DVRPC

Regional Roundabout Analysis

Phase II

DELAWARE VALLEY REGIONAL PLANNING COMMISSION

SEPTEMBER 2009

The Delaware Valley Regional Planning Commission is dedicated to uniting the region's elected officials, planning professionals, and the public with the common vision of making a great region even greater. Shaping the way we live, work, and play, DVRPC builds consensus on improving transportation, promoting smart growth, protecting the environment, and enhancing the economy. We serve a diverse region of nine counties: Bucks, Chester, Delaware, Montgomery, and Philadelphia in Pennsylvania; and Burlington, Camden, Gloucester, and Mercer in New Jersey. DVRPC is the official Metropolitan Planning Organization for the Greater Philadelphia Region – leading the way to a better future.

The symbol in our logo is adapted from the official DVRPC seal, and is designed as a stylized image of the Delaware Valley. The circular shape symbolizes the region as a whole. The diagonal line represents the Delaware River and the two adjoining crescents represent the Commonwealth of Pennsylvania and the State of New Jersey.

DVRPC is funded by a variety of funding sources including federal grants from the U.S. Department of Transportation's Federal Highway Administration (FHWA) and Federal Transit Administration (FTA), the Pennsylvania and New Jersey departments of transportation, as well as by DVRPC's state and local member governments. The authors, however, are solely responsible for the findings and conclusions herein, which may not represent the official views or policies of the funding agencies.

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EXECUTIVE SUMMARY

This report documents the second phase of a two-phased roundabout analysis for the nine-county Delaware Valley region.

With the assistance of Pennsylvania Department of Transportation (PennDOT), New Jersey Department of Transportation (NJDOT), and other planning partners, Phase 1 of this analysis developed screening criteria for selecting feasible locations throughout the nine-county DVRPC region for implementing single-lane roundabouts. The screening resulted in 1,868 possible sites in the region. The information was tabulated, mapped, and distributed to the counties for their review to narrow and prioritize the locations. The counties identified 151 locations (72 in Pennsylvania and 79 in New Jersey) for further study.

The modern roundabout is an adaptation of traffic circles, which were first introduced in the United States in the early 1900s. One of the underlying principles of the modern roundabout is the give-way rule, which requires entering traffic to yield to circulating traffic. This rule prevents the roundabout from locking up by not allowing vehicles to enter the intersection until there are sufficient gaps within the circulating traffic. In addition, there are numerous safety benefits associated with roundabouts. Studies from across the country have shown a reduction in the number and severity of crashes once roundabouts have been installed. See ***Appendix A*** for more background information on roundabouts.

In the Delaware Valley region, roundabouts have not been a common form of intersection treatment due to driver unfamiliarity, the inaccurate associations with unpopular traffic circles or rotaries and other factors. Given the successes of the roundabout from other states and countries, roundabouts may be a viable option to consider when upgrading older or building new intersections in the region.

Although roundabouts are not suitable for all intersections, they are worth considering as an option to improve particular intersections. In Phase 2 of the analysis, select locations identified from Phase 1 were further investigated via traffic data collection and traffic simulation software. In each county, one location was selected for detailed technical analysis. In addition to determining the preliminary feasibility of a roundabout at a small group of locations, this project sought to further understand the applicability of roundabouts throughout the region. Advancing installation of a roundabout would require an engineering analysis, as well as public outreach, particularly at the local level. This report will serve as a resource for stakeholders seeking to advance a roundabout alternative at their intersection, as well as a collection of case studies to help evaluate the plausibility of a roundabout at other locations.

1. REGIONAL ROUNDABOUT CANDIDATE LOCATIONS

Determination of Candidate Locations

A matrix was developed to narrow each county's top three candidate locations into a single location for detailed study. The seven criteria listed in ***Table 1***, were used to evaluate and compare each site's anticipated strengths and weaknesses against the remaining potential locations. These nine criteria were selected because they could be derived from GIS data (as referenced in the Phase 1 analysis) and reflected early comments from stakeholders.

Table 1: Roundabout Candidate Site Determination Criteria

Criteria	Definition/Reasoning
1. Awkward geometry	• Unusual number of approaches • Skewed or non-perpendicular alignment • Because traditional intersection controls are difficult to execute at such locations
2. Heavy-vehicles	• Strong presence of truck and/or bus traffic • Because the presence of larger vehicles necessitate a larger roundabout diameter to accommodate larger turning radii
3. Bike/pedestrians	• Whether the presence of pedestrians and bicyclists was observed during turning movement counts and/or field visits • Roundabouts may serve as a traffic-calming measure, which would allow for safe passage and awareness of bicycle and pedestrian traffic in the area
4. Single-lane approach	• An intersection with a single-lane on each approach • Because the presence of multiple-lane approaches may preclude a single-lane roundabout application
5. Rural or suburban land use	• Adjacent land that will not likely impose right-of-way constraints at the intersection (i.e. avoidance of buildings close to the intersection) • Because roundabouts require a larger intersection footprint than traditional intersection controls
6. Municipal support	• An interest at the local level for pursuing a roundabout application within the municipality • Because political support at the local level may help alleviate concerns about roundabouts, which are often due to lack of driver familiarity
7. Safety concerns	• Crash history, including type, quantity, and severity, as determined by local crash records • Because single-lane roundabouts have been documented to reduce the volume and severity of crashes

Source: DVRPC

The main goal of the two-year study was to demonstrate the potential applicability of roundabouts in various settings throughout the region. Utilizing the matrix and its criteria as a starting point, DVRPC staff carefully selected nine unique intersections that provide a broad cross-section of study locations. The nine locations are displayed in ***Figure 1***.

Figure 1: DVRPC Selected Regional Roundabout Study Locations

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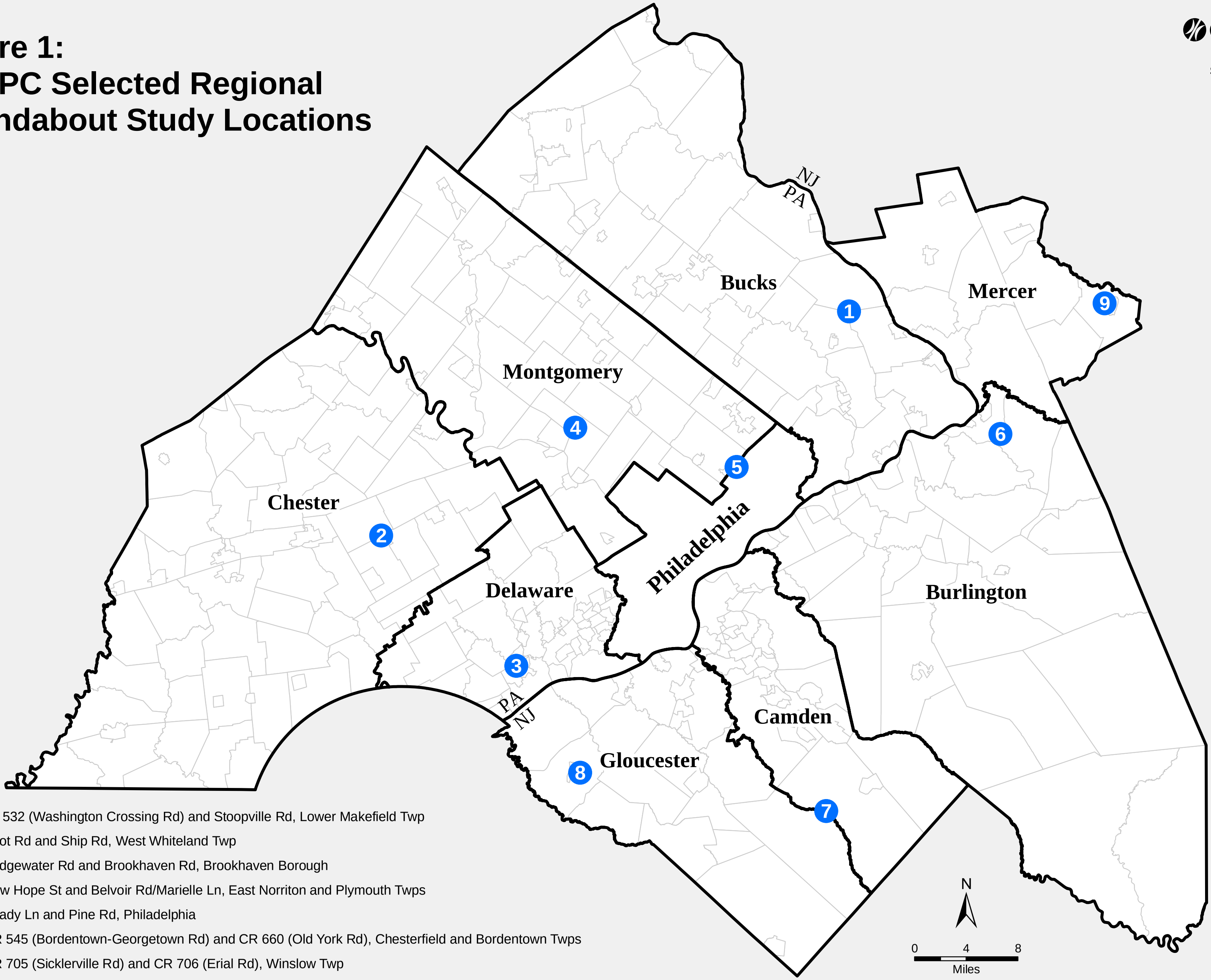


1. PA 532 (Washington Crossing Rd) and Stoopville Rd, Lower Makefield Twp
2. Boot Rd and Ship Rd, West Whiteland Twp
3. Bridgewater Rd and Brookhaven Rd, Brookhaven Borough
4. New Hope St and Belvoir Rd/Marielle Ln, East Norriton and Plymouth Twps
5. Shady Ln and Pine Rd, Philadelphia
6. CR 545 (Bordentown-Georgetown Rd) and CR 660 (Old York Rd), Chesterfield and Bordentown Twps
7. CR 705 (Sicklerville Rd) and CR 706 (Erial Rd), Winslow Twp
8. CR 538 (Franklinville Rd) and CR 694 (Monroeville Rd), Woolrich Twp
9. CR 571 (Stockton St), Oak Lane, Dutch Neck Rd and Harron Ave, Hightstown Borough

2. METHODOLOGY

Various criteria were used to arrive at a single study location per county. For each selected location, an assortment of data was collected and utilized as part of the analysis to simulate existing conditions and better understand the impacts of a roundabout at each study intersection.

Data Collection

Once locations for each of the counties were selected, DVRPC staff embarked on collecting various traffic data with which to perform the analysis. The same steps were done for each location and the results are summarized later in the next chapter.

Field Observations

Field visits were conducted at the selected nine locations to observe traffic and land use patterns surrounding the intersection. Specific types of information collected include signs of pedestrian activity, transit stops, vehicle movements through the intersection, neighboring driveways from residential and commercial properties, vehicle class (heavy-truck, cars, and commercial vehicles), sight distance, approach grades, and environmental constraints.

Crash History

Crash history is an important factor when considering roundabouts. Studies have shown a reduction of the number and severity of crashes at intersections with roundabouts. With the exception of Philadelphia, crash data from the DVRPC Crash Database was utilized for this analysis to determine the crash history at the study intersections. A separate crash analysis conducted by the Philadelphia Streets Department was used for the Philadelphia study intersection.

The database contains crash data from NJDOT and PennDOT and only pertains to reportable crashes. Reportable crashes are defined differently in Pennsylvania and New Jersey. In Pennsylvania, a reportable crash involves an injured person or a vehicle that requires towing from the scene of the accident. A reportable crash in New Jersey involves an injured person or $500 worth of damage to a vehicle as determined by the reporting police officer at the scene of the accident. For the purposes of this report's analysis, to remain consistent with PennDOT's and NJDOT's system of reporting crash data, five and three years of data were used for each state respectively.

Turning Movement Counts

Manual turning movement counts were taken at the study intersections to account for traffic traversing the intersection. If necessary, additional turning movement counts were also taken at signalized intersections adjacent to the study intersection.

Travel Speeds

Travel speeds were measured along each leg of the study intersection. Vehicular speed data was obtained over a 48-hour period in January 2008. Prevailing travel speed for a given peak hour was defined as the 85th percentile speed recorded during that hour. Determining travel speeds is necessary to validate claims of excessive speeding as an issue in the area, and to possibly justify a roundabout as a potential traffic-calming measure.

Vehicle Classification

Vehicle classification counts measured the percent composition of the various classes of vehicles traversing the study intersection. With the exception of Chester County, classification counts were taken over a 48-hour period in January 2008. Due to the change in Chester County's selected study intersection, no vehicle classification data was obtained at this location. For the purposes of this study, passenger vehicles were distinguished from heavy-vehicles and buses.

Signal Timing

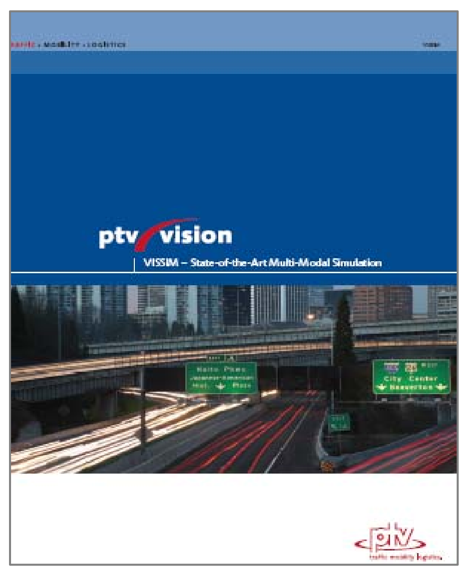
Signal timing information was provided if the study location or adjacent intersection was currently signalized.

VISSIM Analysis

Software Description

The VISSIM software by PTV VISION was chosen to simulate the operation of a roundabout. The program is a microscopic behavior-based simulation model developed to model complex traffic operations. VISSIM was selected because it does the following:

- It accurately models acceleration and deceleration profiles and multimodal operations at weaving and merging areas.
- It provides ready comparison of design alternatives for signalized and stop sign-controlled intersections and roundabouts.
- It facilitates communication with stakeholders by showing 2-D and 3-D animated results.



The software was used to analyze multiple scenarios for each location. The scenarios were the traffic operations associated with the existing intersection configuration and traffic operations if a roundabout were installed at that location.

Results from VISSIM Simulation

The ***level of service analysis (LOS)*** is a common tool for the assessment of transportation facilities and is used extensively in this report. For each location, the LOS for existing conditions and the roundabout alternatives are evaluated. When applied as a measure of effectiveness for an entire intersection or a particular component of it, LOS is a reflection of the average delay experienced by vehicles traversing an intersection. The exact limits of delay that determine the various LOS categories for a signalized and an unsignalized intersection are displayed in ***Table 2***. Eight of the nine intersections analyzed as part of this study are unsignalized.

Table 2: Level of Service (LOS) Designations and Associated Delays

Level of Service	Signalized Intersection Total Delay per Vehicle (seconds/vehicle)	Unsignalized Intersection Total Delay per Vehicle (seconds/vehicle)
A – Desirable	≤ 10	≤ 10
B – Desirable	> 10 and ≤ 20	> 10 and ≤ 15
C – Desirable	> 20 and ≤ 35	> 15 and ≤ 25
D – Acceptable	> 35 and ≤ 55	> 25 and ≤ 35
E – Undesirable	> 55 and ≤ 80	> 35 and ≤ 55
F – Unsatisfactory	> 80	> 55

Source: Highway Capacity Manual

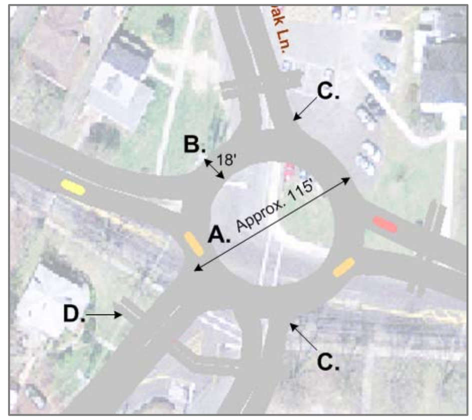
For each intersection, delay and LOS for the existing conditions and roundabout alternatives were conducted using VISSIM. Necessary information for determining LOS delay and LOS measures include turning movement and vehicular classification counts, roadway geometry, signal timing, and actuation plans. The turning movement counts were gathered by DVRPC staff, whereas the signal timing and actuation data were supplied by the relevant municipality, county, or state agency; roadway geometry was accumulated from either source.

The ***95th percentile queue*** was also measured. This queue length is defined as a five-percent probability of being exceeded during the analysis time period. It effectively captures the desired length for turn lanes and link segments that would significantly obstruct queue spillover into adjacent lanes and upstream intersections.

Roundabout Alternatives

Roundabout alternatives were developed for each of the nine intersections. Four major design elements were user defined: (1) inscribed circle diameter, (2) circulatory roadway width, (3) entry and exit flare, and (4) pedestrian crossings (where necessary). See ***Figure 2***.

Figure 2: Roundabout Design Features



Source: DVRPC

A. = Inscribed circle diameter
B. = Circulatory roadway width
C. = Entry and exit flare
D. = Pedestrian crossing

Because this analysis focused on determining the feasibility of single-lane roundabouts, the inscribed circle diameter ranged between 100 and 150 feet for all of the counties' roundabouts alternatives.

Stakeholder Meeting

After the analysis was conducted, stakeholders (counties, DOTs, municipalities, etc.) were given the opportunity to provide feedback on the results. Individual meetings were held with each of the New Jersey and Pennsylvania groups. At these meetings, DVRPC staff presented the various measures of effectiveness from the roundabout analysis. The ability of the software to visually demonstrate the operations of an intersection in 2-D and 3-D proved vital when communicating with stakeholders.

Dependent upon the comments and requests provided by stakeholders, DVRPC conducted further analysis to present a more comprehensive evaluation of potential impacts. After this second round of analysis was conducted, stakeholders were given a final opportunity to provide feedback before finalization of the report.

Roundabout Feasibility

The feasibility of a roundabout at the study intersections must take into consideration a multitude of variables. These include standard traffic operations, but also consist of traffic-calming expectations, the proximity of adjacent intersections, right-of-way availability, driver sight distance and expectancy, local support, and other factors. The information presented summarized strengths and weaknesses associated with the analysis performed.

3. ROUNDABOUT LOCATION ANALYSIS

Bucks County

Candidate Location

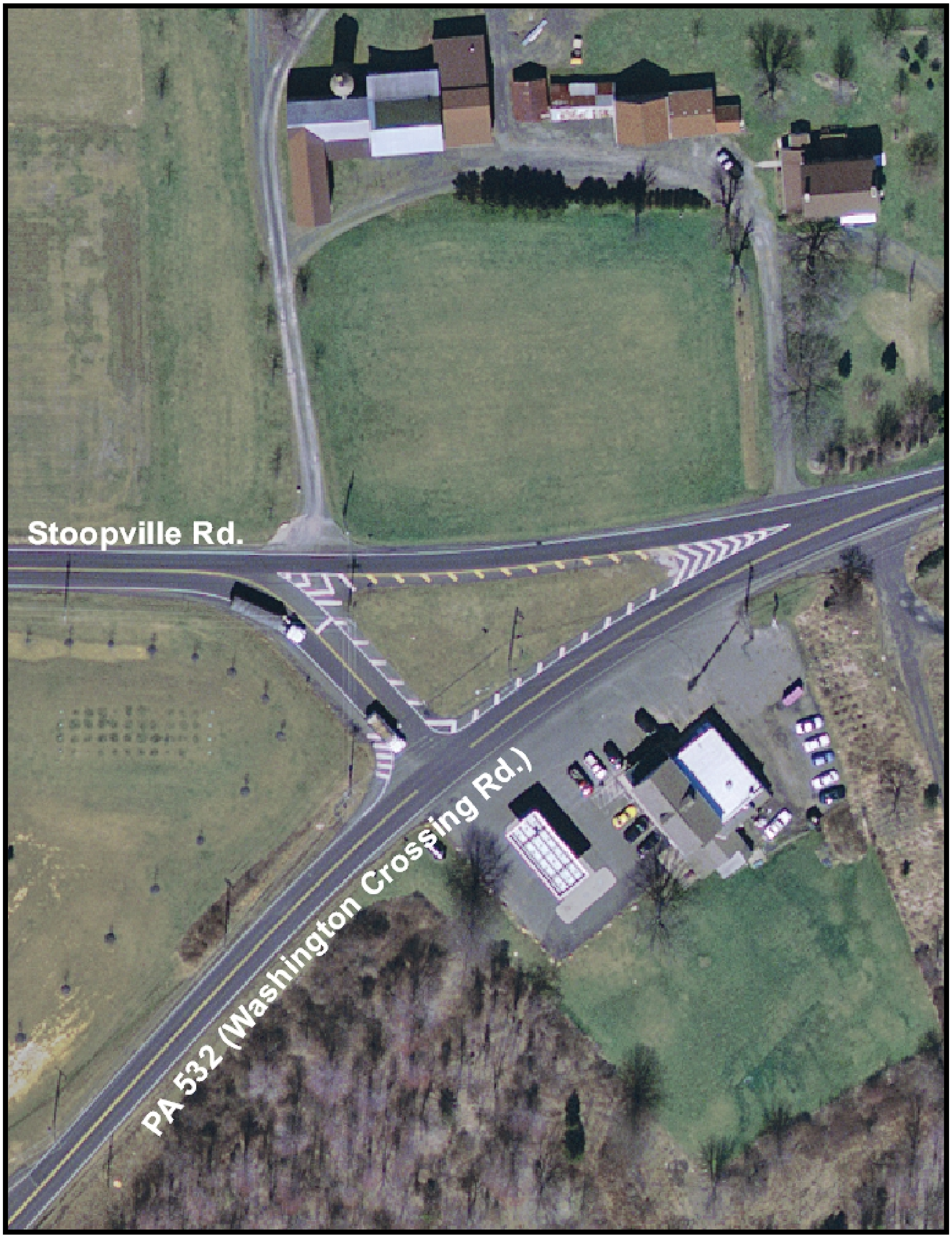
The intersection of PA 532 (Washington Crossing Road) and Stoopville Road bordering Upper Makefield and Lower Makefield townships was selected for analysis from the final three potential locations prioritized by Bucks County. As shown in ***Table 3***, this intersection contains four of the seven qualifying DVRPC criteria. In addition, a roundabout was recommended for this location in DVRPC's *2007 Bucks County Regional Traffic Study*.

Table 3: Bucks County's Site Determination Matrix

Criteria	Prioritized Location #1	Prioritized Location #2	Prioritized Location #3
	Washington Crossing Road (PA 532) and Stoopville Road	***Broad Street (PA 313) and Front Street***	***Street Road (PA 132) and State Road***
Awkward geometry	✓	✓	--
Heavy-vehicles	✓	--	✓
Bike/pedestrians	--	✓	--
Single-lane approach	✓	✓	--
Rural or suburban land use	✓	✓	--
Municipal support	--	--	--
Safety concerns	--	--	--

Source: DVRPC

Figure 3: Bucks County Study Location Aerial Photo



Source: DVRPC

Data Collection

The following provides a summary of data collected for analyzing a potential roundabout at the intersection of Washington Crossing Road and Stoopville Road.

Field Observations

Figure 4 highlights observations from a field visit to the study location.

Figure 4: Bucks County Study Location Field Visit Summary

OBSERVATIONS:

- High speeds approaching and traveling through the intersection
- No separate queue area for northbound Washington Crossing Road left-turns
- Minimal shoulder width for the northbound approach
- Significant amount of heavy-vehicle traffic
- No clearly defined ingress and egress points for gas station and market
- There were no significant grade changes
- Wide open layout

Source: DVRPC

Crash History

Crash data was obtained from the DVRPC Crash Database. Between 2003 and 2007, nine crashes occurred at this intersection. Eight of the nine crashes involved injuries. There were no crashes reported in 2004. The crashes were classified in the following four categories: angle (6), sideswipe (1), head on (1), and hit-fixed object (1).

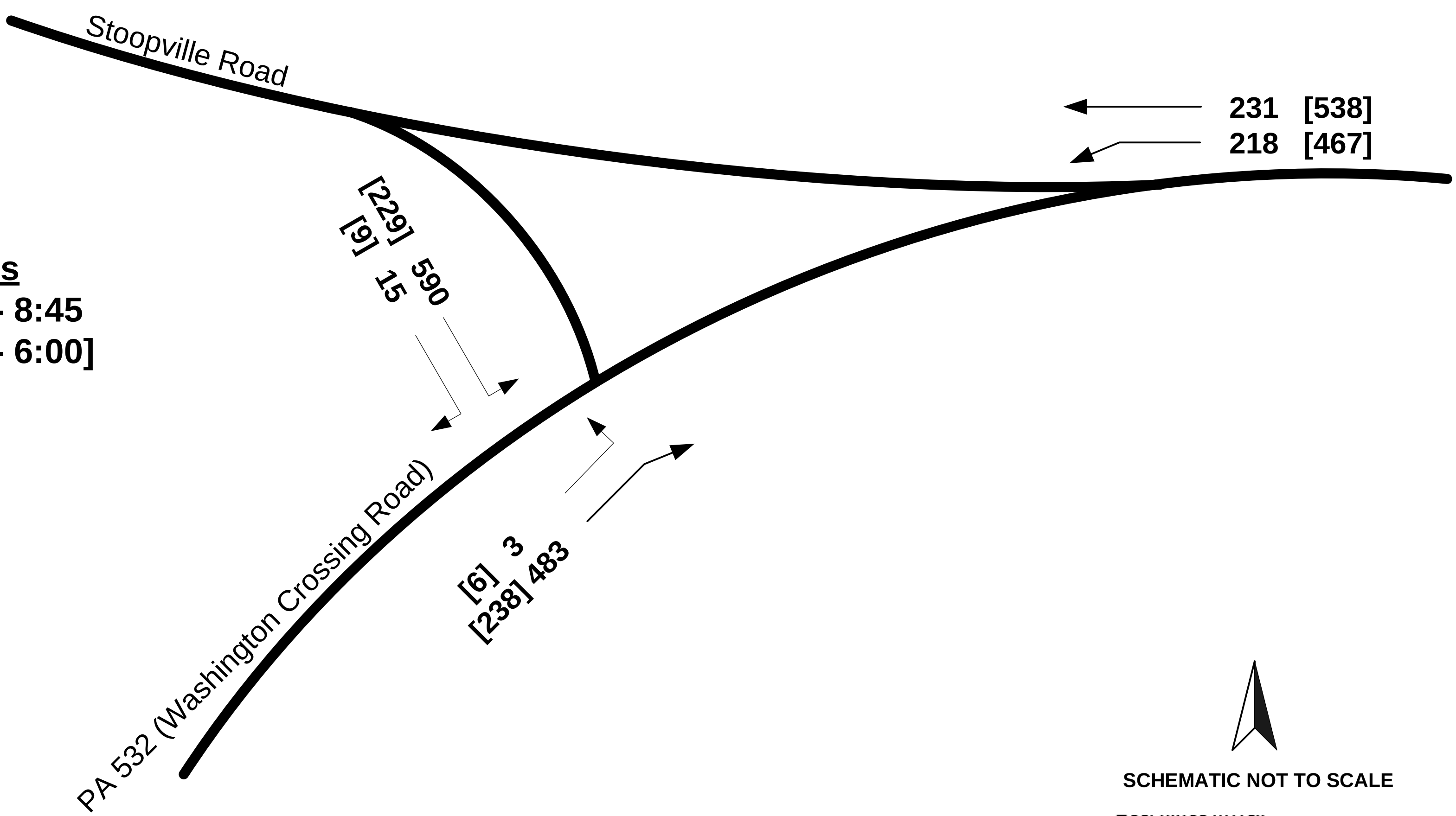
Turning Movements

A peak hour turning movement diagram is shown in ***Figure 5***. The morning peak hour is 7:45 AM to 8:45 AM and the afternoon peak hour is 5:00 PM to 6:00 PM.

Figure 5

Bucks County Study Location Turning Movements

EXISTING Peak Hour Turning Movement Counts AM & [PM]



Peak Hours
AM: 7:45 - 8:45
PM: [5:00 - 6:00]

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Turning movement data was collected in 2005 by McMahon Associates. During the AM peak hour, the dominant traffic movement occurs in the eastbound direction. In the afternoon peak hour, the dominant traffic movement is westbound and southbound. The heaviest movement at the intersection is the eastbound Stoopville Road left-turn movement onto Washington Crossing Road.

Approach Speeds

The posted speed limit along Washington Crossing Road and Stoopville Road is 35 MPH. As shown in ***Table 4***, the approach speeds calculated exceeded the posted speed limit. Most approaches experience speeds of at least 46 MPH. Along the westbound Washington Crossing Road approach, speeds are slightly slower during the afternoon peak hour.

Table 4: Bucks County Study Location – Approach Speeds

Intersection Leg	Vehicle Speeds (MPH)	
	AM	PM
NB Washington Crossing Road	51 - 55	51 - 55
WB Washington Crossing Road	46 - 50	41 - 45
EB Stoopville Road	51 - 55	51 - 55

Source: DVRPC

Vehicle Classification

As indicated in ***Table 5***, the eastbound Stoopville Road approach experiences the largest concentration of heavy-vehicles. Bus traffic through the area is fairly light.

Table 5: Bucks County Study Location – Vehicle Classification

Intersection Leg	Cars	Heavy-vehicles (2+ Axles, 6+ Wheels)	Buses
NB Washington Crossing Road	96%	3.5%	0.5%
WB Washington Crossing Road	94%	5.5%	0.5%
EB Stoopville Road	93%	6.5%	0.5%

Source: DVRPC

Results and Findings

The following is a summary of the analysis performed for existing, signalization, and roundabout scenarios during the AM and PM peak hours, respectively. Assumptions regarding geometry of the roundabout include a 130-foot inscribed circle.

Existing Scenario

During the AM peak hour, existing conditions perform at an overall LOS of E, with 38 seconds of average delay. This is entirely a product of heavy delay for the eastbound Stoopville Road approach, which is stop-controlled. The Washington Crossing Road approaches are free flowing and experience zero delay. The 95th percentile queue along the Stoopville Road approach is 361 feet, or roughly 18 vehicle lengths. During the PM peak hour, existing conditions operate with a minimal delay of three seconds, for a LOS of A. The most delay is experienced by the eastbound Stoopville Road approach, with 19 seconds of delay and a LOS of C. The 95th percentile queuing is nonexistent for all approaches.

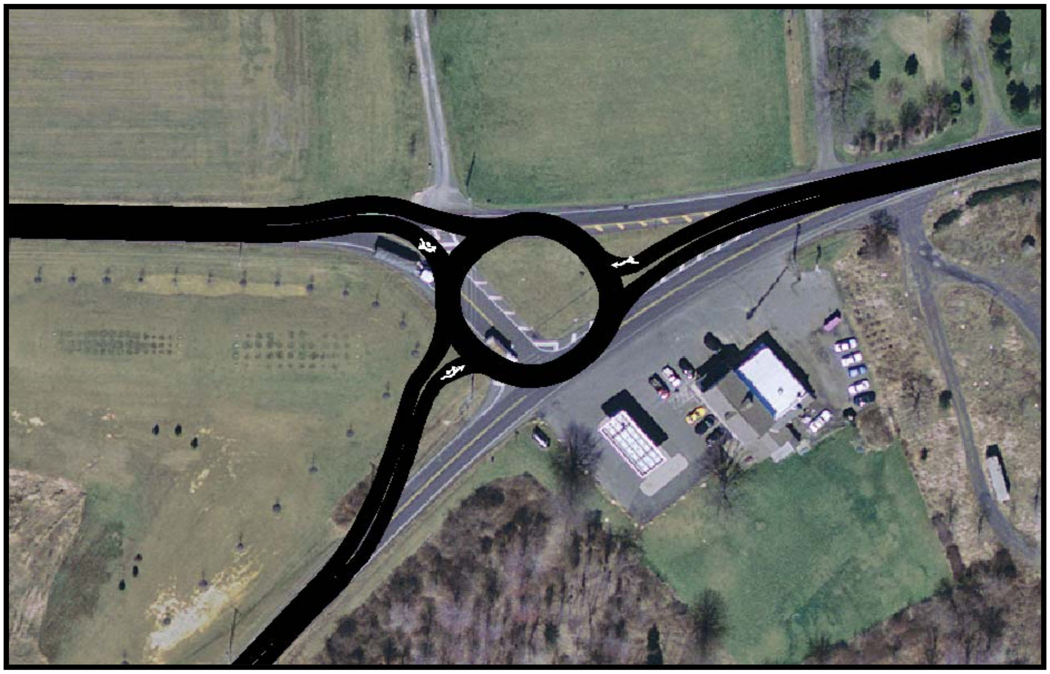
Signalization Scenario

The signalization scenario consists of a 60-second cycle length semi-actuated signal at this intersection for both peak hours. For the AM peak hour, signalization results in an overall LOS of B, with an average delay of 14 seconds per vehicle. The eastbound Stoopville Road approach experiences a dramatic decrease in delay, from almost two minutes under existing conditions to19 seconds. During the PM peak hour, this intersection operates at an overall LOS of B, with 16 seconds of average delay. Eastbound Stoopville Road experiences the most delay at 26 seconds, a seven-second increase from existing conditions. At this approach, the 95th percentile queue is 259 feet, or 13 vehicle lengths.

Roundabout Scenario

A roundabout (as depicted in ***Figure 6***) at this location with AM peak hour traffic volumes operates at an overall LOS of C, with 17 seconds of average delay. This represents a 21-second improvement from existing conditions, but a marginal decline from the signalization scenario. The roundabout also achieves a reduction in delay for the eastbound Stoopville Road approach, which performs at a LOS of A, with only eight seconds of average delay. However, delay and queues result on the previously free-flowing Washington Crossing Road approaches. In particular, northbound Washington Crossing Road experiences 42 seconds of delay, for a LOS of E and a 95th percentile queue of 400 feet, or 20 vehicle lengths. During the PM peak hour, the intersection performs at an overall LOS of A, with only six seconds of average delay. This is comparable to existing conditions and ten seconds better than the signalization scenario. All three approaches operate with less than ten seconds of delay for a LOS of A and zero 95th percentile queuing.

Figure 6: Bucks County Study Location – Roundabout Rendering



Source: DVRPC – VISSIM Software

Roundabout with Estimated Volumes from White Farm Development Scenario

This scenario combined the roundabout scenario with vehicle trips generated by the proposed 80-unit White Farm residential development along Stoopville Road, immediately west of the study intersection. During the AM peak hour, this scenario operates at an overall LOS of C, with 23 seconds of average delay, a six-second increase from the previous roundabout scenario, but a 15-second improvement from existing conditions. The northbound Washington Crossing Road approach experiences a disproportionate delay of 64 seconds, whereas the remaining approaches operate with less than ten seconds of delay. During the PM peak hour, the intersection continues to operate at an overall LOS of A, with an average delay of only six seconds, despite the additional volume. All approaches operate with less than ten seconds of average delay and experience zero 95th percentile queuing.

The LOS and vehicle delay associated with each of the Buck County scenarios is presented in ***Tables 6 and 7***.

Table 6: Bucks County – AM Peak Hour Scenarios

	Scenario	**Intersection Leg**	**Delay**	**LOS**	**95th % Queue (ft)**
AM Peak Hour					
	Existing	NB Washington Crossing Road	0.0	A	0.0
		WB Washington Crossing Road	0.0	A	0.0
		EB Stoopville Road	114.1	F	361.0
		Intersection Total	**38.1**	**E**	
	Signalization	NB Washington Crossing Road	15.9	B	142.0
		WB Washington Crossing Road	6.1	A	29.0
		EB Stoopville Road	19.1	B	189.0
		Intersection Total	**14.3**	**B**	
	Roundabout	NB Washington Crossing Road	42.2	E	404.0
		WB Washington Crossing Road	2.4	A	0.0
		EB Stoopville Road	8.1	A	0.0
		Intersection Total	**17.1**	**C**	
	Roundabout with White Farm Development	NB Washington Crossing Road	63.8	F	427.0
		WB Washington Crossing Road	2.4	A	0.0
		EB Stoopville Road	9.1	A	0.0
		Intersection Total	**23.4**	**C**	

Source: DVRPC

Table 7: Bucks County – PM Peak Hour Scenarios

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
PM Peak Hour					
	Existing	NB Washington Crossing Road	0.0	A	0.0
		WB Washington Crossing Road	0.0	A	0.0
		EB Stoopville Road	19.0	C	0.0
		Intersection Total	**2.9**	**A**	
	Signalization	NB Washington Crossing Road	13.3	B	118.0
		WB Washington Crossing Road	5.0	A	26.0
		EB Stoopville Road	25.9	C	259.0
		Intersection Total	**15.8**	**B**	
	Roundabout	NB Washington Crossing Road	4.0	A	0.0
		WB Washington Crossing Road	5.0	A	0.0
		EB Stoopville Road	9.2	A	0.0
		Intersection Total	**5.5**	**A**	
	Roundabout with White Farm Development	NB Washington Crossing Road	4.6	A	0.0
		WB Washington Crossing Road	5.4	A	0.0
		EB Stoopville Road	9.1	A	0.0
		Intersection Total	**5.9**	**A**	

Source: DVRPC

Strengths and Weaknesses of a Roundabout at this Location

Highlighted below are strengths and weaknesses resulting from the analysis performed. Comments from Bucks County and PennDOT stakeholders are also provided.

Strengths

- Travel speeds are reduced at the approaches and through the intersection;
- The analysis showed a reduction in overall delay from existing conditions during the AM peak hour, and delays comparable to existing conditions during the PM peak hour;
- The number of conflicts at the intersection was reduced; and
- A roundabout at this location could serve as a potential gateway or landmark for the Washington Crossing National Cemetery.

Weaknesses

- A larger inscribed diameter is necessary to accommodate large vehicles, which may require additional right-of-way; and
- There was not a large crash issue at the intersection.

Bucks County Comments

- Access to the driveways at and near the intersection must be further addressed; and
- The size of the roundabout should be designed to adequately address the above-average proportion of heavy-vehicle traffic at this intersection.

PennDOT Comments

This intersection is currently part of PennDOT's "Stoopville Road Improvements" project (MPMS #84096). As a result, the project intersection will receive mast arm-supported flashing warning beacons while being converted into an All-Way-Stopped-Control (AWSC) intersection. The westbound spur road will be removed and this movement will be realigned along Washington Crossing Road. This project is being expedited due to its funding from the 2009 American Recovery and Reinvestment Act. The project's estimated start is September 2009 and its estimated completion is October 2010.

Chester County

Candidate Location

The intersection of Boot Road and Ship Road in West Whiteland Township was selected for analysis from the three locations prioritized by Chester County. According to county officials, this location was chosen after a change in municipal interest and support for a roundabout at the initially selected location, the intersection of PA 896 (New London Road) and PA 841(Chesterville Road). Chester County stakeholders suggested the Boot Road and Ship Road intersection due to ongoing private development interests in the immediate area. As shown in ***Table 8***, this intersection contains three of the seven qualifying DVRPC criteria. This location also provided an opportunity to examine the impacts of a closely spaced signalized intersection on a roundabout's operations.

Table 8: Chester County's Site Determination Matrix

	PA 796 (Daleville Jennersville Road) and PA 926 (Street Road)	*PA 896 (New London Road) and PA 841 (Chesterville Road)*	*Boot Road and Ship Road*
Awkward geometry	✓	--	✓
Heavy-vehicles	--	--	--
Bike/pedestrians	--	--	--
Single-lane approach	✓	✓	✓
Rural or suburban land use	✓	✓	✓
Municipal support	✓	✓	--
Safety concerns	--	✓	--

Source: DVRPC

Figure 7: Chester County Study Location Aerial Photo

Source: DVRPC

Data Collection

Various types of data were collected for the preliminary feasibility analysis of a roundabout at this intersection. The following provides a summary of the data collected to analyze a potential roundabout at the intersection of Boot Road and Ship Road.

Field Observations

Figure 8 highlights observations from a field visit to the study location.

Figure 8: Chester County Study Location Field Visit Summary

OBSERVATIONS:

- Ship Road intersects Boot Road at a severely acute angle
- It is difficult for drivers traveling along Ship Road to judge sufficient gaps in eastbound Boot Road traffic due to the acute approach angle in combination with high approach speeds and the upstream horizontal curvature along Boot Road
- It is difficult for drivers traveling along Ship Road to judge sufficient gaps in westbound Boot Road traffic due to a lack of distinction between through and right-turning westbound vehicles
- The signalized intersection of Boot Road and Phoenixville Pike is approximately 500 feet east of the study intersection
- A commercial property is sited within the triangular parcel between the eastbound Boot Road and southbound Ship Road approaches; this property has access to both streets and is set back away from the study intersection
- The #92 SEPTA bus route travels along Boot Road in both directions at a frequency of 60 to 90 minutes
- Boot Road crosses the Chester Creek Branch immediately east of this study intersection

Source: DVRPC

Crash History

According to the DVRPC Crash Database System, 14 crashes were reported at this intersection between 2003 and 2007. Ten of the 14 crashes involved injuries. Angle crashes represented 43 percent of the crashes. The remaining types of crashes recorded at this location include rear-end, head on, hit-fixed object, sideswipe, and hit pedestrian. Seven of the crashes occurred on wet pavement surface conditions.

Turning Movements

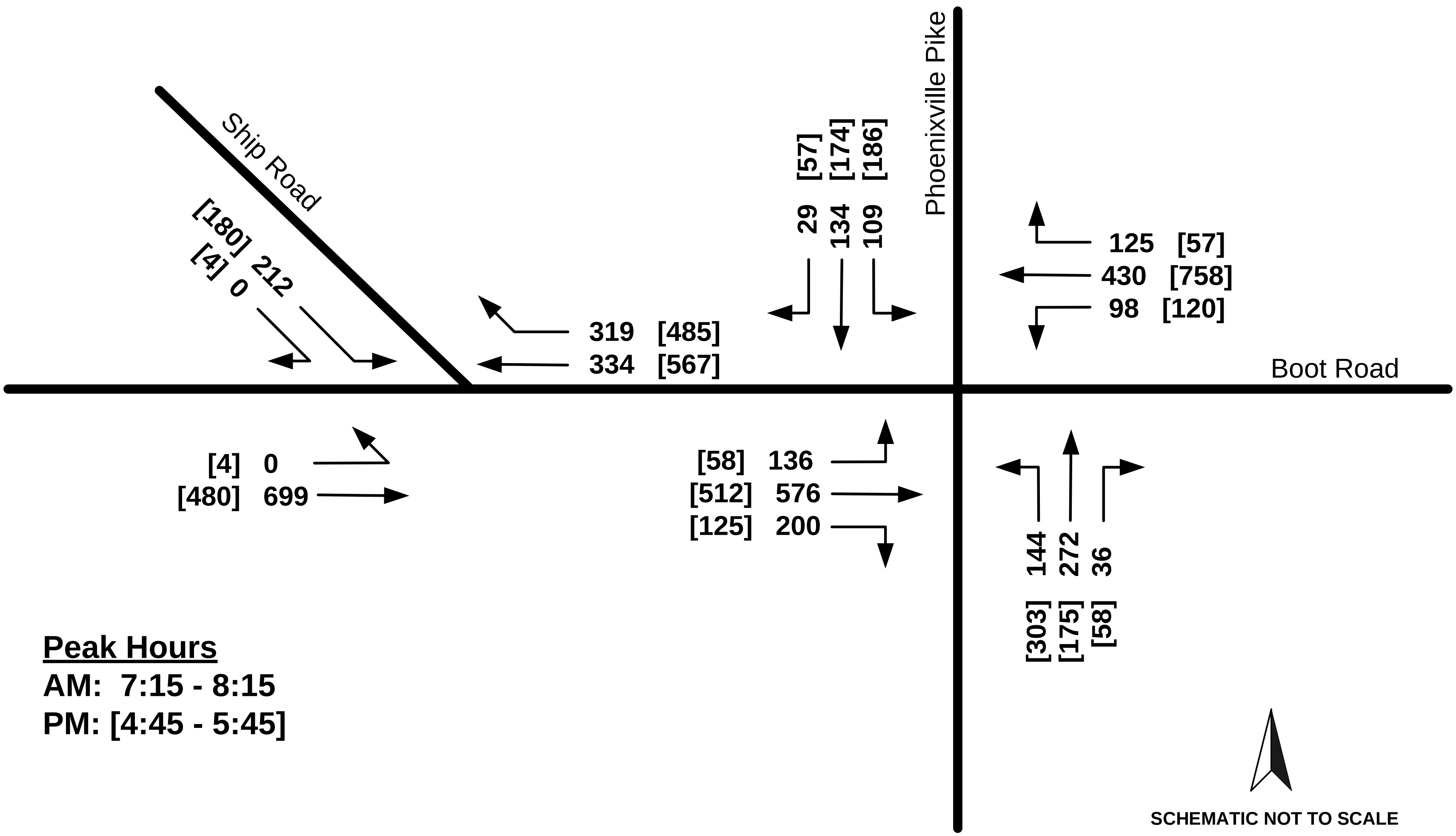
A peak hour turning movement diagram is shown in ***Figure 9.*** The morning and afternoon peak hour for the study area is 7:15 AM to 8:15 AM and 4:45 PM to 5:45 PM, respectively. The following highlights the key findings from the turning movements:

- Turning movement data for the Ship Road and Boot Road intersection was collected by Chester County in April 2008;
- Turning movement data for the Boot Road and Phoenixville Pike intersection was collected by Caruolo Associates in September 2005 as part of a Traffic Impact Study (TIS) for Rite Aid Pharmacy. A 2.5 percent annual growth rate was applied to this data for a two-year period;
- At the Ship Road and Boot Road intersection, Ship Road comprises 14 percent and 11 percent of the intersection's total AM and PM peak hour volumes, respectively. Of these vehicles, regardless of peak hour, 99 percent are left-turn movements continuing eastbound along Boot Road. Similarly, 99 percent of vehicles from eastbound Boot Road are through movements also continuing east along Boot Road. This intersection's dominant AM peak hour direction is eastbound, with 911 vehicles. Of westbound Boot Road's 653 vehicles during the AM peak hour, roughly half are through movements and half are right turns. The dominant direction during the PM peak hour is westbound, with 1,052 vehicles, and these are almost equally split between through and right-turn movements; and
- At the Boot Road and Phoenixville Pike intersection, the Boot Road approaches supply the majority of the intersection's total volume. This intersection's dominant AM peak hour approach is eastbound Boot Road, with 912 vehicles, the majority of which are through movements, with 200 vehicles turning right. The dominant PM peak hour approach is westbound Boot Road, with 935 vehicles, the vast majority of which continue as through movements toward the Ship Road intersection.

Figure 9

Chester County Study Location Turning Movements

EXISTING Peak Hour Turning Movement Counts AM & [PM]



Peak Hours
AM: 7:15 - 8:15
PM: [4:45 - 5:45]

SCHEMATIC NOT TO SCALE

DELAWARE VALLEY REGIONAL PLANNING COMMISSION (dvrpc) September 2009

Data Source: Chester County and Caruolo Associates

Approach Speeds

Due to the change in Chester County's selected study intersection, no vehicular approach speed data was obtained at this location.

Vehicle Classification

As indicated in ***Table 9***, classification counts for the Ship Road and Boot Road intersection were collected by Chester County in April 2008. The distribution of cars and heavy-vehicles is approximately the same for all approaches.

Table 9: Chester County Study Location – Vehicle Classification

Intersection Leg	Cars	Heavy-vehicles (2+ Axles, 6+ Wheels)	Buses
EB Boot Road	97%	3%	0%
WB Boot Road	97%	3%	0%
SB Ship Road	97%	3%	0%

Source: DVRPC

Signal Timing

The signal plan for the Boot Road and Phoenixville Pike intersection is semi-actuated, with the phases dwelling on the Boot Road movements. Based upon actuation by westbound Boot Road left turns, the signal will provide a protected lead phase for the westbound approach during both peak hours. Eastbound Boot Road left-turns never receive signal protection. Assuming presence actuation, concurrent protected phasing is provided for the northbound and southbound Phoenixville Pike left-turns.

Results and Findings

Below are the results for each of the scenarios for the Boot Road/Ship Road and Boot Road/Phoenixville Pike intersections.

Existing Scenario

Boot Road and Ship Road Intersection
For the AM peak hour, the intersection operates at an overall LOS of C, with 24 seconds of average delay. The vast majority of the delay is along the southbound Ship Road approach, which is stop-controlled and experiences a sizeable 95th percentile queue, at 325 feet, or roughly 16 car lengths. The eastbound and westbound Boot Road approaches average ten and one seconds of vehicle delay, respectively. During the PM peak hour, the intersection operates at an overall LOS of A, with only four seconds of average delay. The Ship Road approach experiences the greatest amount of average delay, at 32 seconds for a LOS of D. However, it has a minimal 95th percentile queue.

Boot Road and Phoenixville Pike
During the AM peak hour, the intersection operates at a LOS of C, with an average delay of 30 seconds. The most delayed approach is eastbound Boot Road, at 39 seconds for a LOS of D and a 95th percentile queue of about 540 feet, extending into and beyond the Ship Road intersection. During the PM peak hour, the intersection operates at a LOS of C, with an average delay of 28 seconds. The most delayed approach is northbound Phoenixville Pike, with an average delay of 34 seconds and a LOS of C. Eastbound Boot Road experiences 29 seconds of delay, for a LOS of C and a 95th percentile queue of 311 feet, or 16 vehicle lengths.

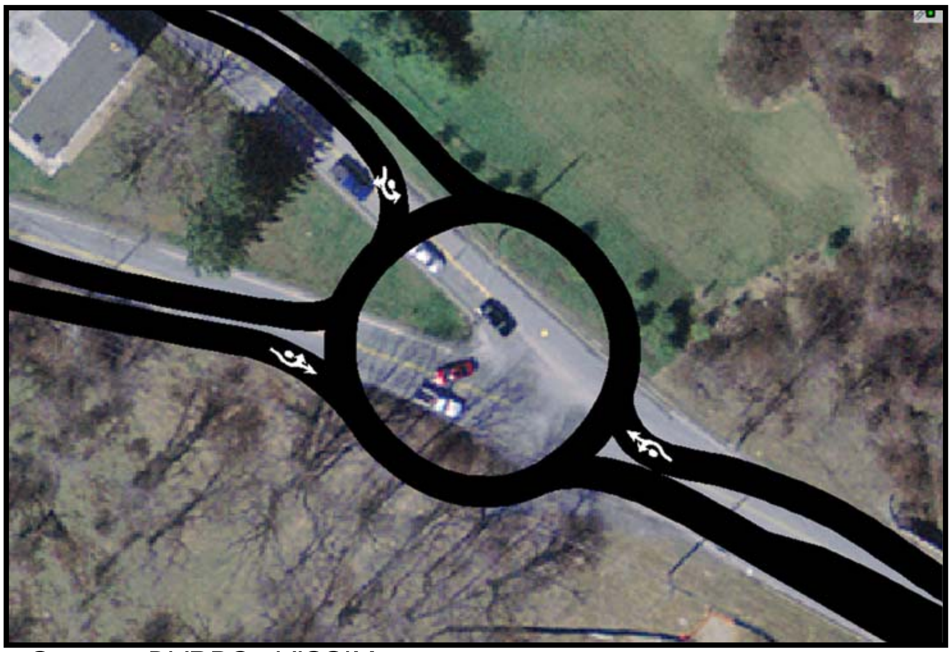
Roundabout Scenario

Figure 10 depicts the roundabout scenario.

Boot Road and Ship Road Intersection
During the AM peak hour, a roundabout is modeled to operate at an overall LOS of E, with 49 seconds of average delay. Though delay for the southbound Ship Road approach is reduced by 50 percent from existing conditions, the previously free-flowing Boot Road approaches incur additional delay of up to 81 seconds for eastbound Boot Road. The 95th percentile queue increases for both Boot Road approaches, particularly along the eastbound leg, which reaches almost 420 feet, or 21 vehicle lengths. During the PM peak hour, the roundabout operates at an overall LOS of A, with an average of eight seconds of delay. All approaches experience less than ten seconds of delay and operate at a LOS of A. Unlike a roundabout under AM peak hour conditions, the 95th percentile queue for all approaches is zero.

Boot Road and Phoenixville Pike
During the AM peak hour, the intersection operates at a LOS of D, with 43 seconds of average delay. The most delayed approach is eastbound Boot Road, with 79 seconds of delay, a LOS of E, and a 95th percentile queue of roughly 650 feet, or 150 feet greater than the distance between the two intersections. During the PM peak hour, the intersection operates at a LOS of C, with 28 seconds of average delay. Similar to the existing conditions scenario, the most delayed approach is northbound Phoenixville Pike, with 33 seconds of delay and a LOS of C. Eastbound Boot Road's 95th percentile queue is 166 feet, or approximately eight vehicle lengths.

Figure 10: Chester County Study Location – Roundabout Rendering #1



Source: DVRPC - VISSIM

Roundabout Scenario with Signal Timing Modifications at the Adjacent Intersection

For this scenario, a protected left-turn phase is introduced during both peak hours for eastbound Boot Road at the signalized Phoenixville Pike intersection. As a result, both Boot Road left-turns are concurrently signal-protected, assuming the presence of actuation. The roundabout remains at the Ship Road intersection.

Boot Road and Ship Road Intersection
During the AM peak hour, the roundabout operates at an overall LOS of A, with only eight seconds of average delay. The most delayed approach is eastbound Boot Road, with an average delay of 13 seconds, a LOS of B, and a 95th percentile queue of 111 feet. These improvements are the product of greater downstream capacity created by signal plan modifications at the Phoenixville Pike intersection. During the PM peak hour,

similar to the original roundabout scenario, the roundabout operates at a LOS of A, with eight seconds of average delay, and a nonexistent 95th percentile queue.

Boot Road and Phoenixville Pike

During the AM peak hour, the intersection operates at a LOS of C, with an average delay of 31 seconds, a 12-second improvement from the previous scenario. The most delayed approach is eastbound Boot Road, which performs at a LOS of C, with a 296-foot 95th percentile queue and 34 seconds of delay, a 45-second improvement from the previous scenario. During the PM peak hour, the intersection operates at a LOS of D, with an average delay of 40 seconds. This is a 12-second increase in overall delay from the previous scenario. Northbound Phoenixville Pike and westbound Boot Road are the most delayed approach, with 46 seconds of average delay and a LOS of D.

Roundabout Scenario with Geometric Modifications at the Adjacent Intersection

For this scenario, an exclusive 250-foot right-turn lane is provided for the eastbound Boot Road approach at the signalized Phoenixville Pike intersection. The roundabout as depicted in ***Figure 11*** remains at the Ship Road intersection.

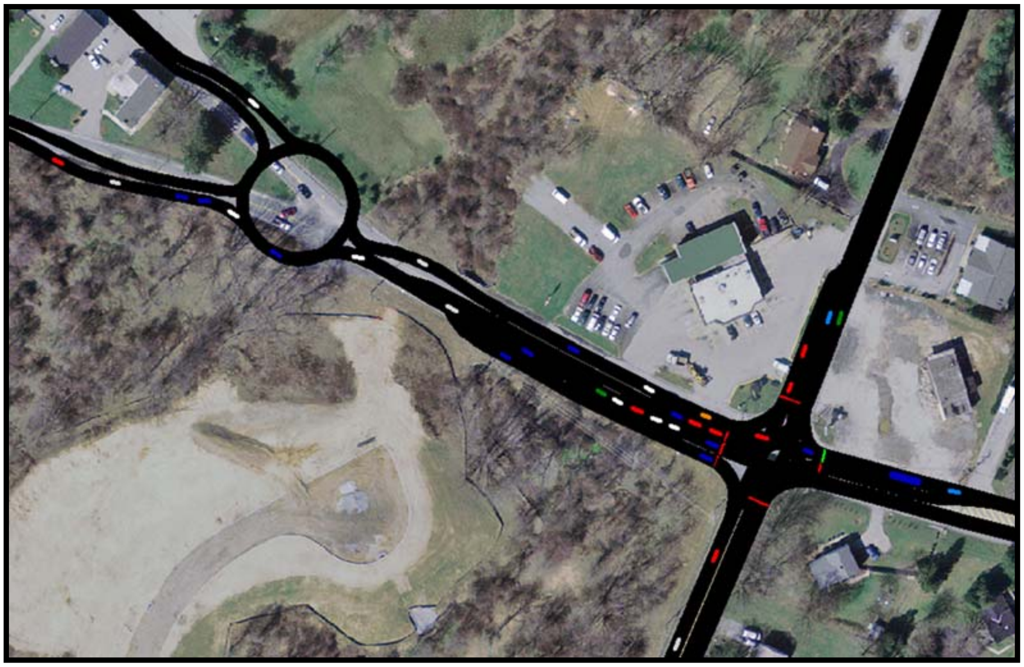
Boot Road and Ship Road Intersection

During the AM peak hour, the roundabout operates at a LOS of A, with seven seconds of average delay, representing a 42-second improvement from the original roundabout scenario. All approaches perform with less than ten seconds of delay and with a minor or nonexistent 95th percentile queue. During the PM peak hour, the roundabout operates at a LOS of A, with eight seconds of average delay. The southbound Ship Road approach experiences the most delay (11 seconds) and LOS B. The 95th percentile queues are nonexistent along all three approaches.

Boot Road and Phoenixville Pike

During the AM peak hour, the intersection operates at an overall LOS of C, with 22 seconds of average delay, for an eight- and nine-second improvement from the existing and the previous roundabout scenarios, respectively. Unlike all prior scenarios, eastbound Boot Road experiences less delay than most of the other approaches, at 20 seconds and a LOS of B. In addition, the eastbound approach's 95th percentile queue is 159 feet, or eight vehicle lengths. During the PM peak hour, the intersection operates at an overall LOS of C, with 28 seconds of average delay, a 12-second improvement from the previous roundabout scenario. The eastbound Boot Road approach experiences the least delay of all four approaches, with 21 seconds of delay and a LOS of C. The most delayed approach remains northbound Phoenixville Pike, with 36 seconds and a LOS of D.

Figure 11: Chester County Study Location – Roundabout Rendering #2



Source: DVRPC - VISSIM

Roundabout Scenario with Signal Timing Modifications and an Exclusive Right-Turn Lane at the Adjacent Intersection

This scenario combined the timing adjustments and geometric modifications at the Phoenixville Pike intersection from previous scenarios. The roundabout remains at the Ship Road intersection.

Boot Road and Ship Road Intersection

During the AM peak hour, the roundabout operates at an overall LOS of A, with an average delay of seven seconds, with all approaches experiencing ten seconds or less of average delay. At 52 feet, or approximately 3 vehicle lengths, eastbound Boot Road is the only approach to experience 95^{th} percentile queuing. During the PM peak hour, the roundabout operates at an overall LOS of A, with an average delay of eight seconds, with all approaches experiencing average delays of ten seconds or less and zero 95^{th} percentile queuing.

Boot Road and Phoenixville Pike

During the AM peak hour, the intersection operates at an overall LOS of C, with 29 seconds of average delay. The eastbound Boot Road approach experiences the least delay, at 27 seconds and a LOS of C. The most delayed approach is northbound Phoenixville Pike, with 34 seconds of delay and a LOS of C. During the PM peak hour, the intersection operates at an overall LOS of D, with 36 seconds of average delay. Similar to the morning peak, eastbound Boot Road experiences the least delay, at 26 seconds and a LOS of C. The most delayed approach is westbound Boot Road, at 45 seconds and a LOS of D.

Tables 10 – 13 summarize the LOS analysis performed for the above mentioned scenarios.

Table 10: Chester County – AM Peak Hour Scenarios (Boot Road & Ship Road)

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
AM Peak Hour					
	Existing	EB Boot Road	10.4	B	27.0
		WB Boot Road	1.4	A	0.0
		SB Ship Road	136.2	F	325.0
		Intersection Total	**24.1**	**C**	
	Roundabout	EB Boot Road	80.6	F	416.0
		WB Boot Road	16.8	C	347.0
		SB Ship Road	67.2	F	304.0
		Intersection Total	**48.6**	**E**	
	Roundabout Scenario with Concurrent East/West Protected Left-Turns	EB Boot Road	12.6	B	111.0
		WB Boot Road	4.4	A	0.0
		SB Ship Road	6.0	A	0.0
		Intersection Total	**8.4**	**A**	
	Roundabout Scenario with Exclusive Eastbound Right-Turn Lane	EB Boot Road	9.7	A	49.0
		WB Boot Road	3.8	A	0.0
		SB Ship Road	5.0	A	0.0
		Intersection Total	**6.7**	**A**	
	Roundabout Scenario with Concurrent Timing and Eastbound Right-Turn Lane	EB Boot Road	10.1	B	52.0
		WB Boot Road	4.4	A	0.0
		SB Ship Road	4.9	A	0.0
		Intersection Total	**7.1**	**A**	

Source: DVRPC

Table 11: Chester County – PM Peak Hour Scenarios (Boot Road & Ship Road)

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
PM Peak Hour					
	Existing	EB Boot Road	1.0	A	0.0
		WB Boot Road	0.6	A	0.0
		SB Ship Road	31.8	D	0.0
		Intersection Total	**3.9**	**A**	
	Roundabout	EB Boot Road	2.4	A	0.0
		WB Boot Road	9.5	A	0.0
		SB Ship Road	9.2	A	0.0
		Intersection Total	**7.5**	**A**	
	Roundabout Scenario with Concurrent East/West Protected Left-Turns	EB Boot Road	5.1	A	0.0
		WB Boot Road	8.8	A	0.0
		SB Ship Road	8.8	A	0.0
		Intersection Total	**7.8**	**A**	
	Roundabout Scenario with Exclusive Eastbound Right-Turn Lane	EB Boot Road	5.2	A	0.0
		WB Boot Road	9.2	A	0.0
		SB Ship Road	10.6	B	0.0
		Intersection Total	**8.3**	**A**	
	Roundabout Scenario with Concurrent Timing and Eastbound Right-Turn Lane	EB Boot Road	5.0	A	0.0
		WB Boot Road	8.9	A	0.0
		SB Ship Road	9.4	A	0.0
		Intersection Total	**7.9**	**A**	

Source: DVRPC

Table 12: Chester County – AM Peak Hour Scenarios (Boot Road & Phoenixville Pike)

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
AM Peak Hour					
	Existing	NB Phoenixville Pike	28.3	C	118.0
		SB Phoenixville Pike	27.0	C	66.0
		EB Boot Road	39.2	D	541.0
		WB Boot Road	19.0	B	137.0
		Intersection Total	**29.8**	**C**	
	Roundabout	NB Phoenixville Pike	28.9	C	118.0
		SB Phoenixville Pike	27.7	C	66.0
		EB Boot Road	79.3	E	646.0
		WB Boot Road	21.9	C	253.0
		Intersection Total	**42.8**	**D**	
	Roundabout Scenario with Concurrent East/West Protected Left-Turns	NB Phoenixville Pike	32.0	C	138.0
		SB Phoenixville Pike	28.5	C	65.0
		EB Boot Road	34.2	C	296.0
		WB Boot Road	28.5	C	247.0
		Intersection Total	**31.4**	**C**	
	Roundabout Scenario with Exclusive Eastbound Right-Turn Lane	NB Phoenixville Pike	26.6	C	108.0
		SB Phoenixville Pike	27.4	C	66.0
		EB Boot Road	19.9	B	159.0
		WB Boot Road	18.2	B	140.0
		Intersection Total	**21.6**	**C**	
	Roundabout Scenario with Concurrent Timing and Eastbound Right-Turn Lane	NB Phoenixville Pike	34.3	C	143.0
		SB Phoenixville Pike	29.5	C	66.0
		EB Boot Road	27.1	C	174.0
		WB Boot Road	28.4	C	241.0
		Intersection Total	**29.2**	**C**	

Source: DVRPC

Table 13: Chester County – PM Peak Hour Scenarios
(Boot Road & Phoenixville Pike)

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
PM Peak Hour					
	Existing	NB Phoenixville Pike	34.3	C	149.0
		SB Phoenixville Pike	29.6	C	95.0
		EB Boot Rd	29.2	C	311.0
		WB Boot Rd	23.3	C	302.0
		Intersection Total	**28.2**	**C**	
	Roundabout	NB Phoenixville Pike	33.1	C	146.0
		SB Phoenixville Pike	29.3	C	97.0
		EB Boot Rd	23.3	C	166.0
		WB Boot Rd	28.0	C	304.0
		Intersection Total	**28.4**	**C**	
	Roundabout Scenario with Concurrent East/West Protected Left-Turns	NB Phoenixville Pike	46.4	D	255.0
		SB Phoenixville Pike	37.9	D	130.0
		EB Boot Rd	29.0	C	175.0
		WB Boot Rd	46.0	D	310.0
		Intersection Total	**40.1**	**D**	
	Roundabout Scenario with Exclusive Eastbound Right-Turn Lane	NB Phoenixville Pike	36.1	D	155.0
		SB Phoenixville Pike	31.1	C	97.0
		EB Boot Rd	20.5	C	159.0
		WB Boot Rd	27.5	C	304.0
		Intersection Total	**28.1**	**C**	
	Roundabout Scenario with Concurrent Timing and Eastbound Right-Turn Lane	NB Phoenixville Pike	34.2	C	145.0
		SB Phoenixville Pike	35.2	D	108.0
		EB Boot Rd	25.5	C	127.0
		WB Boot Rd	45.3	D	309.0
		Intersection Total	**35.9**	**D**	

Source: DVRPC

Strengths and Weaknesses of a Roundabout at this Location

Highlighted below are strengths and weaknesses resulting from the analysis performed. Comments from Chester County and PennDOT officials are also provided.

Strengths

- Significant reduction in delay and queuing during the AM peak hour, assuming signal timing and/or geometric modifications at the Phoenixville Pike intersection;
- Reduction of the intersection's conflict points, acute approach angles, and potential for severe crashes; and
- Reduction of the difficulty for vehicles from Ship Road to enter and navigate the intersection.

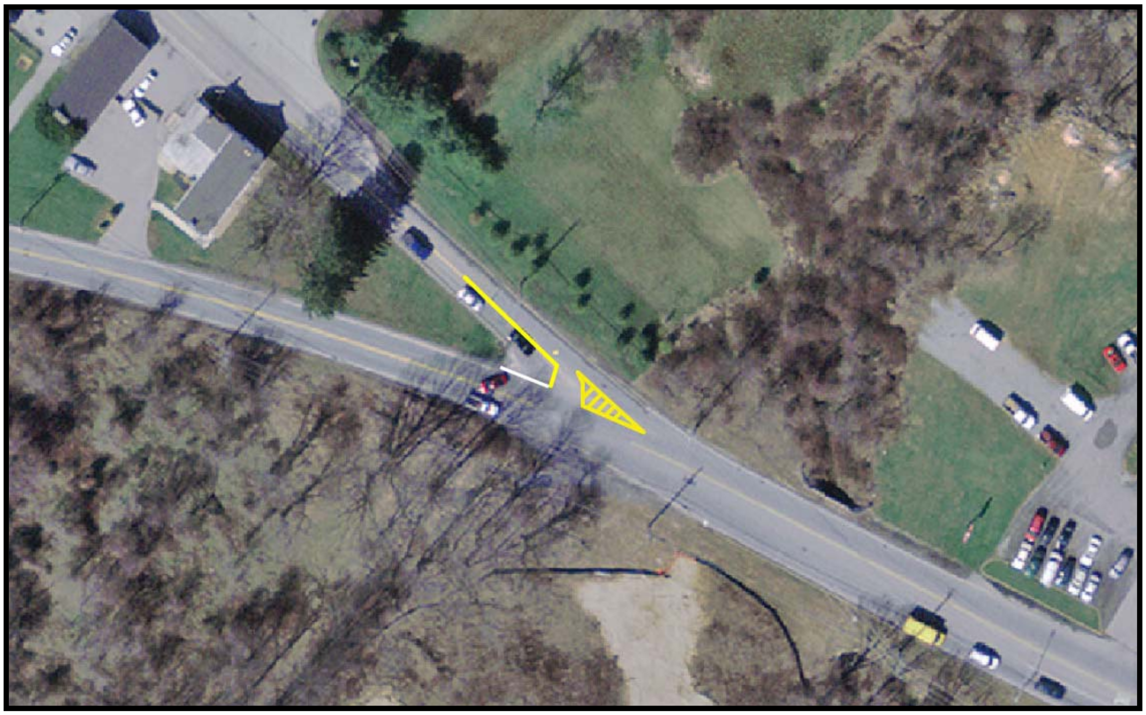
Weaknesses

- Large increase in delay and queuing during the AM peak hour, assuming no modifications at the Phoenixville Pike intersection;
- Close proximity to the adjacent signalized intersection will allow queue spillover into the roundabout, assuming no modifications at the Phoenixville Pike intersection;
- Increased intersection footprint area required for the roundabout; and
- Potential realignment of the westbound Boot Road approach may require reconstruction of the culvert over the Chester Creek Branch.

Chester County Comments

- Originally, Chester County officials were concerned about the close proximity of the Phoenixville Pike intersection and thus sought to utilize VISSIM in order to explore various means to alter the signalized intersection to accommodate a roundabout at the Ship Road intersection;
- After examination of the refined scenarios, Chester County officials do not endorse a roundabout at the study location; and
- As shown in ***Figure 12***, Chester County desires to have short-term safety and operational improvements implemented at this location. This improvement includes a stop bar and painted median along Ship Road that meets Boot Road at a 90 degree angle, and a painted gore area that may serve as a splitter island to differentiate westbound Boot Road through movements from right-turns.

Figure 12: Chester County Study Location – Short-term Improvement



Source: DVRPC

PennDOT Comments

PennDOT does not consider this location a strong roundabout candidate given the proximity to the Phoenixville Pike intersection and the traffic volumes experienced there. PennDOT encourages future evaluation of the remaining two prioritized candidate locations identified by Chester County.

Delaware County

Candidate Location

The intersection of Bridgewater Road and Brookhaven Road which borders Brookhaven Borough and Chester Township was selected for analysis from the three potential locations prioritized by Delaware County. As shown in ***Table 14***, this intersection contains three of the seven qualifying DVRPC criteria. This location was specifically chosen due to the presence of multiple-lane approaches, potential bicycle and pedestrian traffic, and existing signalization.

Table 14: Delaware County's Site Determination Matrix

	Bridgewater Road and Brookhaven Road	*East Dutton Mill Road and Chester Creek Road*	*Bridgewater Road and Chester Creek Road*
Awkward geometry	✓	✓	✓
Heavy-vehicles	--	--	--
Bike/pedestrians	✓	--	--
Single-lane approach	--	✓	✓
Rural or suburban land use	✓	✓	✓
Municipal support	--	--	--
Safety concerns	--	--	--

Source: DVRPC

Figure 13: Delaware County Study Location Aerial Photo

Source: DVRPC

Data Collection

Various types of data were collected for the preliminary feasibility analysis of a roundabout at this intersection. A summary of the data collected is highlighted.

Field Observations

Figure 14 highlights observations from a field visit to the study location.

Figure 14: Delaware County Study Location Field Visit Summary

OBSERVATIONS:

- Signalized intersection with three approaches
- High speeds along the intersection's approaches
- Limited sight distances, particularly for the southbound Brookhaven Road approach
- Moderate approach grades
- Two large radii and yield-controlled channelized right-turn lanes
- A culvert carrying a tributary of the Chester Creek is immediately west of the intersection

Source: DVRPC

Crash History

Crash data was obtained from the DVRPC Crash Database. Between 2003 and 2007, 36 crashes occurred at this intersection. Eighty-six percent of the crashes fell within the following three categories: angle (14), hit-fixed object (10), and rear-end (7). The remaining crashes were classified as non-collision, head on, and sideswipe (opposite direction). Eighteen of the crashes involved injuries. Ten of the 36 crashes occurred on wet pavement.

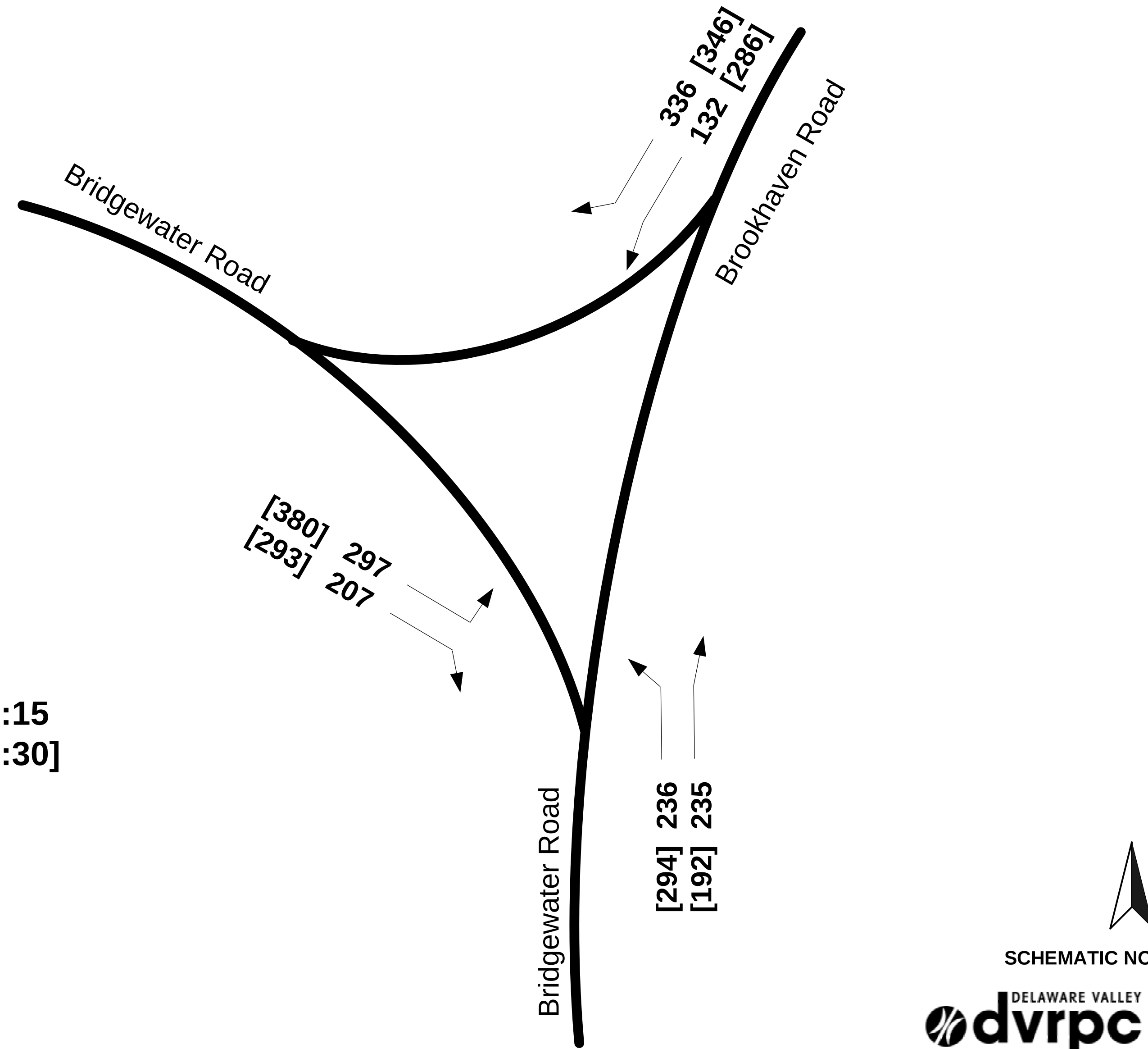
Turning Movements

A peak hour turning movement diagram is shown in ***Figure 15***. The morning and afternoon peak hour for this intersection is 7:15 AM to 8:15 AM and 4:30 PM to 5:30 PM, respectively.

Figure 15

Delaware County Study Location Turning Movements

EXISTING Peak Hour Turning Movement Counts AM & [PM]



Peak Hours
AM: 7:15 - 8:15
PM: [4:30 - 5:30]

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During the AM peak hour, all three approach legs carry similar volume of vehicles; the heaviest movement is the right-turn from southbound Brookhaven Road onto Bridgewater Road. In the afternoon peak hour, the eastbound Bridgewater Road approach experiences the most volume; the heaviest movement is this approach's left-turn movement onto Brookhaven Road.

Approach Speeds

The posted speed limit in the area is 35 MPH. As shown in ***Table 15***, measured speeds exceeded 35 MPH in the AM and PM peak period.

Table 15: Delaware County Study Location – Approach Speeds

Intersection Leg	Vehicle Speeds (MPH)	
	AM	PM
NB Bridgewater Road	41 – 45	41 – 45
SB Brookhaven Road	36 – 40	36 – 40
EB Bridgewater Road	41 – 45	41 – 45

Source: DVRPC

Vehicle Classification

Table 16 summarizes classification counts at this location. Heavy-vehicles constitute a relatively large proportion of the eastbound Bridgewater Road approach leg.

Table 16: Delaware County Study Location – Vehicle Classification

Intersection Leg	Cars	Heavy-vehicles (2+ Axles, 6+ Wheels)	Buses
NB Bridgewater Road	93%	6%	1%
SB Brookhaven Road	97%	2.5%	0.5%
EB Bridgewater Road	85%	13.5%	1.5%

Source: DVRPC

Signal Timing

The intersection is controlled with a semi-actuated signal that dwells on the northbound Bridgewater Road and southbound Brookhaven Road phases. Northbound Bridgewater Road left-turns are signal protected and permitted movement. The cycle length for the intersection is 60 seconds and 80 seconds for the AM and PM peak hours, respectively. The signal timing was last updated in 1984.

Results and Findings

Below are the results for each of the scenarios for the Bridgewater Road and Brookhaven Road intersection.

Existing Scenario

For the AM peak hour, existing conditions perform at an overall LOS of A, with only eight seconds of average delay. The heaviest delays and longest queues are experienced along the eastbound Bridgewater Road approach, though its average delay is only 12 seconds and its 95th percentile queue is 62 feet, or three vehicle lengths. For the PM peak hour, existing conditions provide an overall LOS of B, with 11 seconds of average delay. Similar to the AM peak hour, the eastbound Bridgewater Road approach experiences the greatest delay and 95th percentile queue, at 15 seconds and 106 feet, or five vehicle lengths, respectively.

Roundabout Scenario

During the AM peak hour, a roundabout at the project intersection operates at a LOS of A, with an average delay of six seconds. This represents a marginal improvement from existing conditions. All approaches experience less than ten seconds of delay, with nonexistent 95th percentile queuing. During the PM peak hour, the roundabout operates at a LOS of B, with an average delay of 12 seconds. This is a marginal deterioration from existing conditions. The most congested approach is eastbound Bridgewater Road, though it operates at a LOS of B, with 14 seconds of average delay, and a 95th percentile queue of approximately 180 feet, or nine vehicle lengths.

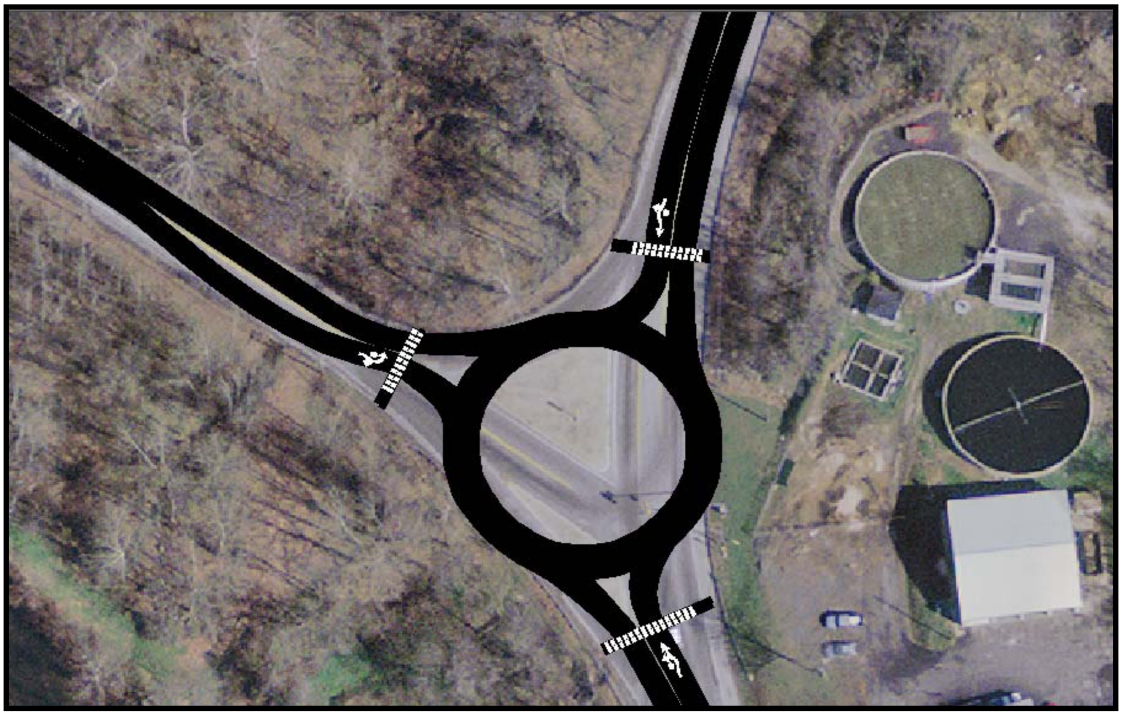
Roundabout with Heavy Pedestrian Volumes Scenario

This scenario sought to quantify the impact of heavy pedestrian usage of the roundabout due to its close proximity to the planned Chester Creek Rail Trail. In the area of the study intersection, the trail is anticipated to run along the western bank of Chester Creek, which is roughly parallel to and west of Bridgewater Road. A parking lot and trailhead are proposed for a location along Creek Road, a half-mile north of the study intersection. Also proposed at this location is a new pedestrian/bicycle bridge spanning Chester Creek, to connect the trail with the parking lot and trailhead. Despite the lack of a planned direct connection to the trail, the roundabout should anticipate pedestrian traffic due to the numerous nearby residential developments. As a result, this scenario introduced a pedestrian presence of 100 pedestrians per crosswalk per peak hour, with the existing vehicular volumes. ***Figure 16*** displays a conceptual rendering of a roundabout with crosswalks at the study intersection.

During the AM peak hour, the roundabout operates at a LOS of A, with an average delay of eight seconds, a marginal increase from the original roundabout scenario. All approaches experience a slight deterioration in delay, though the largest approach delay, experienced along northbound Bridgewater Road, is only 11 seconds. The 95th

percentile queue is nonexistent for all approaches. During the PM peak hour, the roundabout operates at an overall LOS of C, with 17 seconds of average delay, or five seconds more than the original roundabout scenario. All approaches experience 20 seconds or less delay; however, no approach's delay increased by more than six seconds from the original roundabout scenario. The 95th percentile queues increase for all approaches, especially eastbound Bridgewater Road, whose 95th percentile queue is 284 feet, or 14 vehicle lengths.

Figure 16: Delaware County Study Location – Roundabout Rendering #1



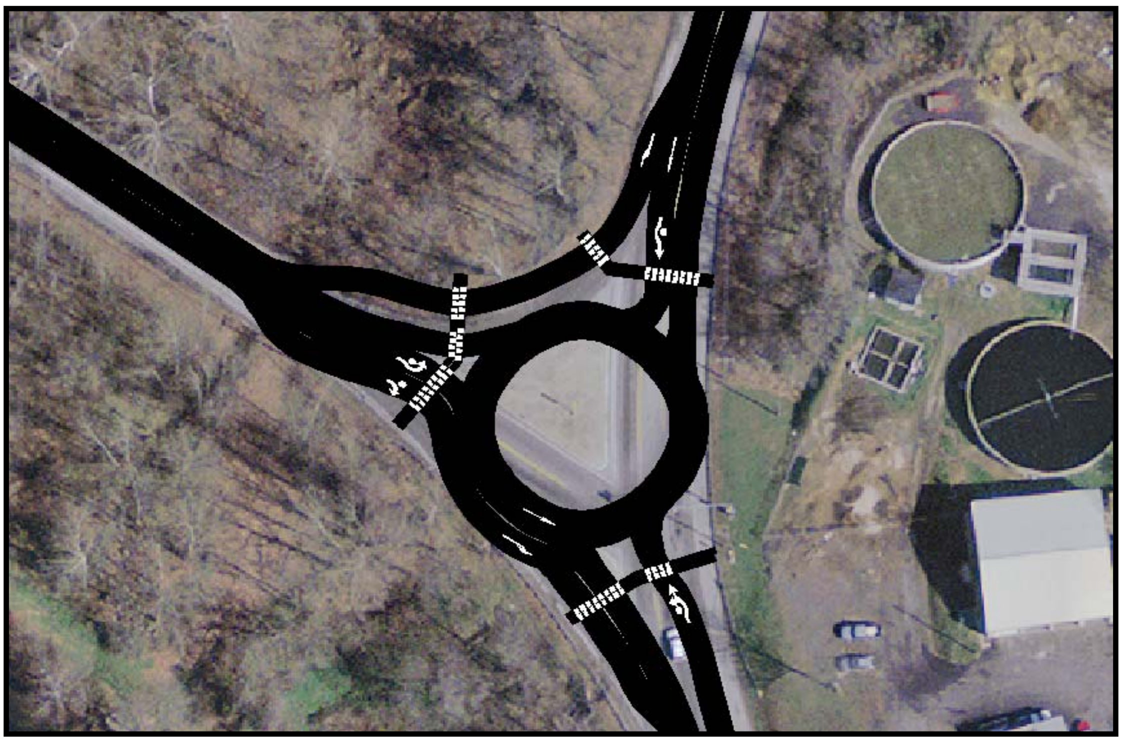
Source: DVRPC

Roundabout with Heavy Pedestrian Volumes and Exclusive Right-Turn Lanes Scenario

This scenario retained the pedestrian volumes from the previous scenario and introduced exclusive right-turn lanes for the eastbound Bridgewater Road and southbound Brookhaven Road approaches. For the former, a second approach and circulatory lane is utilized, whereas for the latter, a channelized right-turn slip lane is employed. ***Figure 17*** displays a roundabout with crosswalks and exclusive right-turn lanes at the study intersection.

During the AM peak hour, the roundabout operates at a LOS of A, with an average delay of six seconds, a marginal improvement from the two previous roundabout scenarios. All approaches experience less than ten seconds of delay, a LOS of A, and no 95th percentile queuing. During the PM peak hour, the roundabout operates at a LOS of B, with an average delay of 12 seconds, a minor five-second improvement from the previous roundabout scenario, while performing comparably to the existing and original roundabout scenarios. The two approaches with exclusive right-turn lanes experience LOS of A, with less than seven seconds of delay. The remaining approach, northbound Bridgewater Road, experiences 23 seconds of delay, for a LOS of C, and is the only approach with a perceptible 95th percentile queue, with 76 feet, or four vehicle lengths.

Figure 17: Delaware County Study Location – Roundabout Rendering #2



Source: DVRPC

Tables 17 and 18 summarize the results from the LOS analysis performed for the scenarios at the Bridgewater and Brookhaven intersection.

Table 17: Delaware County AM Peak Hour Scenarios

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
AM Peak Hour	Existing	NB Bridgewater Road	7.3	A	39.0
		SB Brookhaven Road	4.0	A	11.0
		EB Bridgewater Road	11.6	B	62.0
		Intersection Total	**7.8**	**A**	
	Roundabout	NB Bridgewater Road	8.3	A	0.0
		SB Brookhaven Road	6.0	A	0.0
		EB Bridgewater Road	4.3	A	0.0
		Intersection Total	**6.2**	**A**	
	Roundabout with Heavy Pedestrian Volume	NB Bridgewater Road	10.6	B	0.0
		SB Brookhaven Road	8.2	A	0.0
		EB Bridgewater Road	5.7	A	0.0
		Intersection Total	**8.1**	**A**	
	Roundabout with Heavy Pedestrian Volume and Right-turn Lanes	NB Bridgewater Road	9.6	A	0.0
		SB Brookhaven Road	3.9	A	0.0
		EB Bridgewater Road	4.3	A	0.0
		Intersection Total	**5.9**	**A**	

Source: DVRPC

Table 18: Delaware County PM Peak Hour Scenarios

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
PM Peak Hour					
	Existing	NB Bridgewater Road	11.5	B	64.0
		SB Brookhaven Road	7.6	A	38.0
		EB Bridgewater Road	14.7	B	106.0
		Intersection Total	**11.3**	**B**	
	Roundabout	NB Bridgewater Road	11.7	B	61.0
		SB Brookhaven Road	10.7	B	78.0
		EB Bridgewater Road	13.9	B	175.0
		Intersection Total	**12.2**	**B**	
	Roundabout with Heavy Pedestrian Volume	NB Bridgewater Road	15.5	C	98.0
		SB Brookhaven Road	16.2	C	175.0
		EB Bridgewater Road	19.6	C	284.0
		Intersection Total	**17.3**	**C**	
	Roundabout with Heavy Pedestrian Volume and Right-turn Lanes	NB Bridgewater Road	22.7	C	76.0
		SB Brookhaven Road	6.7	A	0.0
		EB Bridgewater Road	5.7	A	0.0
		Intersection Total	**11.6**	**B**	

Source: DVRPC

Strengths and Weaknesses of a Roundabout at this Study Location

Highlighted below are strengths and weaknesses resulting from the analysis performed. Comments from Delaware County and PennDOT stakeholders are also provided.

Strengths

- Likely to reduce approach and intersection travel speeds;
- Clearer lines of sight;
- Reduction of the intersection's conflict points;
- Likely to fit within the footprint of the existing intersection;
- Potential to accommodate and assist future pedestrians from the anticipated Chester Creek Rail Trail; and
- Reduced maintenance costs due to removal of existing traffic signal.

Weaknesses

- Minor increases in delay, assuming heavy pedestrian usage of the roundabout; and
- Potential impact upon the existing culvert for the tributary of the Chester Creek.

Delaware County Comments

- Potentially a very good location, but the local municipalities need to be incorporated into any future planning for this intersection;
- The impact of high pedestrian traffic needs to be evaluated due to the proximity of the anticipated Chester Creek Rail Trail;
- Evaluate a roundabout with exclusive right-turn lanes, similar to those that currently exist at the intersection;
- Reduced maintenance costs due to the removal of the existing traffic signal; and
- An overall decrease in vehicle emissions is likely.

PennDOT Comments

PennDOT considers this to be an ideal location for a roundabout; however sight distance is a concern. A more detailed understanding of the connection between the study intersection and the anticipated Chester Creek Rail Trail is needed. PennDOT prefers the layout of the original roundabout scenario over the roundabout scenario with exclusive right-turn lanes.

Montgomery County

Candidate Location

The intersection of New Hope Street, Belvoir Road, and Marielle Lane in East Norriton and Plymouth townships was selected for analysis from the three potential locations prioritized by Montgomery County. As depicted in ***Table 19***, this intersection displayed three of the seven qualifying criteria. This location was primarily chosen to determine the impact of modeling a roundabout at an intersection within close proximity to a signalized intersection.

Table 19: Montgomery County's Site Determination Matrix

Criteria	Prioritized Location #1	Prioritized Location #2	Prioritized Location #3
	Whitehall Road and Sterigere Street	***New Hope Street and Belvoir Road/Marielle Lane***	***Township Line Road and Cemetery Road/Seitz Road***
Awkward geometry	--	✓	--
Heavy-vehicles	--	--	--
Bike/pedestrians	✓	✓	--
Single-lane approach	--	--	--
Rural or suburban land use	✓	✓	✓
Municipal support	--	--	--
Safety concerns	--	--	--

Source: DVRPC

Figure 18: Montgomery County Study Location Aerial Photo

Source: DVRPC

Data Collection

Various types of data were collected for the preliminary feasibility analysis of a roundabout at this intersection. This includes observations by the study team during a site visit, crash records from the local municipality, and traffic data.

Field Observations

Observations from the field visit are highlighted below in ***Figure 19***.

Figure 19: Montgomery County Study Location Field Visit Summary

OBSERVATIONS:

- Wide, straight, and flat approaches encourage excessive speeding along New Hope Street
- The line-of-sight for the posted stop sign for northbound New Hope Street vehicles is severely limited due to the minimal setback and close proximity of large trees
- Belvoir Road approaches the intersection with a consistent and mild uphill incline
- Presence of school-aged pedestrians, given the close proximity of two schools (Central Montgomery County Technical High School and Colonial Middle School)
- Potential for queues from adjacent signalized intersection (roughly 1,000 feet to the northeast) to impact project location
- Dominant movements at this location are through movements along New Hope Street

Source: DVRPC

Crash History

According to the DVRPC Crash Database, no crashes were reported at this intersection between 2003 and 2007.

Turning Movements

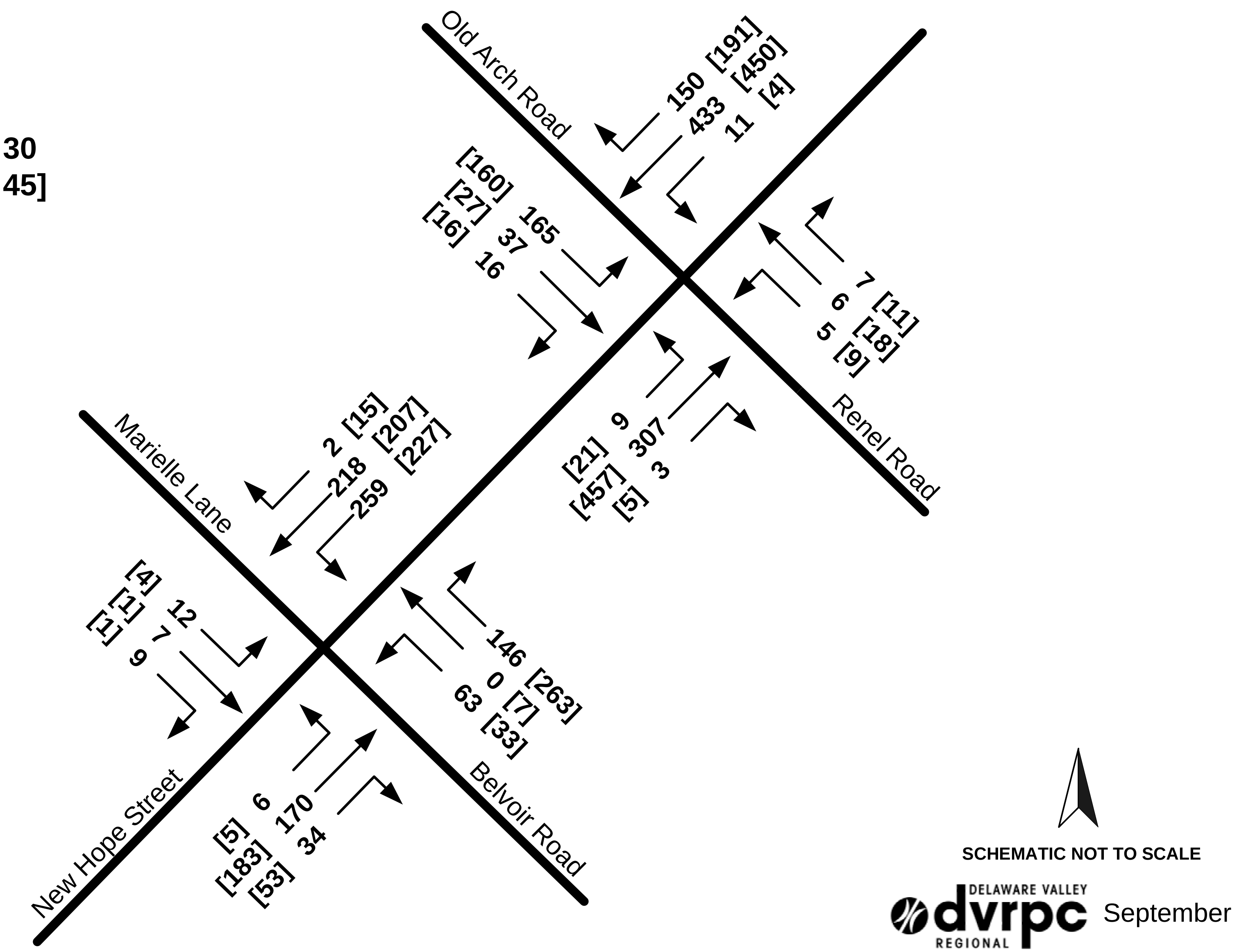
As shown in ***Figure 20*** at the New Hope Street/Belvoir Road intersection, the southbound New Hope Street approach is the most heavily traveled during both peak hours, supplying approximately 50 percent of the intersection's total peak hour volume. At this approach, the majority of the movements are left turns onto Belvoir Road. Conversely, 70 percent and 87 percent of the movements from the Belvoir Road approach are right turns onto New Hope Street during the AM and PM peak hours, respectively.

Figure 20

Montgomery County Study Location Turning Movements

EXISTING Peak Hour Turning Movement Counts AM & [PM]

Peak Hours
AM: 7:30 - 8:30
PM: [4:45 - 5:45]



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At the Old Arch Road/Renel Road intersection, during both peak hours, the heaviest approach is southbound New Hope Street, which carries roughly 50 percent of the intersection's total vehicles. For both peak hours, this approach's southbound through movement comprises the majority of that approach's movements. There is a large proportion of right-turn movements onto Old Arch Road, and this is reflected by a comparable volume of vehicles turning left from Old Arch Road onto New Hope Street.

Approach Speeds

The posted speed limit along New Hope Street and Belvoir Road is 25 MPH. As depicted in ***Table 20***, the measured approach speeds along New Hope Street are 41 to 45 MPH and 36 to 40 MPH for the northbound and southbound directions, respectively. Speeds ranging between 36 to 40 MPH were measured in the AM and PM peak hours for the Belvoir Road approach. No speed data was collected for Marielle Lane due to its context as a no-outlet residential street.

Table 20: Montgomery County Study Location – Approach Speeds

Intersection Leg	Vehicle Speeds (MPH)	
	AM	PM
NB New Hope Street	41 – 45	41 – 45
SB New Hope Street	36 – 40	36 – 40
WB Belvoir Road	36 – 40	36 – 40

Source: DVRPC

Vehicle Classification

Table 21 summarizes the results of the vehicle classification for the Montgomery County location. Heavy-vehicles and buses comprise a very small proportion of the total volume. Bus volumes peak between the hours of 6:00 AM and 9:00 AM and between 2:00 PM and 4:00 PM.

Table 21: Montgomery County Study Location – Vehicle Classification

Intersection Leg	Cars	Heavy-vehicles (2+ Axles, 6+ Wheels)	Buses
NB New Hope Street	94.5%	3.5%	2%
SB New Hope Street	96%	3%	1%
WB Belvoir Road	95.5%	3.5%	1%

Source: DVRPC

Results and Findings

Presented below are the results for each of the scenarios for the New Hope Street/Belvoir Road and New Hope Street/Old Arch Road intersections.

Existing Scenario

New Hope Street, Belvoir Road, and Marielle Lane Intersection
During the AM peak hour, the intersection performs at a LOS of D, with an overall average delay of 35 seconds. Though minimal delay is experienced by three of the four approaches, from seven to 13 seconds, the southbound New Hope Street approach experiences a substantial average delay of 56 seconds, for a LOS of F, with a 95th percentile queue length of 415 feet. During the PM peak hour, the intersection performs at an overall LOS of D, with 29 seconds of average delay. Similar to the AM peak hour, three of the four approaches operate with minor delay (14 seconds or less), but the southbound New Hope Street approach experiences the vast majority of the intersection's total delay, with a LOS of E, 48 seconds of delay, and a 95th percentile queue of 265 feet, or 13 vehicle lengths.

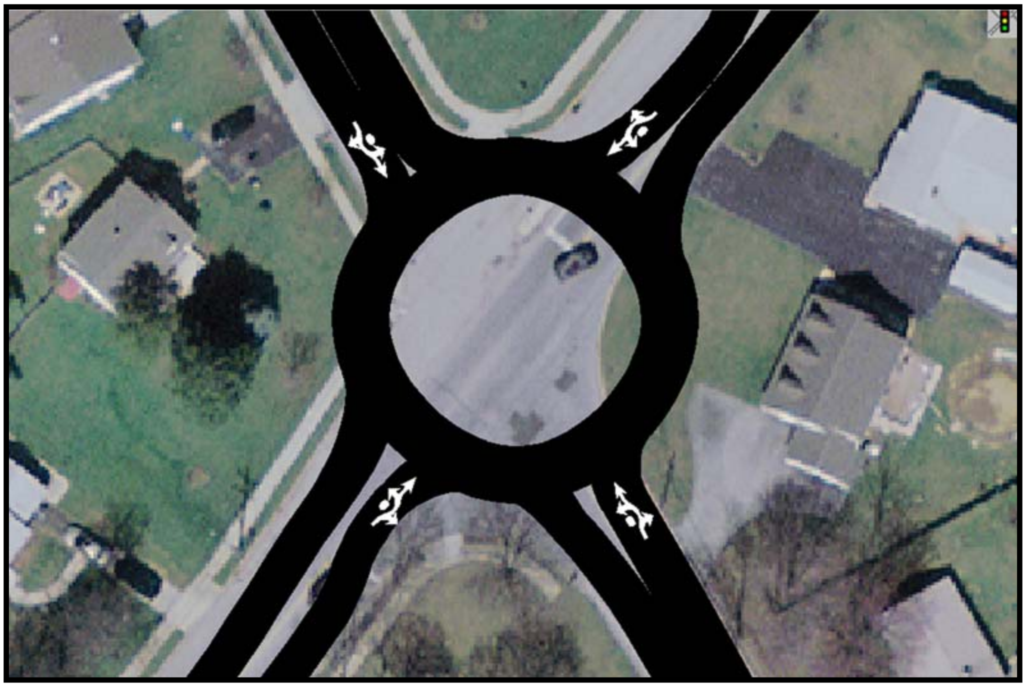
New Hope Street, Old Arch Road, and Renel Road Intersection
During the AM peak hour, the signalized intersection performs at a LOS of A, with eight seconds of average delay. The northbound and southbound New Hope Street approaches operate with five seconds of delay, for a LOS of A. During the PM peak hour, similar to the AM peak hour, the intersection performs at a LOS of A, with eight seconds of average delay. The northbound New Hope Street approach operates with seven seconds of delay, for a LOS of A and a 95th percentile queue of 78 feet, or four vehicle lengths.

Roundabout Scenario

Assumptions regarding geometry of the roundabout include a 110-foot inscribed circle. ***Figure 21*** depicts a conceptual rendering of the roundabout scenario.

New Hope Street, Belvoir Road, and Marielle Lane Intersection
During the AM peak hour, the roundabout operates at a LOS of A, with eight seconds of average delay, representing a 27-second improvement from existing conditions. All four approaches experience less than nine seconds of delay, for a LOS of A. The greatest 95th percentile queue is encountered along the southbound New Hope Street approach, at 60 feet, or three vehicle lengths. During the PM peak hour, the roundabout operates at a LOS of A, with nine seconds of average delay, a 20-second improvement from existing conditions. The most delayed approach is westbound Belvoir Road, with 11 seconds of delay, for a LOS of B. The remaining three approaches experience less than ten seconds of delay. The intersection's longest 95th percentile queue is along the southbound New Hope Street approach, at 90 feet.

Figure 21: Montgomery County Study Location – Roundabout Rendering



Source: DVRPC

New Hope Street, Old Arch Road, and Renel Road Intersection

During the AM peak hour, the signalized intersection operates at a LOS of A, with eight seconds of average delay. All four approaches and the overall intersection perform with similar delays, identical LOS, and comparable 95th percentile queues as the existing scenario. During the PM peak hour, the intersection operates at a LOS of A, with eight seconds of average delay. Again, all approaches and the overall intersection experience very similar delays, LOS, and 95th percentile queues as the existing scenario. As a result, it is very unlikely that this approach's queue will extend 1,000 feet upstream and affect the operations of a roundabout at the study intersection during either peak hour.

Tables 22 – 25 summarize the LOS analysis performed for the above mentioned scenarios.

Table 22: Montgomery County – AM Peak Hour Scenarios (New Hope Street & Belvoir Road)

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
AM Peak Hour	Existing	NB New Hope Street	13.2	B	0.0
		SB New Hope Street	55.7	F	415.0
		WB Belvoir Road	11.8	B	0.0
		EB Marielle Lane	7.4	A	0.0
		Intersection Total	**34.5**	**D**	
	Roundabout	NB New Hope Street	8.4	A	39.0
		SB New Hope Street	7.4	A	60.0
		WB Belvoir Road	7.3	A	37.0
		EB Marielle Lane	6.8	A	0.0
		Intersection Total	**7.6**	**A**	

Source: DVRPC

Table 23: Montgomery County – PM Peak Hour Scenarios (New Hope Street & Belvoir Road)

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
PM Peak Hour	Existing	NB New Hope Street	14.4	B	24.0
		SB New Hope Street	47.5	E	265.0
		WB Belvoir Road	14.4	B	33.0
		EB Marielle Lane	7.6	A	0.0
		Intersection Total	**29.1**	**D**	
	Roundabout	NB New Hope Street	7.7	A	38.0
		SB New Hope Street	9.6	A	90.0
		WB Belvoir Road	10.6	B	76.0
		EB Marielle Lane	5.0	A	0.0
		Intersection Total	**9.4**	**A**	

Source: DVRPC

Table 24: Montgomery County – AM Peak Hour Scenarios (New Hope Street & Old Arch Road)

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
AM Peak Hour					
	Existing	NB New Hope Street	4.5	A	41.0
		SB New Hope Street	4.6	A	51.0
		WB Renel Road	12.0	B	0.0
		EB Old Arch Road	20.4	C	80.0
		Intersection Total	**7.6**	**A**	
	Roundabout	NB New Hope Street	5.9	A	59.0
		SB New Hope Street	4.3	A	58.0
		WB Renel Road	12.7	B	0.0
		EB Old Arch Road	21.2	C	93.0
		Intersection Total	**8.0**	**A**	

Source: DVRPC

Table 25: Montgomery County – PM Peak Hour Scenarios (New Hope Street & Old Arch Road)

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
PM Peak Hour					
	Existing	NB New Hope Street	6.9	A	78.0
		SB New Hope Street	4.5	A	60.0
		WB Renel Road	12.9	B	13.0
		EB Old Arch Road	21.0	C	80.0
		Intersection Total	**8.0**	**A**	
	Roundabout	NB New Hope Street	7.3	A	83.0
		SB New Hope Street	4.5	A	46.0
		WB Renel Road	13.1	B	13.0
		EB Old Arch Road	21.6	C	84.0
		Intersection Total	**8.3**	**A**	

Source: DVRPC

Strengths and Weaknesses of a Roundabout at this Location

Strengths and weaknesses resulting from the analysis performed are summarized below. Comments from Montgomery County and PennDOT stakeholders are also provided.

Strengths

- The analysis performed showed a reduction in the following: travel speeds between adjacent intersections, intersection and approach delay, and 95^{th} percentile queue lengths;
- Given the proximity of two schools, a roundabout at this location would likely facilitate safe pedestrian movements; and
- A roundabout at this intersection would possibly eliminate the compromised sight line of the stop sign serving northbound New Hope Street drivers.

Weaknesses

- The larger intersection footprint will encounter right-of-way limitations; and
- A smaller inscribed diameter may be difficult for the navigation of larger vehicles, such as multi-axle trucks.

Montgomery County Comments

- New Hope Street runs parallel to US 202 and is thus used as an alternate route;
- Police enforcement of excessive speeding is already occurring along New Hope Street;
- Montgomery County officials desire a traffic calming impact, specifically to reduce excessive travel speeds between the study area intersections;
- County officials requested the analysis of a roundabout that would minimize right-of-way conflicts. Suggestions made include a roundabout with a smaller inscribed diameter or an alternatively shaped center-island;
- Montgomery County officials highlighted the close proximity of two schools and how a roundabout could facilitate pedestrian crossings at the study intersection; and
- Driver familiarity may improve given the new roundabout in Lower Frederick Township and the increasing number of locations throughout the county where roundabouts are being proposed.

PennDOT Comments

PennDOT officials expressed preference for a roundabout design that incorporated a smaller inscribed diameter that would reduce or eliminate right-of-way conflicts. Optimism was expressed regarding the new roundabout at the intersection of PA 29 and PA 73 in Lower Frederick Township, and given that it is the first roundabout in Montgomery County, its anticipated success may encourage future roundabout installations in the county.

Philadelphia County

<u>Candidate Location</u>

The intersection of Pine Road and Shady Lane in the City of Philadelphia was selected for analysis from the three locations prioritized by Philadelphia Streets Department officials. As shown in ***Table 26***, this intersection contains four of the seven qualifying DVRPC criteria. This location was chosen due to its large open layout and substantial distance from signalized intersections.

Table 26: Philadelphia County's Site Determination Matrix

Criteria	Prioritized Location #1	Prioritized Location #2	Prioritized Location #3
	Pine Road and Shady Lane	***Byberry Road and Worthington Road***	***Tomlinson Road and Rennard Street***
Awkward geometry	✓	✓	✓
Heavy-vehicles	--	✓	--
Bike/pedestrians	✓	✓	✓
Single-lane approach	--	--	✓
Rural or suburban land use	✓	--	--
Municipal support	--	--	✓
Safety concerns	✓	✓	✓

Source: DVRPC

Figure 22: Philadelphia County Study Location Aerial Photo

Source: DVRPC

Data Collection

Various types of data were collected for the preliminary feasibility analysis of a roundabout at this intersection. This includes observations by the study team during a site visit, crash records from the local municipality, and traffic data.

Field Observations

Observations from the field visit area highlighted below in ***Figure 23***.

Figure 23: Philadelphia County Study Location Field Visit Summary

OBSERVATIONS:

- Intersection is stop-controlled for all three approaches except for the southbound right-turn movement which utilizes a slip lane that is yield-controlled
- High speeds approaching the intersection
- Partially limited sight distance of intersection, particularly for the northbound Pine Road approach
- Continuous sidewalk along south-side of Pine Road
- Pedestrians walk along Pine Road
- Absence of crosswalks
- Wide shoulders
- "Share the Road" signage posted along Pine Road at the intersection
- Intersection located close to the entrances of Fox Chase Farm and Pennypack Park
- A tributary of the Pennypack Creek runs in a culvert along the study intersection

Source: DVRPC

Crash History

Crash data was provided by the Philadelphia Streets Department. Between 2005 and 2007, 23 crashes occurred at this intersection. Of the 23, seven were reportable and 16 were non-reportable. There were six crashes in 2005, six crashes in 2006, and eight crashes in 2007; the year is unknown for three of the crashes. These crashes fell within the following six categories: hit fixed object (8), sideswipe (opposite direction) (5), angle (3), rear-end (3), head on (2), and other/unknown (2). According to police reports, several of the hit-fixed object crashes involved vehicles hitting the guide rail.

Turning movements

A peak hour turning movement diagram is shown in ***Figure 24.*** The AM and PM peak hours for the study area are 7:30 AM to 8:30 AM and 4:30 PM to 5:30 PM, respectively. The heaviest approach for the AM and PM peak hours was southbound Pine Road, with 704 and 731 vehicles, respectively. For both instances, this approach constituted 48 percent of the peak hour's total volume. The approach with the lightest volume during both peak hours was eastbound Shady Lane, with 260 and 349 vehicles, respectively. Of these vehicles, between 60 and 70 percent of the movements were left-turns.

Approach Speeds

The posted speed limit along Pine Road and Shady Lane is 25 MPH. ***Table 27*** summarizes the measured approach speeds for the Pine Road and Shady lane intersection. During the AM and PM peak hours, travel speeds measured along Pine Road exceeded the posted speed limit of 25 MPH. The slowest approach speed was eastbound Shady Lane, with an 85^{th} percentile speed between 21 – 25 MPH, and 31 – 35 MPH for the AM and PM peak hours, respectively.

Table 27: Philadelphia County Study Location – Approach Speeds

Intersection Leg	Vehicle Speeds (MPH)	
	AM	PM
NB Pine Road	46 – 50	46 – 50
SB Pine Road	36 – 40	36 – 40
EB Shady Lane	21 – 25	31 – 35

Source: DVRPC

Vehicle Classification

As shown in ***Table 28***, the approach with the highest percent composition of heavy-vehicles was eastbound Shady Lane. Heavy-vehicles comprise approximately two and six percent of the northbound and southbound Pine Road Lane approaches, respectively.

Table 28: Philadelphia County Study Location – Vehicle Classification

Intersection Leg	Cars	Heavy-vehicles (2+ Axles, 6+ Wheels)	Buses
NB Pine Road	98%	1.5%	0.5%
SB Pine Road	94%	5.5%	0.5%
EB Shady Lane	92%	8%	0%

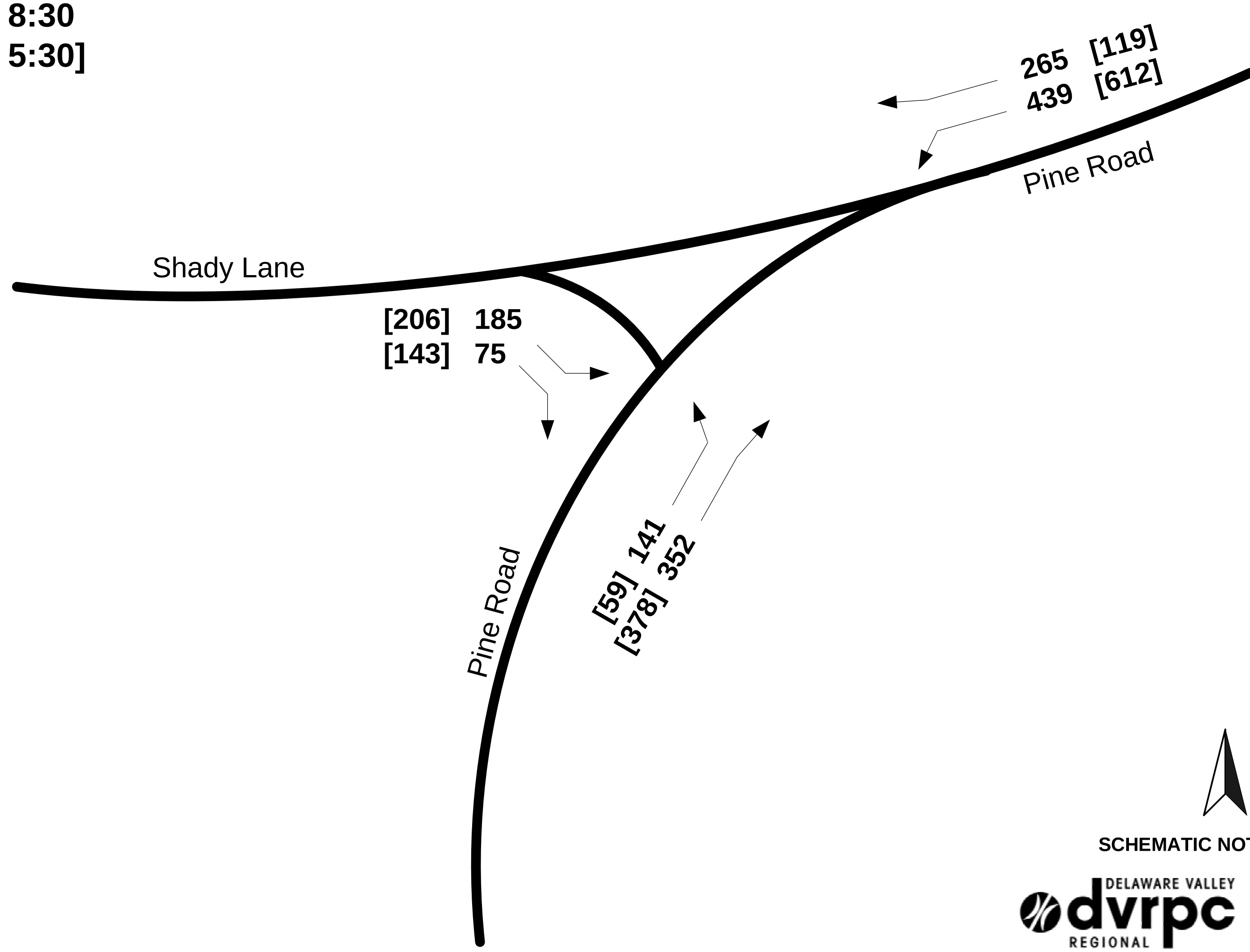
Source: DVRPC

Figure 24

Philadelphia County Study Location Turning Movements

EXISTING Peak Hour Turning Movement Counts AM & [PM]

Peak Hours
AM: 7:30 - 8:30
PM: [4:30 - 5:30]



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Results and Findings

Presented below are the results for each of the scenarios for the study location.

Existing Scenario

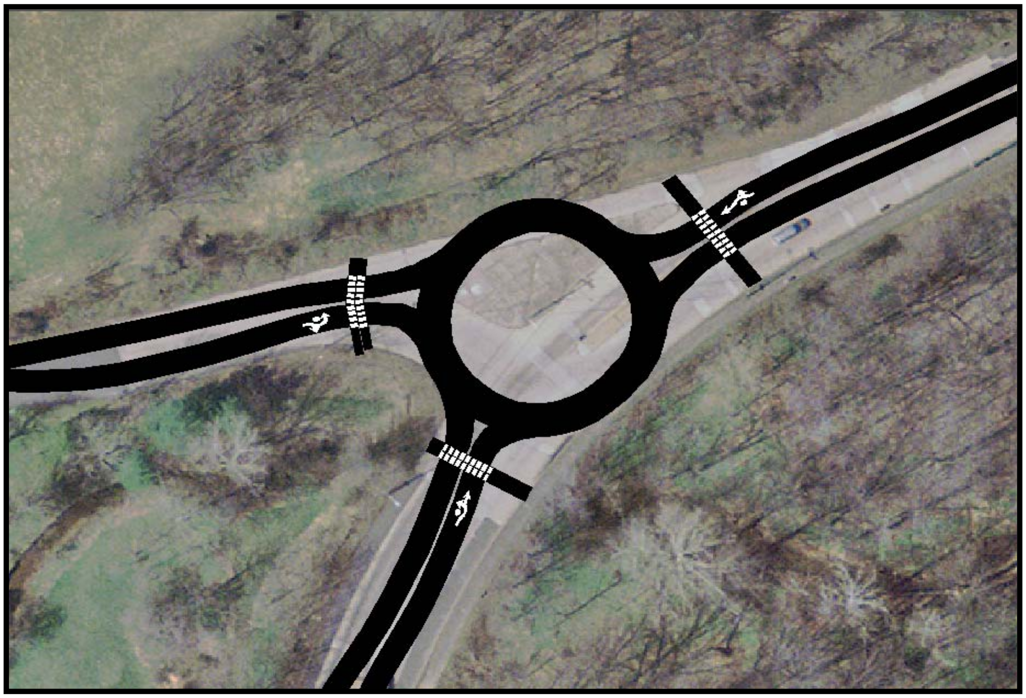
During the AM peak hour, the intersection operates at a LOS of C, with an average delay of 15 seconds. All approaches experience a similar delay of nearly 15 seconds. The 95th percentile queue is nonexistent for all approaches. During the PM peak hour, the intersection operates at a LOS of F, with an average delay of 56 seconds. The vast majority of this delay is experienced along southbound Pine Road, with 102 seconds of average delay. In the afternoon, this approach's 95th percentile queue extends over 330 feet.

Roundabout Scenario

The geometry of the roundabout is assumed to be a 130-foot inscribed circle. ***Figure 25*** represents a conceptual rendering of a roundabout at the study intersection.

During the AM peak hour, the roundabout operates at a LOS of B, with 12 seconds of average delay. The southbound Pine Road approach experiences the highest delay (17 seconds), operating at a LOS of C and 95th percentile queue of 167 feet, or eight vehicle lengths. The remaining two approaches experience less than ten seconds of delay and operate at a LOS of A. During the PM peak hour, the roundabout operates at a LOS of C, with 17 seconds of average delay. This represents a 39-second decrease in vehicle delay from existing conditions. In the afternoon, the southbound Pine Road approach has the highest delay (25 seconds) and a LOS of C. Despite the consolidation of this approach's right-turn slip lane into a single entry leg for the roundabout, its average delay is 75 percent less than experienced during the existing scenario. This approach also decreases its 95th percentile queue to 221 feet, or 11 vehicle lengths.

Figure 25: Philadelphia County Study Location – Roundabout Rendering



Source: DVRPC

Roundabout with Heavy Pedestrian Volumes Scenario

This roundabout scenario sought to quantify the impact of heavy pedestrian activity, potentially due to events at either the Pennypack Park or Fox Chase Farm. Thus, this scenario incorporated 100 pedestrians per crosswalk per peak hour, with the existing vehicular volumes.

During the AM peak hour, the roundabout operates at an overall LOS of C, with 23 seconds of average delay. This represents an eight and 11-second increase from the existing and the previous roundabout scenario, respectively. Similar to the earlier scenarios, southbound Pine Road experiences the greatest delay (37 seconds), for a LOS of E and 95th percentile queue of 550 feet. This approach's average delay is approximately 20 seconds greater than experienced during both the existing and earlier roundabout scenarios. During the PM peak hour, the roundabout operates at a LOS of E, with 36 seconds of average delay. Though this is almost 20 seconds greater than the previous roundabout scenario, it represents a 20-second improvement from existing conditions. The most delayed approach is southbound Pine Road, with 57 seconds of delay, a LOS of F, and 95th percentile queue of 501 feet, or 25 vehicle lengths. This is approximately a 30-second deterioration from the previous roundabout scenario; however, it is almost a 50-second improvement from existing conditions.

Tables 29 and 30 summarize the LOS analysis performed for the above mentioned scenarios.

Table 29: Philadelphia County – AM Peak Hour Scenarios

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
AM Peak Hour					
	Existing	NB Pine Road	14.6	B	0.0
		SB Pine Road	15.8	C	0.0
		EB Shady Lane	15.1	C	0.0
		Intersection Total	**15.2**	**C**	
	Roundabout	NB Pine Road	4.3	A	0.0
		SB Pine Road	17.3	C	167.0
		EB Shady Lane	9.2	A	0.0
		Intersection Total	**11.5**	**B**	
	Roundabout with Heavy Pedestrian Volumes	NB Pine Road	7.9	A	0.0
		SB Pine Road	37.0	E	550.0
		EB Shady Lane	11.5	B	0.0
		Intersection Total	**22.6**	**C**	

Source: DVRPC

Table 30: Philadelphia County – PM Peak Hour Scenarios

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
PM Peak Hour					
	Existing	NB Pine Road	18.5	C	0.0
		SB Pine Road	102.3	F	333.0
		EB Shady Lane	17.6	C	0.0
		Intersection Total	**55.9**	**F**	
	Roundabout	NB Pine Road	4.3	A	0.0
		SB Pine Road	24.6	C	221.0
		EB Shady Lane	15.0	C	15.0
		Intersection Total	**16.6**	**C**	
	Roundabout with Heavy Pedestrian Volumes	NB Pine Road	7.5	A	0.0
		SB Pine Road	56.5	F	501.0
		EB Shady Lane	28.1	D	111.0
		Intersection Total	**35.7**	**E**	

Source: DVRPC

Strengths and Weaknesses of a Roundabout at this Location

Highlighted below are strengths and weaknesses resulting from the analysis performed. Comments from the Philadelphia Streets Department are also provided.

Strengths

- Likely reduction in high approach speeds, thus providing a traffic-calming effect;
- Significant reduction in overall delay during the PM peak hour, even with heavy pedestrian volumes, and minor reduction in overall delay during the AM peak hour, assuming minimal pedestrian volume;
- Reduction in conflict points and their severity, thus lessening the potential for crashes;
- No additional right-of-way required;
- Opportunity for robust crosswalks (two-stage crossings with pedestrian refuges); and
- Gateway opportunity for Pennypack Park and Fox Chase Farm.

Weaknesses

- Potential for greater queuing along the southbound Pine Road approach during both peak hours.

Philadelphia Streets Department Comments

- There is extreme pressure from local and state officials to signalize this intersection. However, given that the nearest signal is over one-half mile in all directions, there is the potential to increase the rear-end crash rate and the travel speeds between intersections, which may result in greater injuries and/or fatalities;
- This is a high-crash location. The Commonwealth of Pennsylvania reports that a typical crash results in $30,000 of damages; thus, the anticipated reduction in the crash rate may reduce the cost upon city and state taxpayers;
- The all-way-stop-control currently in place at the study intersection is a temporary intermediate solution that is not appropriate for Pine Road, as it is wide and winding at the intersection, thus potentially causing serious visibility issues;
- Fox Chase Farm and Pennypack Park, which are closely located to the study intersection, generate significant amounts of pedestrian and bicycle traffic, especially during the summer season;
- The number of conflict points will be considerably reduced, likely making the intersection safer for drivers, pedestrians, and bicyclists;
- No right-of-way acquisition is needed for the roundabout;
- A roundabout may serve as a gateway to the City of Philadelphia, as well as to eastern Montgomery County;
- Currently, excessive speeding occurs throughout the day due to the clear lines of visibility between intersections and the absence of traffic controls along Pine Road.
- A roundabout at this intersection will possibly save costs from fuel, poor traffic flow, vehicle wear-and-tear, emissions, lost time, driver anxiety, etc.

Burlington County

Candidate Location

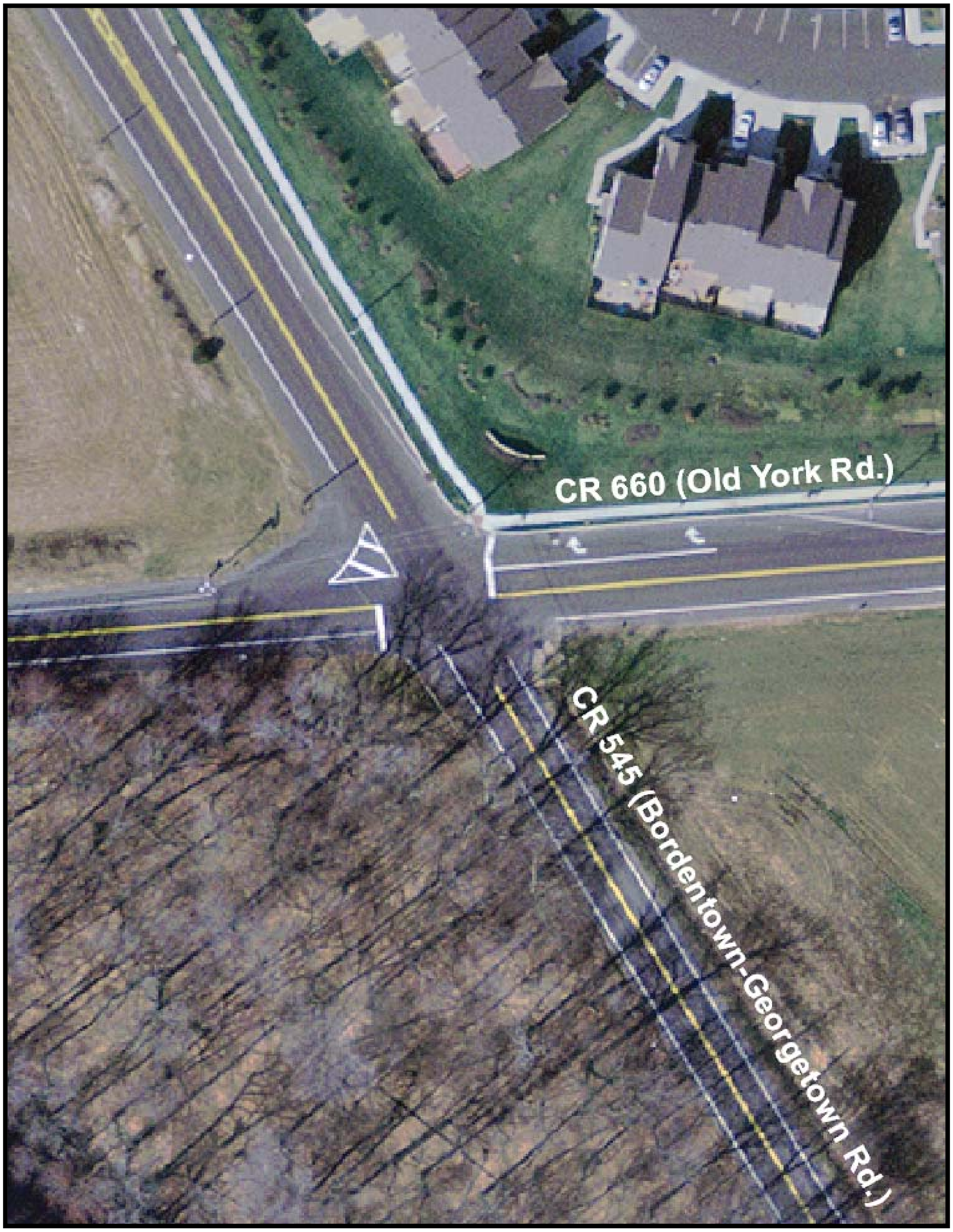
Of Burlington County's top three prioritized locations, the intersection of CR 545 (Georgetown-Burlington Road) and CR 660 (Old York Road) located on the border of Chesterfield and Bordentown townships was selected by the DVRPC project team for further roundabout investigation. As indicated in ***Table 31***, this location met four of the seven qualifying criteria for roundabout consideration. This intersection was specifically selected because it is a classic location with two-way stop control, it contains heavy-vehicle traffic, it has high travel speeds, and it is located within a rural setting.

Table 31: Burlington County's Site Determination Matrix

Criteria	Prioritized Location #1	Prioritized Location #2	Prioritized Location #3
	CR 545 (Georgetown-Bordentown Road) and CR 660 (Old York Road	*CR 543 (Burlington Columbus Road) and Petticoat Bridge Road*	*CR 532 (Tabernacle-Medford Lakes Road and CR 648 (Carranza Road)*
Awkward geometry	✓	--	--
Heavy-vehicles	✓	--	--
Bike/pedestrians	--	--	--
Single-lane approach	--	--	--
Rural or suburban land use	✓	✓	✓
Municipal support	--	--	--
Safety concerns	✓	--	--

Source: DVRPC

Figure 26: Burlington County Study Location Aerial Photo



Source: DVRPC

Data Collection

The pages that follow provide a summary of data collected for analyzing a potential roundabout at the intersection of Bordentown-Georgetown Road and Old York Road.

Field observations

Figure 27 highlights observations from a field visit to the study location.

Figure 27: Burlington County Study Location Field Visit Summary

OBSERVATIONS:

- Four-leg, two-way stopped controlled
- Slightly skewed along Bordentown-Georgetown Road;
- Main traffic flow along Bordentown-Georgetown Road;
- Adjacent land use is wooded, open field and residential;
- During field visit, it appeared that a traffic signal was about to be installed;
- Heavy-vehicle traffic along Old York Road; and
- Limited sight distance from Bordentown-Georgetown Road due to overgrown vegetation on the southwest corner parcel

Source: DVRPC

Crash History

Crash data was provided by the DVRPC Crash Database System. Between 2005 and 2007, 29 reportable crashes occurred at this intersection. These crashes fell within the following six categories: right angle (18), hit fixed object (7), rear end (1), left turn (1), animal related (1), and other (1). Of the 28 crashes, 13 involved injury. Over 82 percent of the recorded crashes occurred during daylight hours and on dry surface conditions.

Turning Movements

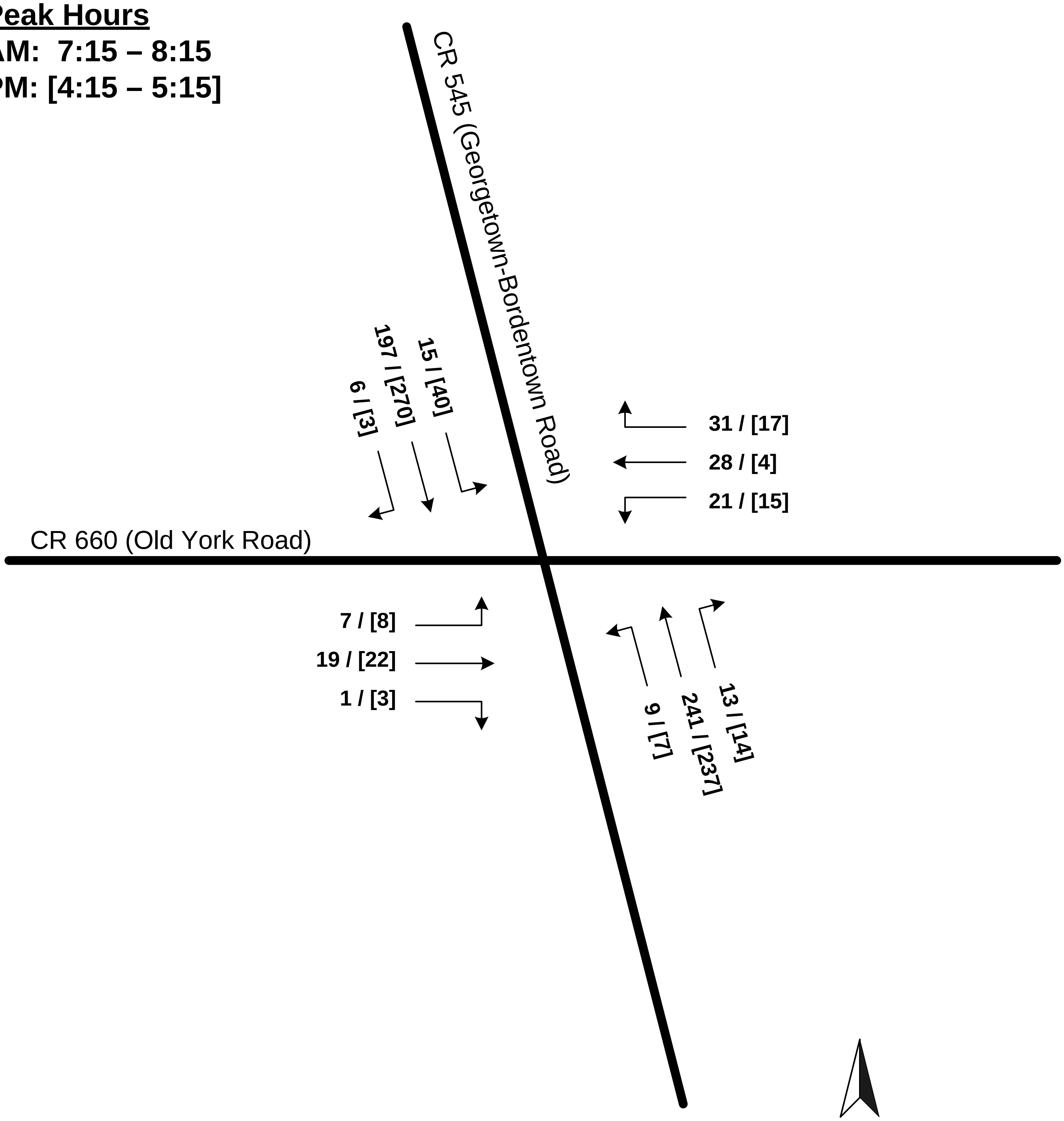
A peak-hour turning movement diagram is shown in ***Figure 28***. The morning peak hour is 7:15 AM to 8:15 AM and the afternoon peak hour is 4:15 PM to 5:15 PM.

Figure 28

Burlington County Study Location Turning Movements

EXISTING Peak Hour Turning Movement Counts AM & [PM]

Peak Hours
AM: 7:15 – 8:15
PM: [4:15 – 5:15]



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During the morning and afternoon peak period, 588 and 640 vehicles, respectively, travel through the intersection. The dominant approach movements in both peak periods are the Georgetown-Bordentown Road northbound and southbound approaches.

Approach Speeds

The posted speed limit in the area is 50 MPH. As shown in ***Table 32***, the highest speeds measured were along the southbound Georgetown-Bordentown Road approach. In the AM and PM peak period, speeds along westbound Old York Road were lower than the posted speed limit.

Table 32: Burlington County Study Location – Approach Speeds

Intersection Leg	Vehicle Speeds (MPH) AM	Vehicle Speeds (MPH) PM
EB Old York Road	46 – 50	46 – 50
WB Old York Road	41 – 45	41 – 45
NB Georgetown-Bordentown Road	46 – 50	41 – 45
SB Georgetown-Bordentown Road	51 – 55	51 – 55

Source: DVRPC

Vehicle Classification

Table 33 summarizes classification counts at this location. The eastbound Old York Road approach carries the highest amount of heavy-vehicle and bus traffic.

Table 33: Burlington County Study Location – Vehicle Classification

Intersection Leg	Cars	Heavy-Vehicles (2+ Axles, 6+ Wheels)	Buses
EB Old York Road	86%	9%	5%
WB Old York Road	89%	7%	4%
NB Georgetown-Bordentown Road	95%	4%	1%
SB Georgetown-Bordentown Road	95.5%	4%	0.5%

Source: DVRPC

Results and Findings

Presented below are the results for each of the scenarios for the study location.

Existing Scenario

The overall LOS for the existing intersection is A, with two and one second vehicle delay in the morning and afternoon, respectively. Due to free-flow traffic conditions, the northbound and southbound Georgetown-Bordentown Road experiences barely any vehicle delay. The eastbound and westbound approaches of Old York Road experience about seven seconds of vehicle delay in the morning and afternoon. The LOS for all approaches during the AM and PM is A.

Roundabout Scenario – 150' Diameter

Two different sized roundabouts were analyzed to determine any differences in their operation.

Figure 29 depicts a conceptual rendering of a 150' roundabout at the study location. Compared to the existing intersection, this scenario reveals a decrease in vehicle delay by a few seconds in the morning and afternoon for the eastbound and westbound approaches of Old York Road. With this option there is no delay generated for the Georgetown-Bordentown Road approaches. Overall LOS for this intersection is LOS A.

Figure 29: Burlington County Study Location – Roundabout Rendering #1

Source: DVRPC – VISSIM Software

Roundabout Scenario – 110’ Diameter

Figure 30 depicts a smaller sized roundabout at this study location. The results indicate that vehicle delay along Georgetown-Bordentown Road and Old York Road would barely exist with this alternative. Compared with existing and previous roundabout scenarios, during the AM and PM peak period, there is a slight increase in vehicle delay on the northbound and southbound approaches. The LOS for all approaches in the AM and PM peak hour is A.

Figure 30: Burlington County Study Location – Roundabout Rendering #2

Source: DVRPC – VISSIM Software

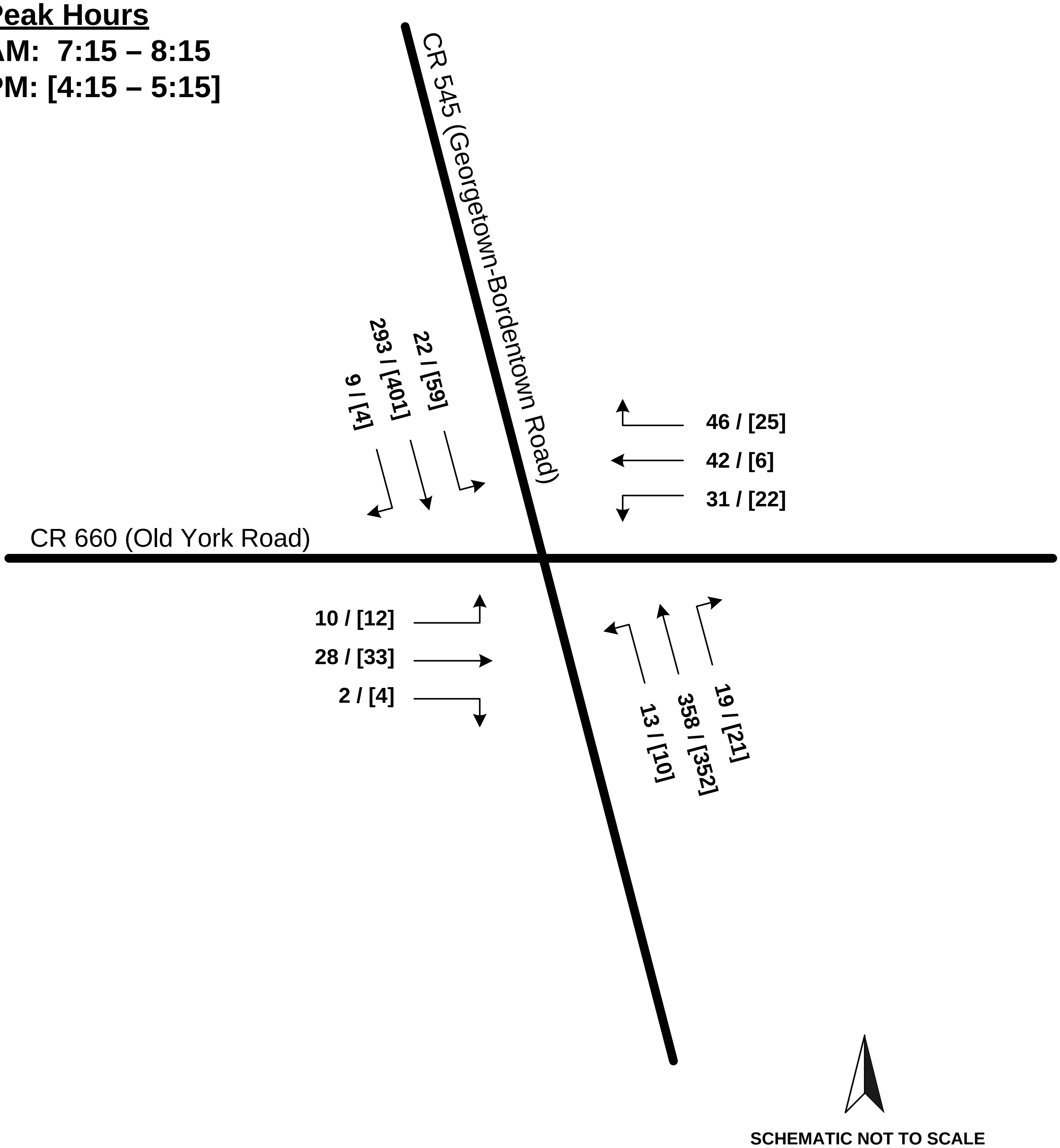
Traffic through this intersection is expected to increase in the coming years due to future development in the surrounding area. Existing traffic volumes at this intersection are fairly low and do not currently meet warrants for obtaining a traffic signal. As an alternative to a roundabout, a traffic signal was also analyzed. For this scenario, the following was assumed:

- A two percent growth rate over 20 years was utilized with existing turning movement data;
- 90-second cycle length—60 and 30 seconds allocated for the Georgetown-Bordentown Road and Old York Road approaches, respectively; and
- Semi-actuated signal with detectors on Old York Road approaches.

Figure 31 depicts the turning movement diagram with projected traffic volumes.

Figure 31
Burlington County Study Location
Projected 20 Year Turning Movements
Peak Hour Turning Movement Counts AM & [PM]

Peak Hours
AM: 7:15 – 8:15
PM: [4:15 – 5:15]



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Signalization Scenario

Despite having a signal at this location, the overall LOS is A, with eight and seven seconds of vehicle delay in the AM and PM peak hour, respectively. In the morning, the highest amount of vehicle delay occurs along the westbound Old York Road approach with 35 seconds of delay and a LOS of D. In the afternoon, the westbound Old York Road approach experiences the highest vehicle delay (39 seconds) and LOS D. The southbound Georgetown-Bordentown Road approach has the longest 95th percentile queue (approximately 60 feet, or three car lengths). This is the only alternative presented that develops traffic queues.

Tables 34 and 35 summarize existing measures of effectiveness (MOE) for the morning and afternoon peak hours for both the existing conditions, two roundabout alternatives sized at 150 and 110 feet, and a future signalization scenario.

Table 34: Burlington County – AM Peak Hour Scenarios

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
AM Peak Hour	Existing	EB Old York Road	7.5	A	0.0
		WB Old York Road	6.8	A	0.0
		NB Georgetown-Bordentown Road	0.6	A	0.0
		SB Georgetown-Bordentown Road	0.0	A	0.0
		Total Intersection	**1.8**	**A**	
	Roundabout 150’ Diameter	EB Old York Road	0.9	A	0.0
		WB Old York Road	2.4	A	0.0
		NB Georgetown-Bordentown Road	0.0	A	0.0
		SB Georgetown-Bordentown Road	0.0	A	0.0
		Total Intersection	**0.4**	**A**	
	Roundabout 110’ Diameter	EB Old York Road	0.7	A	0.0
		WB Old York Road	0.4	A	0.0
		NB Georgetown-Bordentown Road	1.1	A	0.0
		SB Georgetown-Bordentown Road	0.4	A	0.0
		Total Intersection	**0.7**	**A**	
	Signalization	EB Old York Road	32.7	C	37.3
		WB Old York Road	35.2	D	41.2
		NB Georgetown-Bordentown Road	2.2	A	42.9
		SB Georgetown-Bordentown Road	3.7	A	37.5
		Total Intersection	**8.3**	**A**	

Source: DVRPC

Table 35: Burlington County – PM Peak Hour Scenarios

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
PM Peak Hour					
	Existing	EB Old York Road	6.3	A	0.0
		WB Old York Road	6.9	A	0.0
		NB Georgetown-Bordentown Road	0.0	A	0.0
		SB Georgetown-Bordentown Road	0.0	A	0.0
		Total Intersection	**0.6**	**A**	
	Roundabout 150' Diameter	EB Old York Road	0.8	A	0.0
		WB Old York Road	3.2	A	0.0
		NB Georgetown-Bordentown Road	0.0	A	0.0
		SB Georgetown-Bordentown Road	0.0	A	0.0
		Total Intersection	**0.3**	**A**	
	Roundabout 110' Diameter	EB Old York Road	0.5	A	0.0
		WB Old York Road	0.3	A	0.0
		NB Georgetown-Bordentown Road	0.6	A	0.0
		SB Georgetown-Bordentown Road	1.1	A	0.0
		Total Intersection	**0.8**	**A**	
	Signalization	EB Old York Road	36.8	D	39.3
		WB Old York Road	39.4	D	37.0
		NB Georgetown-Bordentown Road	3.2	A	39.8
		SB Georgetown-Bordentown Road	3.6	A	59.6
		Total Intersection	**6.6**	**A**	

Source: DVRPC

Strengths and Weaknesses of a Roundabout in this Location

Highlighted below are strengths and weaknesses resulting from the analysis performed. Comments from Burlington County officials are also provided.

Strengths

- According to the DVRPC Crash Database, between 2005 and 2007, 28 crashes occurred at this intersection; therefore, a roundabout at this location would prove beneficial in reducing crashes;
- Given concern at the stakeholder meeting regarding speeding through this intersection, the alternatives analyzed (and as common with roundabouts), travel speeds are likely to be reduced;
- Adjacent property will be impacted minimally with the "Roundabout – 110' scenario"; and
- Compared to the signal alternative, this intersection operates better with the roundabout alternatives (minimal delay on the approaches).
- Roundabout probably has the highest B/C ratio of the other alternatives (flashing beacon, traffic signal)

Weakness

- As shown in the "Roundabout – 150' scenario", if a roundabout were to be constructed, more adjacent property (residential open field) will be impacted.

Burlington County Comments

- The main issue is speeding and maintaining safety at this intersection;
- Sight distance is major problem due to the trees on the southwest quadrant;
- Traffic volumes will increase at this location due to development taking place in the area (Old York Village's 1,200 homes and mixed use community);
- Although development is forthcoming in the area, this intersection currently does not meet a warrant for a signal, which could be another alternative for improving the existing intersection;
- Burlington County agrees that this intersection is a good location to install a roundabout because it will reduce speed, create an entryway, and provide an educational opportunity to the public; and
- The 28 crashes occurring between January 1, 2005, and December 31, 2008, have a tendency to be more severe and have included a fatality.

Camden County

Candidate Location

The intersection of CR 705 (Sicklerville Road) and CR 706 (Erial Road) located in Winslow Township was selected by the DVRPC project team from Camden County's top three prioritized locations to analyze for further roundabout investigation. As indicated in ***Table 36***, this location met five of the seven qualifying criteria for roundabout consideration. The assessment was based on information provided by the Camden County Engineering Office. This location was selected because it is a three-leg intersection with a skewed alignment and is located approximately 500 feet west of the signalized intersection, CR 536 (Malaga Road) and CR 705 (Sicklerville Road).

Table 36: Camden County's Site Determination Matrix

Criteria	Prioritized Location #1	Prioritized Location #2	Prioritized Location #3
	CR 705 (Sicklerville Road) and CR 706 (Erial Road)	***CR 630 (Collings Avenue) and Essex Street***	***CR 701 (Hilliards Road) and CR 700 (Norcross Road)***
Awkward geometry	✓	✓	✓
Heavy-vehicles	✓	--	--
Bike/pedestrians	--	--	--
Single-lane approach	✓	✓	✓
Rural or suburban land use	✓	✓	✓
Municipal support	--	--	--
Safety concerns	✓	--	--

Source: DVRPC

Figure 32: Camden County Study Location Aerial Photo

Source: DVRPC

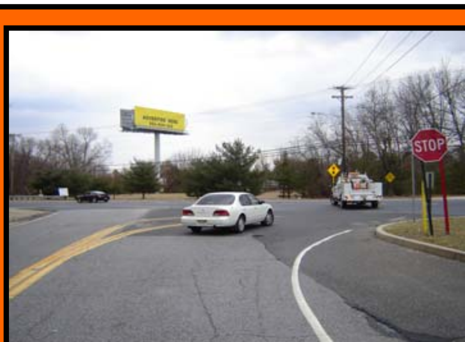
Data Collection

The following pages provide a summary of data collected for analyzing a potential roundabout at the intersection of Sicklerville Road and Erial Road.

Field Observations

Figure 33 highlights observations from a field visit to the study location.

Figure 33: Camden County Study Location Field Visit Summary



OBSERVATIONS:

- Three-leg intersection
- Skewed alignment
- Located in a residential environment
- Northeastern leg of the intersection borders New Brooklyn County Park
- Speeding traffic along northbound Erial Road
- A private driveway is located at the base of the intersection
- Traffic signal is located near intersection
- Heavy-vehicle traffic along Erial Road

Source: DVRPC

Crash History

Crash data was provided by the DVRPC Crash Database System. Between 2005 and 2007, 27 reportable crashes occurred at this intersection. Seven of the 27 crashes involved injury. Rear-end (7), hit-fixed-object (7), and right-angle (6) collisions represented 74 percent of the crashes reported. The other types of crashes reported included sideswipe (same-direction), struck parked vehicle, left-turn, and overturned vehicle. Twelve crashes occurred on wet pavement surface. Over 81 percent of the recorded crashes occurred during daylight hours.

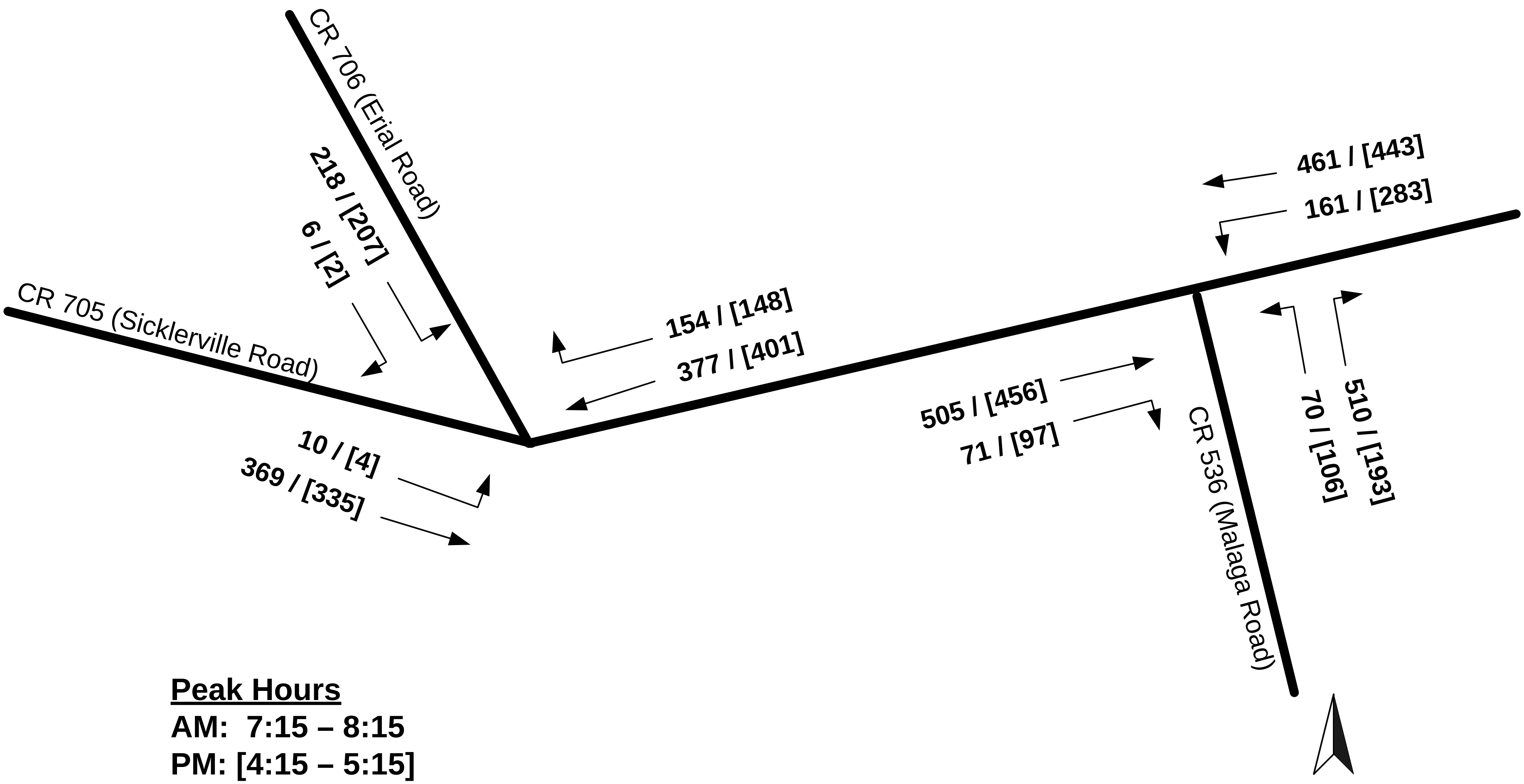
Turning Movements

Turning movement counts were taken at the intersections of Sicklerville Road/Erial Road and Malaga Road/Sicklerville Road. A peak hour turning movement diagram is shown in ***Figure 34***.

Figure 34

Camden County Study Location Turning Movements

EXISTING Peak Hour Turning Movement Counts AM & [PM]



Peak Hours
AM: 7:15 – 8:15
PM: [4:15 – 5:15]

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The morning peak hour is 7:15 AM to 8:15 AM and the afternoon peak hour is 4:15 PM to 5:15 PM. The following highlights the key findings from the turning movements:

Sicklerville Road/Erial Road Intersection

- During the morning and afternoon peak period, 1134 and 1097 vehicles travel through this intersection, respectively;
- Right-turns from southbound Erial Road and left-turns from eastbound Sicklerville Road are low;
- Over 200 vehicles turn left from southbound Erial Road to head east on Sicklerville Road; and
- During AM and PM peak period, approximately 150 vehicles make right-turns from westbound Sickerville Road onto northbound Erial Road.

Sicklerville Road/Malaga Road Intersection

- During the morning and afternoon peak period, 1,778 and 1,578 vehicles travel through this intersection;
- The majority of the vehicles travel along Sicklerville Road; and
- From northbound Malaga Road, over 500 vehicles turn right onto eastbound Sicklerville Road.

Approach Speeds

The posted speed limit along Sicklerville Road and Erial Road are 45 and 50 MPH, respectively. As shown in ***Table 37***, the measured speeds along the eastbound and westbound Sicklerville Road approaches in the AM peak hour are higher than PM peak hour speeds. Southbound Erial Road approach speeds are lower than the posted speed limit of 50 MPH.

Table 37: Camden County Study Location – Approach Speeds

Intersection Leg	Vehicle Speeds (MPH)	
	AM	PM
EB Sicklerville Road	46 – 50	41 – 45
WB Sicklerville Road	51 – 55	46 – 50
SB Erial Road	36 – 40	41 – 45

Source: DVRPC

Vehicle Classification

Table 38 summarizes the vehicle classification counts taken at the study location. The westbound Sicklerville Road approach carries the highest amount of heavy-vehicle traffic through the intersection.

Table 38: Camden County Study Location – Vehicle Classification

Intersection Leg	Cars	Heavy-Vehicles (2+ Axles, 6+ Wheels)	Buses
EB Sicklerville Road	92%	6%	2%
WB Sicklerville Road	83%	13.5%	3.5%
SB Erial Road	93%	6%	1%

Source: DVRPC

Signal Timing

The signal plan for the Sicklerville Road and Malaga Road intersection is semi-actuated, with phases dwelling on the westbound Sicklerville Road and northbound Malaga Road movements. Based upon actuation by the westbound Sicklerville Road left turns, the signal will provide a protected lead phase for the westbound approach during both peak hours. This signal has a variable cycle length ranging between 67 and 92 seconds.

Results and Findings

Presented below are the results for each of the scenarios for the Sicklerville Road/Erial Road and Sicklerville Road/Malaga Road intersections.

Existing Conditions

Sicklerville Road/Erial Road Intersection
The overall LOS for the existing intersection is A, with an approximate three-second and four-second vehicle delay in the morning and afternoon, respectively. During the morning and afternoon peak periods, the southbound Erial Road approach experiences the greatest amount of delay, with six and eight seconds, respectively. The eastbound and westbound approaches along Sicklerville Road have the least amount of delay, ranging from one to two seconds.

At Sicklerville Road/Malaga Road intersection
In the morning the overall LOS is C, with 31 seconds in vehicle delay. During the morning peak period, the northbound Malaga Road approach has the highest amount of vehicle delay, with 74 seconds and LOS E. This approach also contains the longest 95^{th} percentile traffic queue length of 650 feet. The eastbound and westbound Sicklerville Road approaches experience vehicle delays of 17 and eight seconds respectively. Compared to the morning peak period, the overall vehicle delay in the afternoon is decreased by half, at 16 seconds and LOS B. The northbound approach experience a LOS B with 19 seconds of vehicle delay, which is a 55 second decrease in delay compared to the morning peak. The eastbound Sicklerville Road approach experiences the highest amount of vehicle delay with 23 seconds and has a 95^{th} percentile queue length of 257 feet or 13 vehicle lengths.

Roundabout Scenario

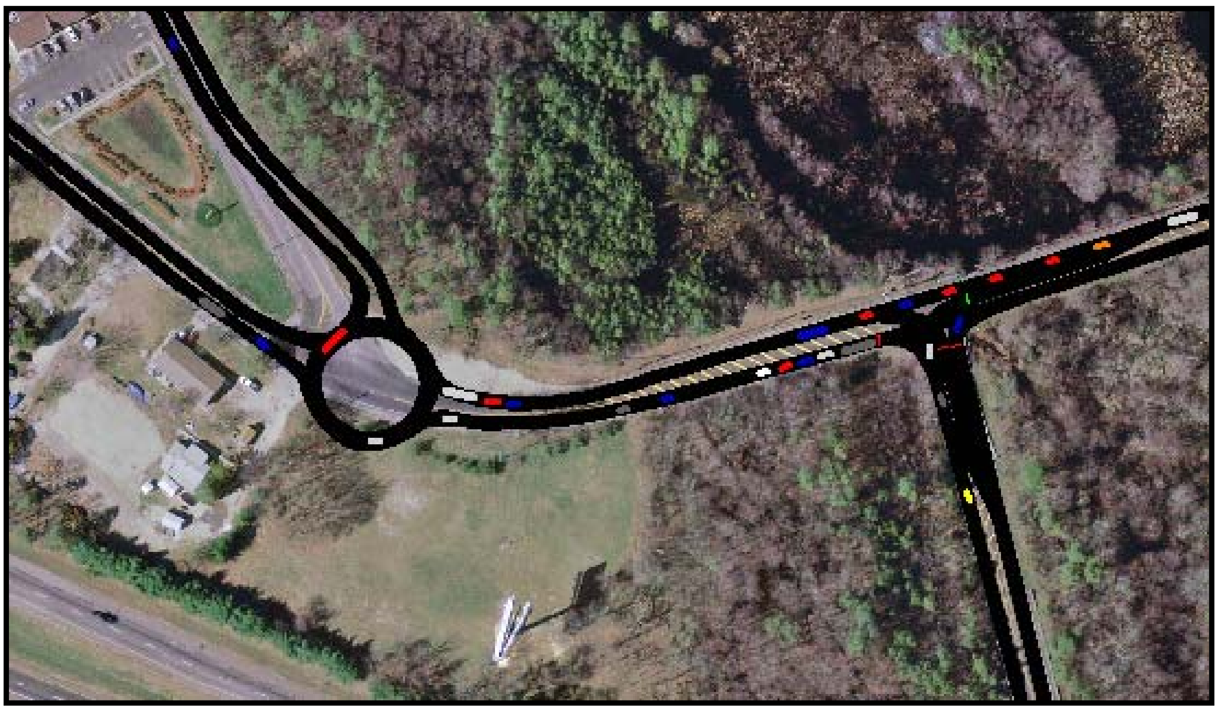
Figure 35 depicts a conceptual rendering of the roundabout and signalized intersection of Sicklerville Road and Malaga Road. The geometry of the roundabout is assumed to be a 135-foot inscribed circle.

At Sicklerville Road/Erial Road Intersection
Overall, with this alternative, the intersection operates at a LOS A, with four and seven seconds of delays in the morning and afternoon peak periods. Compared to the existing intersection, in the afternoon, the westbound Sicklerville Road approach experiences the highest amount of delay, with 11 seconds and LOS B. The 95^{th} percentile queue is non-existent.

At Sicklerville Road/Malaga Road intersection

This scenario contains similar results to the existing conditions. In the morning, the northbound Malaga Road leg has the highest amount of vehicle delay of 81 seconds and a 95th percentile queue length of 653 feet. The eastbound and westbound legs of Sicklerville Road are LOS B and A respectively. The afternoon peak period has an overall LOS B, with 14 seconds in vehicle delay. Eastbound Sicklerville Road approach has the highest amount of delay (27 seconds) and 95th percentile queue length of 197 feet or ten vehicles. Although the traffic signal is approximately 500 feet east of the study intersection, the simulation revealed traffic queues from the signal did not impact the operation of the roundabout.

Figure 35: Camden County Study Location – Roundabout Rendering



Source: DVRPC – VISSIM Software

Tables 39 and 40 summarize the LOS performance for the morning and afternoon peak hours for both the existing and roundabout scenarios.

Table 39: Camden County – AM Peak Hour Scenarios (Sicklerville Road & Erial Road)

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
AM Peak Hour	Existing	EB Sicklerville Road	0.7	A	0.0
		WB Sicklerville Road	2.3	A	0.0
		SB Erial Road	6.4	A	0.0
		Total Intersection	**3.1**	**A**	
	Roundabout	EB Sicklerville Road	1.4	A	0.0
		WB Sicklerville Road	5.4	A	0.0
		SB Erial Road	4.5	A	0.0
		Total Intersection	**3.8**	**A**	

Source: DVRPC

Table 40: Camden County – PM Peak Hour Scenarios (Sicklerville Road & Erial Road)

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
PM Peak Hour	Existing	EB Sicklerville Road	1.6	A	0.0
		WB Sicklerville Road	1.1	A	0.0
		SB Erial Road	8.2	A	0.0
		Total Intersection	**3.6**	**A**	
	Roundabout	EB Sicklerville Road	2.1	A	0.0
		WB Sicklerville Road	10.8	B	0.0
		SB Erial Road	8.8	A	0.0
		Total Intersection	**7.2**	**A**	

Source: DVRPC

Table 41: Camden County – AM Peak Hour Scenarios (Sicklerville Road & Malaga Road)

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
AM Peak Hour					
	Existing	EB Sicklerville Road	16.5	B	208.0
		WB Sicklerville Road	7.6	A	107.0
		NB Malaga Road	73.8	E	650.0
		Total Intersection	**31.4**	**C**	
	Roundabout	EB Sicklerville Road	15.0	B	206.0
		WB Sicklerville Road	8.0	A	104.0
		NB Malaga Road	80.5	F	653.0
		Total Intersection	**33.0**	**C**	

Source: DVRPC

Table 42: Camden County – PM Peak Hour Scenarios (Sicklerville Road & Malaga Road)

	Scenario	Intersection Leg	Delay	LOS	95th % Queue (ft)
PM Peak Hour					
	Existing	EB Sicklerville Road	23.3	C	257.0
		WB Sicklerville Road	9.2	A	99.0
		NB Malaga Road	18.7	B	87.0
		Total Intersection	**15.7**	**B**	
	Roundabout	EB Sicklerville Road	27.3	C	197.0
		WB Sicklerville Road	6.5	A	83.0
		NB Malaga Road	12.2	B	58.0
		Total Intersection	**14.3**	**B**	

Source: DVRPC

Strengths and Weaknesses of a Roundabout in this Location

Highlighted below are strengths and weaknesses resulting from the analysis performed. Comments from Camden County officials are also provided.

Strengths

- Given the existing traffic volumes traversing this intersection, there should not be any problems associated with capacity, delay, queue back-ups, and oversaturated conditions with the roundabout alternative;
- As demonstrated during the simulation, the traffic signal at Sicklerville Road and Malaga Road does not have a negative impact on the roundabout. There were no traffic queues backing into the roundabout; and
- According to the DVRPC Crash Database, between 2005 and 2007, there were 27 crashes reported at this intersection, which indicates that there is a safety issue at this intersection.

Weaknesses

- Vehicle delays are relatively low and the intersection operates at a LOS A with the existing geometry and roundabout alternative; and
- If a roundabout were to be constructed, adjacent property (residential and park) will be impacted.

Camden County Comments

- Given the outcome of analysis and viewing the simulation, county staff agreed that this intersection is not an optimal location for a roundabout due to the following:
    - Although speeding may be an issue, the existing intersection currently operates at LOS A with minimal delay; therefore, a roundabout would not provide any benefit to the operation of the intersection.

Gloucester County

Candidate Location

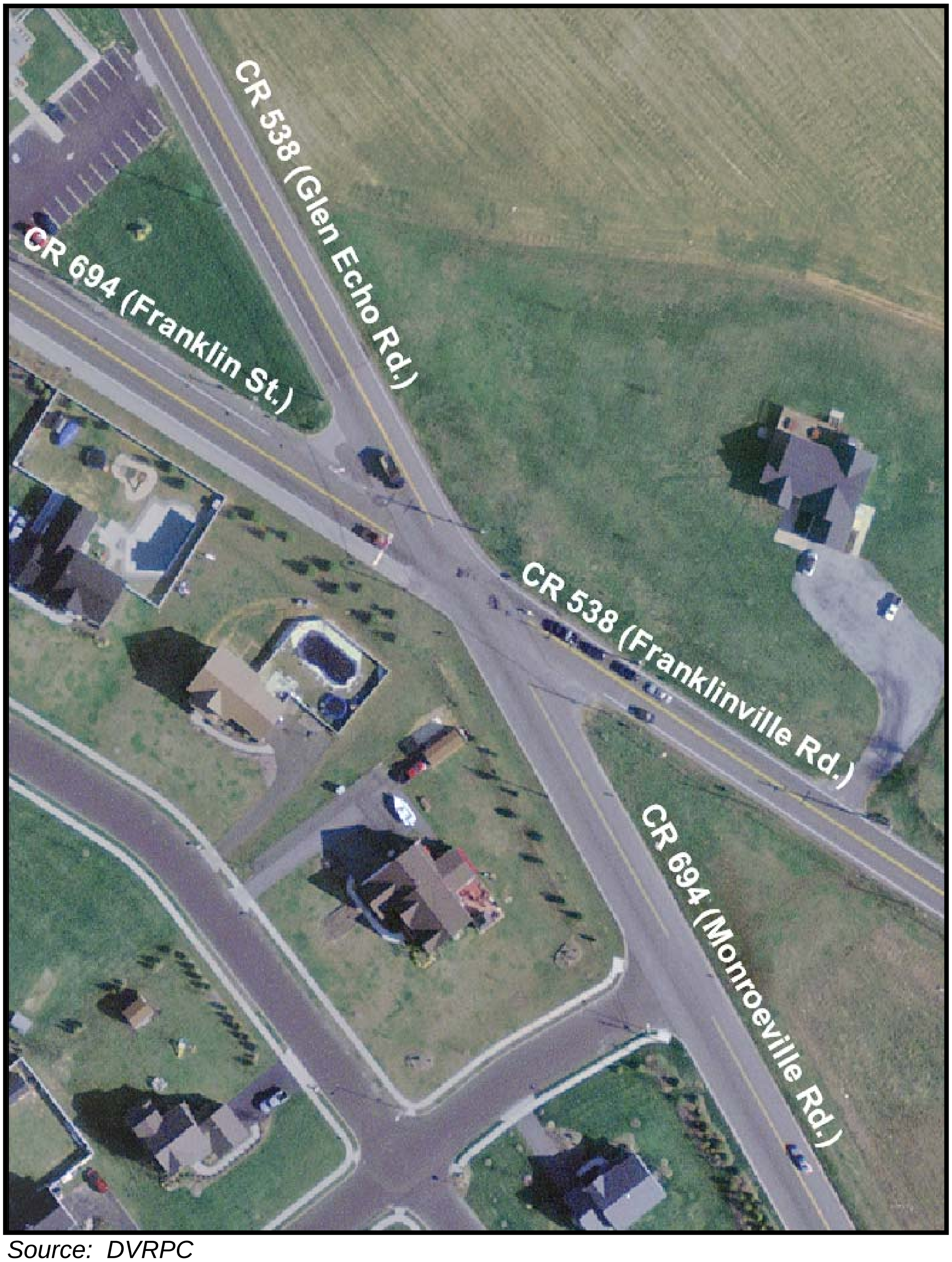
Of Gloucester County's top three prioritized locations, the intersection of CR 538 (Franklinville Road/Glen Echo Road) and CR 694 (Monroeville Road/Franklin Street), located in Woolwich Township, was selected by the DVRPC project team to analyze for further roundabout investigation. As indicated in ***Table 43***, this location met three of the seven qualifying criteria for roundabout consideration. The assessment was based on the information provided by the Gloucester County Engineering and Planning departments. This location was specifically selected because it is located near Swedesboro Borough, it has a skewed alignment, it is stop-controlled, and it is within a rural setting.

Table 43: Gloucester County's Site Determination Matrix

Criteria	Prioritized Location #1	Prioritized Location #2	Prioritized Location #3
	CR 612 (Corkery Lane/Franklinville-Williamstown Road) and CR 610 (Clayton Road)	***CR 538 (Franklinville Road/Glen Echo Road) and CR 694 (Monroeville Road/Franklin Street)***	***CR 643 (Grove Street) and CR 640 (Delaware Street)***
Awkward geometry	✓	✓	--
Heavy-vehicles	--	--	✓
Bike/pedestrians	--	--	✓
Single-lane approach	✓	✓	--
Rural or suburban land use	✓	✓	✓
Municipal support	--	--	--
Safety concerns	✓	--	--

Source: DVRPC

Figure 36: Gloucester County Study Location Aerial Photo



Source: DVRPC

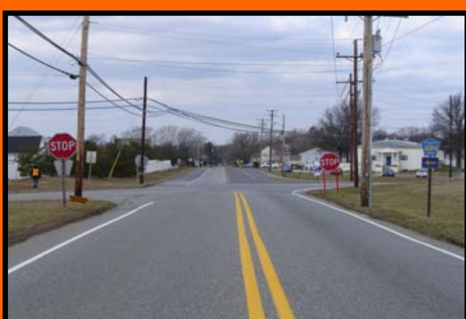
Data Collection

The following pages provide a summary of data collected for analyzing a potential roundabout at the intersection of Franklinville Road/Glen Echo Road and Monroeville Road/Franklin Street.

Field Observations

Figure 37 highlights observations from a field visit to the study location.

Figure 37: Gloucester County Study Location Field Visit Summary



OBSERVATIONS:

- Four-leg, two-way stopped controlled; recently converted to four-way stop
- Skewed geometry
- Adjacent land use is open field, residential and commercial
- Near Swedesboro Borough
- Heavy-vehicle movement along southbound Monroeville Road

Source: DVRPC

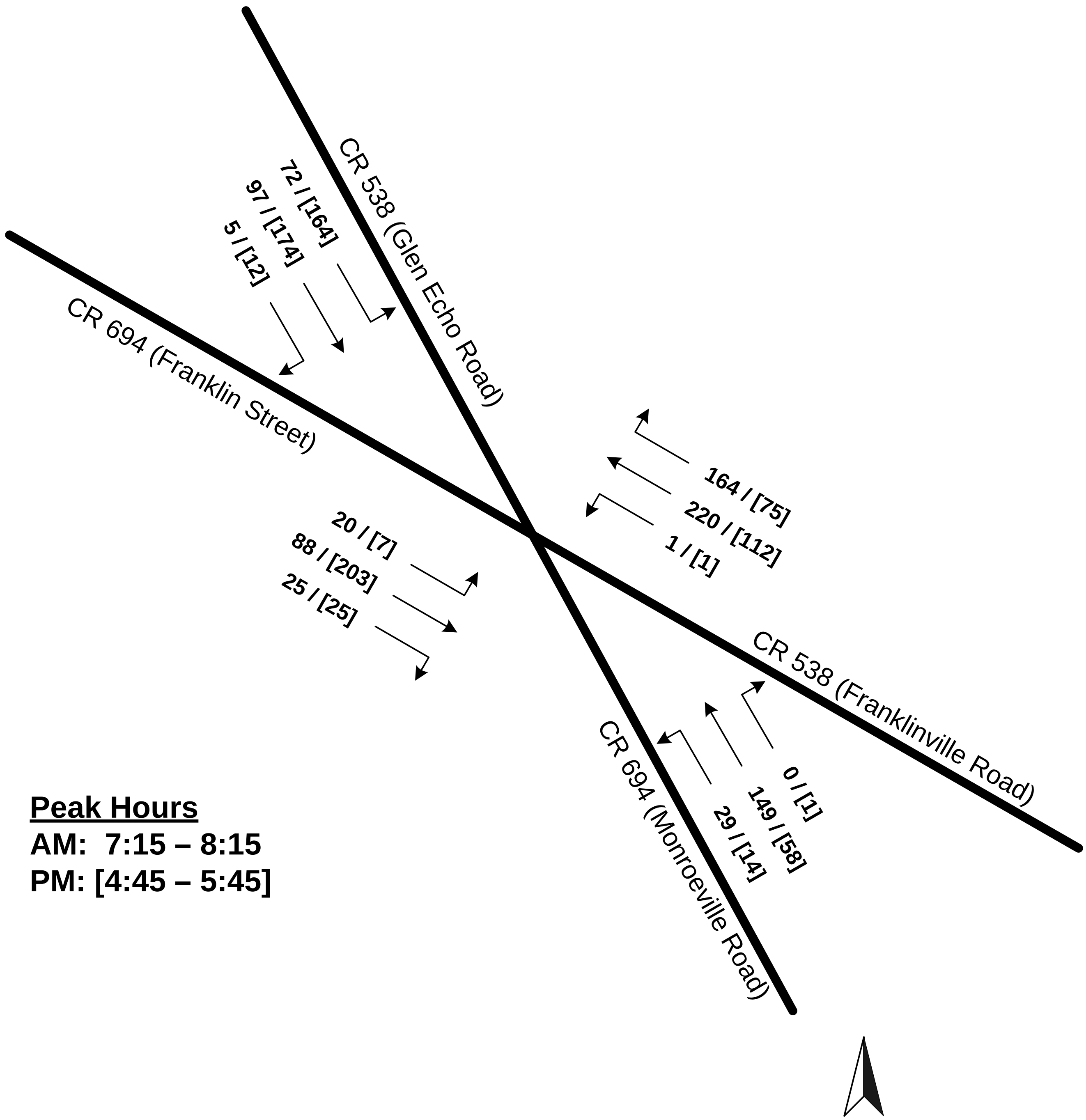
Crash History

According to the DVRPC Crash Database System, two crashes were reported at this intersection between 2005 and 2007. Both crashes were fatal. The crashes were classified as right angle and opposite direction and both occurred during daylight hours on dry road surface conditions.

Turning Movements

Turning movement counts were taken at the intersection of Franklinville Road and Monroeville Road. A peak-hour turning movement diagram is shown in ***Figure 38***. The morning peak hour is 7:15 AM to 8:15 AM and the afternoon peak hour is 4:45 PM to 5:45 PM.

Figure 38
Gloucester County Study Location Turning Movements
EXISTING Peak Hour Turning Movement Counts AM & [PM]



Peak Hours
AM: 7:15 – 8:15
PM: [4:45 – 5:45]

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In the summertime, this intersection typically experiences an increase in traffic volumes, especially on weekends, as it is used by many motorists traveling to the New Jersey Shore from Pennsylvania. Since the data was collected, traffic volumes used in this analysis reflect the higher traffic volumes. During the morning and afternoon peak period, 870 and 846 vehicles, respectively, travel through the intersection. In the morning, the westbound through and right-turn movements are dominant. The westbound left-turn movement averages one vehicle during the morning and afternoon peak period.

Approach Speeds

Franklinville Road and Glen Echo Road have a posted speed limit of 35 MPH. The posted speed limit along Monroeville Road and Franklin Street is 45 and 50 MPH, respectively. As shown in ***Table 44***, during the AM and PM peak hour, the speeds measured at the Glen Echo Road and Franklin Street approaches ranged between 41 to 45 MPH. The highest speeds were recorded along the Franklinville Road approach.

Table 44: Gloucester County Study Location – Approach Speeds

Intersection Leg	Vehicle Speeds (MPH)	
	AM	PM
NB Monroeville Road	46 – 50	51 – 55
SB Glen Echo Road	41 – 45	41 – 45
EB Franklin Street	41 – 45	41 – 45
WB Franklinville Road	51 – 55	51 – 55

Source: DVRPC

Vehicle Classification

As depicted in ***Table 45*** the southbound Glen Echo Road approach carries the highest amount of heavy-vehicle traffic through the intersection.

Table 45: Gloucester County Study Location – Vehicle Classification

Intersection Leg	Cars	Heavy-Vehicles (2+ Axles, 6+ Wheels)	Buses
NB Monroeville Road	90.5%	8%	1.5%
SB Glen Echo Road	81.5%	15.5%	3%
EB Franklin Street	94.5%	5%	0.5%
WB Franklinville Road	94.5%	3%	2.5%

Source: DVRPC

Results and Findings

Presented below are the results for each of the scenarios for the study intersection.

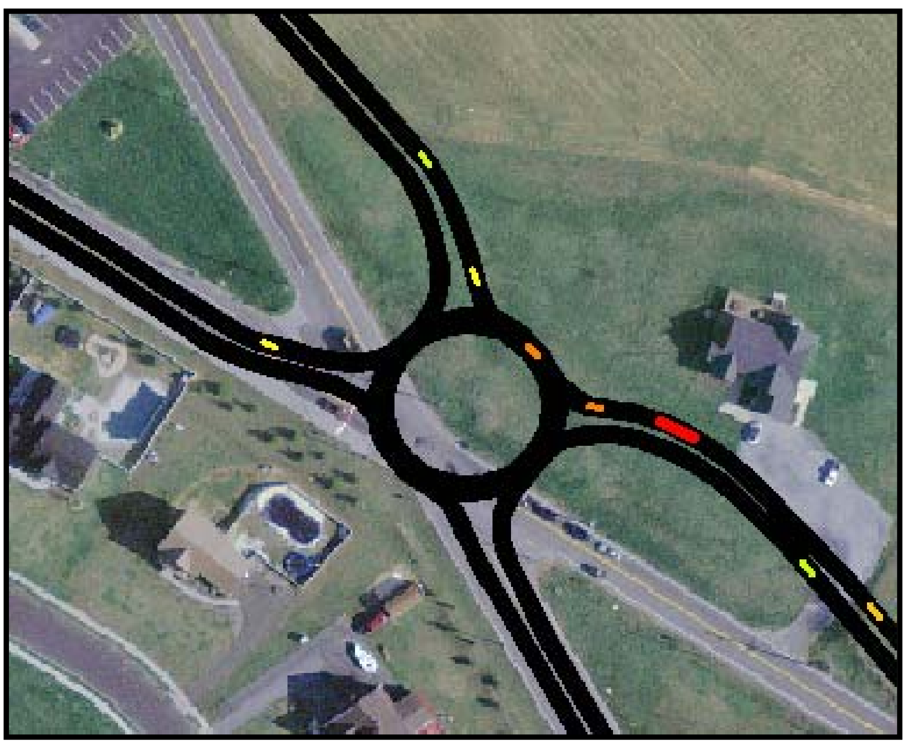
Existing Scenario

In the morning and afternoon peak period, the overall LOS for the existing intersection is A, with approximately ten seconds of vehicle delay. The northbound, southbound and eastbound approaches experience vehicle delay ranging between seven to eight seconds during both peak periods. The westbound approach in the morning and afternoon has the highest amount of vehicle delay (approximately 18 seconds) and a LOS of C.

Roundabout Scenario

Figure 39 depicts the roundabout alternative. Compared to the existing intersection, the overall vehicle delay experienced with a roundabout is decreased six seconds. The roundabout alternative allows for vehicles to pass through the intersection without stopping, hence during the morning and afternoon peak periods, delay on all four of the approaches ranges between three to five seconds and has an overall LOS of A.

Figure 39: Gloucester County Study Location – Roundabout Rendering



Source: DVRPC – VISSIM Software

Tables 46 and 47 summarize existing MOE for the morning and afternoon peak hours for both the existing and roundabout scenarios.

Table 46: Gloucester County – AM Peak Hour Scenarios

	Scenario	Intersection Leg	Delay	LOS
AM Peak Hour				
	Existing	NB Monroeville Road	6.8	A
		SB Glen Echo Road	6.9	A
		EB Franklin Street	7.9	A
		WB Franklinville Road	18.4	C
		Total Intersection	**10.0**	**A**
	Roundabout	NB Monroeville Road	3.0	A
		SB Glen Echo Road	4.6	A
		EB Franklin Street	2.7	A
		WB Franklinville Road	4.3	A
		Total Intersection	**3.7**	**A**

Source: DVRPC

Table 47: Gloucester County – PM Peak Hour Scenarios

	Scenario	Intersection Leg	Delay	LOS
PM Peak Hour				
	Existing	NB Monroeville Road	7.3	A
		SB Glen Echo Road	6.6	A
		EB Franklin Street	7.6	A
		WB Franklinville Road	18.2	C
		Total Intersection	**9.9**	**A**
	Roundabout	NB Monroeville Road	4.0	A
		SB Glen Echo Road	3.4	A
		EB Franklin Street	4.2	A
		WB Franklinville Road	3.3	A
		Total Intersection	**3.7**	**A**

Source: DVRPC

Strengths and Weaknesses of a Roundabout in this Location

Highlighted below are strengths and weaknesses resulting from the analysis performed. Comments from Gloucester County officials are also provided.

Strengths

- The layout and location of this intersection are favorable for roundabout consideration (odd layout, open space, located near the entrance to Swedesboro Borough); and
- The overall operation of the intersection (LOS and vehicle delay) is improved with the roundabout option versus the current four-way stop configuration.

Weaknesses

- If a roundabout were to be constructed, it would impact the adjacent property (residential property located in the northeast quadrant).

Gloucester County Comments

- CR 538 is a high priority for the county; therefore, any alternatives to improve this intersection is of great interest;
- There is future development planned in the area, which would generate more traffic traveling through the study intersection;
- This intersection was recently converted from a two-way stop controlled into an all-way stop. Since this conversion, the number of crashes reported at this intersection has decreased; and
- North of the study area, a roundabout is planned as part of a development.

Mercer County

Candidate Location

The intersection of CR 571 (Stockton Street), Oak Lane, Dutch Neck Road, and Harron Avenue, located in Hightstown Borough, was selected by the DVRPC project team to analyze for further roundabout investigation. As indicated in ***Table 48***, this location met five of the seven qualifying criteria for roundabout consideration. The assessment was based on the information provided by the Mercer County Planning and Engineering departments. This intersection was specifically selected because it was the only location among any of the nine county's top candidates with a five-leg approach. In addition, it contains heavy-vehicle traffic and is located in an environment with high levels of pedestrian activity.

Table 48: Mercer County's Site Determination Matrix

Criteria	Prioritized Location #1	Prioritized Location #2	Prioritized Location #3
	CR 638 and Post Road	***CR 571 and Faculty Road***	***CR 571, Oak Lane, Dutch Neck Road and Harron Avenue***
Awkward geometry	--	✓	✓
Heavy-vehicles	--	--	✓
Bike/pedestrians	✓	✓	✓
Single-lane approach	✓	✓	✓
Rural or suburban land use	✓	--	--
Municipal support	--	--	✓
Safety concerns	--	--	--

Source: DVRPC

Figure 40: Mercer County Study Location Aerial Photo

Source: DVRPC

Data Collection

The following pages provide a summary of the data collected to analyze a potential roundabout at the intersection of CR 571 (Stockton Street), Oak Lane, Dutch Neck Road, and Harron Avenue.

Field observations

The DVRPC project team conducted a site visit to observe the surrounding land use and traffic patterns at the intersection. ***Figure 41*** highlights the key findings.

Figure 41: Mercer County Study Location – Field Visit Summary

OBSERVATIONS:

- Five-leg intersection
- Unconventional movements from Harron Avenue and Dutch Neck Road
- Main traffic flow along Stockton Street
- Dutch Neck Road, Harron Avenue and Oak Lane stopped controlled
- Pedestrian and cyclists observed
- Schools located adjacent to intersection
- Dutch Neck Road and Harron Avenue are narrow
- No significant elevation grades
- School bus and heavy-vehicle traffic along Stockton Street
- Intersection is in close proximity to US 130

Source: DVRPC

Crash History

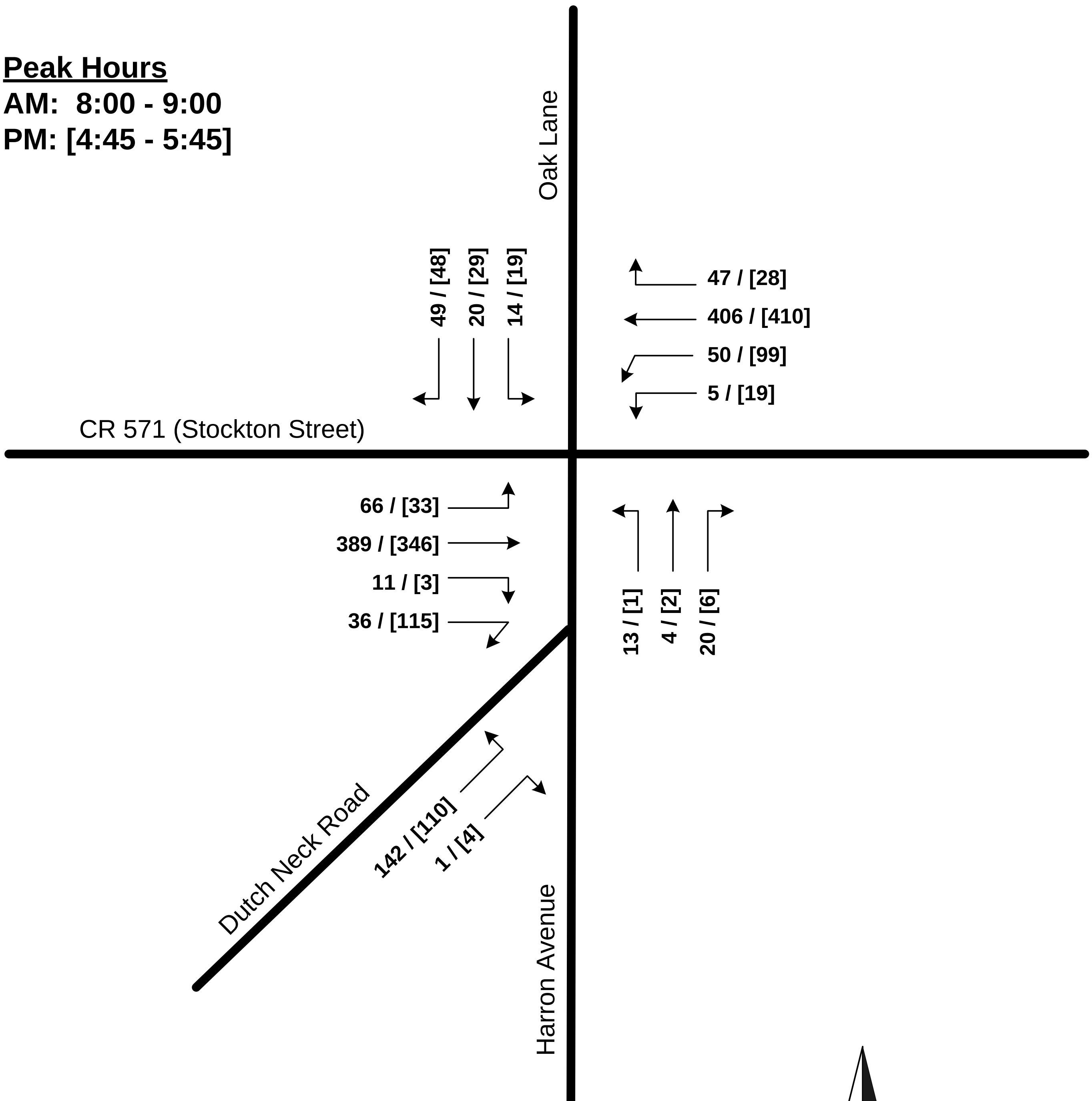
According to the DVRPC Crash Database, three crashes were reported at this intersection between 2005 and 2007. Two of the three crashes were right-angle collisions. The other accident was identified as a rear-end crash. Two of the crashes involved injuries. The three crashes reported occurred during daytime hours.

Turning Movements

A peak hour turning movement diagram is shown in ***Figure 42***. The morning and afternoon peak hour for this intersection is 8:00 AM to 9:00 AM and 4:45 PM to 5:45 PM, respectively.

Figure 42
Mercer County Study Location Turning Movements
EXISTING Peak Hour Turning Movement Counts AM & [PM]

Peak Hours
AM: 8:00 - 9:00
PM: [4:45 - 5:45]



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During the morning and afternoon peak period, 1,273 and 1,158 vehicles travel through the intersection. The dominant movements are along the eastbound and westbound Stockton Street approaches. Harron Avenue carries the least amount of traffic.

Approach Speeds

The posted speed limit in the area is 25 MPH. As shown in ***Table 49***, the measured speed in the AM and PM peak period for the eastbound, southbound, and northbound approaches range between 26 to 30 MPH. During the morning peak hour, the Dutch Neck Road approach had the highest speeds entering the intersection.

Table 49: Mercer County Study Location – Approach Speeds

Intersection Leg	Travel Speeds (mph)	
	AM	PM
EB Stockton Street	26 – 30	26 – 30
WB Stockton Street	31 – 35	31 – 35
SB Oak Lane	26 – 30	26 – 30
NB Harron Avenue	26 – 30	26 – 30
NE Dutch Neck Road	36 – 40	31 – 35

Source: DVRPC

Vehicle Classification

As indicated in ***Table 50***, approximately 100 percent of vehicles leaving Harron Avenue were classified as a car, motorcycle, or two-axle vehicle (very small percentage of school bus traffic).

Table 50: Mercer County Study Location – Vehicle Classification

Intersection Leg	Cars	Heavy-Vehicles (2+ Axles, 6+ Wheels)	Buses
EB CR 571 (Stockton Street)	96%	3%	1%
WB CR 571 (Stockton Street)	96%	3%	1%
SB Oak Lane	98%	1%	1%
NB Harron Avenue	100%	0%	0%
NE Dutch Neck Road	93%	5%	2%

Source: DVRPC

Results and Findings

Presented below are the results for each of the scenarios for the study intersection.

Existing Scenario

The overall LOS for the existing intersection is A, with nine and eight seconds of vehicle delay in the morning and afternoon, respectively. The eastbound and westbound Stockton Street approaches experience barely any vehicle delay. The remaining three approaches are stop-controlled and experience vehicle delay ranging from seven to 19 seconds.

Roundabout Scenario

Figure 43 depicts a rendering of the roundabout for the study intersection. One of the underlying principles of the modern roundabout is the give-way rule, which requires entering traffic to yield to circulating traffic. Compared to the existing intersection, vehicle delay increases in the morning and afternoon for the eastbound and westbound approaches of Stockton Street. Given the traffic volumes, vehicle delay associated at the Oak Lane and Dutch Neck Road approaches is reduced. In the morning, the vehicle delay at the Harron Avenue approach increases from eight seconds to 11 seconds. This is due to vehicles waiting for gaps before entering the circle. In both the morning and afternoon, the overall LOS is B, with 11 and 12 seconds of vehicle delay, respectively.

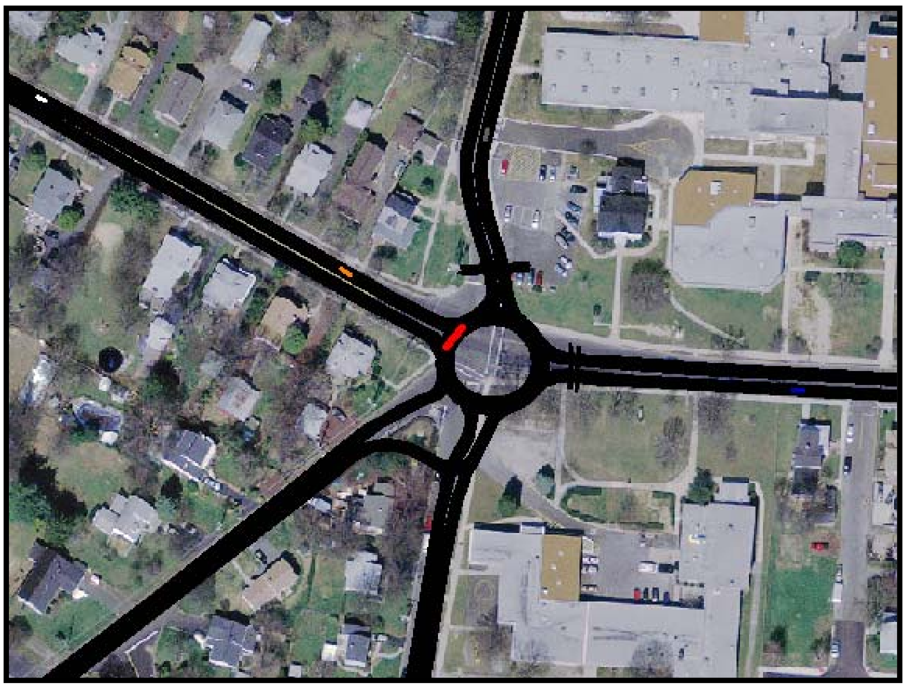
Figure 43: Mercer County Study Location – Roundabout Rendering #1

Source: DVRPC – VISSIM Software

Roundabout Scenario – Dutch Neck Road Leg Out Only

Traffic from Dutch Neck Road enters the roundabout via Harron Avenue and traffic can exit the roundabout directly onto southbound Dutch Neck Road. The LOS and vehicle delay associated with this scenario is very similar to the results calculated with the roundabout alternative. In the morning, the Dutch Neck Road approach continues to experience the highest amount of vehicle delay of 15 seconds, an approximate three-second increase from the roundabout alternative. During the afternoon peak period the westbound Stockton Street, Oak Lane and Harron Avenue legs operate with less than ten seconds of delay for a LOS A. Eastbound Stockton Street experiences the largest amount of delay of 15 seconds and LOS B. The delay associated at the Dutch Neck Road approach is slightly lower with 11 seconds. Compared to existing conditions, the overall vehicle delay is increased by three-seconds in the morning and two seconds in the afternoon.

Figure 44: Mercer County Study Location – Roundabout Rendering #2



Source: DVRPC – VISSIM Software

Table 51: Mercer County – AM Peak Hour Scenarios

	Scenario	Intersection Leg	Delay	LOS
AM Peak Hour				
	Existing	EB Stockton Street	0.9	A
		WB Stockton Street	0.0	A
		SB Oak Lane	15.8	B
		NB Harron Avenue	7.9	A
		NE Dutch Neck Road	18.6	B
		Intersection Total	**8.5**	**A**
	Roundabout	EB Stockton Street	10.5	B
		WB Stockton Street	11.2	B
		SB Oak Lane	7.9	A
		NB Harron Avenue	11.3	B
		NE Dutch Neck Road	12.0	B
		Intersection Total	**10.6**	**B**
	Roundabout with Dutch Neck Road Leg Out Only	EB Stockton Street	11.2	B
		WB Stockton Street	12.0	B
		SB Oak Lane	9.4	A
		NB Harron Avenue	10.1	B
		NE Dutch Neck Road	14.7	B
		Intersection Total	**11.5**	**B**

Source: DVRPC

Table 52: Mercer County – PM Peak Hour Scenarios

	Scenario	Intersection Leg	Delay	LOS
PM Peak Hour	Existing	EB Stockton Street	0.4	A
		WB Stockton Street	2.7	A
		SB Oak Lane	12.9	B
		NB Harron Avenue	7.4	A
		NE Dutch Neck Road	17.1	B
		Intersection Total	**8.1**	**A**
	Roundabout	EB Stockton Street	17.0	B
		WB Stockton Street	10.1	B
		SB Oak Lane	8.2	A
		NB Harron Avenue	7.2	A
		NE Dutch Neck Road	15.0	B
		Intersection Total	**11.5**	**B**
	Roundabout with Dutch Neck Road Leg Out Only	EB Stockton Street	15.2	B
		WB Stockton Street	7.8	A
		SB Oak Lane	8.9	A
		NB Harron Avenue	8.6	A
		NE Dutch Neck Road	11.3	B
		Intersection Total	**10.4**	**B**

Source: DVRPC

Strengths and Weaknesses of a Roundabout at this Location

Highlighted below are strengths and weaknesses resulting from the analysis performed. Comments from Mercer County, Hightstown Borough, and nearby East Windsor Township are also provided.

Strengths

- Given the existing traffic volumes traversing the intersection, there should not be any problems associated with capacity, delay, traffic queues, and oversaturated conditions;
- The odd layout (five legs), pedestrian activity, and location near the entrance to the borough makes this intersection a good roundabout candidate for traffic-calming purposes;
- Given concern at the stakeholder meeting regarding proximity to the signal at US 130, the simulation of both roundabout alternatives did not show any eastbound Stockton Street traffic queues resulting from the roundabout;
- With the “Roundabout with Dutch Neck Road Leg Out Only” scenario, adjacent property will be minimally impacted (most of adjacent property surrounding the intersection is owned by the borough); and
- Among the three scenarios, the longest traffic queue calculated was 175 feet (approximately 9 car lengths). This was calculated along the eastbound approach of Stockton Street for the “Roundabout” scenario. The majority of the approaches did not have any queues.

Weaknesses

- There was not a large crash issue at the intersection, although stakeholders report many near misses;
- Travel speeds and delay are relatively low and the intersection operates at a LOS of A with the existing geometry but degrades slightly to a LOS of B with the two alternatives simulated;
- As shown in the “Roundabout Alternative” scenario, if a roundabout were to be constructed, adjacent property (residential and school parking lot) will be impacted; and
- Due to lack of traffic counts at US 130, it was difficult to simulate the impact of traffic queues with the roundabout scenario.

Mercer County Comments

- In the past, the borough requested a signal at this intersection; however, due to traffic volumes, a signal was not warranted. A roundabout at this location may be a good alternative;
- If a roundabout were considered at this intersection, westbound traffic queues from the US 130 intersection may extend all the way back to this intersection; and

- Concerns were expressed about the heavy influx of traffic at this intersection, particularly school buses during school hours. Before pursuing a roundabout at this location, a traffic analysis on school bus volumes and operations at the intersection would have to be performed.

Hightstown Borough Comments

- During the morning and afternoon peak (with school), there is very heavy school-related traffic at the intersection, which requires a uniformed officer to direct vehicular and pedestrian traffic in the area. Before pursuing a roundabout at this location, a traffic analysis on school bus volumes and operations at the intersection would have to be performed;
- There is a highest peak period of about 15 minutes when parents are dropping off or picking up children and buses are passing through; and
- Municipal officials who attended the stakeholder meeting were supportive of the roundabout concept, but raised concerns about the impact of school traffic.

East Windsor Township Comments

- Since the intersection is within close proximity to the East Windsor border, any further discussion or development of a roundabout in this location should include consultation with the Township of East Windsor.

4. CONCLUSION

The two-phase project that this report completes was designed to gain understanding about how roundabouts could work in different situations in the Delaware Valley. The locations evaluated in this report were selected to represent a range of conditions, rather than necessarily the very best possible location in each county. People interested in siting roundabouts will likely be excited to use this report as a general resource.

At a more specific level, ***Table 53*** summarizes the key strengths and weaknesses for each of the roundabout alternatives modeled and reflect input from decision makers. As demonstrated from the analysis, the traffic operation at many of the intersections is likely to improve with roundabout treatment by reducing the number of conflict movements, travel speeds, delays and occurrence of crashes. One drawback of a roundabout is its size compared to that of a regular intersection. If a roundabout were to be constructed, noted as a problem for many intersections was the limitation of ROW and potential to acquire land from adjacent property.

Table 53: Roundabout Location Feasibility Summary

Location	Technical Pros and Cons	Stakeholders' Comments
Bucks Co. PA 532 & Stoopville Rd	***Pros*** – Reduction in vehicle delays, travel speeds and conflicting movements ***Cons*** – Heavy-truck traffic uses the intersection and not a large crash issue	Intersection is slated to be improved as part of a larger PennDOT project in the area
Chester Co. Boot Rd & Ship Rd	***Pros*** – Reduction in vehicle delays and conflicting movements ***Cons*** – Study intersection is located 500 feet from signalized intersection	Study intersection located too close to signalized intersection with traffic; concern with traffic spillover from signal into the study intersection; this location is not endorsed for further roundabout consideration
Delaware Co. Bridgewater Rd & Brookhaven Rd	***Pros*** – Reduction in travel speeds and conflicting movements; a roundabout could be designed to fit within the existing footprint of the intersection ***Cons*** – Potential environmental impacts due to the close proximity of intersection to Chester Creek	Location is a strong candidate for roundabout consideration, however municipal support would be needed and environmental impacts would have to be performed

Table 53: Roundabout Location Feasibility Summary (continued)

Location	Technical Pros and Cons	Stakeholders' Comments
Montgomery Co. New Hope St, Belvoir Rd, & Marielle Ln	***Pros*** – Reduction in vehicle delays, approach travel speeds and 95th percentile traffic queues ***Cons*** – ROW limitations	A smaller roundabout fitting within the footprint of the existing intersection may be of interest
Philadelphia Co. Pine Rd & Shady Ln	***Pros*** – Reduction in conflicting movements and delay during the PM peak period; a roundabout could be designed to fit within the existing footprint of the intersection ***Cons*** – During peak hours potential for longer traffic queues along southbound Pine Road	No ROW acquisition; area has significant amounts of pedestrian and bicycle traffic; numerous crashes occur at intersection. A roundabout at this location would likely improve safety.
Burlington Co. CR 545 & CR 660	***Pros*** – Reduction in speeds and potentially less crashes ***Cons*** – ROW may need to be acquired depending on the design	Concerns with speeding and severity of crashes at the intersection lead to the conclusion that this location is positive for roundabout consideration
Camden Co. CR 705 & CR 706	***Pros*** – No impact from traffic queuing from signalized intersection into study intersection ***Cons*** – Existing intersection operates the same with roundabout alternative	A roundabout does not seem to be warranted at this location
Gloucester Co. CR 538 & CR 694	***Pros*** – The layout, location, crash history, and analysis of this intersection support a roundabout ***Cons*** – ROW likely to be required from adjacent property owners	Any option for improving operation through this intersection is of great interest (crashes, traffic flow, etc.)
Mercer Co. CR 571, Oak Ln, Dutch Neck Rd, Harron Ave	***Pros*** – Layout, location, and simulation results strongly support a roundabout ***Cons*** – ROW impact to at least one property owner; need to further evaluate potential for queuing under rare conditions toward US 130 intersection	This is a congested intersection with many pedestrians near two schools; it just missed warrants for a signal. The County and two municipalities support a roundabout here to improve safety and operations and to serve as an entryway to Hightstown

Source: DVRPC

Studies in the United States and other countries have showcased roundabouts as a way to increase safety and operations at some intersections. One of the major goals of the analysis done in this project was to simulate an array of Delaware Valley intersections with various designs and layouts, differing surrounding land use patterns, and a range of levels of vehicular and pedestrian traffic activity. Utilizing VISSIM, these intersections were analyzed to compare the existing intersection layout to that of a roundabout. In many instances there were numerous benefits from the roundabout option such as reduction in vehicle delay and improved traffic flow through the intersection. However at some locations due to lack of ROW, traffic patterns, crash history and other circumstances a roundabout may not be the best alternative for improving traffic operation.

Among the array of situations tested, some of the locations showed positive technical results and also initial local support. The technical work would need further development and more discussion would be needed with municipal officials and local stakeholders, but it appears that there is potential to advance the idea of a roundabout in some locations studied. The county and municipal officials could use this report as part of applications for funding to continue investigation of a roundabout at these locations.

Roundabouts have not been a common treatment for intersections in the Delaware Valley region. However with careful design practices and local participation, there seem to be locations where roundabouts are viable options for improving safety and operations. A sample of locations are investigated in this report but more broadly this report provides background for investigating other potential roundabouts in the Delaware Valley.

Appendix A

Background Information on Roundabouts

The following contains background information on roundabouts. This information presented is an excerpt taken from the DVRPC Regional Roundabout Analysis Phase 1 report. (Publication # 07044)

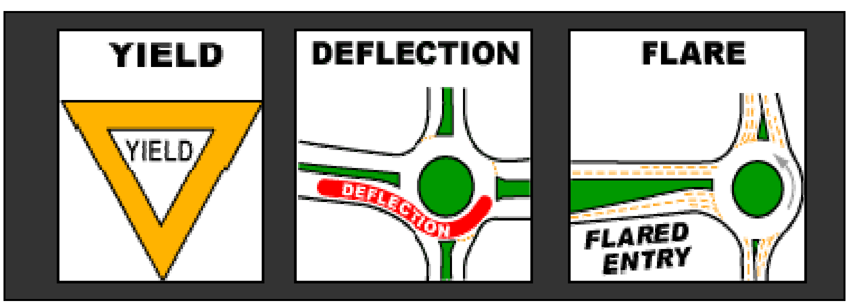
History of Circular Intersection

Commonly known as traffic circles or rotaries, the circular intersection has been a part of the United States transportation since 1905. With the design of a traffic circle, vehicles entering the circle are given priority, which results in higher speeds upon entry into the circle. Traffic signals and stop signs were later installed to help control traffic moving through the circle; however, by the mid-1950's, these intersections fell out of favor due to the high rate of crashes, high travel speeds, and congestion associated with them. In 1963, the traffic circle was redesigned in England into the modern roundabout. The modern roundabout is a type of circular intersection that incorporates a new design to reduce crashes, traffic delays, and speeds at intersections. It is a one-way circular intersection with traffic flowing around a center island. Unlike the rotary, roundabouts do not have traffic signals or stop signs.

Design and Operational Characteristics

A modern roundabout has a number of physical characteristics that differentiate it from stop and signal-controlled intersections, as well as traffic circles. Although each roundabout is unique and designed to accommodate a particular intersection's traffic flow, each shares some basic characteristics. Figure 1 shown below depicts the top three basic features of a roundabout that distinguishes it from a traffic circle.

Figure A-1: Three Basic Design Features of a Roundabout



Source: Alaska Roundabout website (http://www.alaskaroundabouts.com/mythfact1.html)

Yield-at-Entry

At roundabouts the entering traffic yields the right-of-way to the circulating traffic already in the circle. Yield signs are posted on all of the approaches into the roundabout. This yield-at-entry rule prevents traffic from locking and allows free flow movements.

Deflection

The entry and center island deflects entering traffic to slower speeds, thus reinforcing the yielding process.

Flare

The entry to a roundabout often flares out from one to three lanes at the yield line to provide for increased capacity.

Central Island

Other design features of the roundabout include the central island. The central island is a raised area in the center of a roundabout around which traffic circulates. The central island is not limited to the shape of a circle. The roundabout in Towson, Maryland, has an elliptical shaped central island. As indicated in Table 1, the recommended inscribed circle diameter (which is the distance across the circle inscribed by the outer curb of the roundabout) determines the number of lanes that a roundabout can carry. In general, the smaller an inscribed diameter, the lower the circulation speeds. In contrast, the greater a roundabout's diameter, the more lanes it may hold and the better its accommodation for a large design vehicle. The tracking of large vehicles, such as WB-67 trucks and buses, may require a truck apron, which is a mountable portion of the central island adjacent to the circulating roadway.

Table A-1: Roundabout Geometric Summary

Number of lanes	Diameter Range
Single Lane	110 to 150 feet
Two Lane	150 to 230 feet
Three Lane	200 to 260 feet

Source: NE Roundabouts Course Manual

Splitter Island

The splitter island is a unique characteristic of modern roundabouts. Its position along the median of the approach and departure lanes separates entering and exiting traffic, which creates vehicular lateral deflection. The pedestrian crosswalk and its intersection with the splitter island are usually placed approximately one vehicle length upstream of the yield line. Pedestrian mobility is further supported with the splitter islands, which double as pedestrian refuges. These allow a pedestrian to cross the approach and departure lanes in two distinct movements when required, with the pedestrian focusing upon only one direction of vehicle travel at a time. Furthermore, the relatively low speeds of approaching and exiting vehicles are conducive to a high rate of yielding compliance.

Travel Patterns through a Roundabout

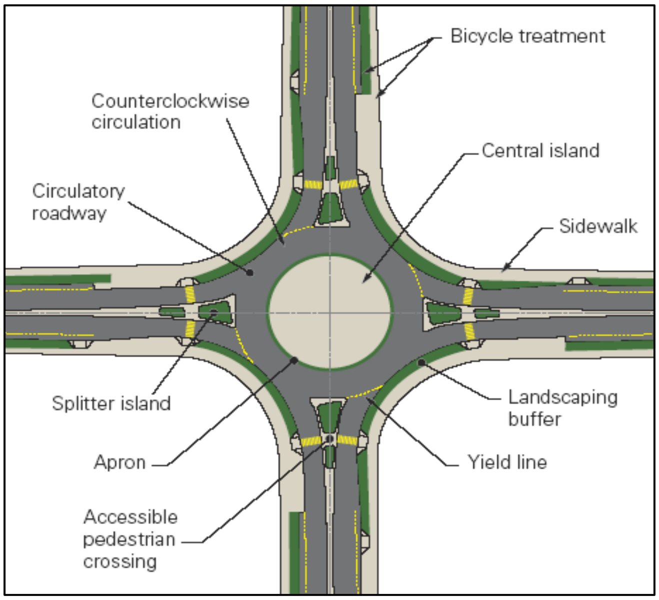
The design of a roundabout allows for traffic to flow in a continuous counterclockwise direction, and is able to accommodate all modes of traffic. Navigation through a roundabout is relatively easy. Drivers approaching a roundabout must remember the following:

- Reduce speeds on entry (20 to 30 mph)
- Yield to pedestrians
- Yield to vehicles in the roundabout
- Drive in a counterclockwise direction within the roundabout
- Exit with slow speeds and yield to pedestrians

Larger trucks and buses follow the same rules as applied to regular size vehicles; however, they may require use of the truck apron provided to negotiate tight turning radii. Pedestrians should use the sidewalks and designated crosswalks around the perimeter of the roundabout. In crossing each leg of the roundabout, pedestrians should be alert to oncoming traffic and use the splitter island, which allows the pedestrian to cross one direction of traffic at a time. Pedestrians should never walk in the roundabout or cross to the central island. Bicyclists have two options in navigating through a roundabout. 1.) Utilize the bicycle as a vehicle, following the same rules of travel through the roundabout 2.) Walk the bicycle around the roundabout, following the same rules as a pedestrian.

When all of these characteristics are combined, the roundabout will encourage slower approach and circulation speeds, creating more acceptable gaps in the circulation stream, which makes travel through the intersection safer for all users. Figure 2 depicts the mentioned design features.

Figure A-2: Roundabout Design Features



Source: FHWA Roundabout Brochure

Roundabout vs. Traffic Signal

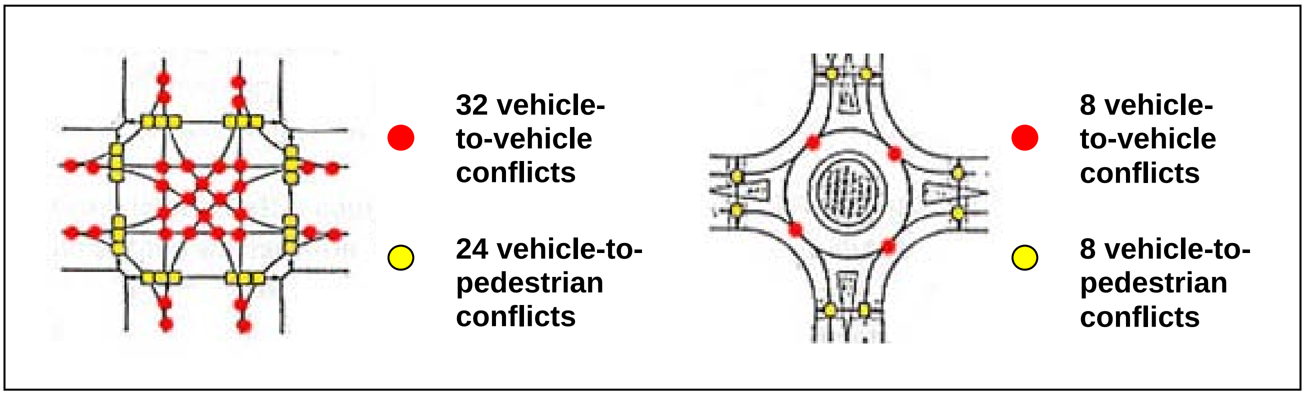
A roundabout has numerous benefits compared to a traffic signal. Table 2 below highlights some of the advantages.

Table A-2: Benefits of Roundabouts vs. Traffic Signals

Benefit	Roundabout	Traffic Signal
Safety (see Figure 3)	• Lower travel speeds • 16 conflict points between vehicles and pedestrians	• Higher travel speeds • 56 conflict points between vehicles and pedestrians
Intersection Efficiency	• Keeps traffic moving, thus less congestion	• Traffic stops in one direction; therefore, may cause congestion
Air Quality	• Traffic passes through without stopping	• As traffic stops, vehicles are left idle, thus causing pollution

Source: DVRPC

Figure A-3: Conflict Points on a 4-Way Intersection Compared to a Roundabout



Source: Roundabout USA website (www.roundaboutusa.com/intro.html)

Roundabout vs. Stop Controlled Intersection

When compared to a two-way stop controlled (TWSC) intersection, roundabouts are helpful when congestion exists on the minor street. Roundabouts do not prioritize approaches; therefore, there is no hierarchy of movements for cross streets at intersections. In comparison to an all-way stop controlled (AWSC) intersection, roundabouts offer greater capacity and lower delays, especially during off-peak periods.

Benefits

According to the Federal Highway Administration (FHWA), other state DOT's, and studies conducted, there are numerous benefits associated with roundabouts. Communities from across the country where roundabouts have been installed have experienced the following benefits:

Safety

- Up to a 90% reduction of fatalities
- 76% reduction in injury crashes
- 30 – 40% reduction in pedestrian crashes
- 75% fewer conflict points

Slower Vehicles Speeds (under 30 mph)

- Drivers have more time to judge and react to other vehicles and/or pedestrians
- Advantageous to older and novice drivers
- Reduces the severity of crashes
- Keeps pedestrians safer

Efficient Traffic Flow

- 30 – 50% increase in traffic capacity

Reduction in Pollution and Fuel Use

- Improved traffic flow for intersections that handle a high number of left turns
- Reduced need for storage lanes

Money Saved

- No signal equipment to install and repair
- Savings estimated at an average of $5,000 per year in electricity and maintenance costs
- Service life of a roundabout is 25 years (vs. the 10-year service life of signal equipment)

Community Enhancement

- Traffic calming
- Aesthetic landscaping

Other Factors to Consider

Roundabouts are safe and efficient; however, they may not be the best solution for every intersection. Roundabout installation may be most appropriate at intersections with the following characteristics:

- Frequent left-turn movements
- Complex intersection geometry
- Balanced traffic flows
- More than four legs
- High traffic delays
- Traffic calming (gateway into a community)
- High number of pedestrians and bicyclists
- Areas where traffic signals are not warranted
- Areas where there is sufficient right-of-way (ROW) surrounding the intersection, such as wooded and agricultural type land use
- Level grades approaching the intersection

Pedestrian Consideration[1]

As with any intersection design, each transportation mode present requires careful consideration. The following presents general issues associated with pedestrians traveling through a roundabout.

Pedestrians are accommodated by crossings around the perimeter of the roundabout. By providing space to pause on the splitter island, pedestrians can consider one direction of conflicting traffic at a time, which simplifies the task of crossing the street. Pedestrian crossings are set back from the yield line by one or more vehicle lengths to:

- Shorten the crossing distance compared to locations adjacent to the inscribed circle;
- Separate vehicle-vehicle and vehicle-pedestrian conflict points; and
- Allow the second entering driver to devote full attention to crossing pedestrians while waiting for the driver ahead to enter the circulatory roadway.

Most intersections are two-way stop controlled, or uncontrolled. Compared to two-way stop-controlled intersections, roundabouts may make it easier and safer for pedestrians to cross the major street. At both roundabouts and two-way stopped-controlled intersections, pedestrians have to judge gaps in the major (uncontrolled) stream of traffic. By reducing stopping distance, the low vehicular speeds through a roundabout generally reduce the frequency and severity of incidents involving pedestrians. In addition, when crossing an exit lane on the minor road, the sight angle is smaller than when watching for left-turning vehicles at a conventional intersection.

[1] FHWA, Roundabouts: An Informational Guide, 2000

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Geographic Area Covered: The study area for this analysis is the nine counties within the Delaware Valley Region: Bucks, Chester, Delaware, Montgomery, Philadelphia, Burlington, Camden, Gloucester, and Mercer.

Key Words: Roundabout, VISSIM, analysis, safety, traffic circle, splitter island, central island, yield, counterclockwise traffic flow, traffic calming, deflection, flare, slower speeds, crashes, signal score, traffic signal, conflict points, community enhancement, complex geometry, truck apron

Abstract: This report examines the potential of constructing roundabouts in a variety of types of locations in the Delaware Valley. Using specific criteria developed for this process and county input, one location per county was chosen from a list developed in the first phase of this project. This second phase utilized VISSIM software to analyze various performance measures of a potential roundabout at each location and included discussing these results with county and other representatives.

Roundabouts may or may not be a viable solution for improving traffic operations at many locations in the region. The information presented in this report provides examples of roundabout treatments applied to various types of intersections. It provides information for localities and agencies considering roundabouts at locations throughout the Delaware Valley.

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Phase II

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