DELAWARE VALLEY
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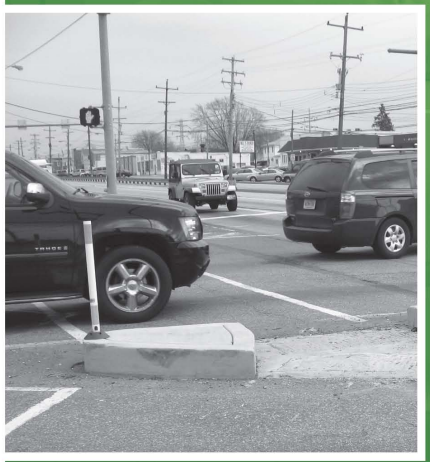
REGIONAL
PLANNING COMMISSION

NOVEMBER 2010

TINICUM TOWNSHIP, DELAWARE COUNTY

CONGESTION & CRASH site Analysis Program



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The symbol in our logo is adapted from the official DVRPC seal and is designed as a stylized image of the Delaware Valley. The outer ring symbolizes the region as a whole while the diagonal bar signifies the Delaware River. The two adjoining crescents represent the Commonwealth of Pennsylvania and the State of New Jersey.

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Executive Summary

The goals of the Congestion and Crash Site Analysis Program (CCSAP) are to improve access and efficiency of the region's transportation system, improve safety and air quality, and reduce congestion through analyses of specific highway locations with demonstrated problems in both New Jersey and Pennsylvania.

Due to their many conflict points, intersections experience more crashes than midblock locations. In addition, the geometry of an intersection can present many issues for the road user. Assuring the efficient operation of intersections is an increasingly important issue as municipalities attempt to maximize roadway capacity to serve the growing demand for travel. The objective is to identify cost-effective improvements that will reduce crashes and congestion.

The Delaware County Planning Department suggested the intersection of Wanamaker Avenue (PA 420) and Industrial Highway/Governor Printz Highway (PA 291), located in Tinicum Township, Pennsylvania, as the candidate location for further study. For the purposes of this report, Industrial Highway/Governor Printz Highway will be referenced as Industrial Highway.

The study area experiences a high number of angle crashes and undesirable levels of congestion. With the help of input from the advisory committee (local, county, and state officials) and the analyses performed by DVRPC, several improvement strategies were developed that would potentially increase the safety and mobility of all road users traveling through this intersection. The list of advisory committee participants is provided in Appendix A.

The range of strategies developed included the following: moving U-turns to a safer location, adding pavement markings, and altering traffic signal timing/phasing. Many of the above-mentioned strategies were recommended for implementation. The majority of these improvements were low-cost and short-term solutions to help improve traffic flow and safety of all roadway users traveling through the intersection of Wanamaker Avenue and Industrial Highway.

CHAPTER 1

Introduction

This technical report provides analysis and recommendations for the intersection of Wanamaker Avenue (PA 420) and Industrial Highway (PA 291) in Tinicum Township, Pennsylvania. The recommended strategies cover both safety and operational improvements. The operational improvements were modeled and the results compared to existing conditions. It was not possible to model the safety improvements, but they were developed based on professional knowledge and discussions with members of the study advisory committee. The resulting recommendations are in the final chapter of the report.

Methodology

The DVRPC study team conducted field visits to observe the issues at this location. Data was then compiled and analyzed. This included crash records data, Average Annual Daily Traffic (AADT) data, turning movement counts, and traffic signal timings. On March 3, 2010 a kick-off meeting was held among representatives from the following agencies: Delaware County Planning Department, Tinicum Township, PennDOT, and DVRPC. The field visit and kick-off meeting assisted in the identification of problems, with discussion of the advisory committee's observations and feedback.

DVRPC staff conducted follow-up field visits to better define the existing conditions and refine the identification of problems. Subsequently, a technical analysis was performed to better understand and quantify the identified transportation problem areas. This included the preparation of a collision diagram displaying crash patterns and conducting a level of service (LOS) analysis for existing conditions.

Based on the crash and LOS analyses, a set of potential improvements was developed that addressed the identified problems.

Findings and preliminary recommendations were presented to the advisory committee at a follow-up meeting held at the Tinicum Township Municipal Building on April 27, 2010. The purpose of the meeting was to discuss the recommendations and to get the advisory committee's perspectives on the practicality of the recommendations.

Level of Service (LOS) Analysis

LOS analysis is a common tool for assessment of transportation facilities and was used extensively for this project. When applied as a measure of performance for an entire or a particular component of an intersection, LOS has a precise meaning: the average delay experienced by a vehicle traveling through the intersection or a specific component of it. The parameters of delay that determine the various LOS categories for a signalized intersection are displayed in Table 1.

A review of the existing conditions and the various potential improvement scenarios was conducted using Synchro software for the study intersection. Necessary information for determining delay and LOS measures include turning movement counts, roadway geometry, signal timing, and signal actuation plans. The turning movement counts were mostly gathered by DVRPC staff; the signal timing, actuation data, and roadway geometrics were supplied by PennDOT.

Table 1: LOS Designations and Associated Delays

LOS	Signalized Intersection Total Delay per Vehicle (seconds/vehicle)
A - Desirable	≤ 10
B - Desirable	> 10 and ≤ 20
C - Desirable	> 20 and ≤ 35
D - Acceptable	> 35 and ≤ 55
E - Undesirable	> 55 and ≤ 80
F - Unsatisfactory	> 80

Source: Highway Capacity Manual, 2000

For signalized intersections, Synchro calculates a control delay and a queue delay. The control delay is calculated by a percentile delay method. This approach uses formulas from the Highway Capacity Manual to calculate delay; however, the final delay measure is taken from an average of the 10th, 30th, 50th, 70th, and 90th percentile volume levels. As a result, the calculated delay is a product of the various operating conditions that a signal may actually encounter.

For the revision of timing plans, Synchro is capable of optimizing intersection splits, cycle lengths, and offsets. These efforts seek to establish a timing plan that provides the most efficient performance and serves an optimal volume of vehicles.

CHAPTER 2

Study Location

The focus of the study as shown in Figures 1 and 2 is the intersection of Wanamaker Avenue and Industrial Highway. Both roads are heavily traveled and developed, and there is significant pedestrian traffic to businesses and retail stores. Industrial Highway runs parallel to I-95 and serves as an alternate traffic route when there are major incidents on I-95. It is also used as an informal alternative when I-95 is congested. Wanamaker Avenue connects with several key roads, including Chester Pike (US 13), and provides direct access to the Delaware River waterfront via Essington, a residential community south of the intersection. On a local level, the study intersection provides direct access to Boeing Company, Harrah's Casino, hotels, restaurants, Airport Industrial Park, and I-95 exit 9.

Wanamaker Avenue and Industrial Highway are classified as minor arterials and run in a north-south and east-west direction, respectively. The intersection is signalized. In the northbound direction Wanamaker Avenue contains one travel lane and on-street parking. In the southbound direction, there is one channelized right-turn lane, one through lane and one dedicated left-turn lane that provides access to eastbound Industrial Highway and Powhattan Avenue. The eastbound Industrial Highway approach contains one left-turn lane, two through lanes and one right-turn lane that allows access to southbound Wanamaker Avenue and Powhattan Avenue. The westbound Industrial Highway approach contains one left-turn lane, two through lanes and one channelized right-turn lane. Sidewalks are located on all approaches to the intersection.

Powhatan Avenue is classified as a local road which runs in an easterly direction. It serves as a frontage road for local businesses occupying the south side of the street. Sidewalks and front-end parking are also provided along Powhattan Avenue.

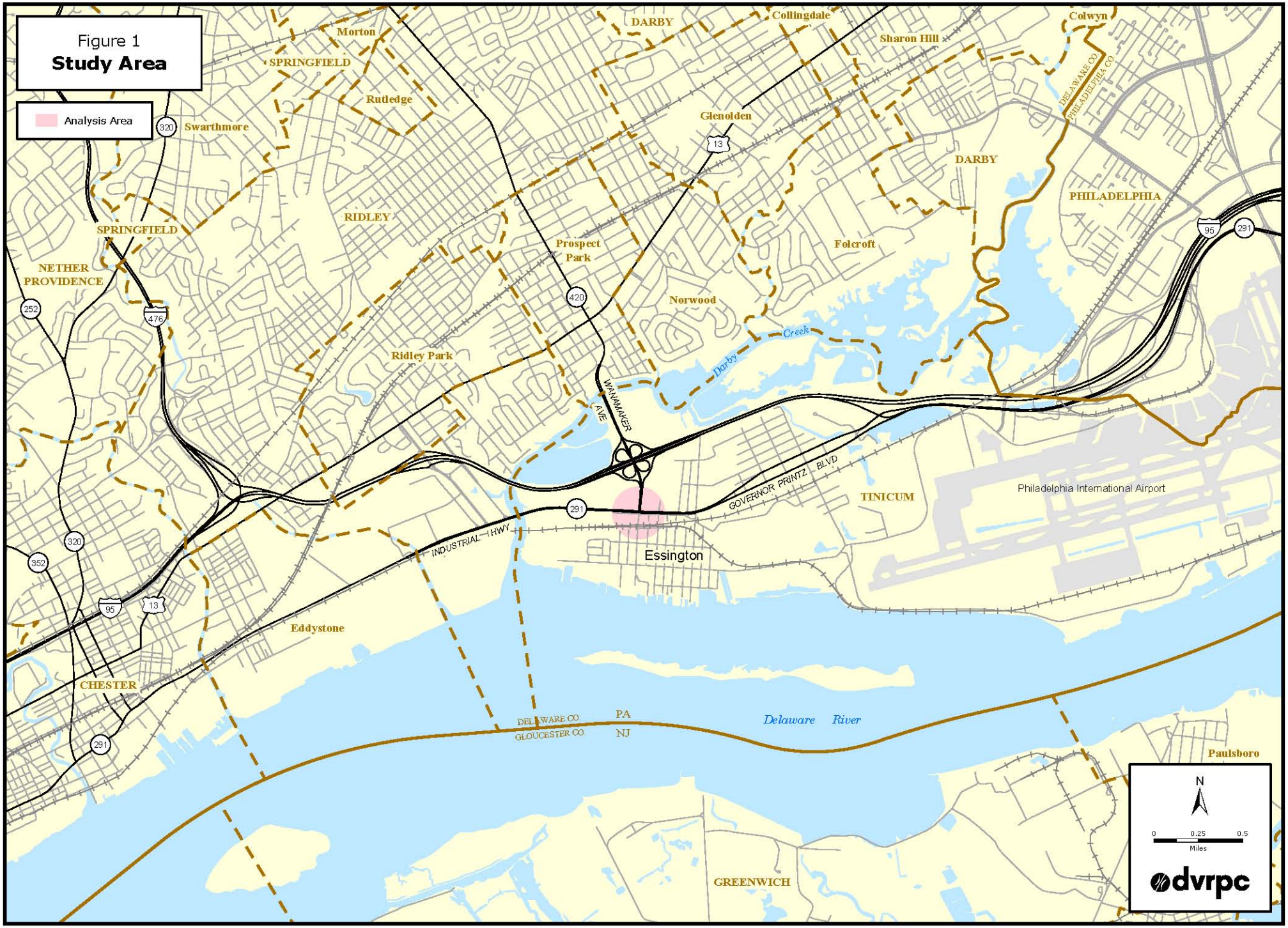


Figure 1
Study Area
Analysis Area
Morton
SPRINGFIELD
Rutledge
Swarthmore
DARBY
Collingdale
Colwyn
Sharon Hill
Glenolden
DELAWARE CO.
PHILADELPHIA CO.
DARBY
PHILADELPHIA
RIDLEY
SPRINGFIELD
NETHER PROVIDENCE
Prospect Park
Folcroft
Norwood
Ridley Park
Darby Creek
WANAMAKER AVE
GOVERNOR PRINTZ BLVD
TINICUM
Philadelphia International Airport
Essington
INDUSTRIAL HWY
Eddystone
CHESTER
DELAWARE CO.
GLOUCESTER CO.
PA
NJ
Delaware River
GREENWICH
Paulsboro
N
0
0.25
0.5
Miles
dvrpc

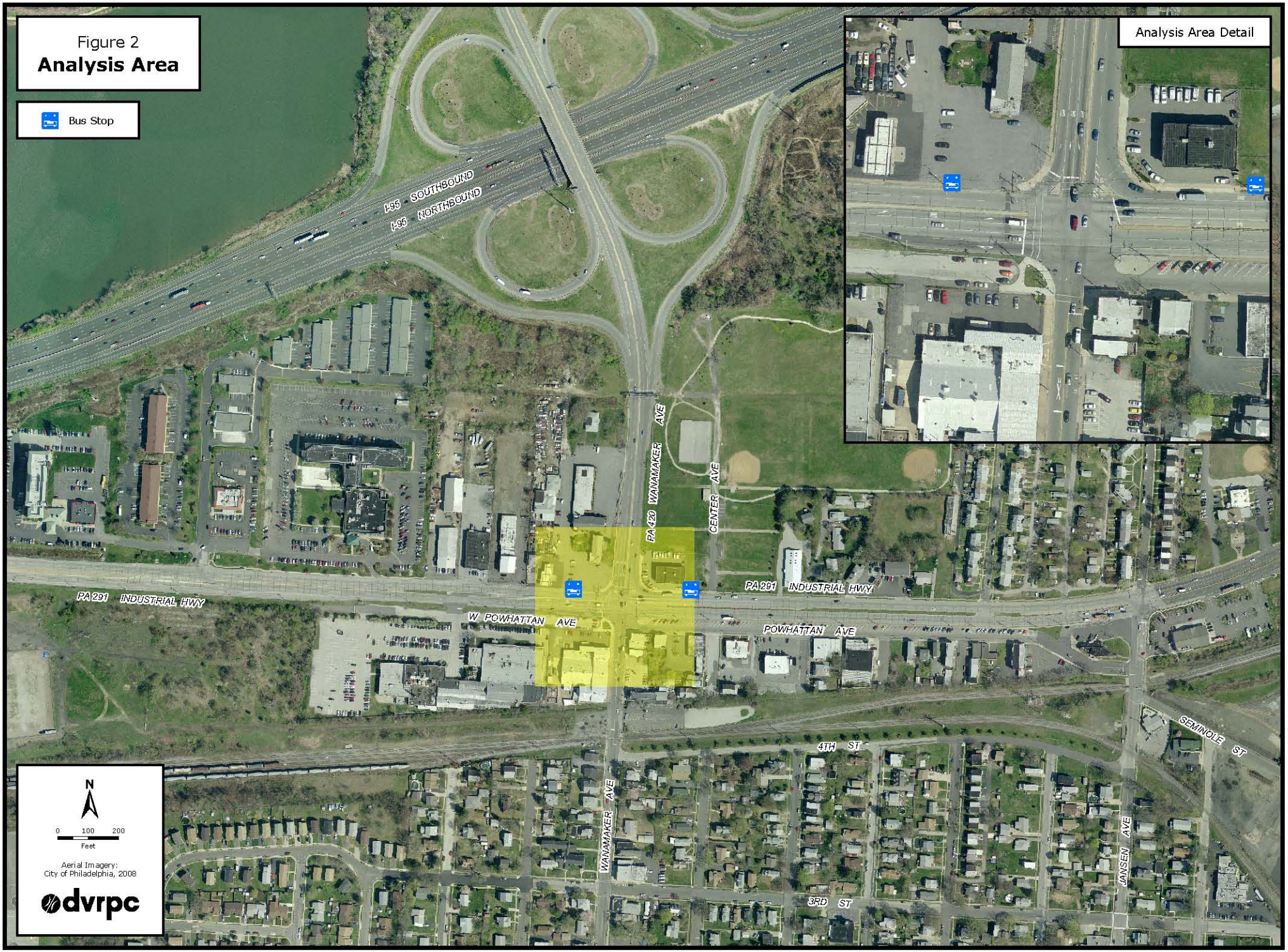


Figure 2
Analysis Area
Bus Stop
Analysis Area Detail
I-95 SOUTHBOUND
I-95 NORTHBOUND
PA 420 WANAMAKER AVE
CENTER AVE
PA 291 INDUSTRIAL HWY
W POWHATTAN AVE
POWHATTAN AVE
4TH ST
3RD ST
SEMINOLE ST
JANSEN AVE
N
0 100 200
Feet
Aerial Imagery:
City of Philadelphia, 2008
dvrpc

CHAPTER 3

Existing Conditions

The Industrial Highway and Wanamaker Avenue intersection is one of the major intersections along Industrial Highway in Tinicum Township, as it provides access to I-95 and Essington. The study area experiences heavy through and turning movements. DVRPC traffic counts taken in 2010 on Industrial Highway showed an AADT volume of 13,355 vehicles in both directions east of the intersection between Wanamaker Avenue and Jansen Avenue. On the west side of the intersection between Sellers Avenue and Wanamaker Avenue, 2010 traffic counts on Industrial Highway showed an AADT volume of 9,769 vehicles. Traffic counts taken in 2009 along Wanamaker Avenue north of the study intersection showed an AADT volume of 12,135 vehicles. No AADT data was available on Wanamaker Avenue south of the study intersection.

Peak hours and local input indicate that many commuters pass through the study intersection. The following are some of the comments made by the study advisory committee at the kick-off meeting concerning existing vehicular and pedestrian movements in the study area:

- The intersection experiences a significant amount of congestion during the morning and afternoon peak period. Turning movement volumes are very high. The amount of heavy traffic volume through this intersection often causes the following situations:
  - In the afternoon peak period, the eastbound left-turn lane on Industrial Highway backs into the through lanes. This is attributed to shift changes at Boeing Company and nearby hotels.
  - The single lane configuration on northbound Wanamaker Avenue results in traffic backing up through the railroad crossing south of the intersection during peak hours. At times the railroad gate malfunctions.
  - Nearby entertainment uses and special events cause traffic to increase during weekend evenings and the summer months, especially headed northbound from Essington.
- There is no lane control guidance for the southbound left turns onto Industrial Highway or Powhattan Avenue. Left turns onto Powhattan Avenue are currently made from both the left-turn lane and the through lane.
- Drivers have submitted complaints stating that they do not receive enough yellow and all-red time to clear the intersection in the northbound direction.
- Two pedestrian refuge islands located on the north side of Wanamaker Avenue provide minimal protection for pedestrians. Pedestrians have difficulty in crossing at this location.
- The police have responded to numerous crashes at the intersection, many of which involve collisions among eastbound left-turning vehicles with westbound through vehicles. Signage and the concrete pedestrian refuge islands on the southbound Wanamaker Avenue approach of the intersection have been hit numerous times.
- There are numerous and redundant signs located at the eastbound approach of the intersection, which can be confusing to drivers.

Signal Timing

This actuated signal is currently coordinated with the traffic signal to the east (Jansen Avenue) and will be incorporated into the airport's coordinated system in the near future. The cycle length remains constant at 120 seconds during all time-of-day programs. The signal accommodates the eastbound and westbound movements as actuated, followed by a southbound lead phase then concurrent northbound/southbound movements. The eastbound/westbound and southbound left turns operate as protected-permitted, while the northbound left turns operate as permitted only.

Turning Movement Counts

Manual turning movement counts were taken at the intersection. These counts were taken in February 2010 between the hours of 6:00 AM and 9:00 AM and between 3:00 PM and 6:00 PM. A peak hour turning movement diagram is shown in Figure 3. The morning peak hour is 7:30 AM to 8:30 AM and the afternoon peak hour is 5:00 PM to 6:00 PM.

During the morning peak hour, 2,167 vehicles traveled through this intersection. The dominant movements in the morning are the southbound left turn (479 vehicles) and westbound right turn movements (319 vehicles), which represents 37 percent of the intersection's volume. The eastbound through and left turn movements and southbound through and right turn movements were fairly even. Turning movements onto Powhattan Avenue was fairly light at 14 vehicles.

During the afternoon peak period, traffic flow in the area increases from traffic conditions in the morning. In the afternoon, 3,618 vehicles traveled through the intersection. The dominant movements are the westbound through (879 vehicles) and right turn (734 vehicles) movements on Industrial Highway, which represents 44 percent of the intersection's volume. The southbound right turn and eastbound left turn movements have 441 and 392 vehicles, respectively. Turning movements onto Powhattan Avenue was fairly light at 30 vehicles.

Existing LOS

LOS analysis was conducted for the study intersection in order to determine the operational quality in terms of vehicle delay. Table 2 below summarizes the LOS of the intersection under existing conditions.

As the table shows, during the morning and afternoon the intersection is currently operating at LOS C and F, respectively. During the afternoon peak hour, eastbound and westbound Industrial Highway approaches experience delays greater than 100 seconds. This is a result of the high volumes traveling along Industrial Highway. During both peak periods, the southbound and northbound Wanamaker Avenue approaches perform at desirable LOS.

Table 2: Existing LOS Analysis

Wanamaker Avenue and Industrial Highway Intersection				
	AM (120 sec.)		PM (120 sec.)	
Direction	Delay (s)	LOS	Delay (s)	LOS
Wanamaker Avenue – northbound	13	B	39	D
Wanamaker Avenue – southbound	17	B	21	C
Industrial Highway – eastbound	56	E	134	F
Industrial Highway – westbound	18	B	115	F
Total Intersection	**27**	**C**	**87**	**F**

Source: DVRPC, 2010

U-Turns

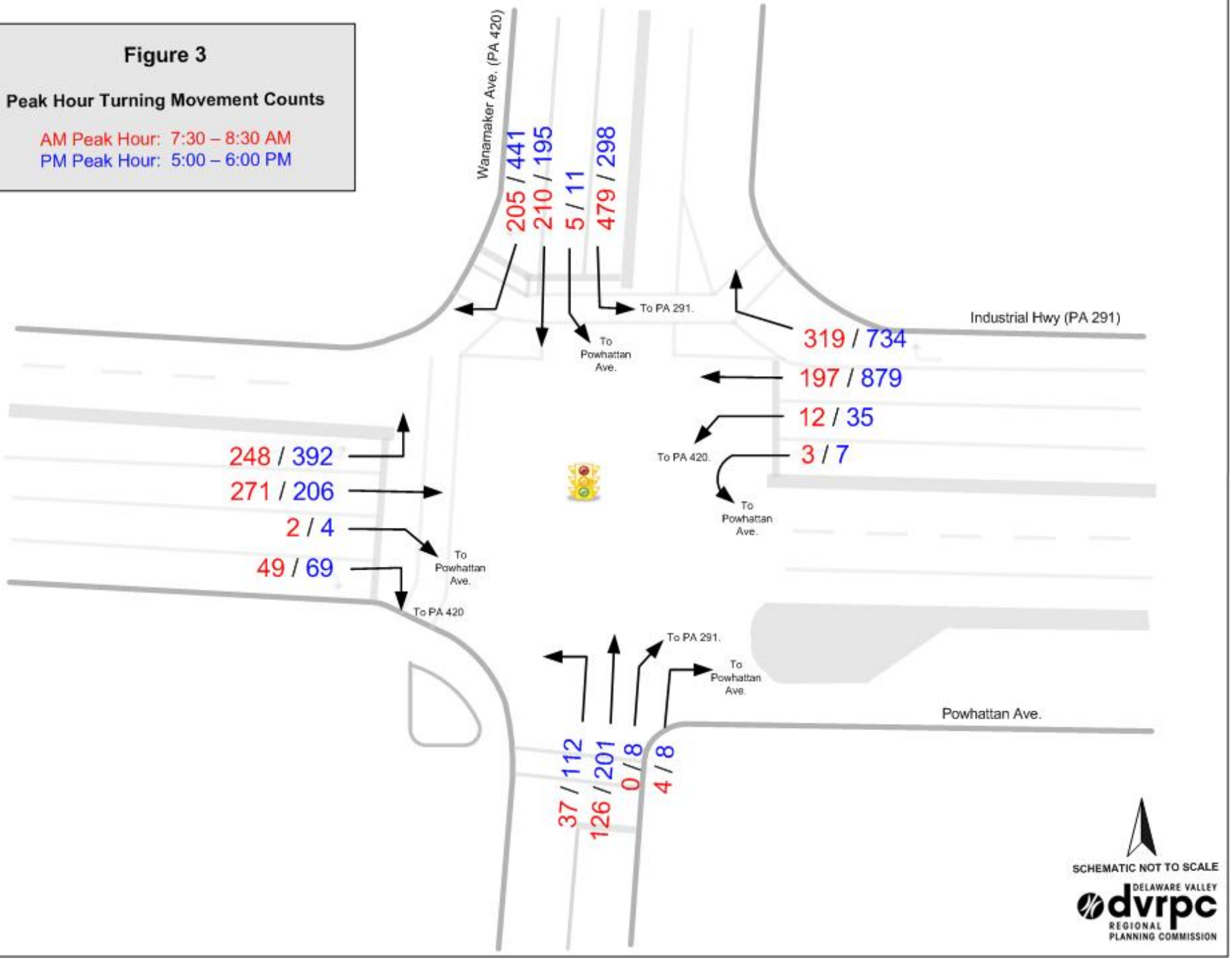
Due to the concrete median and few median breaks, numerous U-turns are made along Industrial Highway at and near the intersection of Wanamaker Avenue and Industrial Highway. Westbound drivers leaving the Sunoco Gas Station and drivers desiring to go to All State Career School and Esstech Company located on the southwest side of the intersection must make U-turns at the median break in front of the All State Career School driveway. The intersection provides the only opportunity for eastbound vehicles to access the Sunoco Gas Station, hotels, and restaurants located on the northwest side of the intersection. Through staff observation and Township police accounts, there have been numerous crashes and near crashes related to vehicles making U-turns at the intersection. The most common is among eastbound U-turn vehicles and southbound right-turning vehicles.

Although U-turns were observed at locations near the study intersection, for the purposes of this report, the conflict of U-turns made only at the study location is documented in this report.

Figure 3

Peak Hour Turning Movement Counts

AM Peak Hour: 7:30 – 8:30 AM
PM Peak Hour: 5:00 – 6:00 PM



Land Use

The land use surrounding the immediate intersection of Wanamaker Avenue and Industrial Highway is commercial. Essington, a residential community, lies south of the intersection. The Sunoco Gas Station and H & H Heating and Air Conditioning are located on the northwest and northeast quadrants of the intersection. The All State Career School and Esstech Company are located on the southwest quadrant of the intersection. A small row of businesses occupies the southeast quadrant of the intersection. A railroad line is located approximately 300 feet south of the intersection. Major changes in land uses elsewhere along these roads have been and continue to affect this intersection. Two examples are the PPL Park soccer stadium and potential development of a large nearby parcel.

View of study location from the southwest quadrant of the intersection.
(Source: DVRPC)

View of study location from the northwest quadrant of the intersection.
(Source: DVRPC)

Pedestrians and Bicyclists

Pedestrian and bicyclist activity is evident throughout the study area. Peak hour counts taken in April 2010, revealed a total of 23 pedestrians and six bicyclists crossing and biking through and around the intersection. Industrial Highway is designated as PA State Bicycle Route E.

Sidewalks and crosswalks are provided on all four legs of the intersection. There are two concrete refuge areas provided for pedestrians crossing the north side of Wanamaker Avenue. According to kick-off meeting comments and through observations, both refuge areas provide minimal protection for pedestrians and have been hazards for hit-fixed-object crashes. Pedestrians also have difficulty in crossing at this location, due to the continuous flow of traffic traveling through the channelized right-turn lane. It was also reported that pedestrians cross through this intersection to access the recreation field located north of H & H Heating and Air Conditioning. The East Coast Greenway project is planned along the south side of Industrial Highway. This project includes sidewalks, lighting, and larger bus stop shelters.

Transit

SEPTA bus route 37 runs along Industrial Highway and Powhattan Avenue. Two bus stops are located within the study area. According to SEPTA FY2010 Annual Service Plan there are 1,476 weekday passenger trips on this route. Peak period headways are every half hour and off-peak headways are every hour.

CHAPTER 4

Crash Analysis

This analysis includes all crashes that occurred at the intersection of Wanamaker Avenue and Industrial Highway, plus a buffer of approximately 500 feet surrounding the intersection box. The intersection box is distinguished from the buffer as the area within the approach leg stop bars.

The main goals of this analysis are to highlight crash trends and determine causal factors. The collision diagram (Figure 4) is a graphic representation of the location, collision type, and frequency of vehicular crashes within the study area.

Data Description

The crash summaries and collision diagram used in this analysis were derived from reportable crash records provided by PennDOT District 6-0, and non-reportable crash records provided by the Tinicum Township Police Department. In Pennsylvania, a crash is considered reportable when a person is injured or killed, or if a vehicle needs to be towed from the scene. Data from years 2004 through 2008 were utilized. Select statistics are summarized in Table 3. There were 41 reportable crashes recorded during the study period, and 59 non-reportable crashes submitted for consideration, though only 50 were suitable for analysis.

Reportable Crashes

Examination of the narratives and crash diagrams included in the police report copies from the reportable crashes uncovered the following issues:

- One crash coded as angle was revealed to be a same direction sideswipe crash and was mapped as such.
- Two crashes coded as head-on were revealed to be angle crashes (left turn involved) and mapped as such.
- Only two true angle crashes were identified (drivers traveling in angular directions to one another collide, e.g.: northbound collides with eastbound), one of which was originally coded as an opposite direction sideswipe crash.
- 21 of the 23 angle crashes involved a left turn movement; these crashes are distinguished from a true angle crash with a unique symbol on the crash diagram.

These exceptions were incorporated in the analysis and are reflected in the collision type summary below.

Non-reportable Crashes

Of the 59 non-reportable crash report copies submitted, only 50 were determined to have occurred within the study area, and contained sufficient detail for analysis. The following describes those reports omitted from the analysis:

- Five incidents occurred north of the study area close to the I-95 interchange.
- Two crashes were coded to I-95.
- Two reports lacked sufficient location information to be useful.

Crash Trends

Major findings of **non-reportable** crash report analysis:

- Rear-end crashes were the most common collision type at 50 percent.
- The most common location for crashes is the channelized right-turn lane from westbound Industrial Highway to northbound Wanamaker Avenue, where 11 crashes occurred, resulting mostly in rear-end collisions.
- The second most common location is the channelized right-turn lane from southbound Wanamaker Avenue to westbound Industrial Highway, where eight crashes occurred, also resulting mostly in rear-end collisions. A few of these crashes were a result of vehicles stopping short to avoid colliding with eastbound U-turning vehicles.
- More than 50 percent of the crashes occurred between 2:00 PM and 7:00 PM.
- When combined, over 50 percent of the crashes occurred on Wednesdays and Mondays.

Major findings of **reportable** crash report analysis:

- Angle crashes where a left turning vehicle was involved accounted for over 50 percent of the total, all of which occurred within the intersection box.
- The most common left turn crash involved drivers traveling eastbound on Industrial Highway turning left onto northbound Wanamaker Avenue colliding with drivers westbound on Industrial Highway resulting in 12 crashes.
- There were nine left turn crashes between 8:00 PM and midnight, and seven between 4:00 PM and 7:00 PM.
- All rear-end crashes occurred at the intersection approaches.
- Four hit-fixed-object crashes were recorded and each involved a driver colliding with an intersection feature (i.e. signage, concrete curbing).

The following crash analysis refers only to the reportable crashes.

Of the 41 reportable crashes recorded during the analysis period there were no fatalities, 21 injury crashes, and 20 property-damage-only crashes.

During the study period years 2004 through 2008 there were four crashes recorded in 2004, and the remaining years had either nine or ten crashes. Considering crashes by month, April and June were the two highest in terms of crash frequency with seven and eight crashes respectively. The remaining months showed between one and three crashes each, except February had five.

Crash trends by day of week showed Monday through Wednesday as having the highest totals accounting for 60 percent. Crashes were spread relatively evenly throughout the day, with the highest concentration during the afternoon commute.

Table 3: Intersection of Wanamaker Avenue and Industrial Highway

Collision Type	Reportable	Non-reportable
Angle – Left Turn Involved	23	5
Angle (true)	2	3
Rear-end	9	26
Head-on	1	0
Same Direction Sideswipe	1	6
Opposite Direction Sideswipe	0	1
Backing	0	3
Hit Fixed Object	5	5
Bicyclist	0	1
Total	**41**	**50**

Source: DVRPC, 2010

Conclusions

As evidenced by the counts and crash frequency, this intersection handles a significant volume of exchanges between Wanamaker Avenue and Industrial Highway, due in no small part to the proximity of the intersection to exit 9 of I-95 located just north of the study area. Crashes involving a left turn were the most frequent crash type. The rear-end crash volume was another significant finding, though only among the non-reportable crashes. Although this number represents over 50 percent of the non-reportable total, these are typically low-speed fender-benders crashes that are less severe than reportable crashes.

To address the left turn involved crash finding, an analysis that considers making the turns protected-only should be explored. A protected-only signal phase provides a dedicated movement where the driver can turn left unimpeded as opposing traffic is held with a red signal.

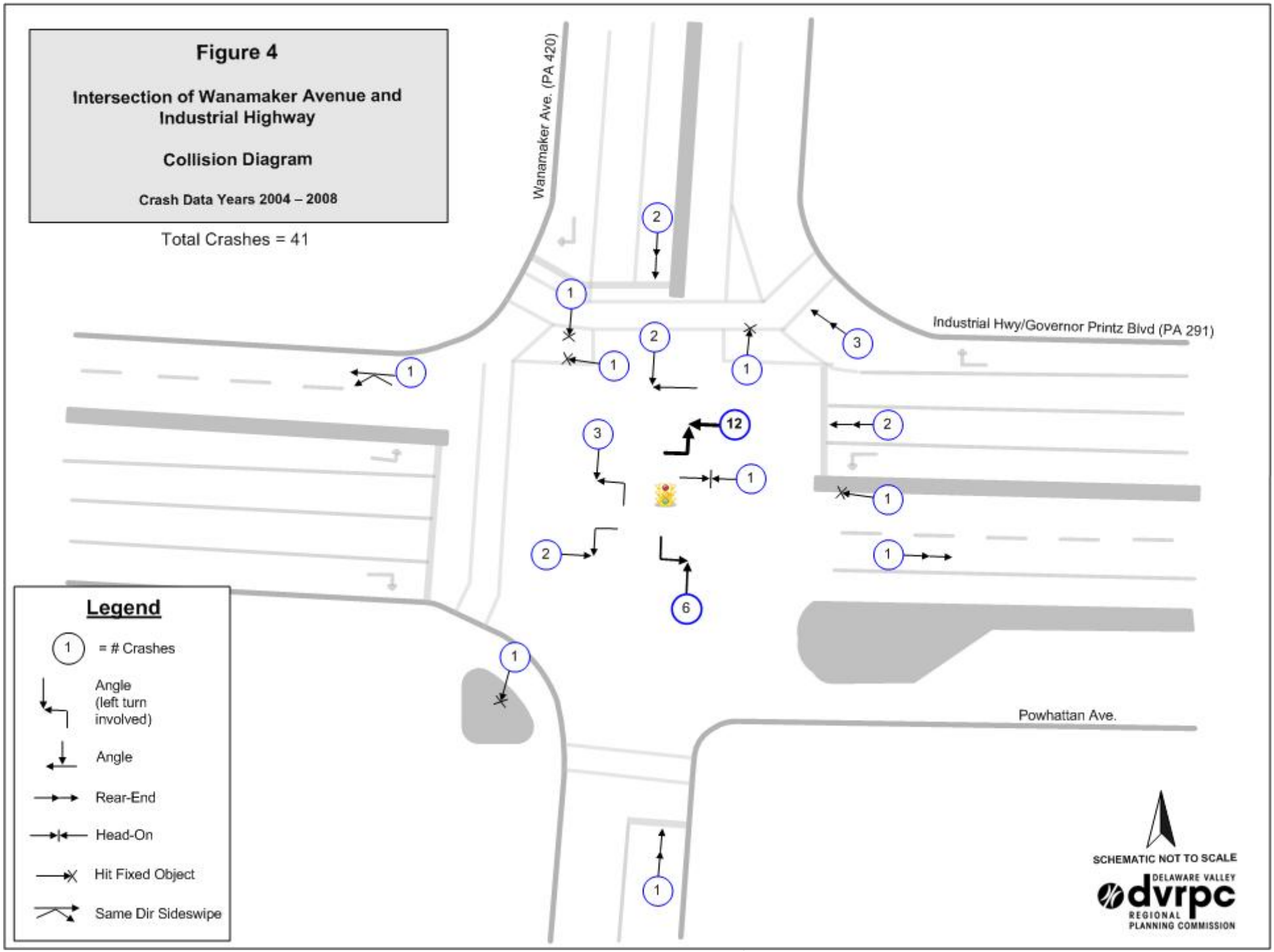


Figure 4
Intersection of Wanamaker Avenue and Industrial Highway
Collision Diagram
Crash Data Years 2004 – 2008
Total Crashes = 41
Wanamaker Ave. (PA 420)
Industrial Hwy/Governor Printz Blvd (PA 291)
Powhattan Ave.
Legend
1 = # Crashes
Angle (left turn involved)
Angle
Rear-End
Head-On
Hit Fixed Object
Same Dir Sideswipe
SCHEMATIC NOT TO SCALE
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CHAPTER 5

Issues and Potential Improvements

A range of strategies was developed by the stakeholders for this study, building on analysis. The strategies developed fell within the following two categories: safety and operational. Safety strategies consist of improvements that enhance and promote safer conditions for all roadway users traveling in the area. Examples of safety strategies include installing signage and adding or modifying pavement markings. Operational strategies include altering the traffic signal timing and geometric improvements at the intersection of Industrial Highway and Wanamaker Avenue.

The following sections describe the main issues and the corresponding strategies for alleviating these safety and operational concerns. LOS analysis was also performed at this intersection to compare existing conditions with conditions if potential operations strategies were implemented.

Issues

- Given the northbound approach lane configuration of Wanamaker Avenue, traffic backs up through the railroad crossing south of the intersection during peak hours.
- Conflicts between vehicles traveling eastbound on Industrial Highway making U-turns at the intersection and vehicles traveling westbound on Industrial Highway and southbound on Wanamaker Avenue making right turns.
- There is no lane control guidance for the southbound left turns onto Powhattan Avenue.
- Drivers have submitted complaints stating that they do not receive enough yellow and all-red time to clear the intersection in the northbound direction.
- Signage clutter near the eastbound approach on Industrial Highway.
- Pedestrian refuge islands on the north side of intersection provide minimal protection for pedestrians and have been hazards for hit fixed object related crashes. Pedestrians also have difficulty crossing Wanamaker Avenue along the north side of intersection.

Goal

- Provide safer driver and pedestrian operations.

Safety Strategies

- Within the existing cartway, stripe a left-turn lane along the northbound Wanamaker Avenue approach and eliminate on-street parking. This effort will allow more northbound vehicles to exit through the intersection and minimize back up.

- Install dual left-turn pavement markings in the southbound left-turn lane to alleviate confusion of lane choice for drivers turning left onto Powhattan Avenue from southbound Wanamaker Avenue.
- Simplify signage and install overhead lane control signage to reduce sign clutter along the eastbound approach to the intersection.
- Enhance pedestrian refuge islands and increase enforcement patrols.
- Install "Yield to Pedestrian in Crosswalk" signs for pedestrians trying to cross Wanamaker Avenue on the north side of the intersection.
- Alleviate conflicts with U-turns at the intersection by one or more of the following strategies:
  - Prohibit U-turns in this location and sign for a safer U-turn maneuver at an alternate location. The advisory committee members recommended the signalized intersection with Jansen Avenue, the next intersection east of the study intersection. This is a more suitable location because the shoulders are wider and therefore minimize the opportunity for vehicle conflict with eastbound U-turning vehicles and southbound right turning vehicles.
  - The existing median width at the west leg of the intersection with Wanamaker Avenue is approximately three feet wide, with a shoulder width of less than one foot. Based on field observations, this width does not allow vehicles larger than a passenger car to complete the U-turn maneuver. The *PennDOT Highway Design Manual*[1] minimum design for U-turns made from a median left-turn lane to the outer lane using the shoulder requires an eight-foot median width to accommodate passenger vehicles[2]. In order to accommodate U-turns, additional shoulder width, in the form of a loon (small curb cut out) could be added to provide additional space for vehicles making U-turns at this location. Additionally, the southbound Wanamaker Avenue continuous right-turn movement conflicts with U-turns made from the eastbound Industrial Highway left-turn lane during the permitted phase. The signalization of this movement should be combined with this strategy. See operational improvement scenario #5 for details.

Operational Strategy – Signal Timing Improvement: Yellow and All-Red Signal Timing

- Ensure that the appropriate change and clearance intervals (yellow and all-red signal timing) are in use at the intersection.
  - Township officials have received phone calls of citizen concern regarding the change interval (yellow time) and clearance interval (all-red time) at the intersection, particularly in the northbound Wanamaker Avenue direction. DVRPC staff calculated the recommended intervals in order to determine if additional time is needed at this location. The calculations shown in Table 4 were completed using the methodology outlined by PennDOT[3], the posted speed limit, and estimated intersection widths.
  - The existing traffic signal timing uses 4.0 seconds for the change interval and 2.0 seconds for the clearance interval across the board. The existing change intervals are adequate for all directions. However, the existing clearance interval is inadequate for northbound Wanamaker Avenue, which should be modified to 3.5 seconds. The existing clearance intervals are adequate for all other directions. Many agencies do not use a

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[1] Pennsylvania Department of Transportation, *Design Manual-Part 2-Highway Design (Pub. 13M),* 8/2009, 3-5.
[2] American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets,* 2004, 710–711.
[3] Pennsylvania Department of Transportation, Traffic Signal Design Handbook (Pub. 149), 3/2009, 11-2.

clearance interval under 2.0 seconds; therefore the intervals do not need to be lowered to 1.1 seconds as shown in Table 5.

Table 4: Recommended Change Intervals

Change Interval				
Direction	Speed (mph)	Existing Change Interval (seconds)	Calculated Change Interval (seconds)	Recommended Change Interval (seconds)
Wanamaker Avenue – northbound	25	4.0	3.0	**4.0**
Wanamaker Avenue – southbound	40	4.0	4.0	**4.0**
Industrial Highway – eastbound	35	4.0	4.0	**4.0**
Industrial Highway – westbound	35	4.0	4.0	**4.0**

Source: DVRPC, 2010

Table 5: Recommended Clearance Intervals

Clearance Interval				
Direction	Width (feet)	Existing Clearance Interval (seconds)	Calculated Clearance Interval (seconds)	Recommended Clearance Interval (seconds)
Wanamaker Avenue – northbound	110	2.0	3.5	**3.5**
Wanamaker Avenue – southbound	65	2.0	1.5	**2.0**
Industrial Highway – eastbound	35	2.0	1.1	**2.0**
Industrial Highway – westbound	35	2.0	1.1	**2.0**

Source: DVRPC, 2010

Operational Strategies – Signal Timing Improvements: Four Synchro Scenarios

The operational strategies were refined so they could be simulated using Synchro software. Five scenarios were analyzed to determine their impact on the operational performance of the study intersection. Four of the scenarios involve revisions to the traffic signal timing or striping modifications. The fifth scenario involves modification of the signalization. Two additional scenarios were considered during the development of potential improvements for the intersection. These improvements were determined to be too costly for further consideration during the CCSAP process, but are included in Appendix B of this report for reference.

Summaries and tables are provided for each of the five scenarios tested. These results are for comparison to the existing LOS conditions documented in Chapter 3. The following five scenarios are described below:

1. Optimize the traffic signal.
2. Investigate split-phasing of the northbound and southbound approaches in order to accommodate the high volume of turning movements at the intersection.
3. Introduce an exclusive left-turn lane along the northbound approach of Wanamaker Avenue in order to ease the backup experienced during peak hours and special events.
4. Add a northbound left-turn lane and prohibit U-turns from the eastbound approach of Industrial Highway.
5. Combine scenarios #3 and #4 and signalize the southbound Wanamaker Avenue continuous right-turn lane.

Scenario #1 – Optimize the traffic signal

The Wanamaker Avenue and Industrial Highway intersection is incorporated within the coordinated signal system along Industrial Highway. This scenario tests the effects of optimizing the existing signal timing splits, while keeping the 120-second cycle lengh.

Characteristics

- Optimize the intersection splits while retaining the 120-second cycle length.

Advantages

- Timing modifications may be implemented in the short-term with little cost.
- Maintaining the 120-second cycle length allows coordination with the signal at Jansen Avenue.

Disadvantages

- This scenario does not provide a decrease in delay over the existing intersection timing plan in the afternoon peak hour.

LOS Analysis

The overall LOS for this scenario shows minimal and negative improvement during the morning and afternoon peak period, respectively. In the morning, the eastbound and westbound Industrial Highway approaches experience a reduction in delay. Compared to existing conditions, during the afternoon peak period the westbound approach experiences a 102-second reduction in delay. The delay on the remaining three approaches increases. This is a result of the fixed amount green time allocated for each approach. These results are shown in Table 6 below.

Table 6: LOS Analysis - Scenario 1

	Existing Condition				Scenario 1			
	AM		PM		AM		PM	
Direction	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS
Wanamaker Avenue – northbound	13	B	39	D	16	B	188	F
Wanamaker Avenue – southbound	17	B	21	C	23	C	81	F
Industrial Highway – eastbound	56	E	134	F	42	D	260	F
Industrial Highway – westbound	18	B	115	F	13	B	13	B
Total Intersection	**27**	**C**	**87**	**F**	**25**	**C**	**94**	**F**

Source: DVRPC, 2010

Scenario #2 – Split phasing of the northbound and southbound approaches

This scenario tests the effects of modifying the signal phasing to improve traffic flow through the intersection. Currently, the signal timing allows for the northbound and southbound approaches to move simultaneously; however, with the split-phase option, the southbound direction will complete its cycle followed by the northbound cycle.

Characteristics

- Retain the existing signal phasing for the Industrial Highway movements.
- Split the Wanamaker Avenue signal phases.

Advantages

- Timing modifications may be implemented in the short-term with little cost.
- Split-phase operation allows the turning movements to be completed during a protected phase, which minimizes the occurrence of left turn crashes involving northbound and southbound vehicles.
- Maintaining the 120-second cycle length allows coordination with the signal at Jansen Avenue.

Disadvantages

- Split-phase operation adds delay to the intersection.

LOS Analysis

Split-phase operation of the signal has a negative impact on the overall delay of the intersection. The southbound movement currently has a lead phase, which is followed by concurrent northbound/southbound movements. Splitting the northbound and southbound movements greatly increases the delay along both approaches, especially northbound. In comparison with existing conditions, the delay in the morning and afternoon on the northbound approach

increases by 54 and 134 seconds, respectively. There is minimal change in delay along the eastbound and westbound Industrial Highway approaches. These results are shown in Table 7 below.

Table 7: LOS Analysis - Scenario 2

	Existing Condition				Scenario 2			
	AM		PM		AM		PM	
Direction	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS
Wanamaker Avenue – northbound	13	B	39	D	67	E	173	F
Wanamaker Avenue – southbound	17	B	21	C	38	D	53	D
Industrial Highway – eastbound	56	E	134	F	43	D	134	F
Industrial Highway – westbound	18	B	115	F	16	B	115	F
Total Intersection	**27**	**C**	**87**	**F**	**37**	**D**	**109**	**F**

Source: DVRPC, 2010

Scenario #3 – Add a northbound exclusive left-turn lane

The third improvement scenario includes modification of the single northbound Wanamaker Avenue lane in order to also accommodate a left-turn lane. This can be accomplished by prohibiting on-street parking along the east side of the roadway and modifying the striping to add an exclusive left-turn lane. The 36-foot roadway width can be divided into a 14-foot southbound lane, a ten-foot left-turn lane, and a 12-foot through and right-turn lane. This scenario can operate on the existing signal timing plan or a split-optimized timing plan with minor adjustments to the signal controller. This idea has been discussed by township staff for several years. They feel that it is now possible.

Characteristics

- Restripe the northbound approach of the intersection to accommodate an exclusive left-turn lane.
- Retain the existing signal phasing for both the Wanamaker Avenue and Industrial Highway movements.

Advantages

- Striping modifications may be implemented with little cost.
- The addition of an exclusive left-turn lane prevents the blocking of traffic by left-turning vehicles stopped while waiting to make turns during permitted phasing.
- More northbound vehicles are able to pass through intersection, thus reducing delay, especially during the afternoon peak period.
- Maintains the 120-second cycle length, which allows coordination with the signal at Jansen Avenue.
- Township staff is supportive that this option would improve operations at the intersection.

Disadvantages

- This scenario does not provide a decrease in delay over the existing intersection configuration.
- Loss of on-street parking along the east side of Wanamaker Avenue.

LOS Analysis

The LOS analysis for this scenario shows minimal improvement over the LOS of existing conditions for the total intersection. The morning peak hour conditions are roughly equivalent with the existing conditions for the northbound approach. The additional lane is not able to be fully utilized during this time period due to the low volume of left turns made during the morning peak hour. However, in the afternoon peak hour, the delay in the northbound direction decreases by 15 seconds with the additional lane due to a left-turn volume three times that of the morning peak hour. Although the northbound approach sees improvement in the afternoon, the delay for the total intersection decreases by only two seconds. The results of the scenario with the existing signal timing plan are illustrated in Table 8.

Table 8: LOS Analysis - Scenario 3

	Existing Condition				Scenario 3			
	AM		PM		AM		PM	
Direction	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS
Wanamaker Avenue – northbound	13	B	39	D	12	B	24	C
Wanamaker Avenue – southbound	17	B	21	C	16	B	21	C
Industrial Highway – eastbound	56	E	134	F	56	E	134	F
Industrial Highway – westbound	18	B	115	F	18	B	115	F
Total Intersection	**27**	**C**	**87**	**F**	**27**	**C**	**85**	**F**

Source: DVRPC, 2010

Scenario #4 – Add a northbound left-turn lane and prohibit eastbound U-turns

The fourth improvement scenario includes modification of the northbound Wanamaker Avenue lane in order to also accommodate a left-turn lane (scenario #3), and adds the prohibition of eastbound U-turns. This scenario can also operate on the existing signal timing plan or a split optimized timing plan with minor adjustments to the signal controller. Additional signage will need to be designed and placed along the eastbound approach to the intersection to inform drivers that U-turns are not permitted at the intersection and direct them to a more appropriate location at the intersection of Jansen Avenue and Industrial Highway.

Characteristics

- Prohibit eastbound U-turn movements at the intersection with sufficient signage to be safe and effective.

Advantages

- Prohibition of eastbound U-turns will improve safety at the intersection because the conflict between U-turns and right-turns will be eliminated.
- This option directs drivers to where they can make a U-turn more safely.

Disadvantages

- This scenario does not provide a decrease in delay over the existing intersection configuration.
- The inconvenience to motorists being rerouted to make U-turns at Jansen Avenue.
- The cost associated with posting clear signage to a safer U-turn location.

LOS Analysis

Similarly to scenario #3, the LOS analysis for this scenario shows minimal improvement over the LOS of existing conditions for the total intersection. There is a slight improvement with a 15-second reduction in delay for the afternoon northbound approach. The results for the scenario under existing signal timing are illustrated in Table 9.

Table 9: LOS Analysis - Scenario 4

	Existing Condition				Scenario 4			
	AM		PM		AM		PM	
Direction	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS
Wanamaker Avenue – northbound	13	B	39	D	12	B	24	C
Wanamaker Avenue – southbound	17	B	21	C	15	B	19	B
Industrial Highway – eastbound	56	E	134	F	56	E	134	F
Industrial Highway – westbound	18	B	115	F	18	B	115	F
Total Intersection	**27**	**C**	**87**	**F**	**27**	**C**	**85**	**F**

Source: DVRPC, 2010

Scenario #5 – Combine scenarios #3 and #4 and signalize the southbound right-turn lane

The fifth improvement scenario includes the addition of a northbound left-turn lane and the prohibition of eastbound U-turns, but also includes the signalization of the southbound Wanamaker Avenue continuous right-turn lane. This can be accomplished by aligning the stop bar for the southbound right-turn lane with the other two approach lanes. The concrete divider island could remain, or could be removed. However, removal of the island would allow trucks and other large vehicles to have the additional space currently occupied by the island to maneuver the right turn, which could prevent the frequent knocking down of signs along the northwest corner of

the intersection. Signalization of the lane may be able to be accomplished by adding an additional signal head to the mast arm on the southwest corner. (An engineering study will be necessary to determine if the existing mast arm is capable of carrying the additional load).

Characteristics

- Retain the existing signal phasing for both the Wanamaker Avenue and Industrial Highway movements, but add protected and overlap indications for the southbound right turn. In this case, the southbound right turn would receive a green arrow indication at the same time as the non-conflicting eastbound and westbound left-turn arrows.

Advantages

- Signalization of the right turn will improve safety at the intersection because right turns will not be allowed during the westbound through movement.

Disadvantages

- This scenario does not provide a decrease in delay over the existing intersection configuration.
- The high cost associated with signalizing the right-turn lane.
- Removal of the concrete divider island between the southbound right and through lanes may be costly.
- Removal of the concrete divider island may make the intersection even more uncomfortable and dangerous for pedestrians.

LOS Analysis

As in the LOS analysis for scenario #4, this scenario shows minimal improvement over the LOS of existing conditions. The results of the scenario with the modification of the existing signal timing plan (including the signalization of the southbound right turn) are illustrated in Table 10.

Table 10: LOS Analysis - Scenario 5

	Existing Condition				Scenario 5			
	AM		PM		AM		PM	
Direction	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS
Wanamaker Avenue – northbound	13	B	39	D	12	B	24	C
Wanamaker Avenue – southbound	17	B	21	C	16	B	24	C
Industrial Highway – eastbound	56	E	134	F	56	E	134	F
Industrial Highway – westbound	18	B	115	F	18	B	115	F
Total Intersection	**27**	**C**	**87**	**F**	**27**	**C**	**86**	**F**

Source: DVRPC, 2010

Conclusions from Scenarios

None of the scenarios considered significantly decrease the delay at the intersection. However, all of the scenarios improve safety at the intersection, which cannot be directly measured through LOS analysis. Improving safety at this intersection will also improve operations by reducing the non-recurring congestion due to crashes.

Many of the strategies described in this chapter are graphically depicted in Figure 5.

Figure 5
Potential Improvements

PA 291 INDUSTRIAL HWY

W POWHATTAN AVE

PA 420 WANAMAKER AVE

CENTER AVE

POWHATTAN AVE

WANAMAKER AVE

SIGNALIZE SOUTHBOUND RIGHT-TURN

INCREASE NORTHBOUND CLEARANCE INTERVAL

INSTALL DUAL LEFT- TURN ARROWS

ELIMINATE SIGN CLUTTER AND CONSIDER OVERHEAD SIGNAGE
(Photo for illustration purposes only - not actual location)

ELIMINATE ON-STREET PARKING AND STRIPE AN EXCLUSIVE LEFT-TURN LANE

N

0 25 50
Feet

Aerial Imagery:
City of Philadelphia, 2008

dvrpc

CHAPTER 6

Recommendations

Representatives from Delaware County Planning Department, Tinicum Township, PennDOT, and DVRPC worked together and developed a set of recommendations. The agreed-upon recommendations should provide safety and operational benefits for the intersection of Wanamaker Avenue and Industrial Highway.

The majority of the recommendations are short-term. These types of recommendations are generally low cost. The short-term recommendations are listed in Table 11.

Table 11: Short-term Recommended Improvements

Issue	Recommended Improvement
Given the northbound approach lane configuration of Wanamaker Avenue, traffic backs up through the railroad crossing south of the intersection during peak hours.	■ Add a northbound left-turn lane along northbound Wanamaker Avenue. This effort will allow more northbound vehicles to exit through the intersection and minimize back up. **The township had funding available prior to the release of this report and has moved forward with implementing this recommendation.**
Conflicts between vehicles eastbound on Industrial Highway making U-turns at the intersection and vehicles traveling westbound on Industrial Highway and southbound on Wanamaker Avenue making right-turns.	■ Prohibit U-turns for eastbound Industrial Highway traffic, where they are currently made in a dangerous manner, and instead add signage directing drivers to the next light at Jansen Avenue where U-turns can be made more safely. This will help to eliminate potential conflict with southbound right-turn movements as well as westbound through movements.
There is no lane control guidance for the southbound left turns onto Industrial Highway or Powhattan Avenue.	■ Install dual left turn arrows (pavement markings and overhead signage) for southbound Wanamaker Avenue in front of St. Margaret Church.
Drivers have submitted complaints that they do not receive enough yellow and all-red time to clear the intersection in the northbound direction. Analysis indicates this is a valid issue.	■ Increase the northbound all-red time to 3.5 seconds to provide an adequate clearance interval (all red time).
Signage clutter near the eastbound approach.	■ Install a mast arm with directional signage over eastbound Industrial Highway. This effort would be done in conjunction with removal of some signage to reduce clutter at the intersection.

Source: DVRPC, 2010

Table 11: Short-term Recommended Improvements (continued)

Issue	Recommended Improvement
Drivers are not yielding to pedestrians crossing at continuous right-turn lanes on north side of Wanamaker Avenue. The two concrete islands on north side of intersection do not provide much protection for pedestrians crossing Wanamaker Avenue.	■ Enhance pedestrian refuge islands and increase enforcement patrols. ■ Erect "Yield to Pedestrian in Crosswalk" signs

Source: DVRPC, 2010

One medium-term improvement was identified for recommendation. It is recognized that this improvement is likely not a low-cost option but could provide some additional benefit in improving safety in the area and should be kept as a potential future consideration. The medium-term recommendation is listed in Table 12.

Table 12: Medium-term Recommended Improvement

Issue	Recommended Improvement
Conflicts between vehicles eastbound on Industrial Highway making U-turns at the intersection and vehicles traveling westbound on Industrial Highway and southbound on Wanamaker Avenue making right turns.	■ Signalize the southbound right turn lane. This effort would work in conjunction with the prohibition on U-turns for eastbound Industrial Highway traffic.

Source: DVRPC, 2010

APPENDIX A

Study Advisory Committee Members

Table A-1: Study Advisory Committee Members

Name	Organization	Title
Lou Hufnagle	Delaware County Planning Department	Transportation Planner
Paul Lutz	PennDOT District 6-0 – Traffic Unit	Senior Civil Engineer Supervisor
Herb MacCombie III	Tinicum Township	Township Engineer
David Schreiber	Tinicum Township	Township Manager
Chief Ralph Slatten Jr.	Tinicum Township	Chief of Police
Tricia Fought	DVRPC	Senior Transportation Engineer
Regina Moore	DVRPC	Transportation Engineer
Zoe Neaderland	DVRPC	Manager, Transportation Safety and Congestion Management

Source: DVRPC, 2010

APPENDIX B

Additional Improvement Scenarios

Two additional improvement scenarios were considered during the development of the potential improvements process. These scenarios require extensive geometric modifications at the intersection and were determined to be too costly for further consideration during the CCSAP process. However, the analyses for these scenarios are included in the document for reference purposes.

Improvement Scenario 6 – Three lanes along northbound Wanamaker Avenue

The sixth improvement scenario includes modification of the northbound Wanamaker Avenue lanes in order to accommodate three northbound lanes. This scenario requires that the existing 36-foot roadway width be widened by two feet on each side of the roadway in order to obtain a 40-foot width. This allows for four 10-foot lanes; one southbound lane, and three northbound lanes (a left-turn lane, a through lane, and a right-turn lane). This scenario can operate on the existing signal timing plan or a split optimized timing plan with minor adjustments to the signal controller.

Characteristics

- Widen the northbound approach to the intersection to accommodate an exclusive left-turn lane and an exclusive right-turn lane.
- Retain the existing signal phasing for the Industrial Highway movements.

Advantages

- The addition of an exclusive left-turn lane prevents the blocking of traffic by left turning vehicles stopped while waiting to make turns during permitted phasing.
- The addition of an exclusive right-turn lane adds capacity to the approach.
- Optimization will provide splits that are more appropriate for the peak hour traffic patterns.
- Maintaining the 120-second cycle length allows coordination with the signal at Jansen Avenue.

Disadvantages

- This scenario requires the widening of the roadway width by four feet (two-feet on each side of the roadway). This may be complicated to implement and makes the location likely less desirable for pedestrians and bicyclists.
- This scenario does not provide a decrease in delay over the existing intersection configuration.
- This scenario would be high in costs.

LOS Analysis

Similar to scenario three, the LOS analysis of scenario six shows little improvement over the LOS of existing conditions. In the afternoon peak hour, the delay in the northbound direction decreases by 16 seconds with the addition of the exclusive turn lanes, but the overall delay decreases by only two seconds. The morning peak hour conditions are virtually unchanged compared to the existing conditions. The results of the scenario with the existing signal timing plan (including the signalization of the southbound right turn) are shown below in Table B–1.

Split optimization of the signal timing results in decreased delay for the eastbound and westbound approaches in the morning peak hour, but slight increases for the remaining movements. In the afternoon peak hour, the delay of the westbound movement is significantly decreased, but at the cost of increased delay on the other approaches. The results of the scenario with split optimized timing are shown in Table B–2.

Table B–1: LOS Analysis - Scenario 6

	Existing Condition				Scenario 6			
	AM		PM		AM		PM	
Direction	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS
Wanamaker Avenue – northbound	13	B	39	D	12	B	23	C
Wanamaker Avenue – southbound	17	B	21	C	16	B	20	B
Industrial Highway – eastbound	56	E	134	F	56	E	134	F
Industrial Highway – westbound	18	B	115	F	18	B	115	F
Total Intersection	**27**	**C**	**87**	**F**	**27**	**C**	**85**	**F**

Source: DVRPC, 2010

Table B–2: LOS Analysis - Scenario 6 Optimized

	Existing Condition				Scenario 6 Optimized			
	AM		PM		AM		PM	
Direction	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS
Wanamaker Avenue – northbound	13	B	39	D	16	B	36	D
Wanamaker Avenue – southbound	17	B	21	C	23	C	77	E
Industrial Highway – eastbound	56	E	134	F	39	D	299	F
Industrial Highway – westbound	18	B	115	F	12	B	15	B
Total Intersection	**27**	**C**	**87**	**F**	**24**	**C**	**85**	**F**

Source: DVRPC, 2010

Improvement Scenario 7 – Dual left-turn lanes along eastbound Industrial Highway

The seventh improvement scenario includes modification along the eastbound approach of Industrial Highway. This modification converts the inside through lane into a left-turn lane, creating dual left-turn lanes in the eastbound direction. Additionally, this scenario requires the signalization of the westbound continuous right-turn lane due to the necessary removal of the channelization island. This right turn may operate in a permitted and overlap phasing plan.

Two alternative methods of creating the second left-turn lane were considered. The first alternative, 7A, is a striping only modification, which would be less costly but potentially confusing to drivers. The second, 7B, modifies the geometry of the eastbound lanes by first closing the inside through lane with a merge taper which creates a second storage lane. Storage and taper lengths were estimated for this alternative using the PennDOT *Conventional Pavement Markings* standards[4]. Both alternatives resulted in the same LOS in the morning and afternoon peak hours for both the existing and optimized timing plans.

The striping-only modification alternative (7A) is the preferable of the two due to its lower price of implementation. However, this alternative should include the addition of advance lane control signing, preferably mounted on a mast arm over the travel lanes.

Characteristics

- Restripe the eastbound approach to accommodate an additional exclusive left-turn lane.
- Signalize the westbound right turn movement.
- The dual left turns are protected-only.
- Consider optimizing the intersection splits while maintaining a 120-second cycle length.

Advantages

- An additional left-turn lane prevents backup of left turning vehicles into the adjacent eastbound through lane.
- The eastbound left turn signal protection will greatly minimize the risk of left turn angle crashes involving eastbound left-turning vehicles and westbound through movement vehicles.
- Optimization will provide splits that are more appropriate for the peak hour traffic patterns.
- Maintaining the 120-second cycle length allows coordination with the signal at Jansen Avenue.

Disadvantages

- This scenario requires the signalization of the westbound right turn movement which currently operates as a continuous right turn.

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[4] Pennsylvania Department of Transportation, Traffic Control-Pavement Markings and Signing Standards (Pub. 111M), 5/2007, TC-8600 3/11.

- This scenario also requires that the left turns have a protected only phase, which reduces the amount of green time received for the movement.
- Striping the inside through lane as a left-turn only lane at this intersection may be confusing to drivers.
- This alternative has a relative high cost.

LOS Analysis

Creating dual left-turn lanes increases the delay for the intersection due to the requirement that dual left turns receive a protected phase and that the westbound right turn be signalized. Optimization of the signal timing in the morning peak hour reduces the overall intersection delay by 11 seconds and raises the LOS from D to C. In the afternoon peak hour, the delay for the intersection is also increased significantly in the westbound direction due to the need to signalize the right turn movement. Optimization in the afternoon peak hour improves the delay by 22 seconds, but is still LOS F.

Split optimization of this scenario greatly improves the overall LOS for the intersection over the existing timing plan. However, the optimized timing plan does not reduce the delay to a level that is lower than the delay under the existing conditions at the intersection. Table B–3 shows the LOS results for the scenario under existing signal timing, while Table B–4 shows the LOS results for split optimized signal timing.

Table B–3: LOS Analysis - Scenario 7A

	Existing Condition				Scenario 7A			
	AM		PM		AM		PM	
Direction	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS
Wanamaker Avenue – northbound	13	B	39	D	25	C	278	F
Wanamaker Avenue – southbound	17	B	21	C	28	C	50	D
Industrial Highway – eastbound	56	E	134	F	90	F	52	D
Industrial Highway – westbound	18	B	115	F	33	C	205	F
Total Intersection	**27**	**C**	**87**	**F**	**45**	**D**	**147**	**F**

Source: DVRPC, 2010

Table B–4: LOS Analysis - Scenario 7A Optimized

	Existing Condition				Scenario 7A Optimized			
	AM		PM		AM		PM	
Direction	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS
Wanamaker Avenue – northbound	13	B	39	D	17	B	218	F
Wanamaker Avenue – southbound	17	B	21	C	16	B	44	D
Industrial Highway – eastbound	56	E	134	F	71	E	165	F
Industrial Highway – westbound	18	B	115	F	30	C	130	F
Total Intersection	**27**	**C**	**87**	**F**	**34**	**C**	**125**	**F**

Source: DVRPC, 2010

APPENDIX C

References

The following resources were used as references in this report.

Publications

- American Association of State Highway and Transportation Officials. *A Policy on Geometric Design of Highways and Streets*. Washington, DC: AASHTO, 2004.
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- Pennsylvania Department of Transportation. *Traffic Signal Design Handbook (Pub. 149)*. 3/2009.

Additional Resource

- Herbert E. MacCombie, Jr., P.E. Consulting Engineers and Surveyors, Inc.. *The Industrial Heritage Highway – East Coast Greenway Trail Project along Route 291 Corridor*. April 3, 2009 Revision.

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Abstract:

This document represents the findings and recommendations for the Delaware County Congestion and Crash Site Analysis Program. This Program represents an effort to improve the mobility and safety on roadways in the DVRPC region. The goal of the program is to identify cost-effective improvement strategies that will reduce congestion and crashes and improve mobility and safety for all road users.

Working with Delaware County Planning Department, the intersection of Industrial Highway/Governor Printz Boulevard (PA 291) and Wanamaker Avenue (PA 420) was chosen for analysis. This intersection was identified as having congestion and safety issues. In-depth crash and level of service analyses were performed to quantify and gain an understanding of the issues. With input from the advisory committee, improvement strategies were identified to address the issues. As appropriate, proposed improvement strategies were tested for level of effectiveness.

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