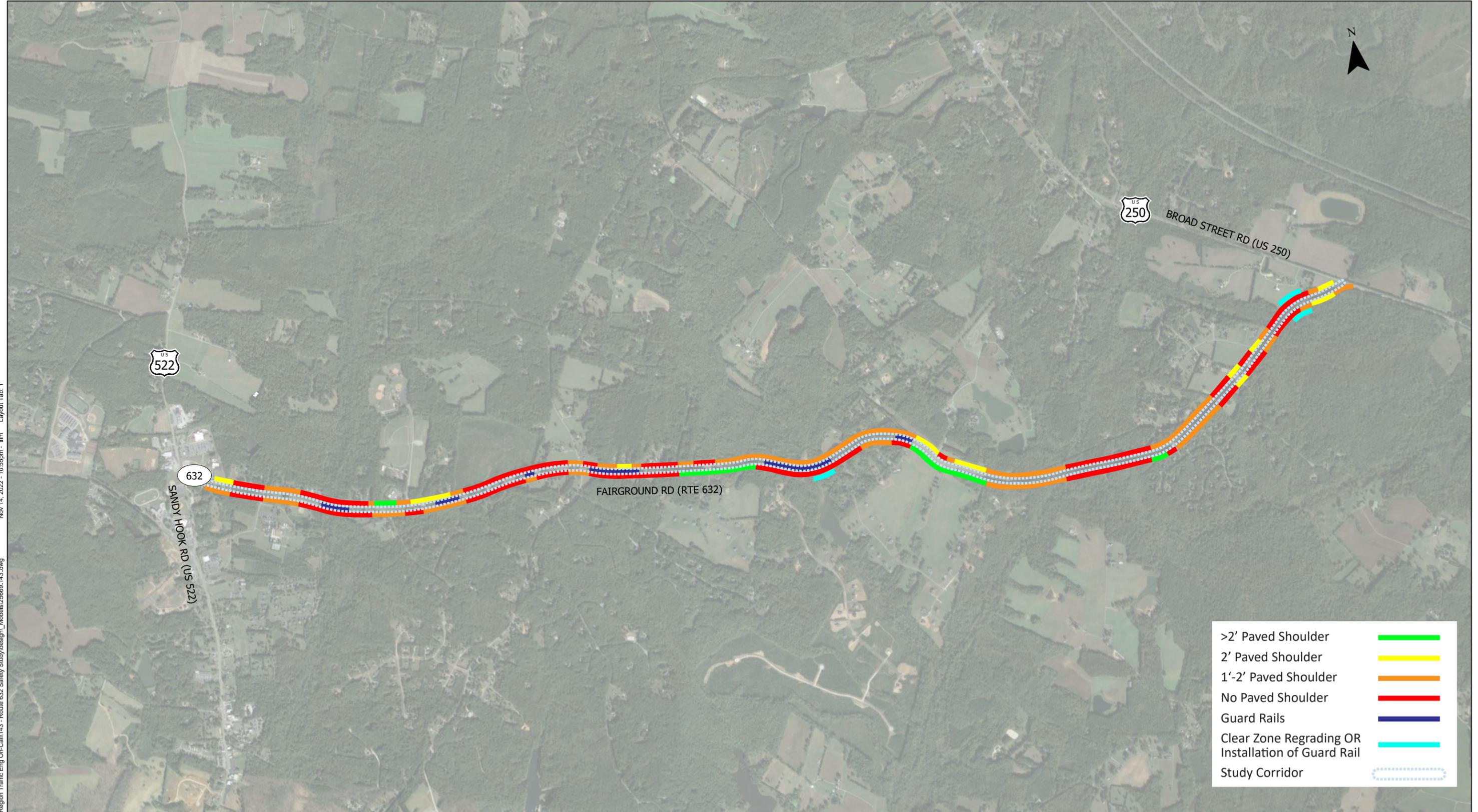
Prior to conducting the field visit, the study team reviewed the crash history (discussed in the following section) as well as roadway characteristics through Google Earth and ArcGIS. The team produced aerial maps that were brought to the field visit. Team members completed the field visit on a weekday in August 2022. They walked along segments of the study corridor and took photographs, videos, and notes of the items listed above. Key findings and potential crash risk factors are described in the following sub-sections. Key findings and potential crash risk factors are described in the following sub-sections.

Narrow Paved Shoulders

Most of the corridor currently has either no paved shoulders or paved shoulders that are less than two feet in width. **Figure 4** illustrates a few examples of sections with narrowly paved shoulders. **Figure 5** provides an inventory of shoulder width along the study corridor, including sections where guardrail is present.



Figure 4. Narrow paved shoulders along Route 632



Roadway Edge Conditions
Goochland County, VA

Figure
5

Missing or Faded Stop Bars

The field visit also illustrated several minor street approaches at several unsignalized intersections have either faded or no stop bars. The presence of stop bars at unsignalized intersections help to direct the attention of drivers to the presence of the intersection, as well as help delineate a safe location for minor road vehicles to stop. This, in turn, can help reduce the potential for angle crashes¹. The following locations and approaches were identified as having stop signs without stop bars:

- Route 632/634 (Maidens Road, SB approach)
- Route 632/Greenbriar Branch Drive
- Route 632/Shade Hunter Lane
- Route 632/698 (Mickeytown Road)
- Route 632/637 (Hawk Town Road)
- Route 632/Ridgewell Drive
- Route 632/1210 (Horsepen Hills Road)
- Route 632/The Preserve Drive

The following locations and approaches were identified with faded stop bars:

- Route 632/634 (Maidens Road, NB approach)
- Route 632/665 (Hidden Rock Lane)

In addition, some stop bars and stop signs at intersections were observed to be located too far upstream from the intersection to provide adequate sight lines. At the northbound approach of the Route 632/Route 634 (Maidens Road) intersection, the stop bar was located too close to the intersection and westbound left-turning vehicles were observed to regularly cross the stop bar. This behavior could result in angle crashes between turning and stopped vehicles. **Figure 6** illustrates the current conditions at the Route 632/Route 634 intersection. At the southbound approach of Route 632/Route 637 (Hawk Town Road) intersection, the stop sign is located farther from the intersection and vehicles may experience poor sight distance due to adjacent trees. **Figure 7** illustrates the pavement marking conditions at the Route 632/Route 637 intersection.

¹ Federal Highway Administration, *Low-Cost Safety Enhancements for Stop-Controlled and Signalized Intersections*, FHWA-SA-09-020. May 2009.



Figure 6. Faded and missing pavement stop bars at Route 632/634 (Maidens Road)



Figure 7. Stop sign and no stop bar at Route 632/637 (Hawk Town Road)

Missing Turn Lane Pavement Markings

Several turn lanes along Route 632 were observed without left-turn or right-turn arrow pavement markings. While not required by the *Manual on Uniform Traffic Control Devices (MUTCD)* in every instance based on engineering judgement², a lack of lane-use arrow markings for turn lanes may to driver confusion and incorrect lane usage. Turn lane arrow pavement markings were observed missing along Route 632 at the following intersections:

- Route 632/Commercial driveway entrance east of US 522 (Sandy Hook Road)
- Route 632/Dickinson Road
- Route 632/Hidden Rock Lane
- Route 632/Breeze Hill Drive
- Route 632/The Preserve Drive

Figure 8 illustrates the missing turn-lane arrows for the left-turn lane on Route 632 at The Preserve Drive.

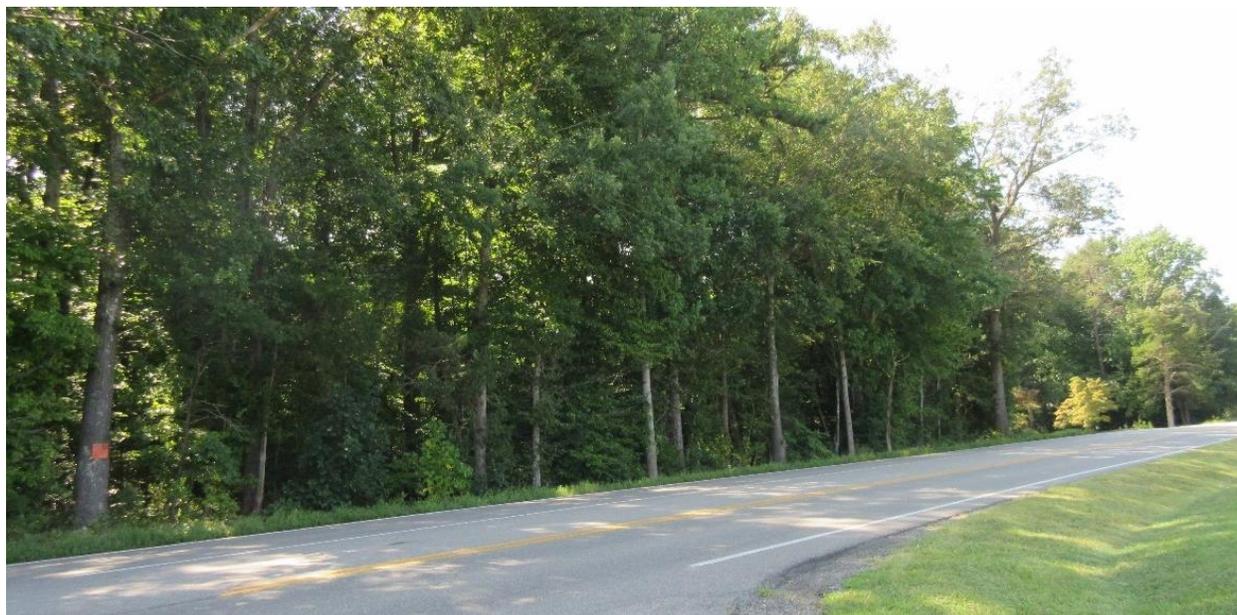


Figure 8. Eastbound turn lane missing arrow pavement markings on Route 632 at The Preserve Drive

Non-Recoverable Slopes

Steep roadside slopes are present in some sections of the corridor and appear to be non-recoverable for vehicles that might exit the roadway. At the edge of many of these slopes is a dense tree line, which can lead to higher severity fixed-object crashes. Where re-grading of the roadside slopes is not feasible, segments may benefit from tree trimming to increase clear zones or the addition of guardrail. These locations include segments within the sections:

- Between Anmar Drive and the area near the Beaverdam Creek
- Between The Preserve Drive and US 250 (Broad Street Road)

Figure 9 illustrates the non-recoverable slopes and dense tree line along Route 632 near Beaverdam Creek.

² Federal Highway Administration. *Manual on Uniform Traffic Control Devices*. Section 3B.20. 2009 Edition.



Figure 9. Example of Non-Recoverable Slopes (Route 632 near Beaverdam Creek)

Historical Crash Review

The study team obtained and analyzed the most recent five (5) years of complete crash data available for Route 632 (Fairground Road) from VDOT's database. The crash data used was from January 1, 2017, to December 31, 2021; there were 117 reported crashes in this period. The location data allowed the study team to geocode the crashes and map them in GIS software. **Attachment C** provides crash diagrams that indicate where each incident occurred on the study corridor. The study team evaluated both corridor-wide and intersection-specific safety trends.

CORRIDOR TRENDS

The study team considered crash patterns and trends in the corridor-wide data by evaluating the following:

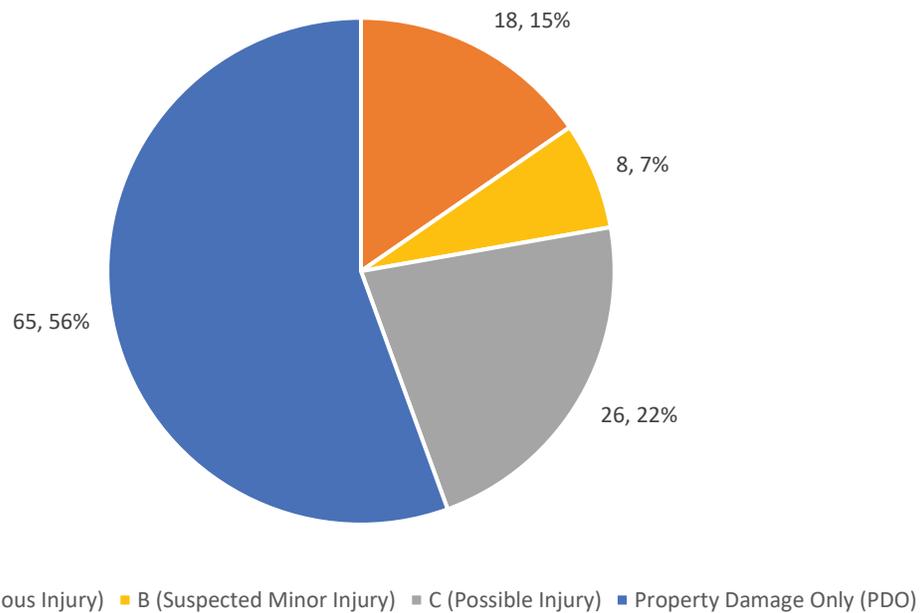
- Crash Severity,
- Crash Type,
- Lighting,
- Speed,
- Weather Conditions, and
- Year

In the five years of data analyzed, all reported crashes involved motor vehicles or motor vehicles and other objects except for one crash involving a pedestrian. Fixed object off road, rear-end, and angle crashes were the top three crash types. The study team used these findings to help identify and prioritize safety treatments.

Severity

Figure 10 summarizes the reported crash types by severity.

- 65 of the 117 crashes recorded resulted in property damage only. This accounted for 56 percent of the total crashes.
- No crashes resulted in a fatality, and eighteen crashes (15 percent of total crashes) resulted in a suspect serious injury.



Source: Virginia Department of Transportation, Kittelson 2021.

Figure 10. Crash Severity, January 2017 to December 2021

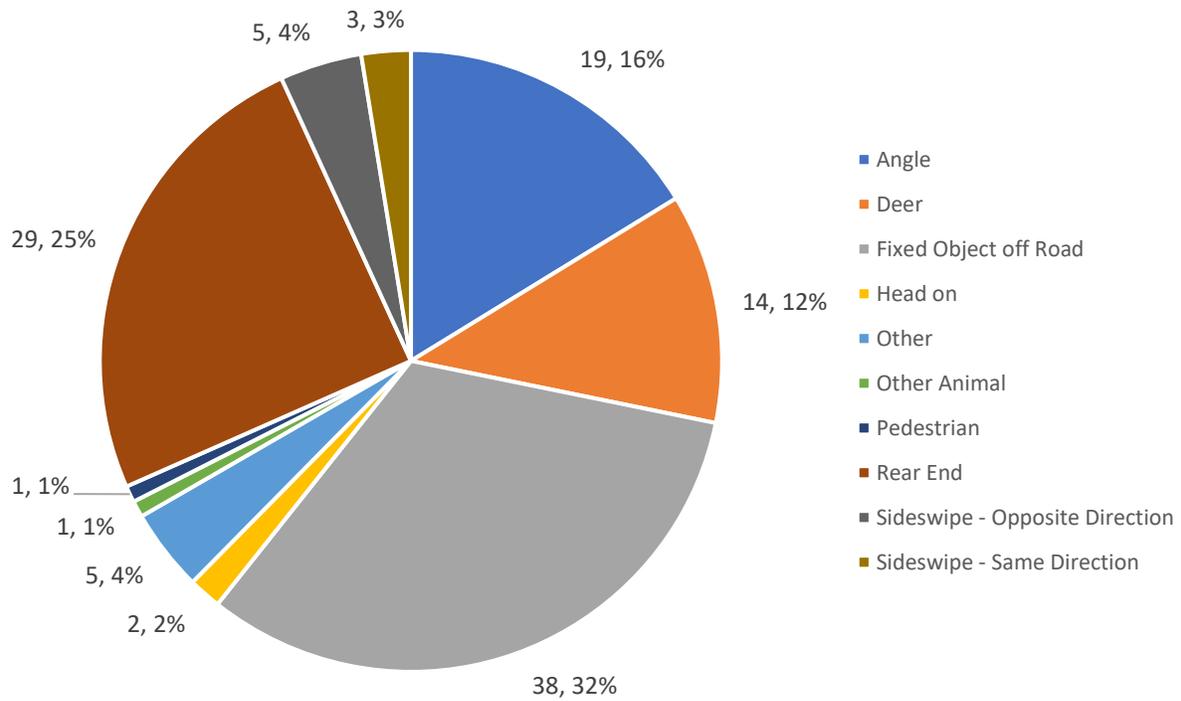
Crash Type

Figure 11 identifies the crash types of the reported crashes.

- Fixed object off road (32 percent), rear end (25 percent), and angle (16 percent) crashes represent the largest proportion of crash types.
- Fixed object off road (38), rear end (29), and animal (19) crashes make up over 73 percent of all crashes.

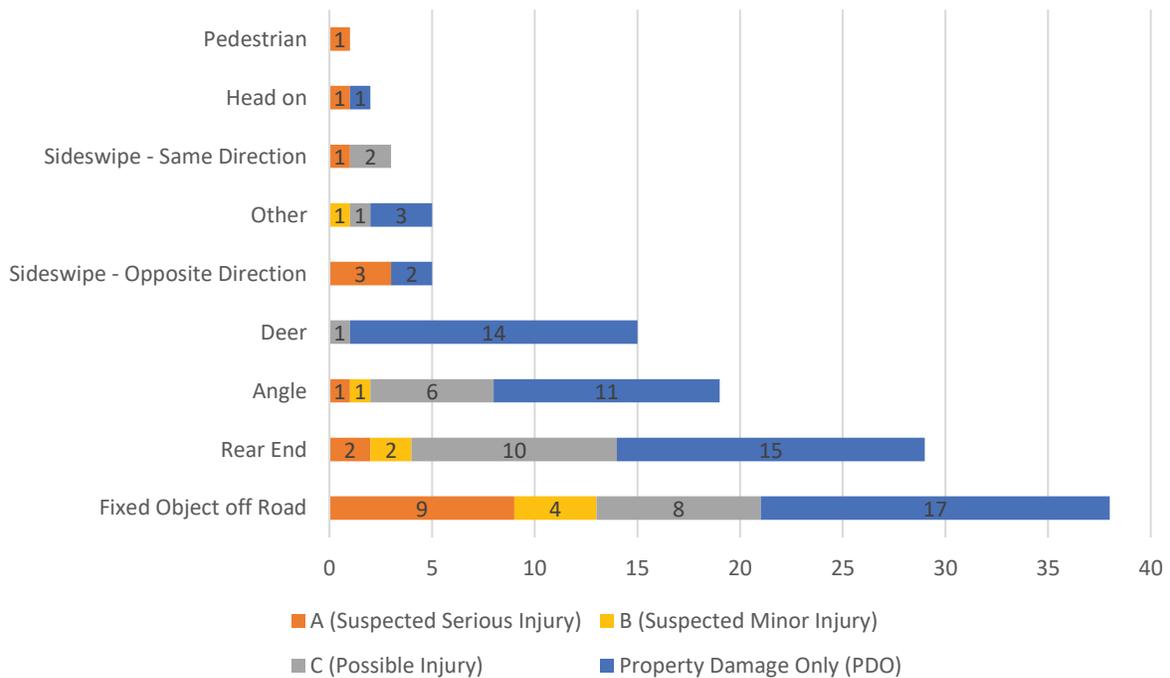
Figure 12 summarizes reported crashes by crash type and severity.

- Of the 38 fixed object off road crashes, 44 percent resulted in property-damage only, 24 percent resulted in suspected serious injury, and the other 32 percent resulted in possible or suspected minor injury.
- Over 93 percent of crashes with deer and other animals were property-damage only.



Source: Virginia Department of Transportation, Kittelson 2021.

Figure 11. Vehicle Crash Types, January 2017 to December 2021



Source: Virginia Department of Transportation, Kittelson 2021.

Figure 12. Reported Crash by Crash Type and Severity, January 2017 to December 2021

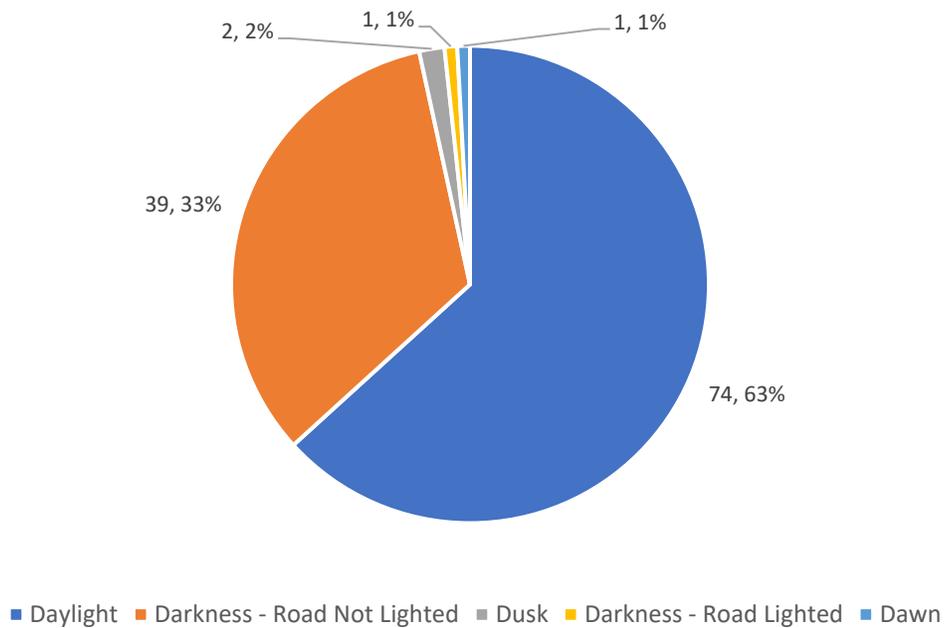
Lighting

Figure 13 displays the study corridor crash count by reported lighting condition.

- More than half of the crashes (63 percent) occurred under daylight conditions.
- 33 percent of the crashes occurred in dark conditions. There is limited lighting along the corridor with wooded areas and occasional residences.

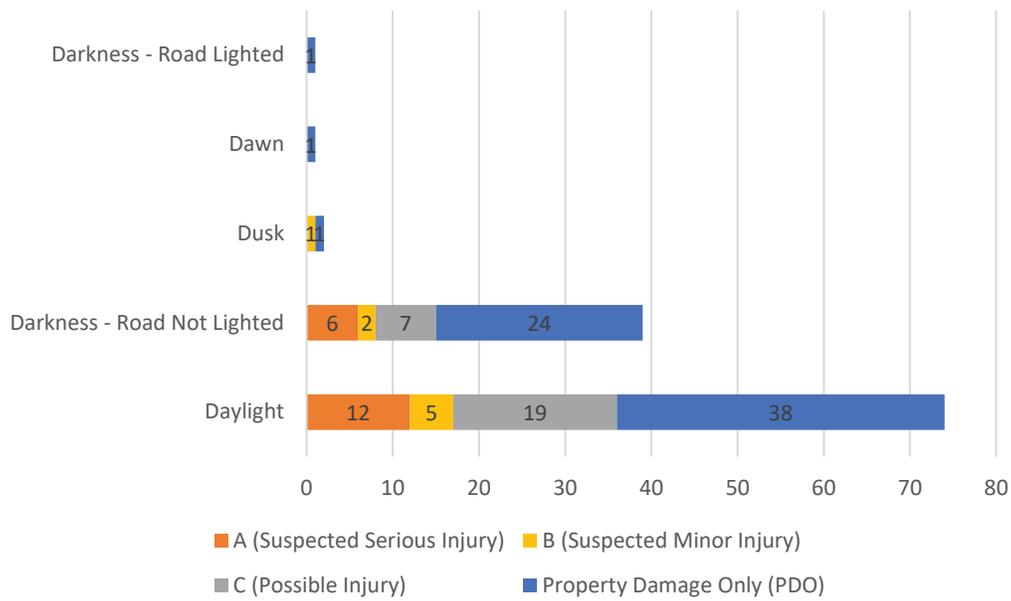
Figure 14 summarizes the reported crashes by lighting and severity.

- 15 percent of crashes that occurred during unlit, dark roadways resulted in a suspected serious injury.
- 16 percent of crashes that occurred during daylight conditions resulted in a suspected serious injury.



Source: Virginia Department of Transportation, Kittelson 2021.

Figure 13. Reported Crashes by Lighting, January 2017 to December 2021



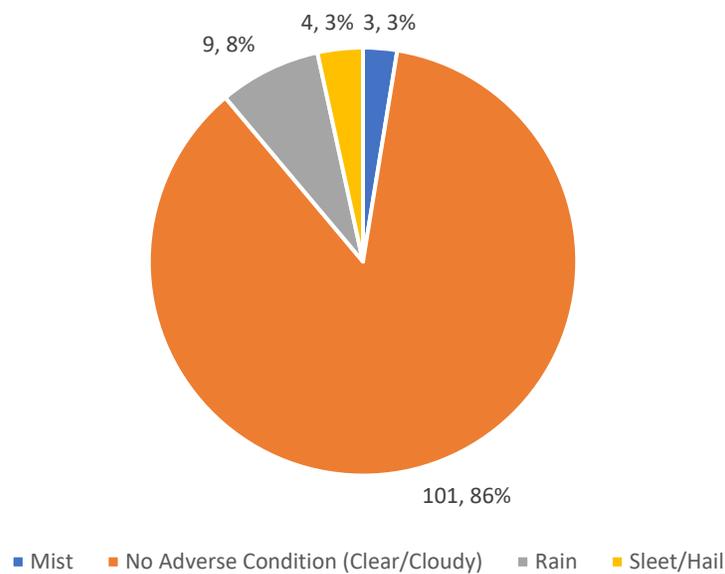
Source: Virginia Department of Transportation, Kittelson 2021.

Figure 14. Reported Crashes by Lighting and Severity, January 2017 to December 2021

Weather

Figure 15 provides the study corridor crash count by weather condition.

- The majority of crashes (86 percent) occurred under dry conditions.
- Rain, sleet/hail, and mist conditions accounted for 16 of the total crashes (14 percent)



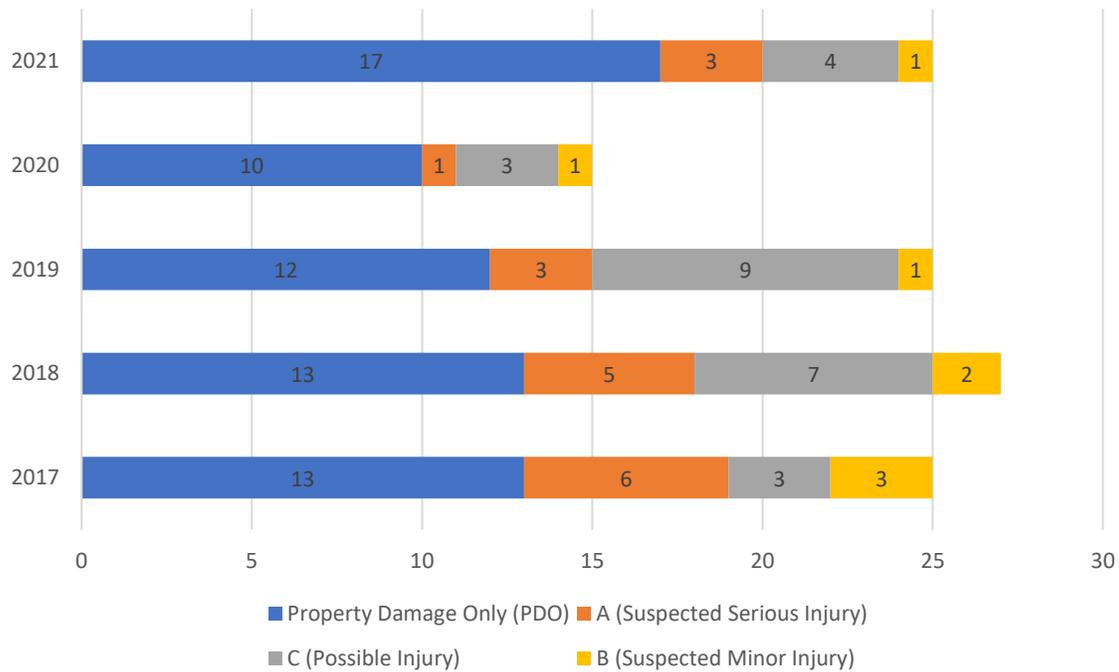
Source: Virginia Department of Transportation, Kittelson 2021.

Figure 15. Reported Crashes by Weather Condition, January 2017 to December 2021

Crash Year

Figure 16 summarizes the study corridor crash count by year and severity.

- 2018 had the highest count of crashes (27 total crashes). 2017, 2019, and 2021 each had 25 total crashes.
- The frequency of crashes per year was between 15 to 27 crashes.



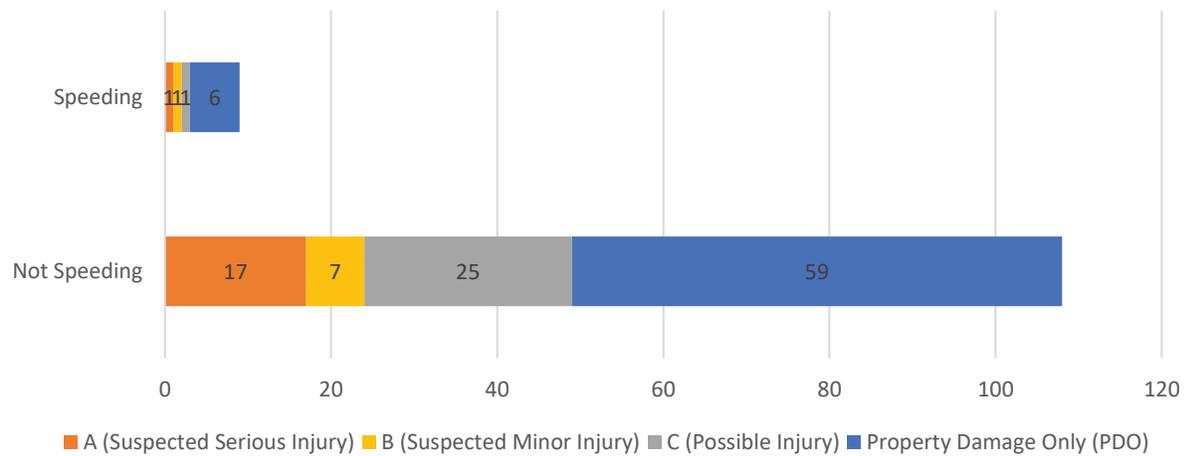
Source: Virginia Department of Transportation, Kittelson 2021.

Figure 16. Reported Crashes by Year and Severity, January 2017 to December 2021

Speeding

Figure 17 summarizes the study corridor crash count by speeding and severity. Statistics related to speeding are based on FR-300 reports, which are based on speculation and should be taken as a reference only.

- Less than eight percent of total crashes involved speeding.
- One of the nine total crashes (11 percent) involving speeding resulted in a suspected serious injury.



Source: Virginia Department of Transportation, Kittelson 2021.

Figure 17. Reported Crashes by Speeding and Severity, January 2017 to December 2021

INTERSECTION FINDINGS

Route 632 and Route 634 (Maidens Road)

Fourteen crashes occurred within 150 feet of the Route 632 and Route 634 (Maidens Road) intersection. Ten of the 14 crashes were angle crashes and these were observed on all approaches. Vehicles did not yield to right of way, did not stop at the stop sign, or were turning and crashed into vehicles at a stopped at a stop sign.

Route 632 and US 250 (Broad Street Road)

Four crashes occurred within 150 feet of the Route 632 and US 250 (Broad Street Road) intersection. A mix of crash types were observed with an angle crash, a sideswipe (same direction) crash, and two out of control/run-off-road crashes.

Route 632 and Route 637 (Hawk Town Road)

Though Route 632 and Route 637 (Hawk Town Road) was not identified as a priority intersection, 10 crashes occurred within 150 feet of this intersection. Fifty percent of these crashes were rear-end crashes. Based on the location of the crashes, it appears that eastbound left-turning vehicles might be waiting to turn and through vehicles are not expecting to stop, resulting in rear ends.

Traffic Operations

The existing year and design year 2042 traffic operations at the two priority intersections were evaluated to determine if any operational/delay constraints may be contributing to the safety performance at these intersections.

Existing Year 2022 Traffic Operations

INTERSECTION OPERATIONS

Two-hour turning movement counts were collected during the weekday a.m. (7 a.m. to 9 a.m.) and weekday p.m. (4 p.m. to 6 p.m.) peak hours at Route 632's intersections with US 250 (Broad Street Road) on a typical weekday in August 2022. Traffic counts at the Route 632/Route 634 (Maidens Road) were obtained from a February 2022 traffic study provided by VDOT staff. Pneumatic tube counts capturing vehicle speeds and classification were collected at two locations along the corridor over a 48-hour period between August 23, 2022, and August 24, 2022. These locations include:

- East of Route 637 (Hawk Town Road)
- West of Route 634 (Maidens Road)

Figure 18 illustrates the count locations. **Attachment D** contains the turning movement count and pneumatic tube count data.

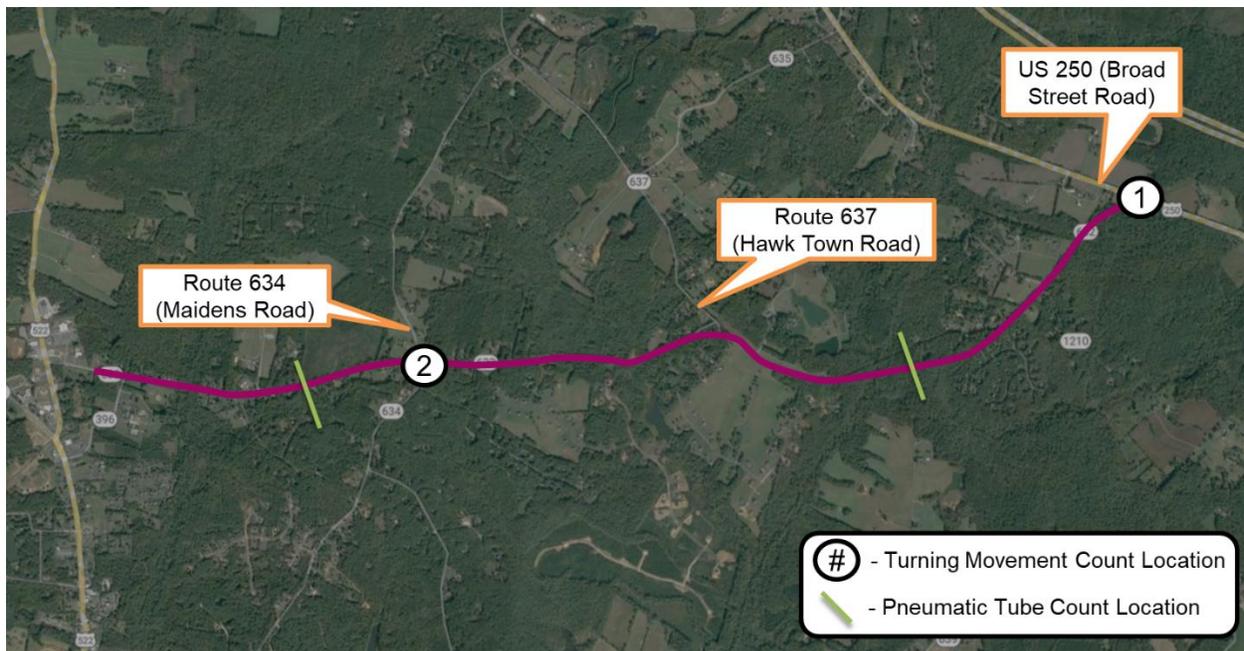


Figure 18. Traffic Count Locations

The level of service (LOS) analysis described in this report was performed in accordance with the procedures stated in the Highway Capacity Manual, 6th Edition (HCM) and report HCM 6th Edition outputs per TOSAM. This analysis is based on the peak 15-minute flow rate during each of the study periods to evaluate all intersection levels of service. For this reason, the analysis reflects conditions that are only likely to occur for 15 minutes out of each average peak hour. Traffic conditions during all other weekday time

periods will likely operate better than described in this report. Traffic operations were evaluated using Synchro 11.

Figure 19 summarizes the existing weekday a.m. and weekday p.m. peak hour operations at the priority intersections. **Table 2** displays the Synchro 11 peak hour levels of service, delay, and 95th-percentile queue for each lane group by intersection. **Attachment E** contains the existing conditions level of service worksheets.

As shown, the critical eastbound left-turn movement at the US 250/Route 632 intersection operates at LOS D and LOS E during the weekday a.m. and weekday p.m. peak hours, respectively. This movement only serves two vehicles during each of the weekday peak hours. At the Route 632/Route 634 intersection, the critical movement operates at LOS C during both peak hours.

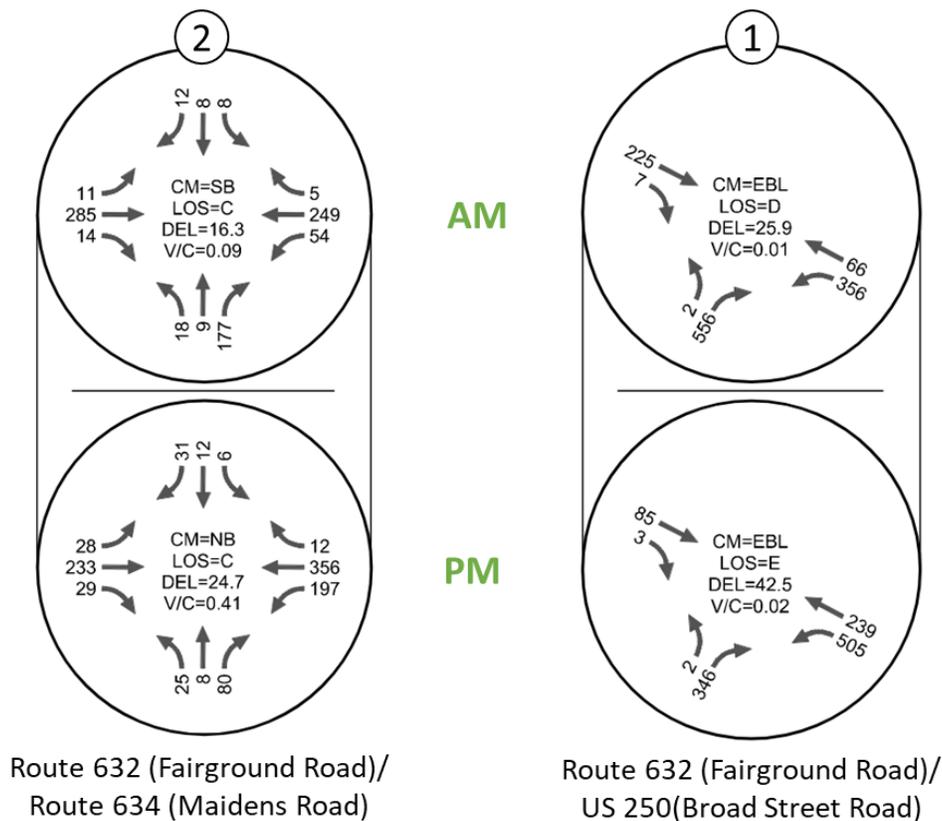


Figure 19. Year 2022 (Existing) Traffic Operations at Priority Intersections

Table 2. Existing Traffic Conditions – Weekday AM and Weekday PM Peak Hours

Intersection (#)	Traffic Control	Approach	Lane Group	Weekday AM			Weekday PM		
				LOS	Delay (s)	Q95 (ft)	LOS	Delay (s)	Q95 (ft)
US 250 (Broad Street Road) (#1)	Two-way Stop-Controlled	EB	L	D	25.9	0	E	42.5	3
			R	A	0.0	0	A	0.0	0
		EB Approach		D	25.9	-	E	42.5	-
		NB	L	A	8.9	30	A	8.7	40
			T	-	0.0	0	-	0.0	0
		NB Approach		-	7.5	-	-	5.9	-
		SB	TR	-	0.0	0	-	0.0	0
SB Approach		-	0.0	-	-	0.0	-		
Route 634 (Maidens Road) (#2)	Two-way Stop-Controlled	EB	LTR	A	7.8	0	A	8.2	3
		EB Approach		-	0.3	-	-	0.8	-
			LTR	A	8.0	3	A	8.4	15
		WB Approach		-	1.4	-	-	2.9	-
		NB	LTR	B	14.0	40	C	24.7	48
		NB Approach		B	14.0	-	C	24.7	-
		SB	LTR	C	16.3	8	C	22.1	18
SB Approach		C	16.3	-	C	22.1	-		

SEGMENT OPERATIONS

Table 3 summarizes the speeds observed and vehicle classification breakdown at each of the pneumatic tube count locations over the 48-hour period. As shown, over 50 percent of vehicles were shown to be traveling above the posted speed limit at either location. The calculated 85th percentile speeds were approximately five to seven miles per hour greater than the posted speed. Guidance in the *Manual on Uniform Traffic Control Devices (MUTCD)* suggests the posted speed should be within five (5) miles-per-hour of the 85th-percentile speed of free-flowing traffic³.

This level of speeding in the 2022 data is indicative of a roadway cross-section and design speed that does not quite align with the intended/posted speed. Rather than suggest increasing the posted speed to better match the observed 85th-percentile speeds, this study will evaluate means of safely reducing speeds along this section through a combination of roadway design treatments/features and targeted enforcement.

The table also shows that over 95 percent of the vehicles traveling in either direction along Route 632 are cars (serving as a heavy commuter route to and from Richmond).

³ Federal Highway Administration. *Manual on Uniform Traffic Control Devices*. Section 2B.13. 2009 Edition.

Table 3. Segment Speed and Vehicle Classification Summary

Segment	Travel Direction	Posted Speed (mph)	85 th Percentile Speed (mph)	Percentage of Vehicles Over Speed Limit (%)	Vehicle Classification (%)		
					Cars	Medium Trucks	Heavy Trucks
East of Route 634 (Maidens Road)	Eastbound	55/45	62.4	69%	95.7%	2.8%	1.5%
	Westbound	55/45	60.6	56%	95.3%	3.1%	1.5%
East of Route 634 (Maidens Road)	Eastbound	45	52.2	53%	96.0%	2.7%	1.3%
	Westbound	45	52.8	55%	96.3%	2.5%	1.2%

Design Year 2042 Traffic Operations

To assess future 2042 traffic conditions, a 1.5 percent compound annual growth rate was applied to existing 2022 volumes. The 1.5 percent growth rate was determined with input from VDOT and County staff after accounting for the historical growth rates along Route 632 between 2010 and 2021, growth rates shown in the Richmond Travel Demand Model's projected growth along the corridor, and known development plans.

INTERSECTION OPERATIONS

Figure 20 summarizes the design year 2042 no-build weekday a.m. and weekday p.m. peak hour operations at the study intersections. **Table 4** displays the Synchro 11 peak hour levels of service, delay, and 95th-percentile queue for each lane group by intersection. The critical eastbound left-turn movement at the US 250/Route 634 intersection is forecast to operate at LOS F and LOS D during the weekday a.m. and weekday p.m. peak hours, respectively. While the delays are projected to be high, the critical movement is only projected to serve three vehicles during each of the weekday peak hours and operate well below capacity. Each of the other movements are anticipated to operate with more reasonable levels of delay.

The delays on the minor street approaches to the Route 632/Route 634 intersection are anticipated to grow substantially with the critical northbound movement anticipated to operate at LOS F during the weekday p.m. peak hour. Queues on the northbound approach are forecast to reach 10 vehicles long. This increase in delay will likely lead to drivers on the minor approaches accepting smaller gaps in traffic on the mainline (Route 632) to complete their maneuver. This, in turn, may lead to an increase in angle crashes.

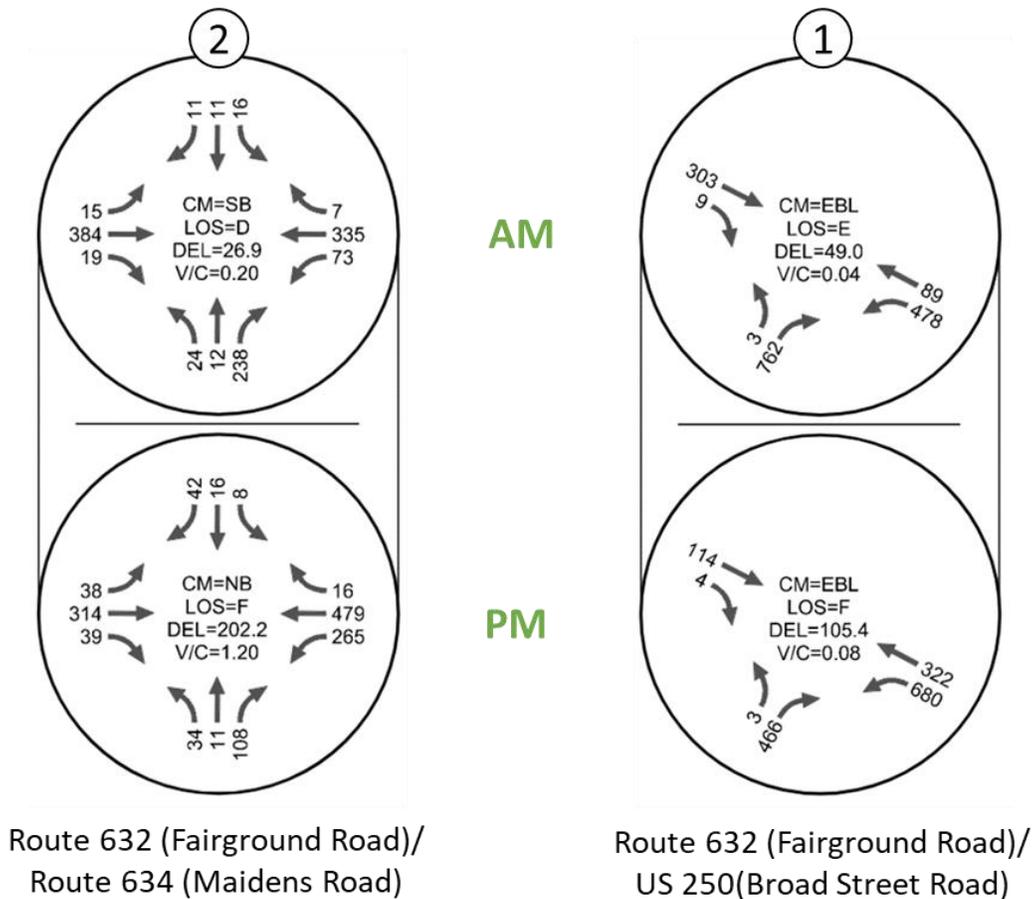


Figure 20. Design Year 2042 Traffic Operations at Priority Intersections

Table 4. Design Year 2042 Traffic Conditions – Weekday AM and Weekday PM Peak Hours

Intersection (#)	Traffic Control	Approach	Lane Group	Weekday AM			Weekday PM			
				LOS	Delay (s)	Q95 (ft)	LOS	Delay (s)	Q95 (ft)	
US 250 (Broad Street Road) (#1)	Two-way Stop-Controlled	EB	L	E	49.0	3	F	105.4	8	
			R	A	0.0	0	A	0.0	0	
		EB Approach			E	49.0	-	F	105.4	-
		NB	L	B	10.2	55	A	9.8	70	
			T	-	0.0	0	-	0.0	0	
		NB Approach			-	8.6	-	-	6.7	-
		SB	TR	-	0.0	0	-	0.0	0	
SB Approach			-	0.0	-	-	0.0	-		
Route 634 (Maidens Road) (#2)	Two-way Stop-Controlled	EB	LTR	A	8.4	0	A	8.7	3	
			EB Approach			-	0.3	-	-	0.8
		WB	LTR	A	8.1	5	A	9.1	25	
			WB Approach			-	1.5	-	-	3.2
		NB	LTR	C	22.5	95	F	202.2	248	
			NB Approach			C	22.5	-	F	202.2
		SB	LTR	D	26.9	18	F	64.8	70	
SB Approach			D	26.9	-	F	64.8	-		

Turn-Lane Evaluations

To reduce the potential for rear-end crashes and angle crashes, the need for mainline left-turn lanes were evaluated at the Route 632/Route 634 (Maidens Road) and Route 632/Route 637 (Hawk Town Road) intersections through application of the warrants in Appendix F of the VDOT *Road Design Manual (RDM)*. The latter was included due to the prevalence of rear-end crashes in the eastbound direction. Per Appendix F of the VDOT *RDM*, left-turn lanes are required on a two-lane roadway if the applicable warrants in Table 3-1 and/or Figures 3-5 through 3-22 are met. The applicable figure varies based on the design speed of the roadway and estimated left-turning volume relative to the overall approach volume.

The existing and projected 2042 traffic volumes at the two intersections were applied to the VDOT thresholds in Appendix F to determine the appropriateness of a left-turn lane on Route 632. Turning movement counts were not collected at the Route 632/Route 634 intersection; however, 48-hour pneumatic tube counts were collected upstream to the east. Assuming the lowest threshold of eastbound left-turning volumes (five percent) from Route 632 onto Route 634 results in a conservative analysis (i.e., if thresholds are met assuming only five percent of eastbound volumes turn left onto Hawk Town Road, the thresholds would also be met at higher left-turning volumes). **Table 5** illustrates the results of the left-turn lane warrant analysis for both existing and design year 2042 traffic volumes. **Attachment F** contains the application of the existing and projected volumes onto the figures from Appendix F of the *RDM*.

Table 5. Left-Turn Lane Warrants - Route 632 at Maidens Road and Hawk Town Road

Intersection	Travel Direction	Left-Turn Lane Thresholds Exceeded?			
		Existing (2022)		Design Year 2042	
		Weekday AM	Weekday PM	Weekday AM	Weekday PM
Route 632/Route 634	Eastbound	No	Yes	Yes	Yes
	Westbound	Yes	Yes	Yes	Yes
Route 632/Route 637	Eastbound	Yes	Yes	Yes	Yes

As shown, left-turn lanes are warranted from Route 632 onto Route 634 in both directions under existing conditions. Similarly, at the Route 632/Route 637 intersection, an eastbound left-turn lane is warranted under existing conditions (assuming left-turns represent at least five percent of the eastbound approach volume). Based on the 55 mile-per-hour posted speed (assumed 60 mile-per-hour design speed), the left-turn lanes should have a minimum of 200 feet of storage and a 200-foot taper.

Recommended Improvements

Using the findings from the existing conditions analyses and collaboration with VDOT, the study team developed intersection and corridor-wide recommendations to address safety along the Route 632 corridor. These recommendations include, but are not limited to, the following:

- Spot improvements at intersections along the corridor;
- Maintenance-type improvements; and
- Access management improvements.

Several methods were used to evaluate the various recommendations, including:

- Evaluate corridor and cross-sectional treatments;
- Evaluate maintenance improvements;
- Evaluate potential safety benefits from crash modification factors
- Evaluate turn lane warrants
- Assess sight distances and clear zones
- Evaluate non-motorized improvements;
- Evaluate potential access management improvements/strategies to consolidate entrances along the corridor; and

Based on this analysis, a corridor plan is proposed. All recommendations focus on improving safety along Route 632. The recommendations are discussed below by corridor or spot improvements:

- Corridor Improvements
 - Reconstruct paved shoulders and provide two-foot paved shoulders where possible
 - Install shoulder rumble strips
 - Trim trees to increase clear zone
- Spot Improvements
 - Install turn lane arrow pavement markings
 - Install, restripe, and/or reposition stop bars at stop-controlled approaches
 - Install two-way large direction arrow signs at T-intersections
 - Install at least 50 feet of double-yellow centerline striping at stop-controlled approaches
 - Re-grade recoverable zone to minimum standard slope (10:1)
 - Conversion of stop-controlled intersection into single-lane roundabout at Route 632/634
 - Provide a left-turn lane on one or both major road approaches
 - Install right-turn lane on minor approach

Attachment A contains concept level diagrams of the recommendations and **Attachment B** contains planning level cost estimate for all recommendations.

CORRIDOR IMPROVEMENTS

Reconstruct Shoulders/Provide 2-ft Shoulders

As described in the field visit section, many segments along the corridor have narrow paved shoulders with less than two feet of width. The lack of sufficient paved shoulders on both sides of the corridor leaves little recovery room for vehicles errantly deviating from the travel way, which can lead to an increase in run-off-the-road and fixed object crashes. It can also lead to an increase in head-on and sideswipe crashes between vehicles in the opposing direction⁴, as any deviation over the roadway centerline becomes more difficult to avoid for an opposing vehicle. However, providing shoulders that are too wide can lead to an increased prevalence of speeding along the corridor. The extra room for recovery on the outside edge of the roadway creates a sense of comfort for drivers who now have more room for error. The Highway Capacity Manual, 6th Edition estimates for every one-foot of additional shoulder width results in a 1.3 to 1.7 mile-per-hour increase in speed on a two-lane roadway⁵. Therefore, widening shoulders need to strike a balance of providing room for recovery and avoidance, while not allowing for drastic increases in speed. Providing two feet of paved shoulder width on both sides of the corridor where possible would help provide extra width for recovery. **Figure 21** displays an example of a two feet wide paved shoulder.



Figure 21. Example of 2-ft Shoulders (Source: Google Streetview)

As such, it is recommended that two-foot shoulders be provided where feasible along the corridor. A study evaluating lane departure countermeasures indicated providing paved shoulders two feet in width on both sides of a two-lane undivided roadway is anticipated to reduce roadside crashes by 34 percent (a crash modification factor of 0.66).⁶

In some cases, however, there may be constraints introduced by topography that make widening the paved shoulders more costly and intensive or less feasible. In these cases, guardrail installation should be considered to help prevent vehicles from traversing down non-recoverable slopes. The figures in

⁴ Florida Department of Transportation, *Update of Florida Crash Reduction Factors and Countermeasures to improve the Development of District Safety Improvement Projects*. FDOT, Tallahassee, FL, 2005.

⁵ Transportation Research Board. *Highway Capacity Manual, 6th Edition*. 2016.

⁶ <https://www.cmfclearinghouse.org/detail.cfm?facid=10415>

Attachment A illustrate locations where guardrail may be more appropriate than widening due to roadside conditions.

Install Shoulder Rumble Strips

The study team recommends that sinusoidal shoulder rumble strips be installed along the corridor to alert drivers who may be exiting the travel lane and reduce the risk of run-off-the-road crashes. Based on the crash analysis, run-off-the-road crashes made up the highest proportion of total crashes observed on the corridor. Additionally, most of the corridor has narrow paved shoulders of less than two-foot widths due to constraints introduced by local topography. Rumble strips are indentations in the pavement that when driven over, create noticeable sound and vibrations to warn drivers that they have left their lane. VDOT standards call for the use of sinusoidal rumble strips, which have been shown to produce less exterior noise compared to traditional rumble strips due to the wave-like pattern. Shoulder rumble strips should be installed per guidance in the corresponding instructional and informational memorandum (IIM-LD-212.7).⁷ **Figure 22** displays an example of shoulder rumble strips.



Figure 22. Example of Shoulder Rumble Strips (Source: Google Streetview)

Based on NCHRP Report 641, installing edge line rumble strips has a crash modification factor of 0.67 for run-off-the-road crashes, indicating a reduction in crashes and an effective safety improvement.⁸ Implementing shoulder rumble strips will improve safety conditions along the corridor without extensive widening of the paved shoulder.

Install Transverse Rumble Strips

The study team recommends that transverse rumble strips be installed at increments along the corridor. **Figure 23** displays an example of installed transverse rumble strips. As previously discussed, the 85th percentile speeds were higher than the posted speed limit in both directions at the two data collection points. Transverse rumble strips can act as a traffic calming device to alert drivers to slow down and take more caution while driving along the corridor. By encouraging less speeding, the risk of exiting the roadway and/or occurrence of run-off-the-road crashes may be reduced.

⁷ https://vdot.virginia.gov/business/resources/LocDes/IIM/IIM212_IIM-TE-368.pdf

⁸ <https://www.cmfclearinghouse.org/detail.cfm?facid=3394>



Figure 23. Example of Transverse Rumble Strips (Source: Google Streetview)

Trim Trees to Increase Clear Zone

The study team recommends that trees be trimmed along the corridor where possible to increase the clear zone adjacent to the roadway and increase the likelihood of vehicles recovering if they were to exit from the roadway. Fixed object crashes (i.e., crashes with trees) often result in higher severity crashes compared to simple run-off-the-road crashes.

SPOT IMPROVEMENTS

Install 50-ft of Double-Yellow Centerline Striping

Through the field visit, the study team noted approaches along Route 632 that did not have double-yellow centerline striping indicating two-way traffic. The study team recommends that at least 50 feet of double-yellow centerline striping be installed at stop-controlled approaches that are currently missing striping to improve driver awareness and guidance of two-way traffic.

Install/Restripe/Relocate Stop Bars

Through the field visit, the study team observed stop-controlled approaches along Route 632 without a stop bar present and/or a faded stop bar present. The study team recommends restriping of the faded stop bars and installation of stop bars at stop-controlled approaches that currently do not have a stop bar. Installing a stop bar will provide guidance on where oncoming vehicles should be while waiting for a gap in traffic to safely enter Route 632. In certain instances, the stop bars were found to be located too close or too far from Route 632, so they are recommended to be relocated.

Install Two-Way Large Direction Arrow Signs (W1-7)

The study team recommends that two-way large direction arrow signs (W1-7) be installed along the corridor at T-intersections for approaches entering Route 632. **Figure 24** displays an example of installed transverse rumble strips. W1-7 signs are present at some T-intersections along the corridor at present. The W1-7 sign can increase driver awareness and caution of cross-traffic for vehicles approaching Route 632.

This may be especially beneficial at T-intersections where angle crashes have been observed, such as Route 632/Hidden Rock Lane (Route 665).



Figure 24. Example of a Two-Way Large Direction Arrow Sign (Source: Google Streetview)

Install Intersection Ahead Warning Signs (W1-10)

The study team recommends that horizontal alignment intersection warning signs (W1-10) be installed on approach to Route 632/637 (Hawk Town Road). Sight distance challenges are currently introduced by the horizontal curve in the roadway geometry. Installing a W1-10 sign can alert drivers of the upcoming intersection and possible turning vehicles up ahead (many rear end crashes happen at the eastbound approach). **Figure 25** displays an example of a W1-10 sign.



Figure 25. Example of a W1-10 Sign (Source: FHWA)

Install Turn Lane Arrow Pavement Markings

Through the field visit, the study team noted many turn lanes on Route 632 lack turn lane arrow pavement markings. The study team recommends installing turn lane arrow pavement markings at identified locations to improve driver awareness and guidance and discourage improper movements.

Regrade Recoverable Zone to Minimum Standard Slope (10:1)

The study team observed several locations along the corridor where the roadside slopes in the recoverable zones in the clear zone appeared steep. If these slopes do not meet the recommended grades, drivers may have difficulty regaining control of their vehicle if they exit the roadway. Given that 32 percent of all crashes in the analysis period were run-off-the-road crashes, the study team recommends the identified locations with non-recoverable slopes be flattened to 10:1 to increase the probability of recovery where feasible.

In locations where re-grading to meet this slope is not feasible, the study team recommends that the either clear zone be increased to reduce the risk of run-off-the-road crashes (preferred) or guardrail be introduced to help prevent vehicles from exiting the roadway. Where feasible, increasing the clear zone is preferable to the installation of guardrail, as guardrail increases the potential for property damage, has the potential to deflect vehicles back into the opposing travel lane, and comes with increased maintenance costs. In segments where work to develop recoverable slopes extended outside of the existing right-of-way or where the cost of construction was expected to exceed guardrail installation, increases to the clear zone or installation of guardrail are called out.

Route 632/Route 634 (Maidens Road): Provide left-turn lanes on the major approaches and right-turn lane on minor approach (Option 1)

To help reduce the potential for intersection-related crashes at the Route 632/Route 634 (Maidens Road) intersection, left-turn lanes can be added on both approaches of Route 632. By separating left-turning vehicles from through vehicles on Route 632, the potential for rear-end crashes is substantially reduced. It also helps vehicles on opposing approaches interpret the intended movement of vehicles in the turn-lanes. Providing a left-turn lane on both major road approaches is anticipated to reduce all crash types at the intersection by 48 percent (i.e., a CMF of 0.52⁹).

In conjunction with (or as a standalone project based on funding) the addition of the left-turn lanes on Route 632, the northbound approach can be widened to accommodate an exclusive right-turn lane. The existing shared left-through-right lane would be converted to a shared left-through lane. By doing so, the heavy northbound right-turn movements would be separated out from the northbound left-turns and through movements, which generally experience higher delay due to the need to wait for gaps in traffic in both directions on Route 632. **Table 6** illustrates the anticipated operations of the intersection with these added turn lanes. **Attachment G** contains the operational analysis worksheets for this alternative.

As shown, the addition of left-turn lanes on Route 632 and a northbound right-turn lane on Route 634 is anticipated to reduce the delay experienced by northbound right-turns (one of the primary movements) substantially. Though no specific CMF is currently available for providing a right-turn lane on a stop-controlled, minor road approach, higher delays on the minor street approaches generally result in vehicles accepting smaller gaps in mainline traffic before completing their maneuver. This can result in an increase in high-severity angle and sideswipe crashes. As such, the addition of a northbound right-turn lane would

⁹ <https://www.cmfclearinghouse.org/detail.cfm?facid=268>

be expected to reduce crash potential, as well as improve operations at the intersection. This solution, however, does not fully alleviate delays experienced by all vehicles at the intersection.

Table 6. Route 632/Route 634 – Design Year 2042 Traffic Conditions – Added Turn Lanes

Intersection (#)	Traffic Control	Approach	Lane Group	Weekday AM			Weekday PM		
				LOS	Delay (s)	Q95 (ft)	LOS	Delay (s)	Q95 (ft)
Route 632 (Fairground Road)/Route 634 (Maidens Road) (#2)	Two-way Stop-Controlled	EB	L	A	8.1	0	A	8.9	3
			TR	-	0.0	0	-	0.0	0
		EB Approach		-	0.3	-	-	0.9	-
		WB	L	A	8.1	5	A	9.4	30
			TR	-	0.0	0	-	0.0	0
		WB Approach		-	1.5	-	-	3.3	-
		NB	LT	D	26.2	18	F	477.2	143
			R	B	14.5	50	B	12.0	20
		NB Approach		C	22.5	-	F	147.7	-
		SB	LTR	D	26.4	18	F	104.9	102.5
SB Approach		D	26.4	-	F	104.9	-		

Route 632/Route 634: Conversion of Stop-Controlled Intersection into Single-Lane Roundabout (Option 2)

As an alternative to providing turn-lanes on key approaches to the Route 632/Route 634 (Maidens Road) intersection, the stop-controlled intersection could be converted to a single-lane roundabout. Converting the intersection to a roundabout would be expected to have several benefits relative to the existing configuration:

- Reduces the number of conflict points (locations where vehicle paths can potentially intersect) from 32 to eight
- Reduces the potential for high-severity angle and head-on crashes due to the angle at which vehicles interact within the roundabout
- Provides natural speed control in the middle of the corridor, as the geometry of the roundabout itself promotes lower vehicle speeds on all approaches

For these reasons, roundabouts have proven to be generally safer alternatives to stop-controlled or signalized intersections. Installing a roundabout at this location would be anticipated to result in a 68 percent reduction in crashes relative to the existing intersection control (a CMF of 0.42)¹⁰. **Table 7** illustrates the anticipated 2042 weekday peak hour operations of a single-lane roundabout. As shown, the critical movement is anticipated to operate at LOS B or better during both the weekday a.m. and weekday p.m. peak hour. **Attachment G** contains the SIDRA software operational worksheets for the analysis.

¹⁰ <https://www.cmfclearinghouse.org/detail.cfm?facid=207>

Table 7. Route 632/Route 634 – Design Year 2042 Traffic Conditions – Single-Lane Roundabout

Intersection (#)	Traffic Control	Approach	Lane Group	Weekday AM			Weekday PM		
				LOS	Delay (s)	Q95 (ft)	LOS	Delay (s)	Q95 (ft)
Route 632 (Fairground Road)/Route 634 (Maidens Road) (#2)	Single-Lane Roundabout	EB	LTR	A	6.5	64	A	8.3	77
		EB Approach		A	6.5	-	A	8.3	-
		WB	LTR	A	6.1	66	B	11.9	188
		WB Approach		A	6.1	-	B	11.9	-
		NB	LTR	A	7.5	53	A	5.7	28
		NB Approach		A	7.5	-	A	5.7	-
		SB	LTR	A	4.4	7	A	7.6	21
		SB Approach		A	4.4	-	A	7.3	-

Route 632/Route 637 (Hawk Town Road): Provide a left-turn lane on major approach

At Route 632/Route 637 (Hawk Town Road), the study team recommends installing a left-turn lane on the eastbound approach at the intersection. During the study period, rear-end collisions were commonly reported here, which are attributed to left-turning vehicles that slow or stop to yield to oncoming traffic prior to turning left. Sight distance challenges due to the horizontal curve prior to this intersection may also contribute to the frequency of rear-end crashes at this location. Additional improvements, such as transverse rumble strips and intersection warning signs, may supplement this improvement. Based on a report on the safety effectiveness of right-turn lanes, the CMF was found to be 0.56 for all crash types and severities, indicating a reduction in crashes and an effective safety improvement.¹¹

PRELIMINARY COST ESTIMATES

Table 8 provides preliminary cost estimates for the various recommendations provided along the Route 632 corridor. Given the nature of some of the improvements, the improvements were broken into several projects where multiple improvements could be implemented at the same time for efficiency. For example, the installation of pavement markings and signage can likely be accommodated through at the same time through scheduled repaving.

Corridor-wide improvements, such as the installation of two-foot shoulders, were separated out to create more manageable projects. The shoulder widening was split into four projects (north/south side of Route 632 and east/west of Route 634). While it would be feasible to install shoulder rumble strips in segments with shoulders greater than two feet prior to obtaining two-foot shoulders in the entire segment, it would be more efficient to install the rumble strips along the entire segment at one time after widening. As such, the installation of shoulder rumble strips was included in the shoulder widening projects, rather than as an individual project.

All costs include estimated costs for construction, a 30 percent contingency for engineering and anticipated right-of-way costs, a 20 percent construction management and inspection contingency, and an additional 30 percent contingency on top of all elements (inflationary pressure, other unknowns, etc.). These cost estimates are in today's dollars and do not account for inflation. **Attachment B** contains itemized preliminary cost estimates for all recommendations.

¹¹ <https://www.cmfclearinghouse.org/detail.cfm?facid=253>

Table 8. Preliminary Cost Estimates

Improvement Project	Cost
Pavement Markings and Signage Updates (Near-term)	\$97,100
Installation of a Left-turn Lane at Hawk Town Road	\$808,000
Route 632/Route 634 – Addition of Turn Lanes (OPTION 1)	\$1,409,100
Route 632/Route 634 – Single-Lane Roundabout (OPTION 2)	\$3,593,600
Shoulder widening & Rumble Strips: North of Route 632 and West of Route 634	\$626,200
Shoulder widening & Rumble Strips: South of Route 632 and West of Route 634	\$781,200
Shoulder widening & Rumble Strips: North of Route 632 and East of Route 634	\$933,600
Shoulder widening & Rumble Strips: South of Route 632 and East of Route 634	\$786,400

Conclusions

A safety assessment was conducted along a 5.1-mile segment of Route 632 (Fairground Road) in Goochland County, Virginia. The study found the following:

- From the five-years of traffic data evaluated, fixed object off road, rear end, and angle crashes were the most frequent crash types, which made up over 73 percent of all crashes.
- Narrow/non-existent paved shoulders and lack of clear zones, including steep/non-recoverable slopes, along the corridor may make it difficult for drivers to recover safely if they exit the roadway.
- A turn lane is warranted at the Route 637 (Hawk Town Road) intersection and may address frequent rear-end crashes reported on the eastbound approach on Route 632.
- Many angle collisions were observed at Route 632/634 (Maidens Road), indicating conflicts between crossing movements. Alternative configurations should be considered at this intersection to improve safety.

Alternatives are recommended as potential solutions to address the crashes and speeding observed along the corridor. Recommendations are summarized below:

- Install shoulder rumble strips along the corridor
- Install transverse rumble strips along the corridor
- Reconstruct paved shoulders to provide two feet of width
- Install 50 feet of double-yellow centerline striping on stop-controlled minor approaches
- Install and/or restripe stop bars at stop-controlled approaches
- Install two-way large direction arrow signs (W1-7) at T-intersections
- Install intersection ahead warning signs (W1-10)
- Install turn lane arrow pavement markings
- Re-grade recoverable zones to slope of 10:1 to improve recoverability
 - Where additional regrading is not feasible, objects within the clear zone should be removed/relocated
- Route 632/634 (Maidens Road) – 2 Potential Options
 - Reconfigure Route 632/634 (Maidens Road) from a stop-controlled intersection to a single-lane roundabout
 - Install left-turn lanes on major road approaches and a right-turn lane on the northbound minor approach at Route 632/634 (Maidens Road)
- Install an eastbound left-turn lane at Route 632/637 (Hawk Town Road)