pennsylvania
DEPARTMENT OF TRANSPORTATION

SMART Intersections

FINAL REPORT

May 2022

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Kittelson & Associates, Inc.

KITTELSON & ASSOCIATES

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION

CONTRACT # E04696
WORK ORDER # 001

DEPARTMENT OF TRANSPORTATION
UNITED STATES OF AMERICA

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-PA-2022-003-E04696 WO 001		

4. Title and Subtitle	5. Report Date
SMART Intersections	May 13, 2022
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Kittelson & Associates, Inc. Transoft Solutions, Inc. Rybinski Engineering, LLC The Pennsylvania State University Imperial Traffic & Data Collection, LLC LingaTech, Inc.	

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Kittelson & Associates, Inc. 922 N. 3rd Street, 1st Floor Harrisburg, PA 17102	11. Contract or Grant No. E04696 WO 001

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
The Pennsylvania Department of Transportation Bureau of Planning and Research Commonwealth Keystone Building 400 North Street, 6th Floor Harrisburg, PA 17120-0064	Final Report (October 2020 to May 2022) 14. Sponsoring Agency Code

15. Supplementary Notes
PI Contact Information: Shannon Warchol, 922 N. 3rd Street, 1st Floor, Harrisburg, PA 17102.

16. Abstract

The Pennsylvania Department of Transportation (PennDOT) is seeking to better understand how vulnerable road users such as pedestrians and bicyclists interact with motor vehicles at signalized intersections. PennDOT intends to use that information to target and deploy engineering countermeasures more appropriately to increase the safety performance. This study used video-based conflict monitoring and crash data to assess interactions of all road users, conflicts, and actual crashes at selected intersections throughout Pennsylvania. Fifteen intersections (one pilot study site, six sites based on crash data, six sites based on known qualitative conflict data/information, and two sites for potential before-after study) were selected for analysis in this study. The sites were selected using historic crash data, existing public open data sources (AADT, bicycle routes, and census data), and input from local jurisdictions. These 15 intersections were monitored over multiple days and video analysis technology was used to measure the post encroachment time (PET) between vulnerable road users (VRU) and motor vehicles. Other traffic and land use data were collected by the study team and used in addition to the video analytics to better understand how pedestrians and bicyclists interact with motor vehicles at intersections. Essential data in this study included PETs, traffic counts, road user types, land use characteristics, traffic signal-related information, and motor vehicle speeds. PET, or the time between the first road user leaving a common spatial point and the second road user arriving at the same point, was used to identify critical events, defined as events with PETs of less than three seconds. Up to 100 critical events were selected and the video data were manually reviewed to confirm if the critical event was a conflict – such confirmed events are referred to as confirmed conflicts. The objective of this study was to explore the relationship between critical events and confirmed conflicts, as well as the influence of other site features. A key finding of this study was that agencies can use critical events identified by video-based event monitoring technology as surrogates for crashes in evaluating VRU safety performance at intersections. While crashes are rare enough that patterns are difficult to discern, critical events occur in sufficient quantity to shed light on repeated interactions between VRUs and motor vehicles that may or may not result in crashes, depending on other contributing factors. This study developed a proposed process for using critical event data and validated the process through five case studies.

17. Key Words	18. Distribution Statement
Intersections, safety performance, critical events, conflicts, vulnerable road user, post encroachment time, crashes	No restrictions. This document is available from the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	68	

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION

SMART INTERSECTIONS
FINAL REPORT

MAY 2022

pennsylvania
DEPARTMENT OF TRANSPORTATION

Project Number 247330

E04696 Smart Intersections: Understanding How Pedestrians and Bicyclists Interact with Motor vehicles at Intersections

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This work was sponsored by the Pennsylvania Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

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EXECUTIVE SUMMARY

WHAT IS A SMART INTERSECTION?

A smart intersection uses technology to document and evaluate how pedestrians, bicyclists, and vehicles interact. Smart intersection tools help us carefully time and analyze user interactions so we can better select, implement, and evaluate countermeasures against conflicts and crashes.

WHAT IS A VULNERABLE ROAD USER (VRU)?

The term "vulnerable road user" means a nonmotorist that falls within the following two categories defined by the Federal Highway Administration.

(A) A nonmotorist with a fatality analysis reporting system person attribute code that is included in the definition of the term 'number of non-motorized fatalities' in section 490.205 of title 23, Code of Federal Regulations (or successor regulations)

(B) A nonmotorist described in the term 'number of non-motorized serious injuries' in that section[1].

A VRU crash indicates a crash that includes both a motor vehicle and a pedestrian, pedestrian conveyance (wheelchair, scooter, skateboard, etc.), bicyclist (not including e-bikes), or other pedalcyclist.

1 The definition of vulnerable road user is provided in 23 U.S.C. 148(a)(15), https://safety.fhwa.dot.gov/hsip/rulemaking/docs/Section148_SpecialRule_Guidance.pdf, February 2022.

Pedestrians and bicyclists are vulnerable road users.

CONFLICTS AS A SAFETY INDICATOR

Vulnerable road users, like pedestrians and bicyclists, are at greater risk in the event of a crash than vehicle drivers and their passengers.

Collecting accurate pedestrian and bicycle volumes is difficult. Gathering data on crashes involving pedestrians and bicyclists requires long study periods and presents data that is difficult to interpret. Because of this, calculating crash rates on a per-user basis is infeasible. Relying exclusively on crash data means waiting for crashes—and the resulting injuries and fatalities—to happen before taking preventative action.

Because we know pedestrians and bicyclists are more likely to suffer serious injuries and fatalities than vehicle occupants, especially because they are unprotected by an outside shield, this study explored whether video analytics can provide more timely information about critical events and confirmed conflicts. We found that video analytics offer engineers an important tool to use alongside crash data when selecting intersection countermeasures. This report proposes a process for using critical events to select and evaluate intersection countermeasures.

WHAT IS AN EVENT?

Broadly speaking, an event describes the relationship between two road users at a given point on the roadway. We measure this relationship using **post-encroachment time** (PET), which is the time between one road user leaving a given point on a roadway and a second road user arriving at that same point. A PET of zero seconds indicates a crash has occurred. While crash data only covers PET zero-second events, this methodology provides a larger data set that encompasses a wider range of events.

For this study, we described three different types of events:

- **Critical Events**, which have a PET of three seconds or less.
- **Potential Events**, which have a PET between three and five seconds.
- **Other Interactions**, which have a PET of more than five seconds.

WHAT IS A CONFIRMED CONFLICT?

A confirmed conflict is a critical event that has been reviewed by an engineer and deemed a conflict given the involved road users' proximity, evasive action, and awareness.

USING DATA TO MAKE PENNSYLVANIA'S INTERSECTIONS SMARTER

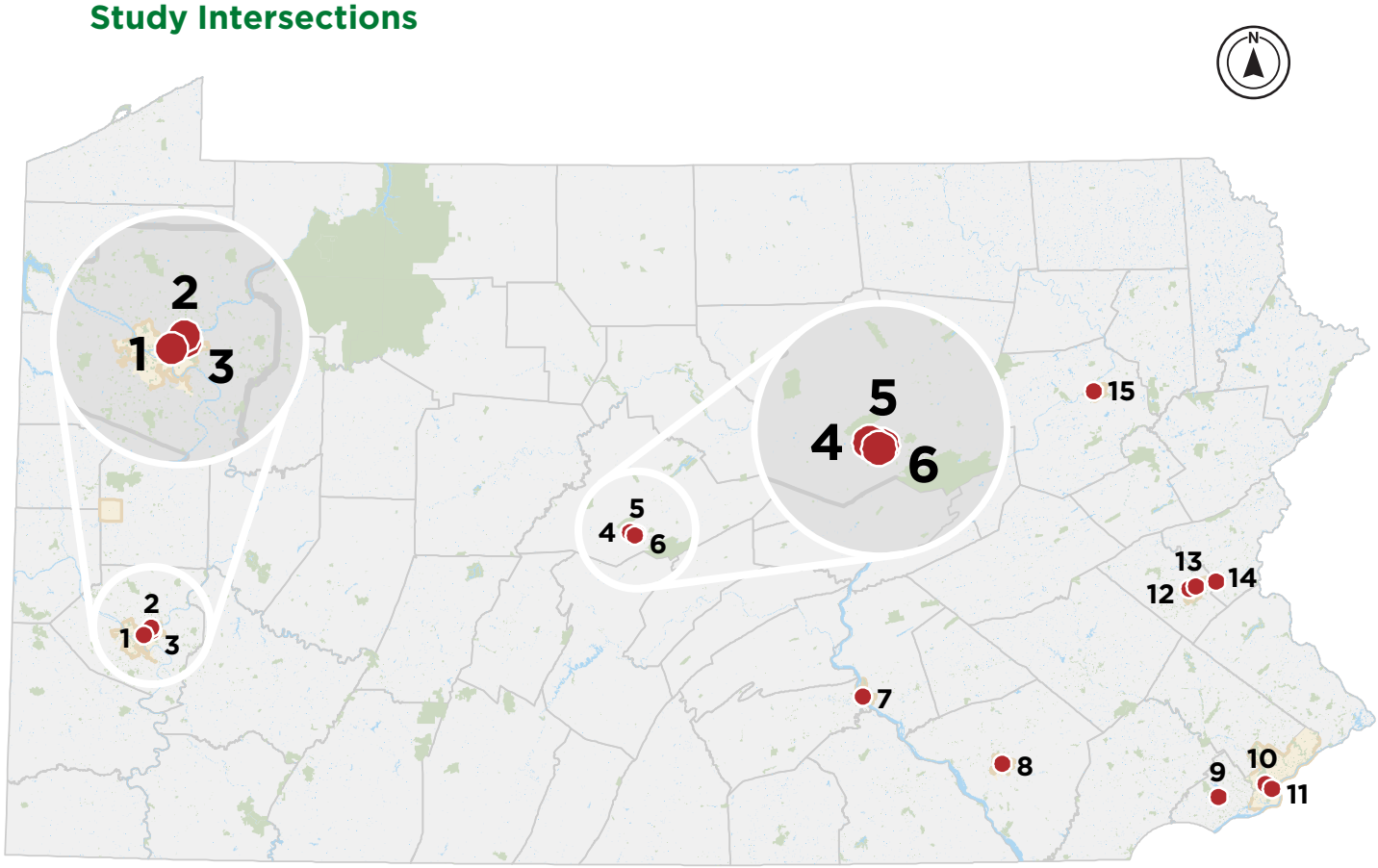
Researchers selected 15 urban and suburban intersections across Pennsylvania to serve as study sites for the smart intersection process. Some intersections had known crash histories and others were recommended by local practitioners based on frequent conflicts.

At each intersection, the study team collected and analyzed one week of video data for all events with PETs less than 10 seconds. Then, to determine the percentage of critical events that could be confirmed as conflicts, they selected 100 critical events for human review. They also collected five years of crash data for each intersection.

The team then combined critical event, confirmed conflict, and crash data to determine whether and how well event data can predict crashes.

Look for this icon to find innovative ways PennDOT can incorporate smart intersection data analysis.

Study Intersections



1. Bigelow Boulevard & Bayard Street (Pittsburgh)
2. Negley Avenue & Stanton Avenue (Pittsburgh)
3. Centre Avenue & Penn Avenue (Pittsburgh)
4. Blue Course Drive & N. Atherton Street (State College)
5. E. College Avenue & Garner Street (State College)
6. E. College Avenue & N. Atherton Street (State College)
7. Forster Street & Front Street (Harrisburg)
8. Queen Street & Orange Street (Lancaster)
9. W. Baltimore Avenue & S. Orange Street (Media)
10. Market Street & 34th Street (Philadelphia)
11. Washington Avenue & Broad Street (Philadelphia)
12. Hamilton Street & 17th Street (Allentown)
13. Hamilton Street & 4th Street (Allentown)
14. Center Street/W. Lehigh Street & New Street (Bethlehem)
15. Market Street & S. River Street (Wilkes-Barre)

Underlined intersections' case studies can be found in Chapter 5.

Vehicle Conflicts with Pedestrians

94% of all critical events

29% vehicle left turn

35% vehicle through

36% vehicle right turn

Vehicle Conflicts with Bicycles

6% of all critical events

32% vehicle left turn

37% vehicle through

31% vehicle right turn

The appendix of this report contains a fact sheet for each intersection analyzed in this study. The fact sheets provide

- A breakdown of the critical events identified at the intersection;
- A visualization of how critical events fluctuate over time of day;
- Demographics of the critical events, such as the percentage of events involving pedestrians versus bicyclists as well as the movement of vehicles involved in critical events; and
- Key takeaways specific to the intersection.

CHAPTER 1

CAPTURING INCIDENTS ON VIDEO

Video monitoring provides important and useful data on traffic volumes, speed, and near-crash conflict indicators.

HOW DOES VIDEO MONITORING WORK?

The team collected one week of videos at each site, and computer software identified events involving interactions between VRUs and vehicles. For each event, the software program automatically recorded user speed, location, and movements along with the time of the event and the event's PET. The software also tabulated information about total volumes by user type and the speed, movement, and location of each road user, whether they were involved in an event or not.

ANALYSIS

The research team looked at the speed data to determine if users followed typical behavior patterns.

Key Findings

Vehicle speeds showed that vehicle users met typical expectations:

Vehicle speeds were lower in college environments compared to urban and suburban environments.

Across all three land use contexts, left- and right-turning vehicle speeds were lower than through-vehicle speeds.

Across all three land use contexts, vehicle speeds were lower than the posted speed limits. The vehicle speeds increased as the posted speed limit increased, among intersection approaches.

The research team also looked for connections between

- Confirmed conflict counts
- Critical event counts
- User volumes
- User speeds
- User movements (left turns, right turns, or through movements)
- Intersection features such as land use, number of lanes, left-turn phasing, permissibility of right turn on red, presence of trails, presence of channelized turn lanes
- Event and conflict time of day

Key Findings

- **10 percent of pedestrians and 12 percent of bicyclists** who interact with other road users are involved in **critical events**.
- About **one-third of pedestrians** involved in critical events interact with right-turning vehicles (35 percent) and one-third interact with through vehicles (36 percent). Similarly, about **one-third of bicycles** involved in critical events interact with left-turning vehicles (33 percent) and about one-third interact with through vehicles (39 percent).
- **No common features** were identified among intersections with the highest critical event rates per 10,000 pedestrians.

CHAPTER 2

CONNECTING CRITICAL EVENTS TO CONFIRMED CONFLICTS

Are some types of critical events more likely to be confirmed conflicts?

Not all critical events are confirmed conflicts. The team reviewed 100 critical events at each intersection to determine which were confirmed conflicts. Using this information, the team then analyzed the relationship between critical events and confirmed conflicts. By understanding the link between critical events and confirmed conflicts, engineers can better draw conclusions about the intersection from computer-generated critical event data alone, without the time-intensive process of visually identifying each conflict.

Key Findings

- On average across all intersections, **five percent of critical events resulted in confirmed conflicts** (standard deviation of two percent). Therefore, for every 20 critical events, you can expect one confirmed conflict.
- One outlier site, Broad and Washington in Philadelphia, had **a confirmed conflict rate of 28 percent**. This site's unusually high pedestrian road-user volumes (42 percent) may account for the higher confirmed conflict rate.
- **We did not observe an increased rate of confirmed conflicts by movement type.** For example, a right-turn critical event is no more likely to be a confirmed conflict than a through-movement or left-turn critical event.

Key Terms

Critical Events have a PET of three seconds or less.

CRITICAL EVENT

Confirmed Conflicts are critical events that have been reviewed by an engineer and deemed a conflict given the involved road users' proximity, evasive action, and awareness.

CHAPTER 3

USING CONFIRMED CONFLICT DATA TO INFORM POTENTIAL CRASH ISSUES

What can confirmed conflicts tell practitioners about potential crash issues?

For each intersection, the team compared one week of confirmed conflict data to five years of crash data to understand how well confirmed conflicts can predict crash patterns.

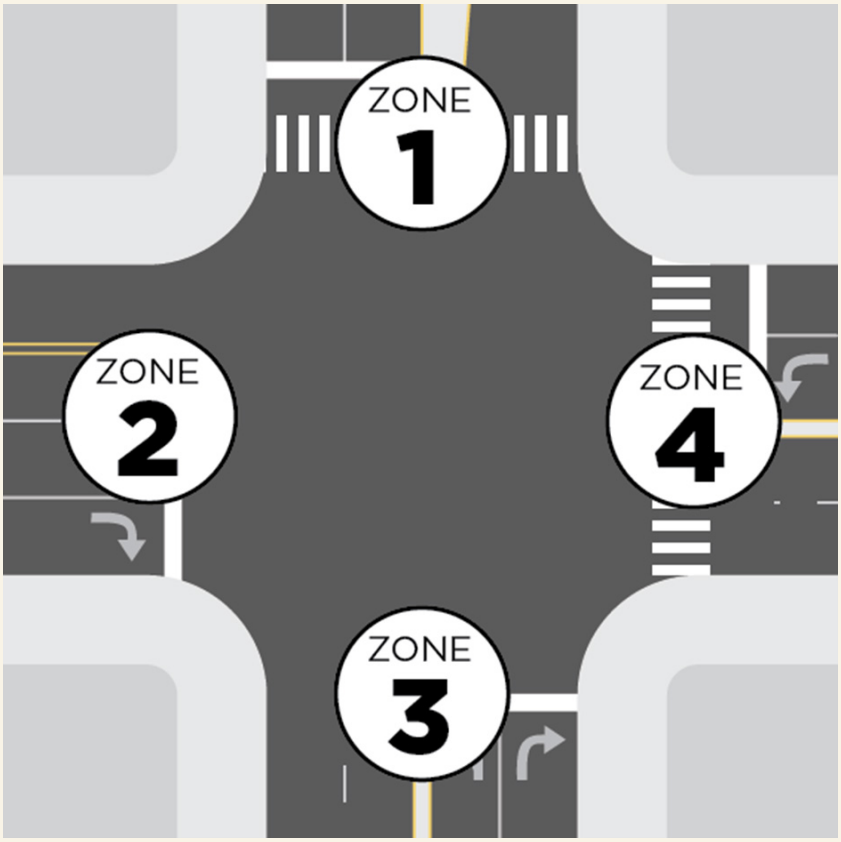
Key Findings

The presence of at least one confirmed conflict in a one-week study period indicates you will more likely see a crash at the same intersection within a five-year period.

1

- About **75 percent of the intersections with confirmed vehicle-pedestrian conflicts** during the one-week study period had a vehicle-pedestrian crash over the five-year study period.
- About **60 percent of the intersections with confirmed vehicle-bicycle conflicts** during the one-week study period had a vehicle-bicycle crash over the five-year study period.
- There is a connection between the location of the crash and the location of the confirmed conflict. If a confirmed conflict was observed in a specific zone at a given intersection, there was about a **60 percent chance of seeing a crash in the same zone over the five-year study period**.

Figure: Illustration of four zones at each intersection



2 A vehicle's maneuver in a confirmed conflict is highly indicative of a vehicle's maneuver in a crash at the same intersection.

NINE INTERSECTIONS had a crash involving a left-turning vehicle and a VRU; eight of these intersections had a confirmed conflict between a left-turning vehicle and VRU.

NINE INTERSECTIONS had a crash involving a through-moving vehicle and a VRU; all nine of these intersections had a confirmed conflict between a through-vehicle and a VRU.

TWO INTERSECTIONS had crashes involving a right-turning vehicle and a VRU; both of these intersections had a confirmed conflict between a right-turning vehicle and a VRU.

3 An increase in confirmed conflicts at an intersection in the one-year study period did not result in an increased likelihood or higher count of crashes at that intersection over the five-year period.

CHAPTER 4

USING CRITICAL EVENT DATA FOR RAPID COUNTERMEASURE EVALUATION

How can critical event data be used to evaluate intersections and countermeasures?

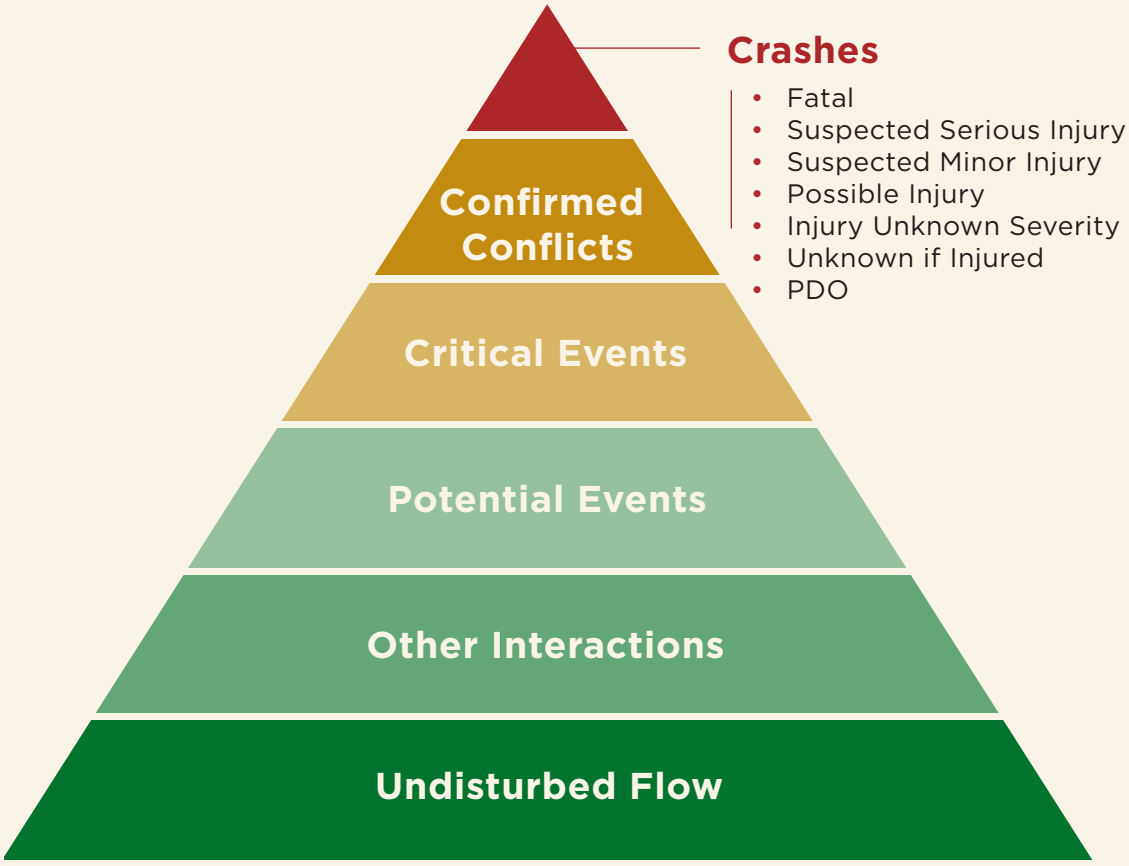
Conflict data can help agencies rapidly select and evaluate low-cost countermeasures as a first line of defense. If greater improvement is still needed, agencies can quickly respond with additional countermeasures.

HOW CAN CONFLICT DATA BE USED TO EVALUATE INTERSECTIONS?

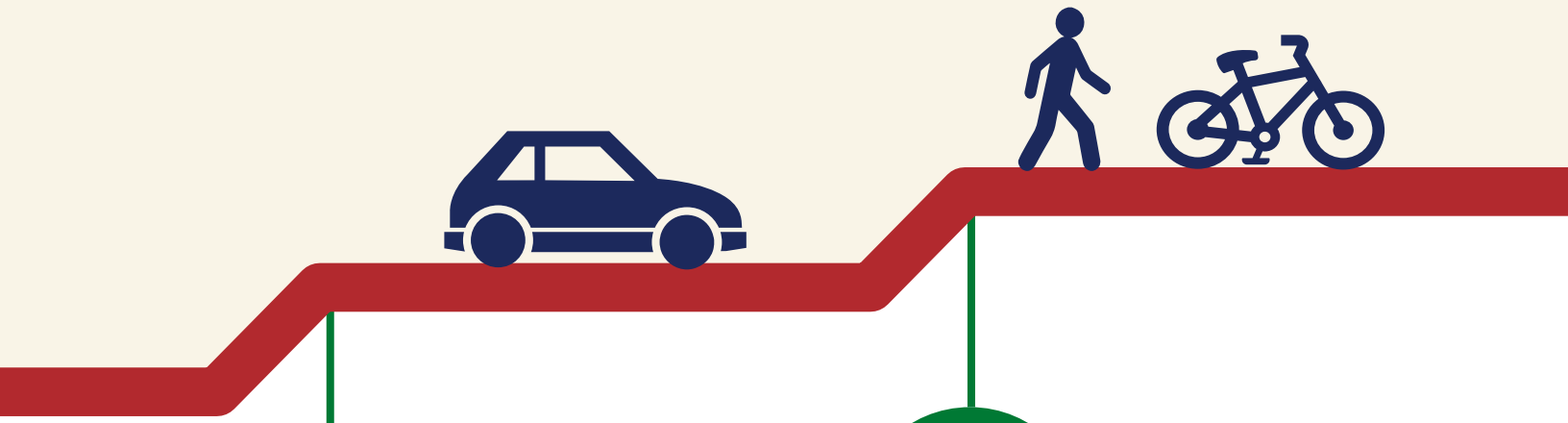
Even though technology exists to measure and flag unsafe interactions between road users, identifying confirmed conflicts within that data is still a manual and time-consuming process.

When evaluating VRU safety at intersections, agencies can instead use critical events as surrogates for crashes. Crashes are rare enough that their patterns can be difficult to spot. Critical events, however, happen often enough to reveal recurring issues between VRUs and vehicles. Detecting events that could ultimately result in a crash helps agencies intervene before crashes happen.

Only looking for crashes obscures the size of the problem.



PROCESS



STEP 1

Conduct a **one-week conflict assessment** between vehicles and VRUs.

STEP 2

Evaluate the critical events using the following rules:

- For every 20 critical events, it's likely one would be considered a confirmed conflict by an engineer.
- If there are more than 20 critical events at an intersection and the intersection remains unchanged, it is more likely a crash has happened or will happen within a five-year period.[2]
- If a high critical event count (more than 20) is clustered in an intersection zone, it is more likely a crash will happen, or has happened, in the same zone.

2 This rule is solely based on key finding #1: "The presence of at least one confirmed conflict in a one-week study period indicates you will more likely see a crash at the same intersection within a five-year period" (see chapter 3).

STEP 3

Identify, select, and install **countermeasures.**

STEP 4

Conduct a **one-week conflict assessment** between vehicles and VRUs.

This can happen as soon as road users have become accustomed to the new environment.

STEP 5

Evaluate critical event data from the after period one-week assessment, selecting and installing additional countermeasures if needed.

Real world examples of how the conflict data evaluation process works

BEFORE AND AFTER

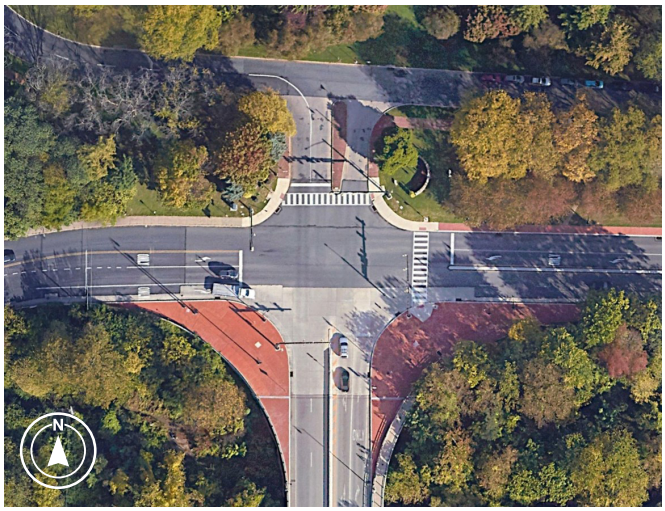
CENTER STREET/W LEHIGH STREET AND NEW STREET

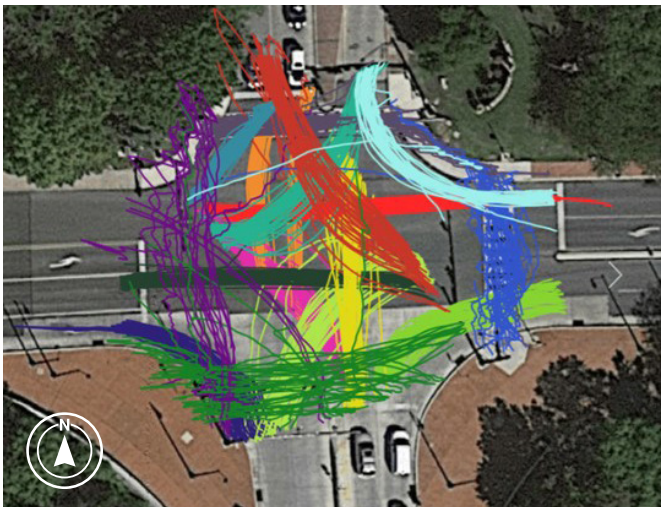
Bethlehem, PA

REASON FOR SELECTING THE LOCATION

In June 2021, the signalization for northbound right-turning vehicles from New Street to Center Street was modified to include a flashing yellow arrow with the standard red, yellow, and green arrows. We conducted a before-and-after study to determine whether conflict patterns and safety performance changed at this intersection. The study period covered the seven days before and after the implemented change.

In the figures below, you'll see the intersection and the road user trajectories. The accompanying table shows the average hourly volumes for drivers, pedestrians, and bicyclists.





Average Hourly Volumes

Driver—Left Turn	Driver—Through	Driver—Right Turn	Pedestrian	Bicycle
890	537	1,260	50	19

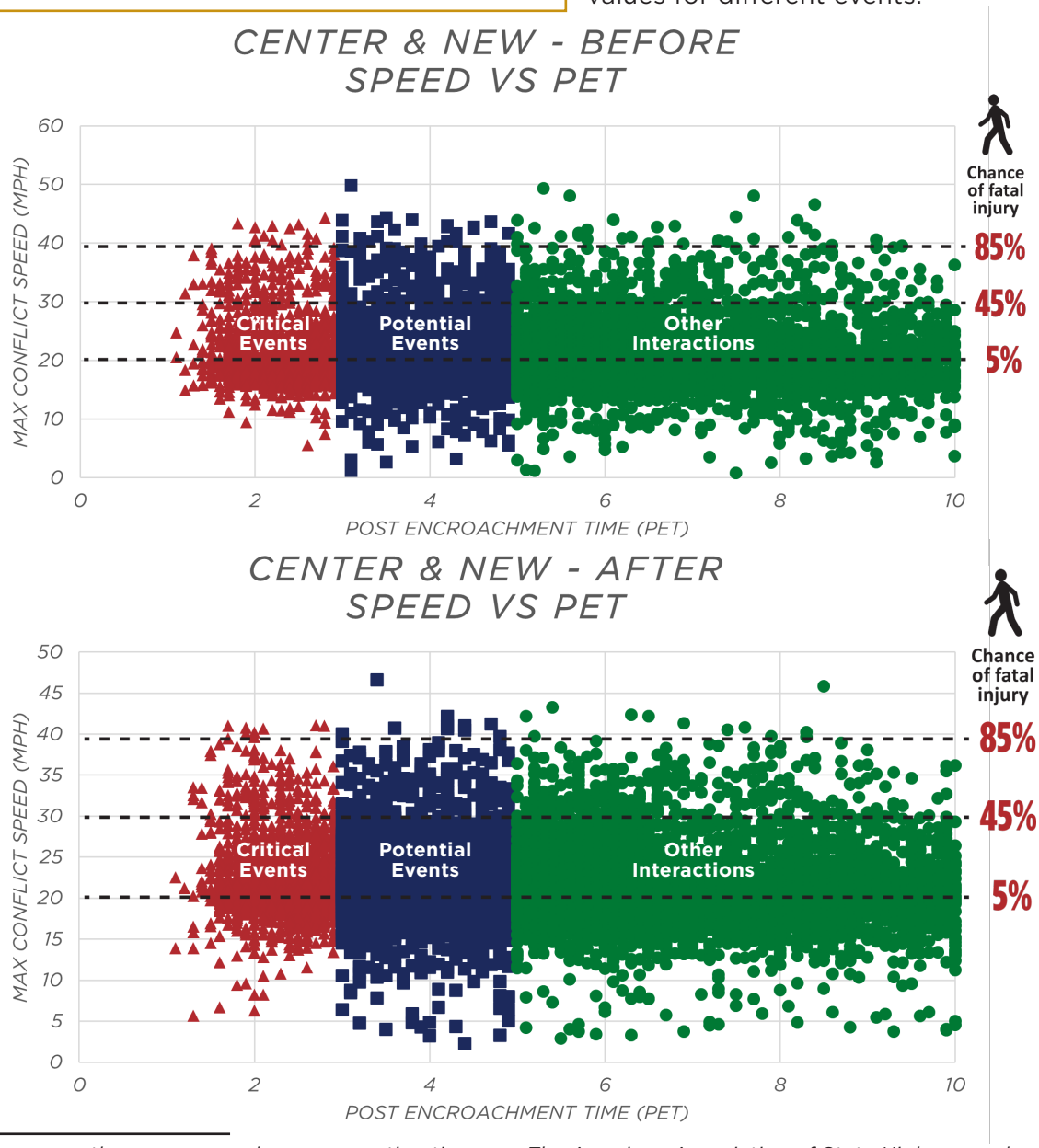
WHAT DOES THE DATA SHOW?

SEVERITY

The severity of the interactions at this intersection can be classified based on the post encroachment time (PET) and speed values.

Remember: A lower PET indicates a situation in which a crash was more likely to occur because of the interaction. PETs below 3 seconds are critical events, as the average road user perception-reaction time is 2.5 seconds (1.5 seconds of which is perception time and 1.0 second is reaction time). PETs greater than 5 seconds, are generally considered interactions.[1]

According to Fuller, the probability of a fatal pedestrian injury involving a driver at 20 mph, 30 mph, and 40 mph vehicle speeds, is 5 percent, 45 percent, and 85 percent, respectively.[2] Interactions observed during the analysis period are represented by points in the figure below. Color coding indicates the PET values for different events.



1 For more on the average road user perception time, see The American Association of State Highway and Transportation Officials (AASHTO), A Policy on Geometric Design of Highways and Streets, 7th Edition (2018), https://store.transportation.org/item/collectiondetail/180?AspxAutoDetectCookieSupport=1.

2 Fuller, R., et al. "Impact of speed change on estimated journey time: Failure of drivers to appreciate relevance of initial speed." Accident Analysis & Prevention 41.1 (2009): 10–14.

EVENT DISTRIBUTION

A total of 562 pedestrian events occurred at this intersection in the before period and 450 occurred in the after period. Of these, 35 (6 percent) in the before period and 38 (8 percent) in the after period were critical events. Similarly, a total of 291 bicycle events occurred at this intersection in the before period and 128 bicycle events occurred in the after period. Of these, 31 (11 percent) in the before period and 19 (15 percent) in the after period were critical events.

CRITICAL EVENT RATE

Overall, from the before period to the after period, the temporal distribution of the critical event rate is consistent.

Before Period

- The pedestrian critical event rate is higher from 10 a.m. to noon and from 6 to 10 p.m. than during other time periods.
- The bicycle critical event rate is higher from 2 to 7 p.m. than during other time periods.

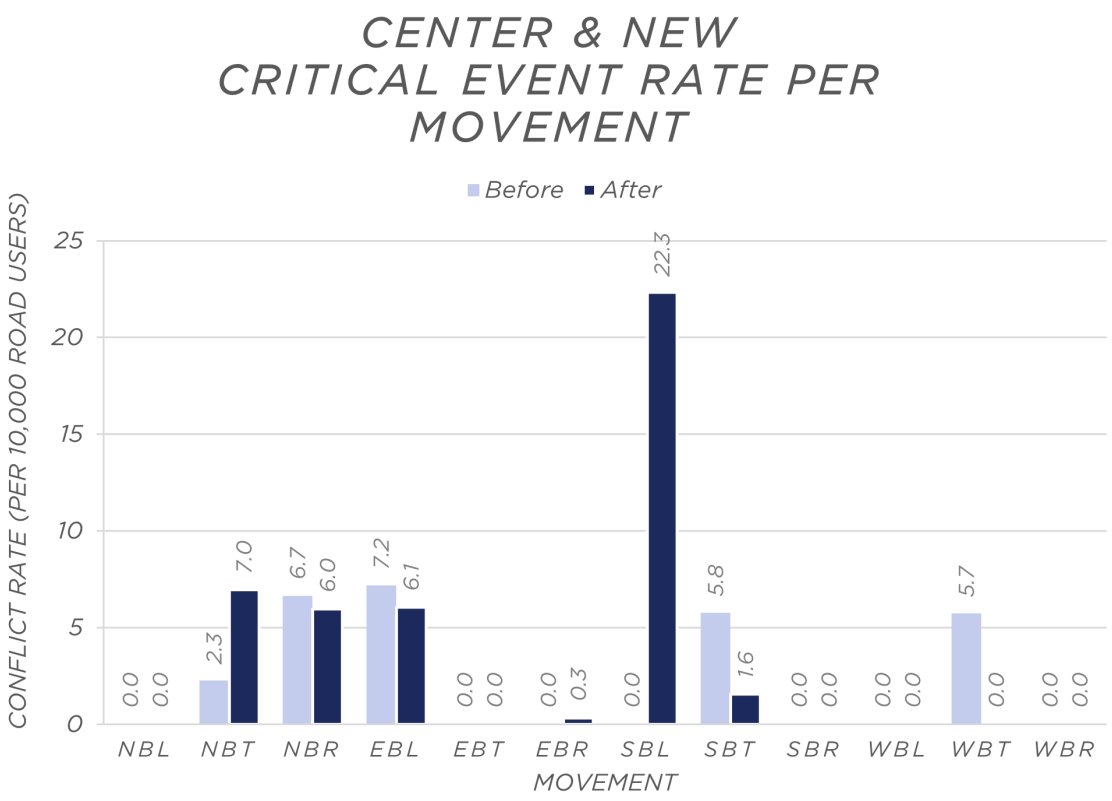
After Period

- The pedestrian critical event rate is higher from noon to 2 p.m. and 5 to 7 p.m. than during other time periods.
- The bicycle critical event rate is higher from 1 to 7 p.m. than during other time periods.

VEHICLE SPEEDS

- For all events, the vehicle speeds for right turns decreased in the after period (14 mph) when compared to the before period (17 mph).
- For critical events and other interactions (PET > 5.0 sec), the vehicle speeds for through movements increased in the after period (17 mph) compared to the before period (13 mph). However, the speeds remained consistent for potential events (3 sec < PET < 5 sec).

CRITICAL EVENT RATE BY MOVEMENT



The movements with the highest conflict rate per movement were the EB left turn and NB right turn. In the after period, the conflict rate decreased for NB right turn, EB left turn, and SB through movements.

The SB left turn movement had the highest conflict rate per movement change between the before and the after period. While this increase is notable, the conflict count reveals a more nuanced picture. In the before period, there were no conflicts between bicyclists and pedestrians and SB left vehicles. In after period, there were two conflicts. The SB left vehicle volumes were low, so even a small conflict count resulted in a high conflict rate.

FIVE STEP PROCESS

STEP 1

Conduct a 1-week conflict assessment between vehicles, pedestrians, and bicyclists.

- *Completed*

STEP 2

Evaluate the critical events using the following rules:

Step 2.1

For every 20 critical events, it's likely that one such event would be considered a confirmed conflict by an engineer.

Step 2.2

If more than 20 critical events are present at an intersection, it is more likely that at least one crash will occur (or has occurred) over a five-year period if no changes are made to the intersection.

Step 2.3

If more than 20 critical events are clustered in an intersection zone, it is more likely that a resulting crash (or a historic crash) will be present in the same zone.

CRITICAL EVENTS

35 pedestrian

31 bicycle

CONFIRMED CONFLICTS

2 pedestrian

2 bicycle

CRITICAL EVENTS

>20

More likely that a crash will occur (or has occurred) at this intersection over a five-year period.

HISTORIC CRASH DATA (2015-2019)

0 pedestrian

0 bicycle

>20 CRITICAL EVENTS

NB right turn

Therefore, it is more likely that a resulting crash (or a historic crash) will be present in that zone of the intersection.

STEP 3

Identify and install a countermeasure.

- Prior to collection of the before data, the City of Bethlehem selected the installation of a flashing yellow arrow for the NB right turn movement.

STEP 4

Conduct a 1-week conflict assessment between vehicles, pedestrians, and bicyclists.

- Approximately 6 weeks after the installation of the flashing yellow arrow, another 1-week conflict assessment was conducted.

STEP 5

Evaluate after period assessment, selecting and installing additional countermeasures as necessary.

Step 5.1

For every 20 critical events, it's likely that one such event would be considered a confirmed conflict by an engineer.

Step 5.2

If more than 20 critical events are present at an intersection, it is more likely that at least one crash will occur (or has occurred) over a five-year period if no changes are made to the intersection.

CRITICAL EVENTS

38 pedestrian

18 bicycle

CONFIRMED CONFLICTS

2 pedestrian

<1 bicycle

CRITICAL EVENTS

>20

More likely that a crash will occur (or has occurred) at this intersection over a five-year period.

Step 5.3

If a high count of critical events (>20) is clustered in an intersection zone, it is more likely that a resulting crash (or a historic crash) will be present in the same zone.

- While the rate of conflicts between pedestrians and NB right-turning vehicles decreased after installation of the flashing yellow arrow, there is still an elevated count of critical events (>20). Therefore, it is more likely that a resulting crash (or a historic crash) will be present in that zone of the intersection.

Additional potential countermeasures for consideration at the northbound right turn include:

- Prohibiting right turn on red (RTOR) may be considered at this intersection.
  - Part time RTOR prohibitions, especially during morning and afternoon peak hours, may be sufficient to address some of these events given the temporal distribution of the events.
  - Signs should be clearly visible to right-turning drivers stopped in the curb lane at the crosswalk.
  - Signs cost about $200–$500 each, electronic signs costs may go up to $3,000–$5,000.
- A leading pedestrian interval could be considered in conjunction with the flashing yellow arrow.
  - Pedestrians could be given the walk signal about three seconds before parallel traffic is given a green light.
  - Signal changes cost $5,000–$10,000

CENTRE AVENUE AND PENN AVENUE

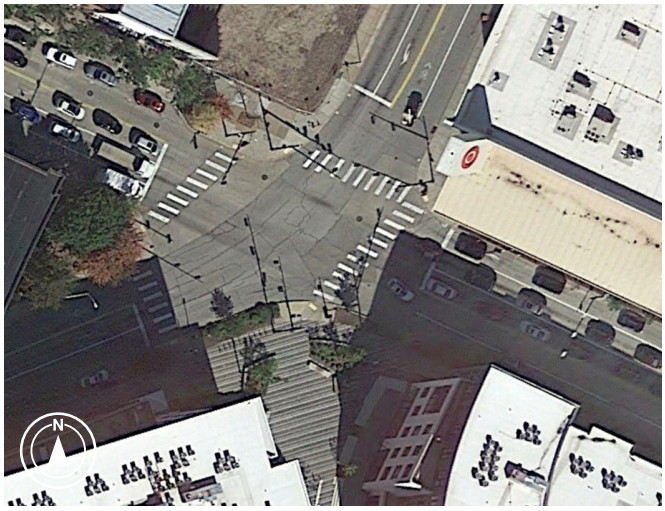
Pittsburgh, PA

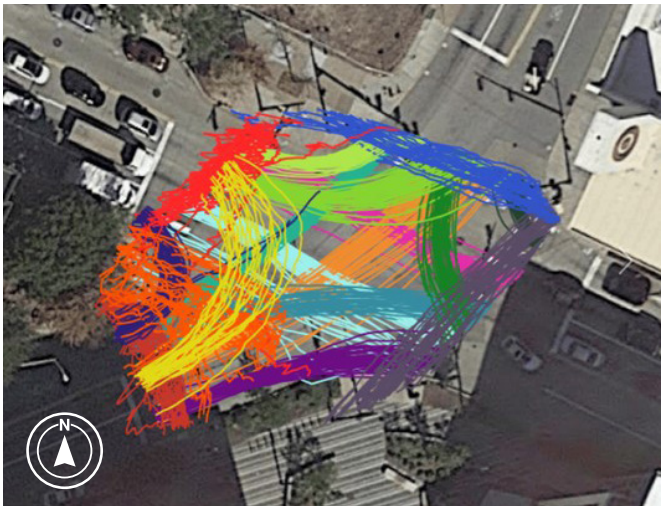
REASON FOR SELECTING THE LOCATION

This intersection had a high share of pedestrians and had a disproportionate number of critical events with right-turning vehicles.

- Pedestrian volumes are about 10 percent of the total vehicle volumes.
  - It has the sixth highest count of pedestrian critical events across all intersections.
- Intersection has the fourth highest count of pedestrian critical events with right-turning vehicles across all intersections.
- Events with right turning vehicles are about four times greater than events with through vehicles in all event groups.

In the figures below, you'll see the intersection and the road user trajectories. The accompanying table shows the average hourly volumes for drivers, pedestrians, and bicyclists.





Average Hourly Volumes

Driver—Left Turn	Driver—Through	Driver—Right Turn	Pedestrian	Bicycle
881	2,926	1,477	382	23

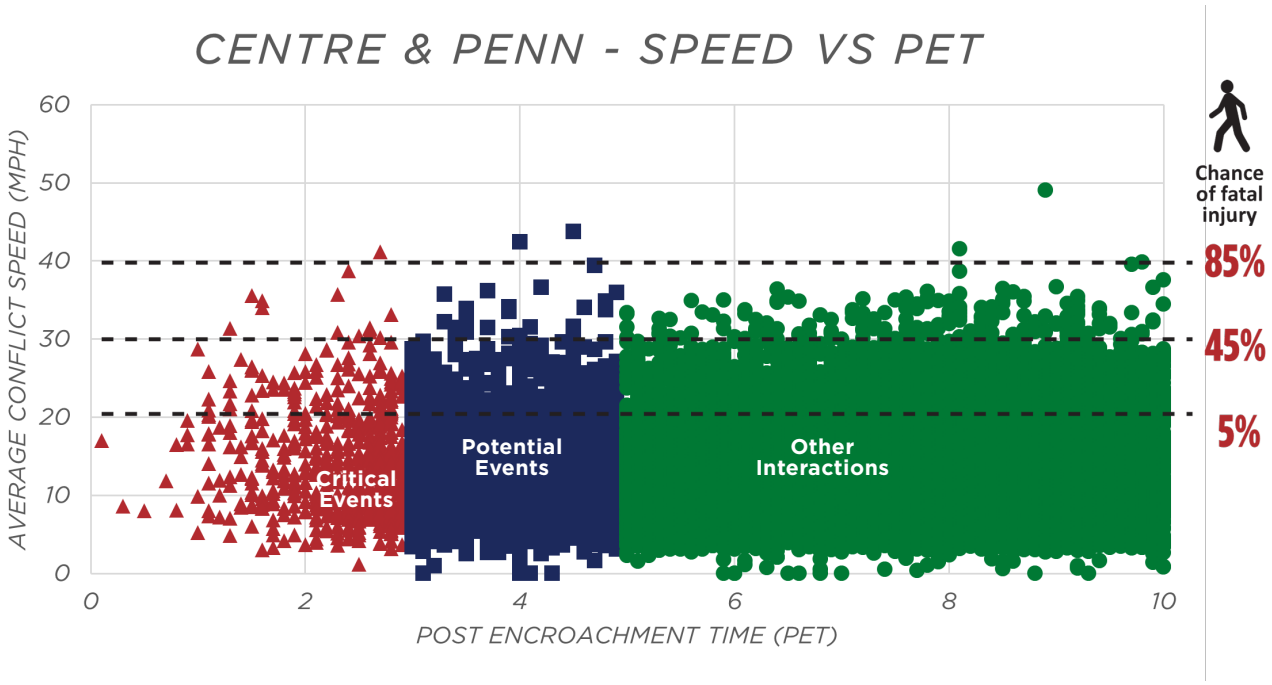
WHAT DOES THE DATA SHOW?

SEVERITY

The severity of the interactions at this intersection can be classified based on the post encroachment time (PET) and speed values.

Remember: A lower PET indicates a situation in which a crash was more likely to occur because of the interaction. PETs below 3 seconds are critical events, as the average road user perception-reaction time is 2.5 seconds (1.5 seconds of which is perception time and 1.0 second is reaction time). PETs greater than 5 seconds, are generally considered interactions.[1]

According to Fuller, the probability of a fatal pedestrian injury involving a driver at 20 mph, 30 mph, and 40 mph vehicle speeds, is 5 percent, 45 percent, and 85 percent, respectively.[2] Interactions observed during the analysis period are represented by points in the figure below. Color coding indicates the PET values for different events.



1 For more on the average road user perception time, see The American Association of State Highway and Transportation Officials (AASHTO), A Policy on Geometric Design of Highways and Streets, 7th Edition (2018), https://store.transportation.org/item/collectiondetail/180?AspxAutoDetectCookieSupport=1.

2 Fuller, R., et al. "Impact of speed change on estimated journey time: Failure of drivers to appreciate relevance of initial speed." Accident Analysis & Prevention 41.1 (2009): 10–14.

EVENT DISTRIBUTION

Of all the pedestrian events at this intersection, 5 percent were critical events, 23 percent were potential events, and 72 percent were other interactions. Of all bicycle events, 10 percent were critical events, 22 percent were potential events, and 68 percent were other interactions.

CRITICAL EVENT RATE

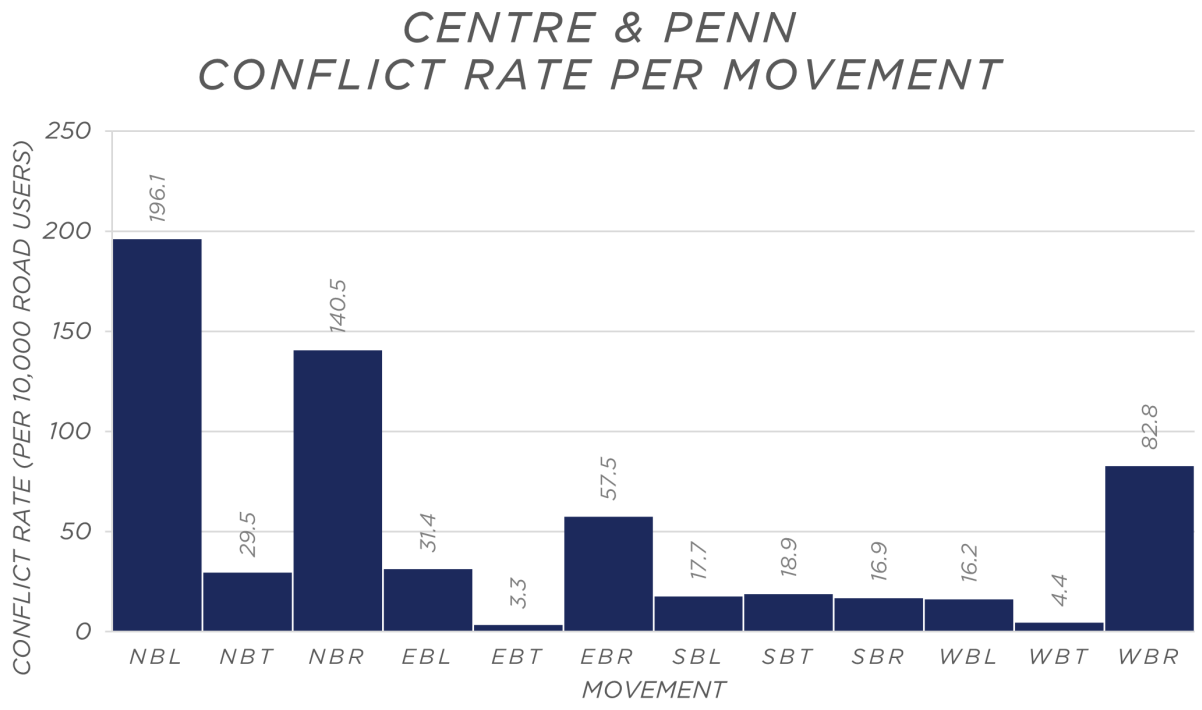
- The pedestrian critical event rate is higher from 3 to 7 p.m. than during other time periods.
- The bicycle critical event rate is higher from 2 to 4 p.m. and at 8 p.m. than during other time periods.

VEHICLE MOVEMENTS BY CROSSWALK

The north-south street is considered to be Centre Avenue and the east-west street is considered to be Penn Avenue. Looking at all 4,778 events in the eastside crosswalk, the NB right turn had 3000 events, and the WB right turn had 742. Of the total 219 critical events in this crosswalk, the NB right turn had 177, and the WB right turn had 20.

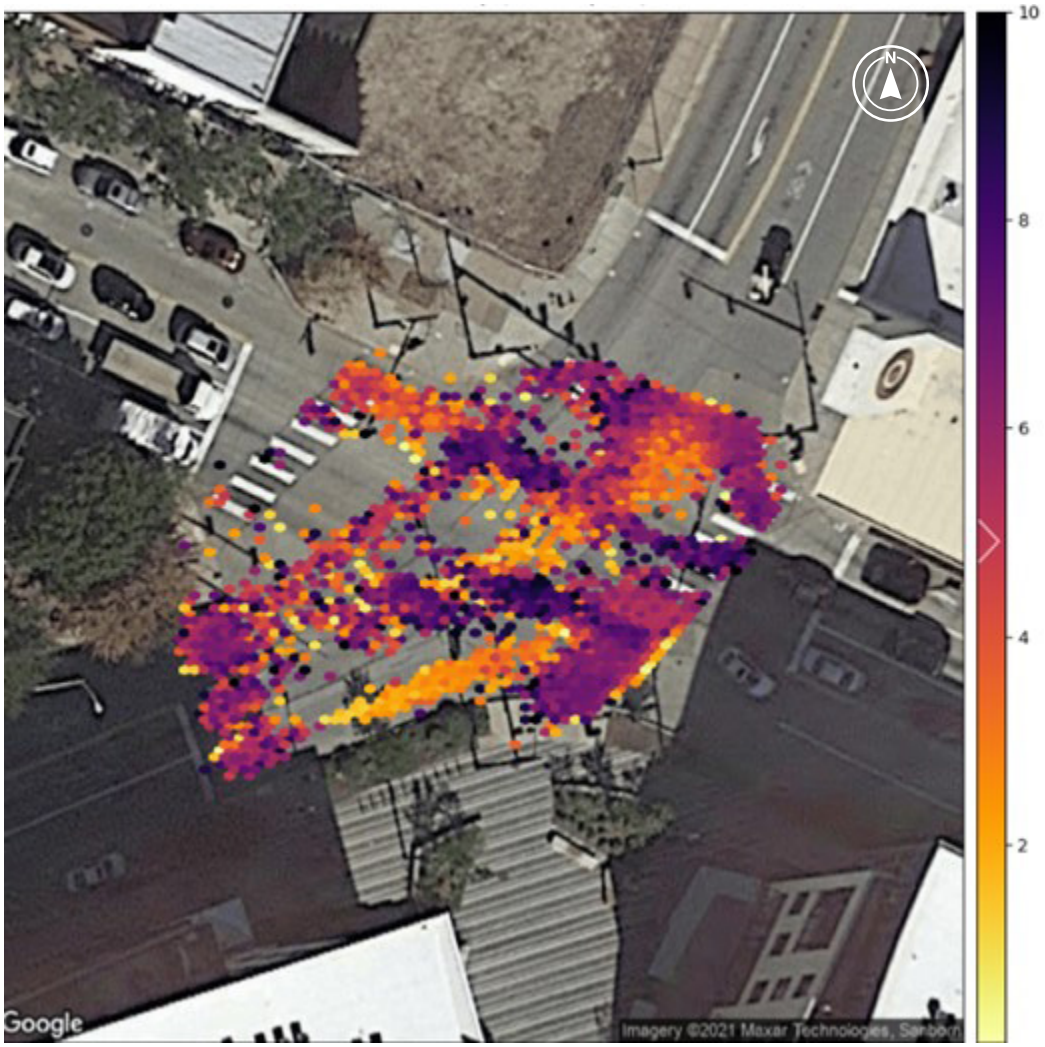
Of the 91 events in the westside crosswalk, the WB through had 47 events, and the SB right turn had 32 events. This crosswalk had 8 critical events, 5 of which occurred in the WB through direction.

CRITICAL EVENT RATE BY MOVEMENT



The four movements with the highest conflict rate per movement were the NB left turn, NB right turn, EB right turn, and WB right turn. This intersection has the highest number of critical events and potential events with left-turning and right-turning drivers.

In the conflict heat map below, we can see locations in the intersection that have more conflicts with lower PETs (yellow). These lower PET areas are along the path of the left- and right-turning vehicles. Currently, the signal phasing for left-turning drivers on all approaches is protected. RTOR is prohibited for all approaches.



FIVE STEP PROCESS

STEP 1

Conduct a 1-week conflict assessment between vehicles, pedestrians, and bicyclists.

- *Completed*

STEP 2

Evaluate the critical events using the following rules:

Step 2.1

For every 20 critical events, it is more likely that one such event would be considered a confirmed conflict by an engineer.

CRITICAL EVENTS

492 pedestrian

47 bicycle

CONFIRMED CONFLICTS

25 pedestrian

3 bicycle

Step 2.2

If more than 20 critical events are present at an intersection, its likely that at least one crash will occur (or has occurred) over a five-year period if no changes are made to the intersection.

CRITICAL EVENTS

>20

More likely that a crash will occur (or has occurred) at this intersection over a five-year period.

HISTORIC CRASH DATA (2015-2019)

1 pedestrian

0 bicycle

Step 2.3

If more than 20 critical events are clustered in an intersection zone, it is more likely that a resulting crash (or a historic crash) will be present in the same zone.

>20 CRITICAL EVENTS

NB right turn, WB right turn, NB through, and SB through movements

Therefore, it is more likely that a resulting crash (or a historic crash) will be present in these zones of the intersection.

STEP 3

Identify and install a countermeasure.

The following are potential countermeasures for consideration at this location:

- Prohibiting RTOR and adding a leading pedestrian interval (i.e., signal changes) can benefit pedestrians while minimizing impact to traffic flow.
  - Pedestrians are given walk signal three seconds before parallel traffic is given a green light.
  - Signal changes cost $5,000–$10,000.

STEP 4

Conduct a 1-week conflict assessment between vehicles, pedestrians, and bicyclists.

- While not part of this study, future work could include installing a countermeasure and conducting a follow up assessment.

STEP 5

Evaluate after period assessment, selecting and installing additional countermeasures as necessary.

W COLLEGE AVENUE AND ATHERTON STREET

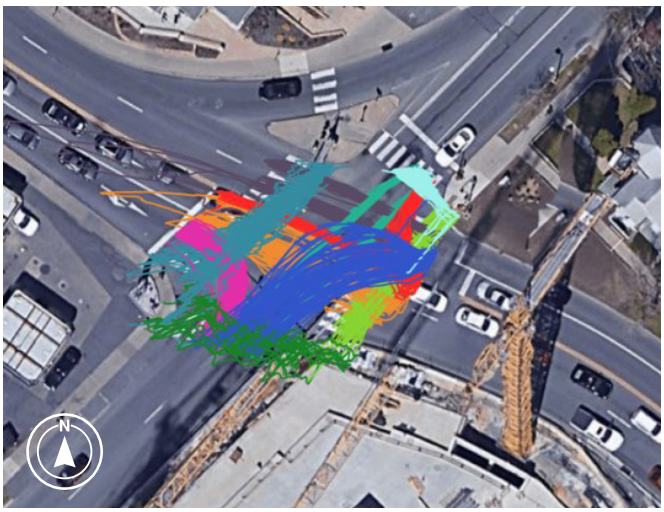
State College, PA

REASON FOR SELECTING THE LOCATION

This intersection had a high share of pedestrians and a disproportionate number of critical events with left-turning vehicles.

- Pedestrian volumes are about 32 percent of the total vehicle volume.
  - This intersection has the third highest count of pedestrian critical events per 10,000 road users across all intersections.
- This intersection has the second highest count of pedestrian critical events with left-turning vehicles across all intersections.
- Events with left-turning vehicles are about two times greater than events with through vehicles in all event groups.

In the figures below, you'll see the intersection and the road user trajectories. The accompanying table shows the average hourly volumes for drivers, pedestrians, and bicyclists.



Average Hourly Volumes

Driver—Left Turn	Driver—Through	Driver—Right Turn	Pedestrian	Bicycle
815	3,027	1,308	1,499	13

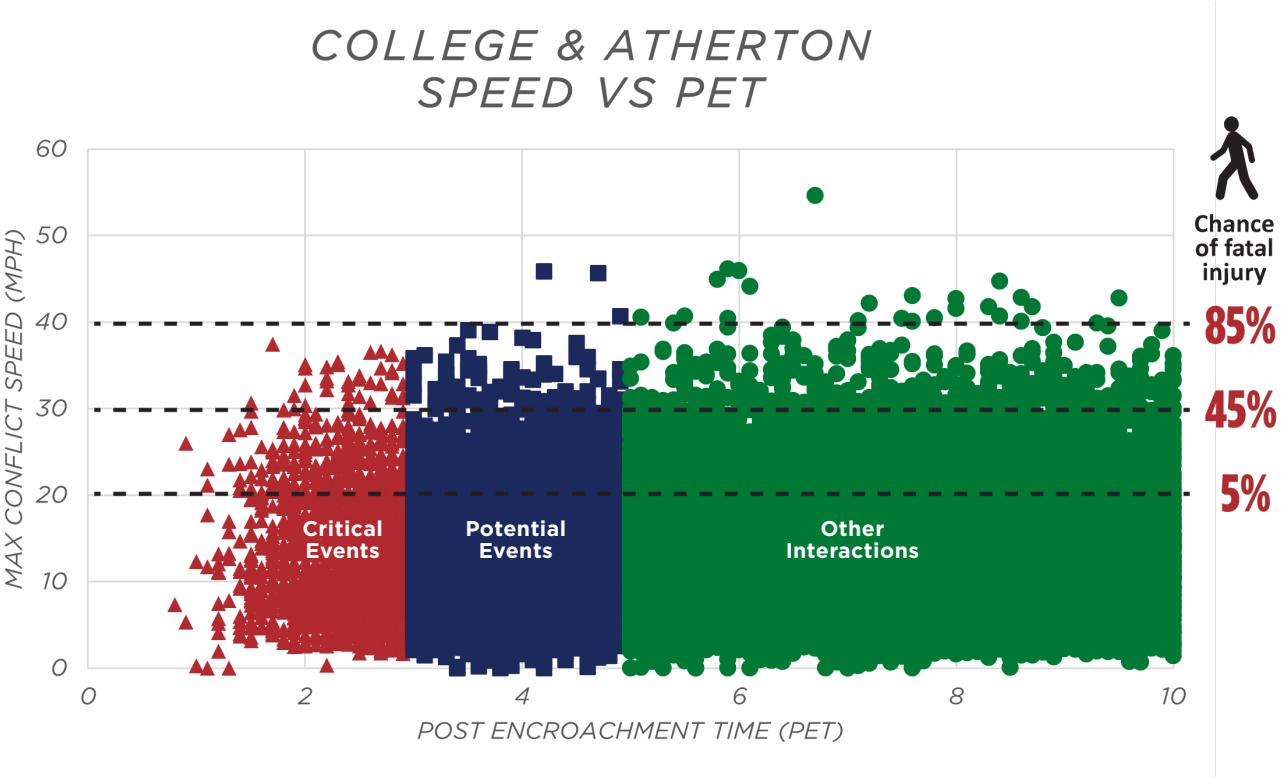
WHAT DOES THE DATA SHOW?

SEVERITY

The severity of the interactions at this intersection can be classified based on the post encroachment time (PET) and speed values.

Remember: A lower PET indicates a situation in which a crash was more likely to occur because of the interaction. PETs below 3 seconds are critical events, as the average road user perception-reaction time is 2.5 seconds (1.5 seconds of which is perception time and 1.0 second is reaction time). PETs greater than 5 seconds, are generally considered interactions.[1]

According to Fuller, the probability of a fatal pedestrian injury involving a driver at 20 mph, 30 mph, and 40 mph vehicle speeds, is 5 percent, 45 percent, and 85 percent, respectively.[2] Interactions observed during the analysis period are represented by points in the figure below. Color coding indicates the PET values for different events.



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2 Fuller, R., et al. "Impact of speed change on estimated journey time: Failure of drivers to appreciate relevance of initial speed." Accident Analysis & Prevention 41.1 (2009): 10–14.

EVENT DISTRIBUTION

Of all the pedestrian events at this intersection, 8 percent were critical events, 29 percent were potential events, and 63 percent were other interactions. Similarly, of all bicycle events, 11 percent were critical events, 25 percent were potential events, and 64 percent were other interactions.

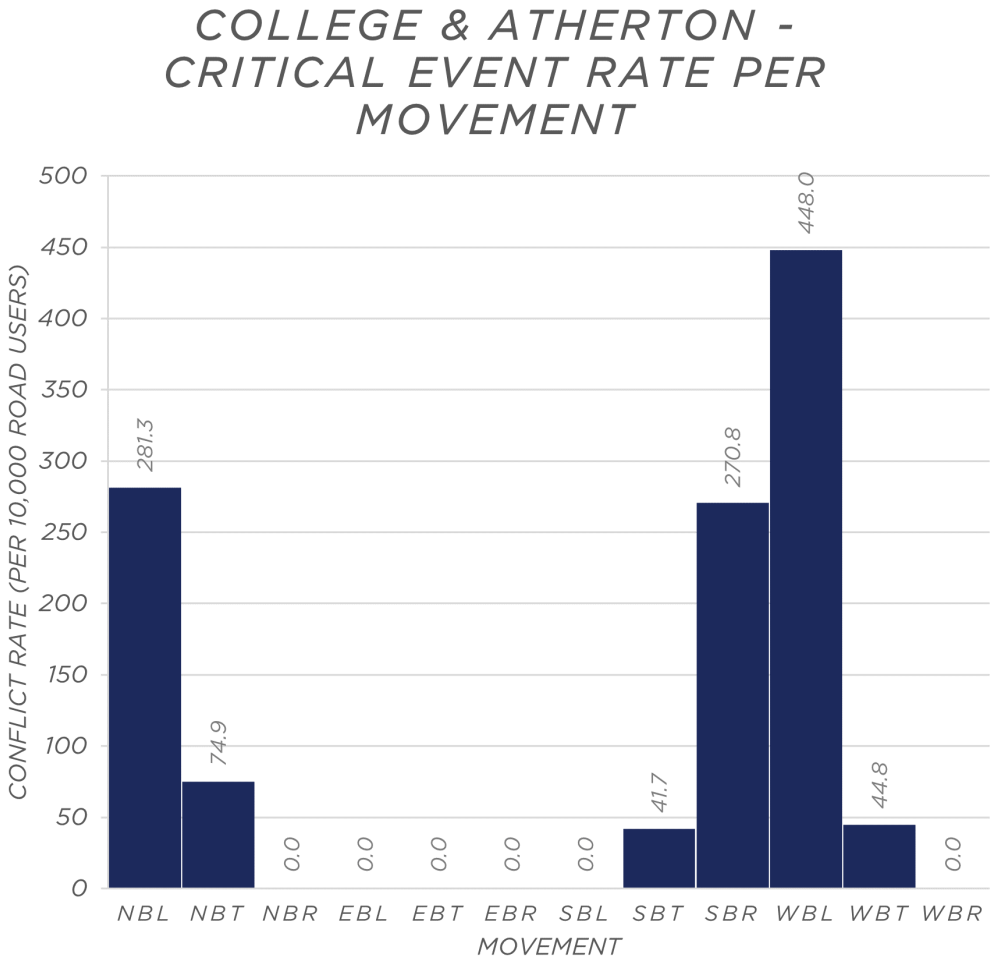
CRITICAL EVENT RATE

- The pedestrian critical event rate is high throughout the day and night. It is higher from 9 a.m. to 12 a.m. and at 2 a.m. than during other time periods.
- The bicycle critical event rate is higher from 10 a.m. to 8 p.m. than during other time periods.

VEHICLE MOVEMENTS BY CROSSWALK

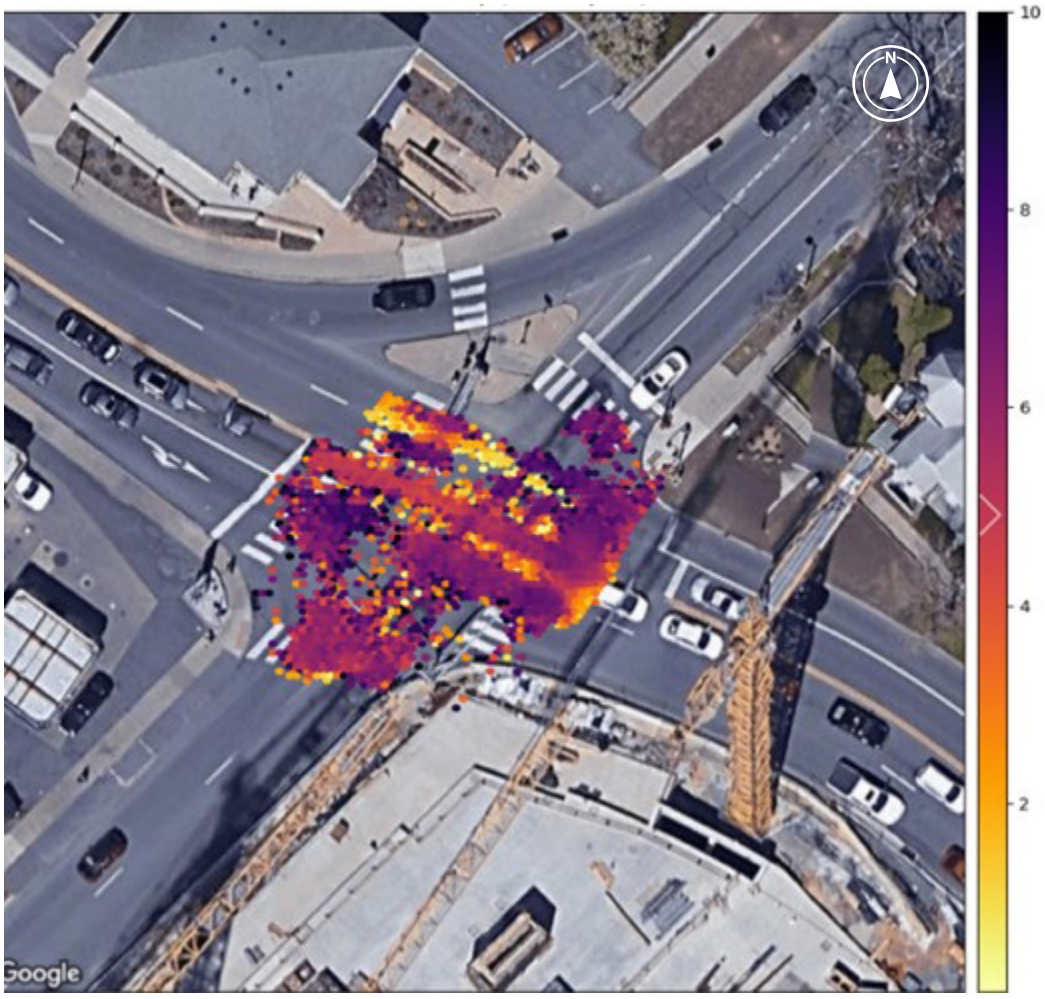
Looking at all 3,619 events in the westside crosswalk, the SB right turn had the most events (2,065), followed by NB left turn (1,045). Of the 320 critical events in this crosswalk, the SB right turn had 177 and the NB left turn had 81.

CRITICAL EVENT RATE BY MOVEMENT



The three movements that had the highest critical event rates per movement were the WB left turn, NB left turn, and SB right turn. This intersection has the highest number of critical events and potential events with left-turning and right-turning drivers.

In the conflict heat map below, we can see locations in the intersection that have more conflicts with lower PETs (yellow). These lower PET areas are along the NB right movement, eastside crosswalk, and westside crosswalk. Currently, the signal phasing for the left-turning drivers for the SB and WB approaches is permissive. Signal phasing for left-turning vehicles on the NB approach is protected/permissive. RTOR is permitted on all approaches.



FIVE STEP PROCESS

STEP 1

Conduct a 1-week conflict assessment between vehicles, pedestrians, and bicyclists.

- *Completed*

STEP 2

Evaluate the critical events using the following rules:

Step 2.1

For every 20 critical events, it is more likely that one such event would be considered a confirmed conflict by an engineer.

CRITICAL EVENTS

1,438 pedestrian

27 bicycle

CONFIRMED CONFLICTS

72 pedestrian

1 bicycle

Step 2.2

If more than 20 critical events are present at an intersection, its likely that at least one crash will occur (or has occurred) over a five-year period if no changes are made to the intersection.

CRITICAL EVENTS

>20

More likely that a crash will occur (or has occurred) at this intersection over a five-year period.

HISTORIC CRASH DATA (2015-2019)

4 pedestrian

0 bicycle

Step 2.3

If more than 20 critical events are clustered in an intersection zone, it is more likely that a resulting crash (or a historic crash) will be present in the same zone.

>20 CRITICAL EVENTS

WB left turn, SB right turn, NB through, NB left turn, SB through, and WB through movements

Therefore, it is more likely that a resulting crash (or a historic crash) will be present in these zones of the intersection.

STEP 3

Identify and install a countermeasure.

The following are potential countermeasures for consideration at this location:

- Consider protected left turns for WB and NB movement, especially during the morning and afternoon peak hours.
  - Signal changes cost $5,000–$10,000.
- Prohibiting RTOR may be considered at this intersection.
  - Part time RTOR prohibitions, especially during the morning and afternoon peak hours, may be sufficient to address some of these events given their temporal distribution.
  - Signs should be clearly visible to right-turning drivers stopped in the curb lane at the crosswalk.
  - Signs cost about $200–$500 each, and electronic sign costs may go up to $3,000–$5,000.

STEP 4

Conduct a 1-week conflict assessment between vehicles, pedestrians, and bicyclists.

- While not part of this study, future work could include installing a countermeasure and conducting a follow up assessment.

STEP 5

Evaluate after period assessment, selecting and installing additional countermeasures as necessary.

HAMILTON STREET AND 17TH STREET

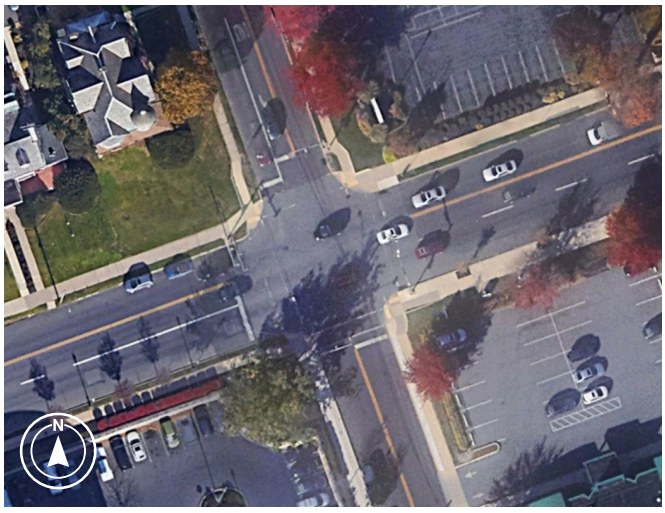
Allentown, PA

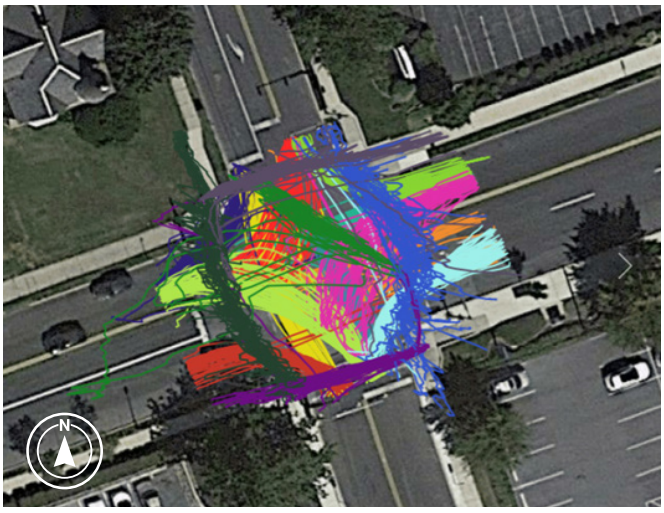
REASON FOR SELECTING THE LOCATION

This intersection had a high confirmed conflict ratio despite having geometric features that tend to reduce turning vehicle speeds.

- 9 percent confirmed conflict ratio
- There are 1.5 times more events with right turning vehicles than events with through vehicles in all event groups.
- This intersection has a tight turn radius at one or more of the approaches.
- There is no channelized right-turn lane.

In the figures below, you'll see the intersection and the road user trajectories. The accompanying table shows the average hourly volumes for drivers, pedestrians, and bicyclists.





Average Hourly Volumes

Driver—Left Turn	Driver—Through	Driver—Right Turn	Pedestrian	Bicycle
306	2,795	522	63	5

WHAT DOES THE DATA SHOW?

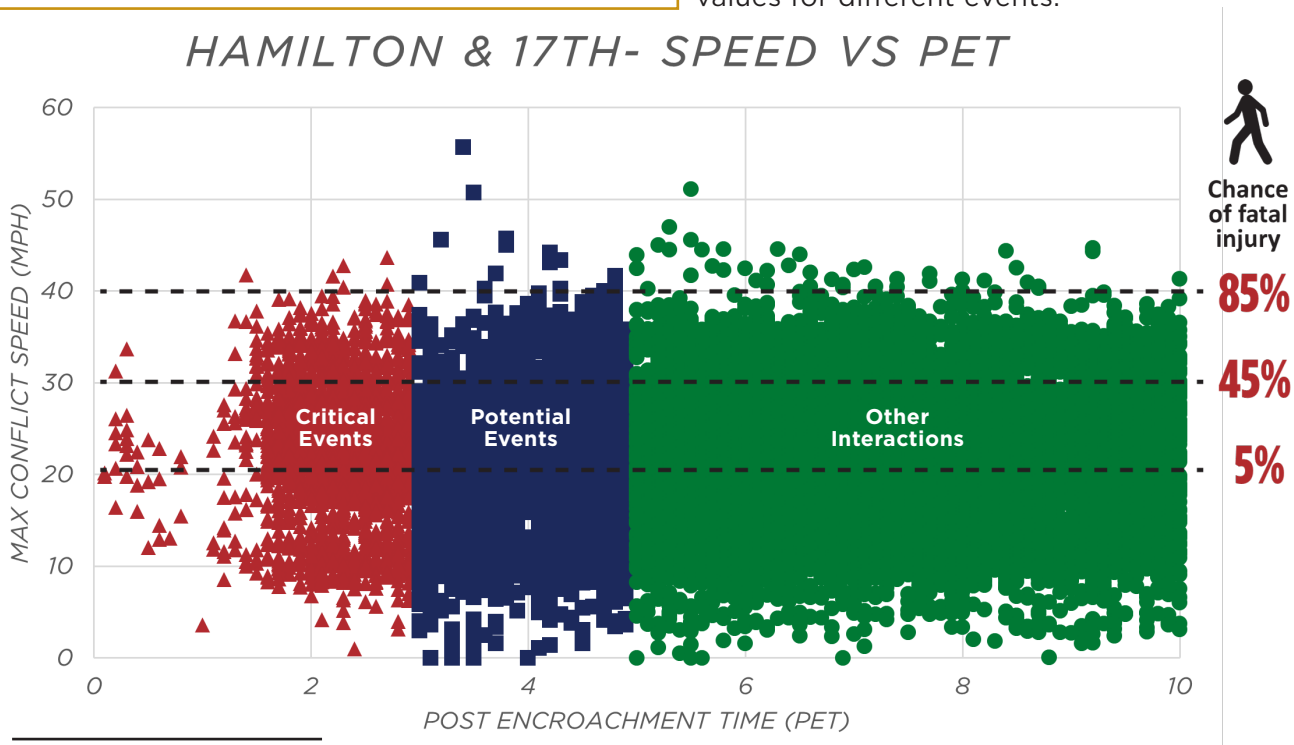
One hundred critical events were selected for human observation and review by Rybinski. This intersection had 72 bicycle- and pedestrian-related critical events, and Kittelson selected 64 for human review after removing duplicates and bicycle-pedestrian events that had been falsely categorized by video detection software. Of the 64 events, 6 events (9 percent) were categorized as confirmed conflicts by engineering judgment and human review. We could observe no clear pattern as to why the confirmed conflict ratio is higher at this intersection than the other study intersections. However, 4 of the 6 confirmed conflicts involved left- or right-turning vehicles, and two of the confirmed conflicts involved SB through movement.

SEVERITY

The severity of the interactions at this intersection can be classified based on the post encroachment time (PET) and speed values.

Remember: A lower PET indicates a situation in which a crash was more likely to occur because of the interaction. PETs below 3 seconds are critical events, as the average road user perception-reaction time is 2.5 seconds (1.5 seconds of which is perception time and 1.0 second is reaction time). PETs greater than 5 seconds, are generally considered interactions.[1]

According to Fuller, the probability of a fatal pedestrian injury involving a driver at 20 mph, 30 mph, and 40 mph vehicle speeds, is 5 percent, 45 percent, and 85 percent, respectively.[2] Interactions observed during the analysis period are represented by points in the figure below. Color coding indicates the PET values for different events.



1 For more on the average road user perception time, see The American Association of State Highway and Transportation Officials (AASHTO), A Policy on Geometric Design of Highways and Streets, 7th Edition (2018), https://store.transportation.org/item/collectiondetail/180?AspxAutoDetectCookieSupport=1.

2 Fuller, R., et al. "Impact of speed change on estimated journey time: Failure of drivers to appreciate relevance of initial speed." Accident Analysis & Prevention 41.1 (2009): 10–14.

EVENT DISTRIBUTION

Of all the pedestrian events, 5 percent were critical events, 21 percent were potential events, and 74 percent were other interactions. Of all bicycle events, 10 percent were critical events, 23 percent were potential events, and 67 percent were other interactions.

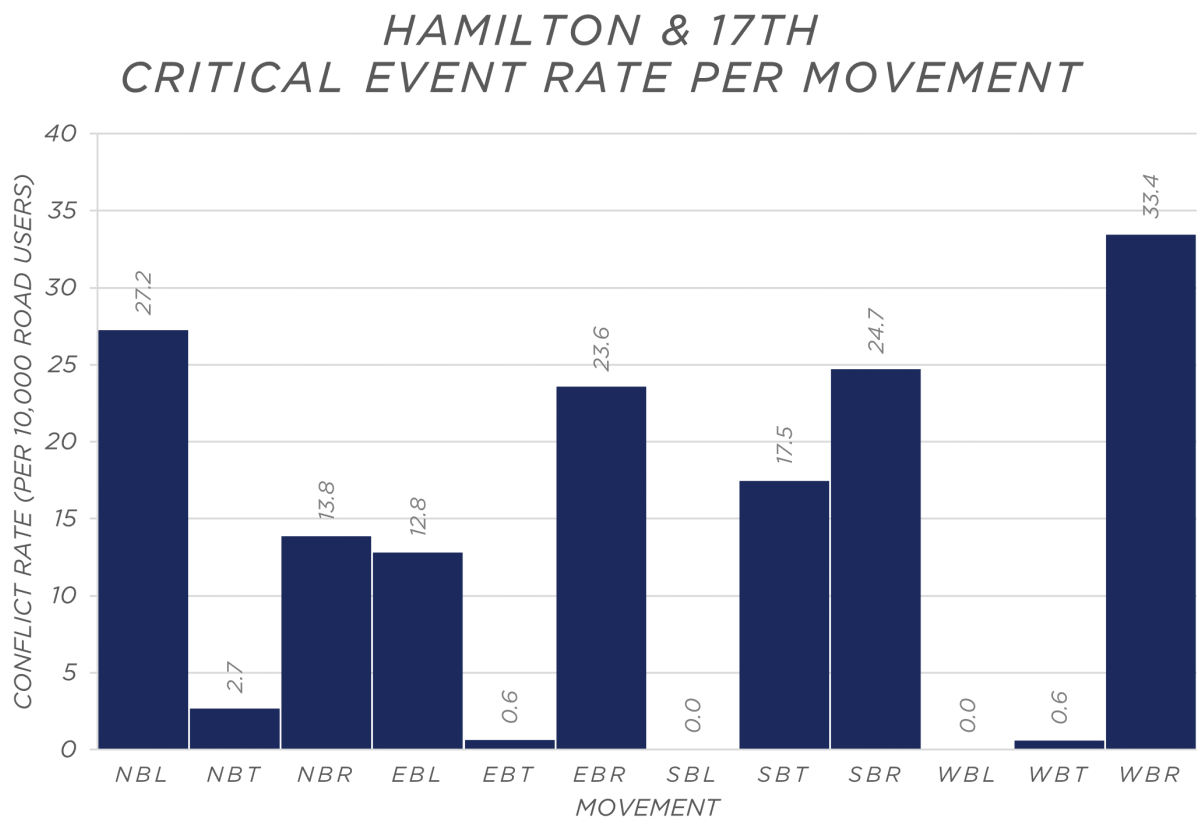
CRITICAL EVENT RATE

- The pedestrian critical event rate is higher from 7 a.m. to 2 p.m. than during other time periods.
- The bicycle critical event rate is higher from 3 to 9 p.m. than during other time periods.

VEHICLE MOVEMENTS BY CROSSWALK

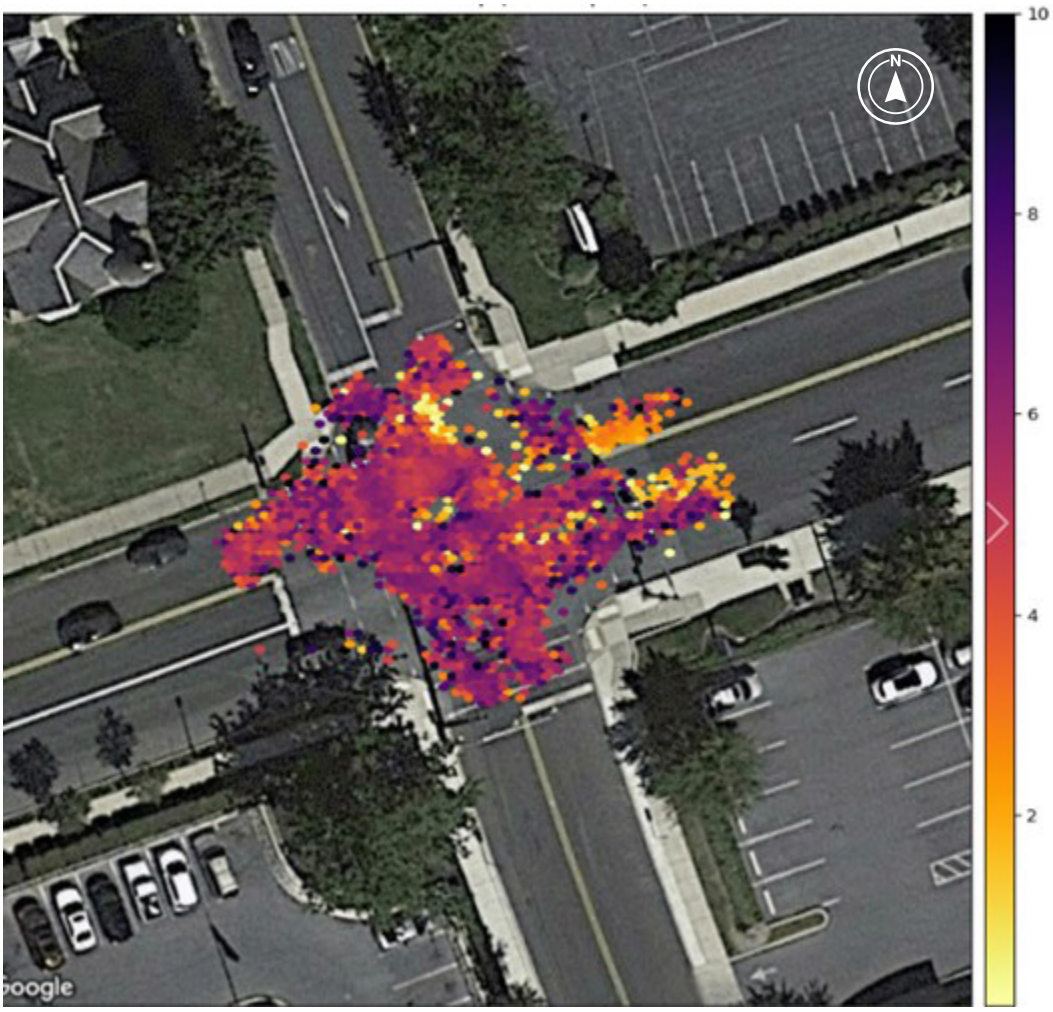
Looking at all 393 events in the eastside crosswalk, the EB through had the most events (204), followed by WB through (99). Of all 7 critical events at this crosswalk, EB through had 2 and WB through had 2.

CRITICAL EVENT RATE BY MOVEMENT



The four movements with the highest critical event rate per movement were the WB right turn, NB left turn, SB right turn, and EB right turn. This intersection had the highest number of critical events and potential events with left- and right-turning drivers.

In the conflict heat map below, we can see locations at the intersection that have more conflicts with lower PETs (yellow). These critical event areas are along the eastside crosswalk and east legs of the intersection. Currently, the signal phasing for the left-turning drivers on all approaches is permissive, and RTOR is permitted for all approaches.



FIVE STEP PROCESS

STEP 1

Conduct a 1-week conflict assessment between vehicles, pedestrians, and bicyclists.

- *Completed*

STEP 2

Evaluate the critical events using the following rules:

Step 2.1

For every 20 critical events, it's likely that one such event would be considered a confirmed conflict by an engineer.

CRITICAL EVENTS

62 pedestrian

10 bicycle

CONFIRMED CONFLICTS

3 pedestrian

1 bicycle

Step 2.2

If more than 20 critical events are present at an intersection, it is more likely that at least one crash will occur (or has occurred) over a five-year period if no changes are made to the intersection.

CRITICAL EVENTS

>20

More likely that a crash will occur (or has occurred) at this intersection over a five-year period.

HISTORIC CRASH DATA (2015-2019)

10 pedestrian

1 bicycle

Step 2.3

If more than 20 critical events are clustered in an intersection zone, it is more likely that a resulting crash (or a historic crash) will be present in the same zone.

>20 CRITICAL EVENTS

has not occurred at this intersection for any movement.

STEP 3

Identify and install a countermeasure.

The following are potential countermeasures for consideration at this location:

- Prohibiting RTOR may be considered at this intersection.
  - Part time RTOR prohibitions, especially during the morning and afternoon peak hours, may be sufficient to address some of these events given their temporal distribution.
  - Signs should be clearly visible to right-turning drivers stopped in the curb lane at the crosswalk.
  - Signs cost about $200–$500 each, and electronic sign costs may go up to $3,000–$5,000.
- Prohibiting RTOR and adding a leading pedestrian interval (i.e., signal changes) can benefit pedestrians while minimizing impact to traffic flow.
  - Pedestrians are given walk signal about three seconds before parallel traffic is given a green indication.
  - Signal changes cost $5,000–$10,000.
- Consider protected left-turn phasing, especially during the morning and afternoon peak hours.
  - Signal changes cost $5,000–$10,000.

STEP 4

Conduct a 1-week conflict assessment between vehicles, pedestrians, and bicyclists.

- While not part of this study, future work could include installing a countermeasure and conducting a follow up assessment.

STEP 5

Evaluate after period assessment, selecting and installing additional countermeasures as necessary.

BEFORE AND AFTER

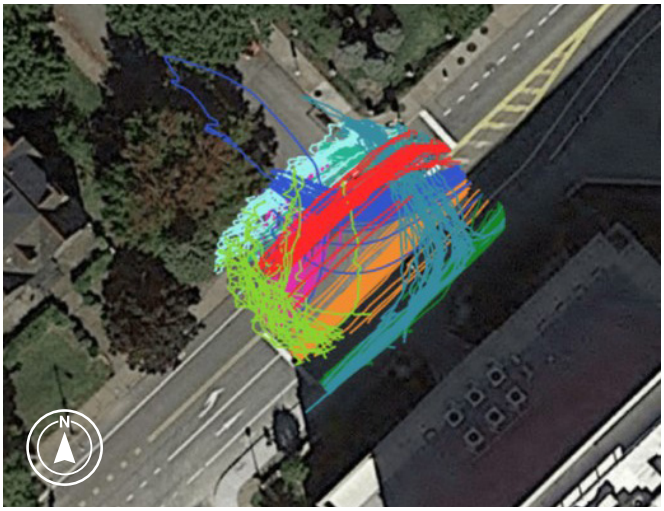
BIGELOW BOULEVARD AND BAYARD STREET

Pittsburgh, PA

REASON FOR SELECTING THE LOCATION

In 2021, a leading pedestrian interval was introduced to phase 4 for pedestrians crossing Bigelow Boulevard. We conducted a before-and-after study to determine whether conflicts and safety performance changed at this intersection. The study period included the seven days before and the seven days after the implemented change. Two days in the after period had periods of snow, and we analyzed these days separately.

In the figures below, you'll see the intersection and the road user trajectories. The accompanying table shows the average hourly volumes for drivers, pedestrians, and bicyclists.



Average Hourly Volumes

Driver—Left Turn	Driver—Through	Driver—Right Turn	Pedestrian	Bicycle
231	395	829	23	5

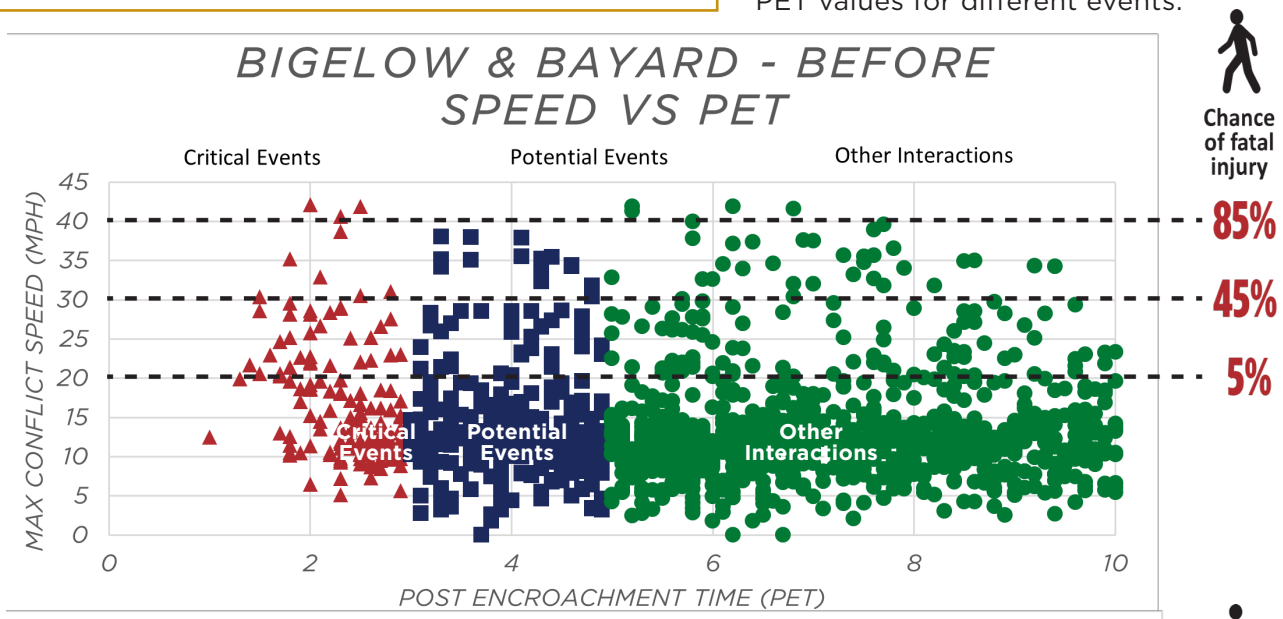
WHAT DOES THE DATA SHOW?

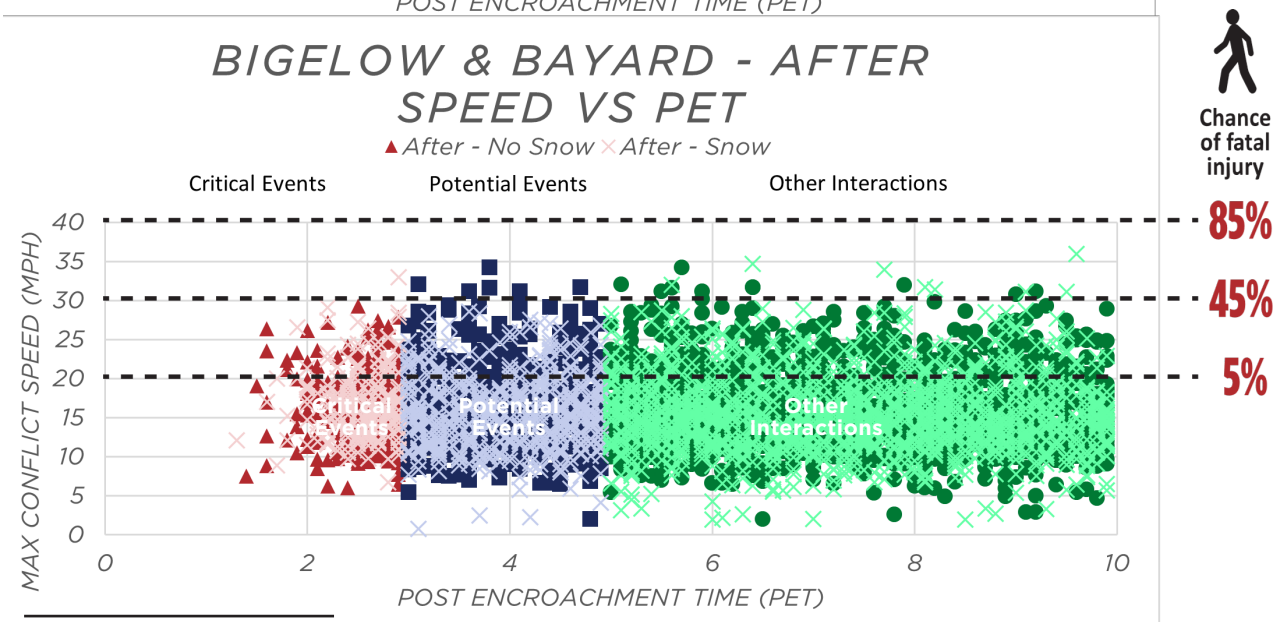
SEVERITY

The severity of the interactions at this intersection can be classified based on the post encroachment time (PET) and speed values.

Remember: A lower PET indicates a situation in which a crash was more likely to occur because of the interaction. PETs below 3 seconds are critical events, as the average road user perception-reaction time is 2.5 seconds (1.5 seconds of which is perception time and 1.0 second is reaction time). PETs greater than 5 seconds, are generally considered interactions.[1]

According to Fuller, the probability of a fatal pedestrian injury involving a driver at 20 mph, 30 mph, and 40 mph vehicle speeds, is 5 percent, 45 percent, and 85 percent, respectively.[2] Interactions observed during the analysis period are represented by points in the figure below. Color coding indicates the PET values for different events.





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2 Fuller, R., et al. "Impact of speed change on estimated journey time: Failure of drivers to appreciate relevance of initial speed." Accident Analysis & Prevention 41.1 (2009): 10–14.

EVENT DISTRIBUTION

A total of 1,062 pedestrian events occurred at this intersection in the before period, and 1,487 occurred in the after period. Of the pedestrian events in the after period, 758 occurred on days with no snow, and 729 occurred on days with snow.

Of the 1,062 pedestrian events in the before period, 73 (7 percent) were critical events. Of the 1,487 pedestrian events in the after period, 47 (3 percent) were critical events on days with no snow, and 33 (2 percent) were critical events on days with snow.

This intersection had 87 bicycle events in the before period and 75 events in the after period. Of the after-period events, 44 occurred on days with no snow and 31 occurred on days with snow. Of the total bicycle events, 26 (30 percent) were critical events in the before period and 10 (13 percent) were critical events in the after period.

CRITICAL EVENT RATE

For days with no snow, the temporal distribution of the critical event rate is consistent between the before and after period. On days with snow, events were more concentrated in the daytime.

Before Period

- The pedestrian critical event rate is higher from 10 a.m. to noon and from 6 to 10 p.m. than during other time periods.
- The bicycle critical event rate is higher from 8 to 10 a.m. than during other time periods.

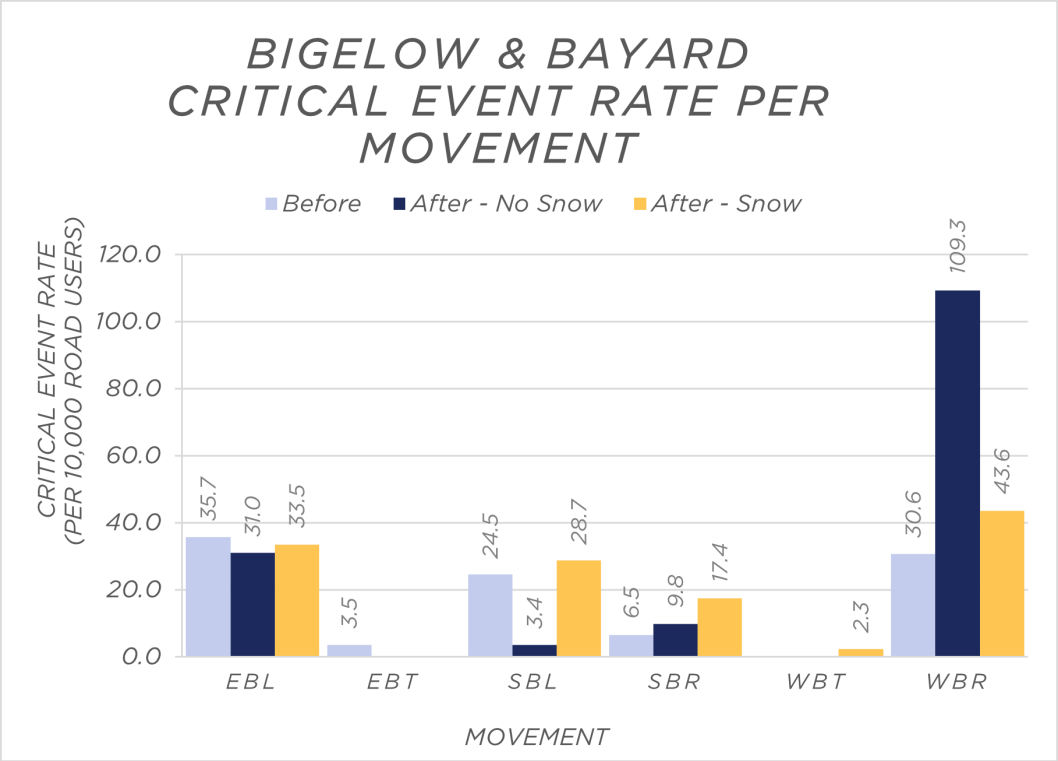
After Period

- On days with no snow, the pedestrian critical event rate was higher from 5 to 9 a.m. and from 4 to 6 p.m. than during other time periods. On days with snow, the pedestrian critical event rate was higher from 1 to 5 p.m.
- On days with no snow, the bicycle critical event rate was higher from 7 to 10 a.m. and from 2 to 5 p.m. than during other time periods. On days with snow, the bicycle critical event rate was higher from 1 to 4 p.m.

VEHICLE SPEEDS

- During the after period, vehicle speeds for right turns increased slightly from 11 mph during the before period to 12 mph on days with no snow and to 13 mph on days with snow.
- During the after period, vehicle speeds for through movements for EB and WB directions decreased. In the before period, these vehicle speeds were measured at 25 mph; in the after period, vehic

CRITICAL EVENT RATE BY MOVEMENT



The two movements with the highest critical event rate per movement during the before period were the WB right turn and EB left turn. During the after period, on days with no snow, the conflict rate decreased for EB left turn, EB through, and SB left turn. On days with snow, the conflict rate decreased for EB left turn and EB through turn.

The greatest difference in conflict rates per movement between before and after periods was observed for the WB right turn. While the number of conflicts in the after period (14) stayed about the same as the number of conflicts during the before period (11), this intersection had a decrease in pedestrian volume in the after period, which increased the conflict rate.

FIVE STEP PROCESS

STEP 1

Conduct a 1-week conflict assessment between vehicles, pedestrians, and bicyclists.

- *Completed*

STEP 2

Evaluate the critical events using the following rules:

Step 2.1

For every 20 critical events, it's likely that one such event would be considered a confirmed conflict by an engineer.

Step 2.2

If more than 20 critical events are present at an intersection, it is more likely that at least one crash will occur (or has occurred) over a five-year period if no changes are made to the intersection.

Step 2.3

If more than 20 critical events are clustered in an intersection zone, it is more likely that a resulting crash (or a historic crash) will be present in the same zone.

CRITICAL EVENTS

73 pedestrian

26 bicycle

CONFIRMED CONFLICTS

4 pedestrian

1 bicycle

CRITICAL EVENTS

>20

More likely that a crash will occur (or has occurred) at this intersection over a five-year period.

HISTORIC CRASH DATA (2015-2019)

0 pedestrian

0 bicycle

>20 CRITICAL EVENTS

EB left turn and SB right turn

Therefore, it is more likely that a resulting crash (or a historic crash) will be present in these zones of the intersection.

STEP 3

Identify and install a countermeasure.

- Prior to collection of the before data, the City of Pittsburgh selected the installation of a leading pedestrian interval for phase 4 for pedestrians crossing Bigelow Boulevard at the stem of the T-intersection.

STEP 4

Conduct a 1-week conflict assessment between vehicles, pedestrians, and bicyclists.

- Approximately six weeks after the installation of the leading pedestrian interval, we conducted another 1-week conflict assessment.

STEP 5

Evaluate after period assessment, selecting and installing additional countermeasures as necessary.

Step 5.1

For every 20 critical events, it's likely that one such event would be considered a confirmed conflict by an engineer.

Step 5.2

If more than 20 critical events are present at an intersection, it is more likely that at least one crash will occur (or has occurred) over a five-year period if no changes are made to the intersection.

CRITICAL EVENTS

80 pedestrian

10 bicycle

CONFIRMED CONFLICTS

4 pedestrian

<1 bicycle

CRITICAL EVENTS

>20

More likely that a crash will occur (or has occurred) at this intersection over a five-year period.

Step 5.3

If a high count of critical events (>20) is clustered in an intersection zone, it is more likely that a resulting crash (or a historic crash) will be present in the same zone.

- While the rate of conflicts between pedestrians and vehicles decreased for the EB left turn, there is still an elevated count of critical events (>20). Therefore, it is more likely that a resulting crash (or a historic crash) will be present in that zone of the intersection.

Additional potential countermeasures for consideration at the NB right turn include:

- Consider protected left turns for EB left turn movement, especially during the morning and afternoon peak hours.
  - Signal changes cost $5,000–$10,000
- Prohibiting RTOR may be considered at this intersection.
  - Part time RTOR prohibitions, especially during the morning and afternoon peak hours, may be sufficient to address some of these events given their temporal distribution.
  - Signs should be clearly visible to right-turning drivers stopped in the curb lane at the crosswalk.
  - Signs cost about $200–$500 each, and electronic sign costs may go up to $3,000–$5,000.

CHAPTER 6

FACT SHEETS

pennsylvania DEPARTMENT OF TRANSPORTATION

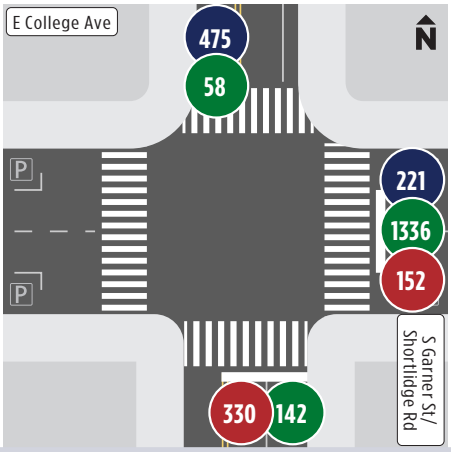
INTERSECTION FACT SHEET

E College Ave & S Garner St/ Shortlidge Rd — State College

COLLEGE

Number of Critical Events by Maneuver Type

Vehicle Conflicts with Pedestrian

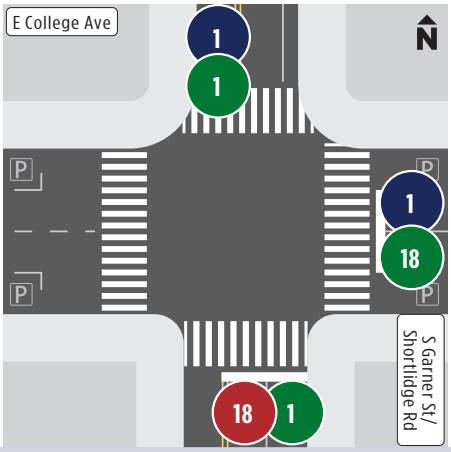


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Vehicle Conflicts with Bicycle

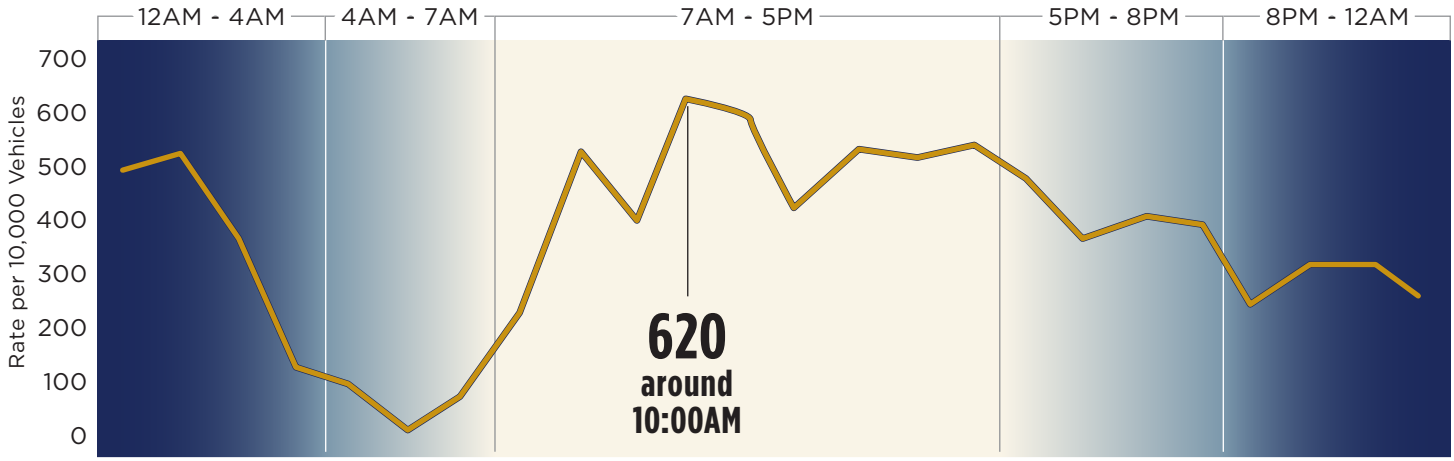


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn | Through | Right Turn

17%	57%	26%

Pedestrian vs. Bicycle

97%	3%

Intersection Volume

53% Pedestrian

<1% Bicycle

47% Vehicle

Key Takeaways

- 5% Confirmed conflict rate
- Pedestrians are the dominant roadway users, common to a college site
- Unusually high percentage of critical events with through vehicles suggests low right-of-way compliance

pennsylvania DEPARTMENT OF TRANSPORTATION

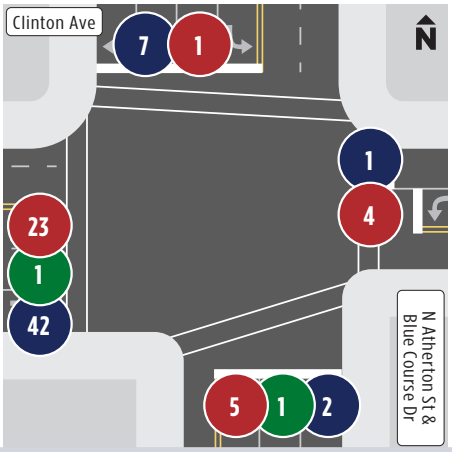
INTERSECTION FACT SHEET

N Atherton St & Blue Course Dr/ Clinton Ave — State College

SUBURBAN

Number of Critical Events by Maneuver Type

Vehicle Conflicts with Pedestrian

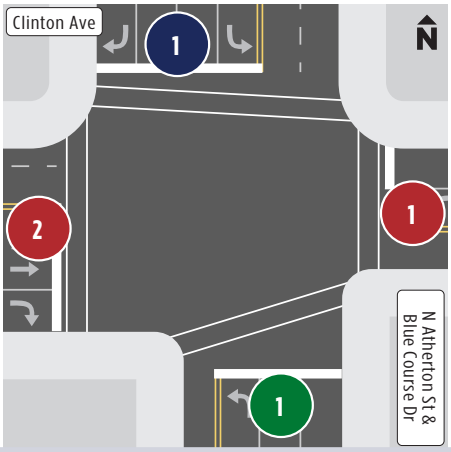


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Vehicle Conflicts with Bicycle

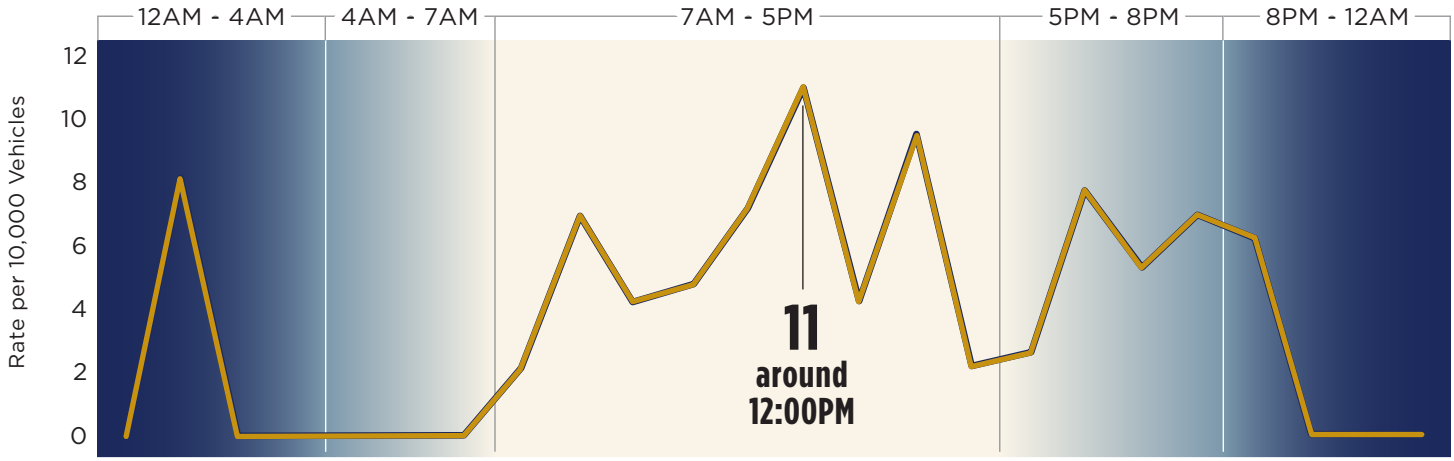


Vehicle Left Turn

Vehicle Through

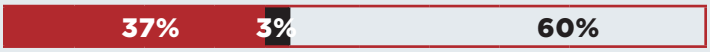
Vehicle Right Turn

Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn | Through | Right Turn



Pedestrian vs. Bicycle

Intersection Volume

1% Pedestrian

<1% Bicycle

99% Vehicle

Key Takeaways

- 4% Confirmed conflict rate
- Eastbound vehicles involved in more than half of critical events
- Right turning vehicles involved in more than half of critical events

pennsylvania DEPARTMENT OF TRANSPORTATION

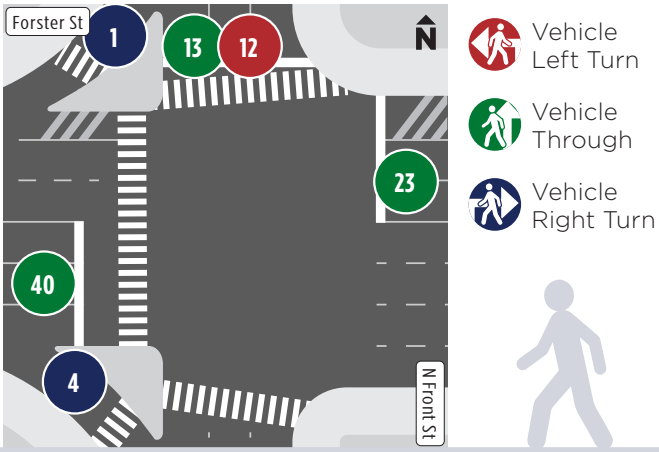
INTERSECTION FACT SHEET

N Front St & Forster St — Harrisburg

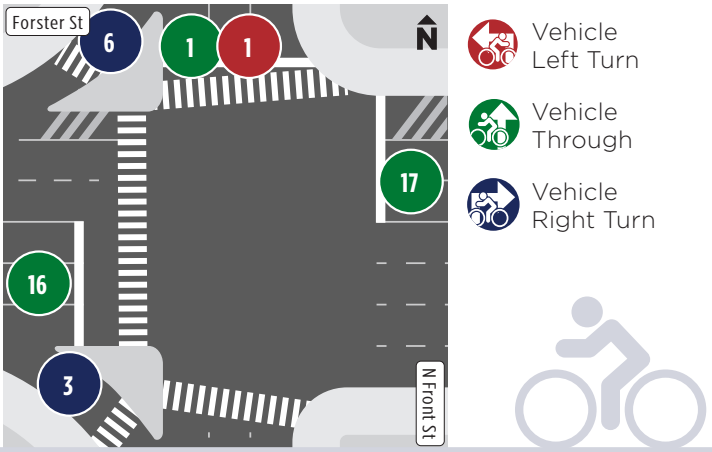
URBAN

Number of Critical Events by Maneuver Type

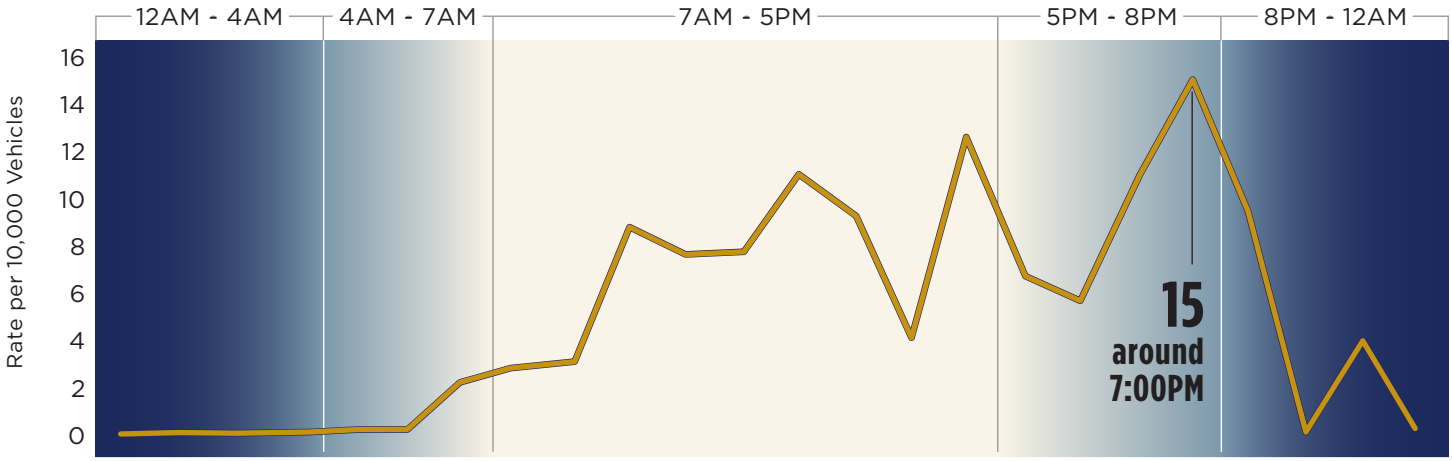
Vehicle Conflicts with Pedestrian



Vehicle Conflicts with Bicycle



Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn | Through | Right Turn

12%	82%	6%

Pedestrian vs. Bicycle

66%	34%

Intersection Volume

5% Pedestrian

3% Bicycle

93% Vehicle

Key Takeaways

- 8% Confirmed conflict rate
- Relatively high percentage of critical events involve bicycles
- More than half of critical events involve westside crosswalk suggesting trail users are particularly impacted

pennsylvania DEPARTMENT OF TRANSPORTATION

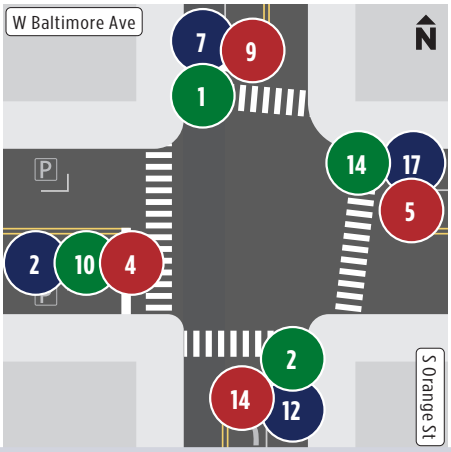
INTERSECTION FACT SHEET

W Baltimore Ave & S Orange St — Media

SUBURBAN

Number of Critical Events by Maneuver Type

Vehicle Conflicts with Pedestrian

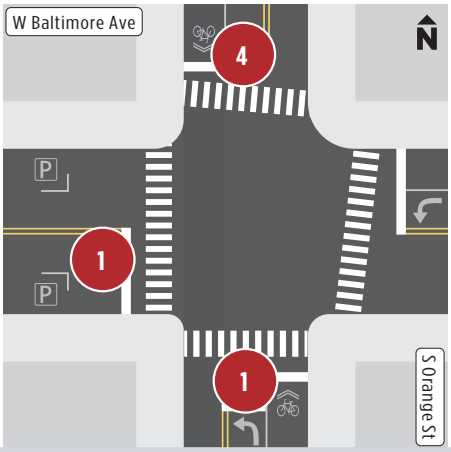


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Vehicle Conflicts with Bicycle

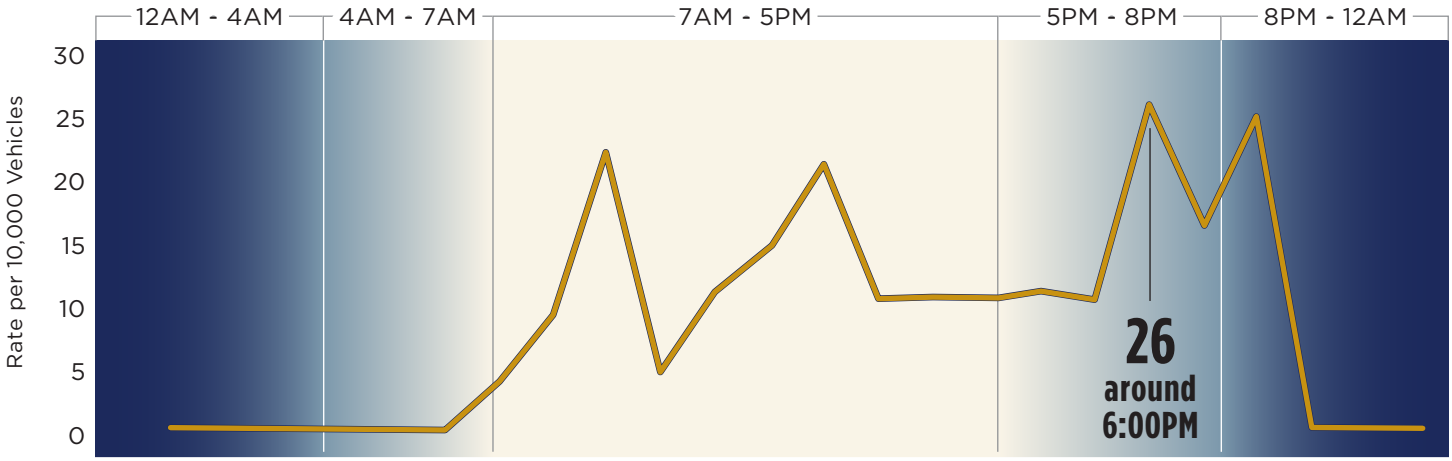


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn | Through | Right Turn

34%	28%	38%

Pedestrian vs. Bicycle

93%	7%

Intersection Volume

3% Pedestrian

<1% Bicycle

96% Vehicle

Key Takeaways

- 2% Confirmed conflict rate
- More than half of critical events occur along eastside and westside crosswalks
- Critical events between northbound through bicycles and southbound left vehicles overrepresented

pennsylvania DEPARTMENT OF TRANSPORTATION

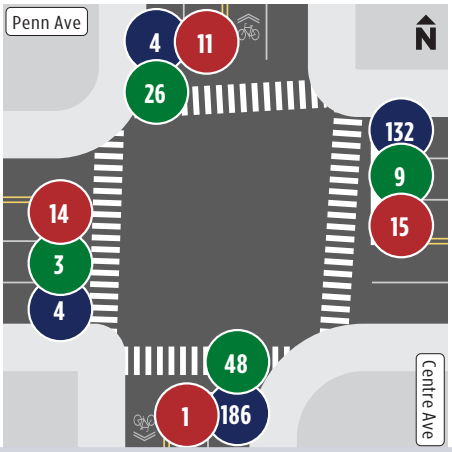
INTERSECTION FACT SHEET

Centre Ave & Penn Ave — Pittsburgh

URBAN

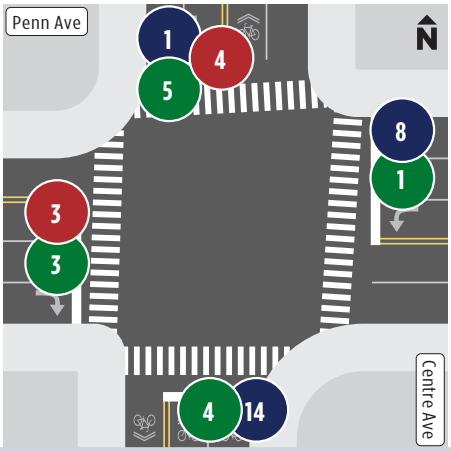
Number of Critical Events by Maneuver Type

Vehicle Conflicts with Pedestrian



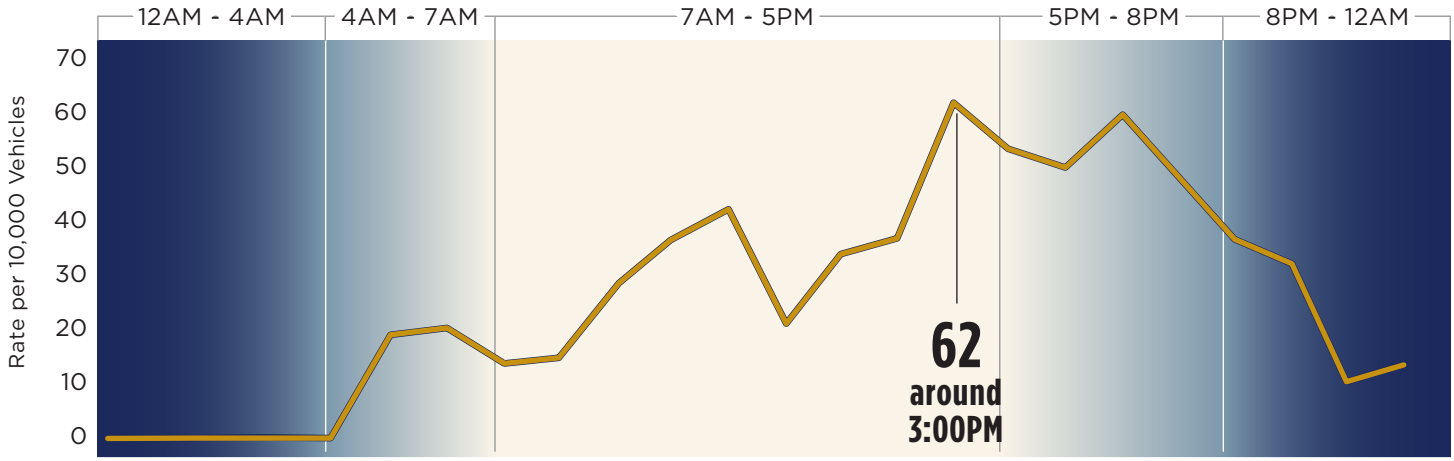
Vehicle Left Turn
Vehicle Through
Vehicle Right Turn

Vehicle Conflicts with Bicycle



Vehicle Left Turn
Vehicle Through
Vehicle Right Turn

Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn | Through | Right Turn

Pedestrian vs. Bicycle

Intersection Volume

7% Pedestrian

<1% Bicycle

93% Vehicle

Key Takeaways

- 4% Confirmed conflict rate
- Northbound and westbound right turn vehicles involved in more than half of critical events
- Most right turning involved critical events occur in the second crosswalk the vehicle passes through

pennsylvania DEPARTMENT OF TRANSPORTATION

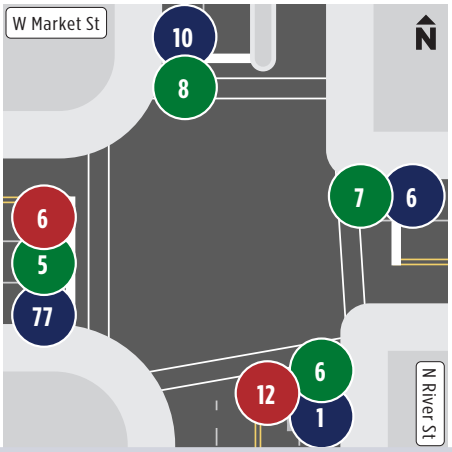
INTERSECTION FACT SHEET

W Market St & N River St — Wilkes Barre

COLLEGE

Number of Critical Events by Maneuver Type

Vehicle Conflicts with Pedestrian

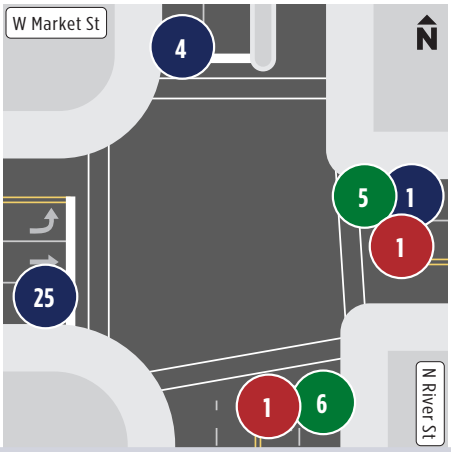


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Vehicle Conflicts with Bicycle

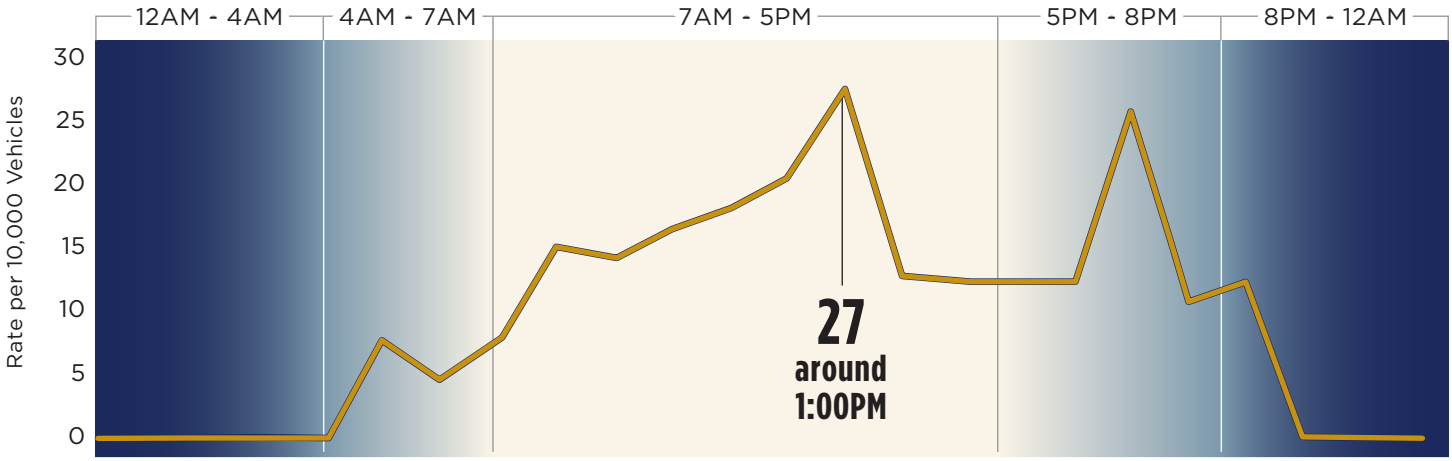


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn | Through | Right Turn

13%	18%	69%

Pedestrian vs. Bicycle

75%	25%

Intersection Volume

1% Pedestrian

<1% Bicycle

99% Vehicle

Key Takeaways

- 3% Confirmed conflict rate
- More than half of critical events occur between eastbound right turning vehicles and bicyclists or pedestrians in the southside crosswalk
- Bicyclists are overrepresented in critical events

pennsylvania DEPARTMENT OF TRANSPORTATION

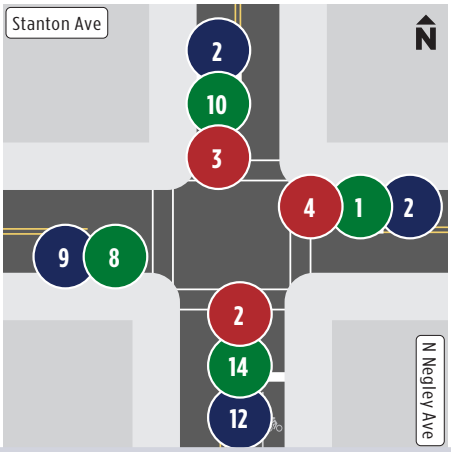
INTERSECTION FACT SHEET

N Negley Ave & Stanton Ave — Pittsburgh

URBAN

Number of Critical Events by Maneuver Type

Vehicle Conflicts with Pedestrian

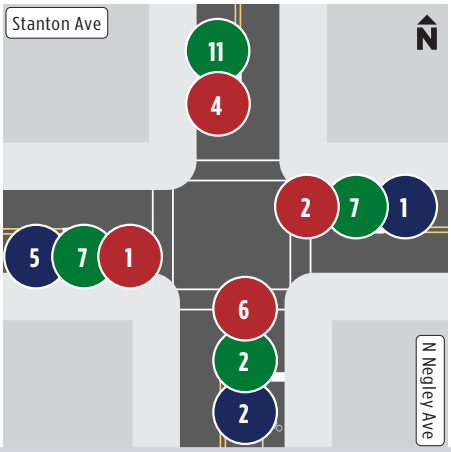


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Vehicle Conflicts with Bicycle

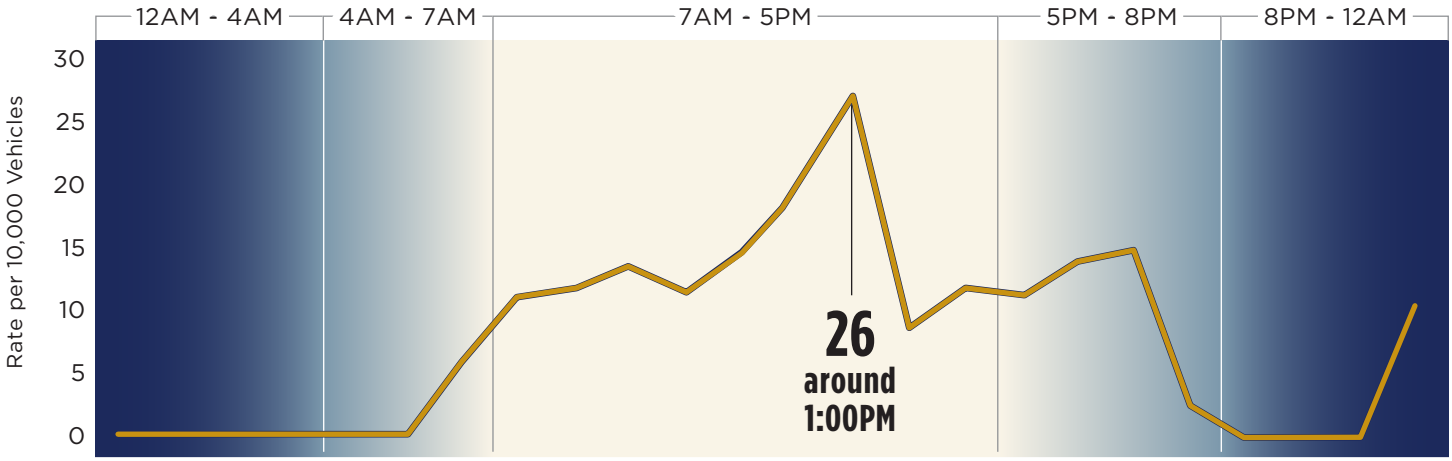


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn | Through | Right Turn

20%	44%	36%

Pedestrian vs. Bicycle

57%	43%

Intersection Volume

3% Pedestrian

1% Bicycle

96% Vehicle

Key Takeaways

- 2% Confirmed conflict rate
- Bicyclists are overrepresented in critical events
- Relatively even distribution of critical events across all vehicle movement types compared to other sites in the study

pennsylvania DEPARTMENT OF TRANSPORTATION

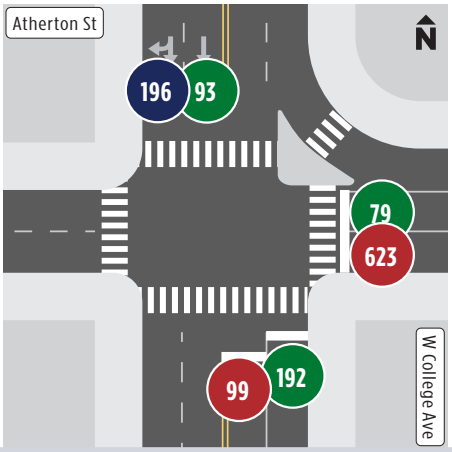
INTERSECTION FACT SHEET

W College Ave & Atherton St — State College

COLLEGE

Number of Critical Events by Maneuver Type

Vehicle Conflicts with Pedestrian

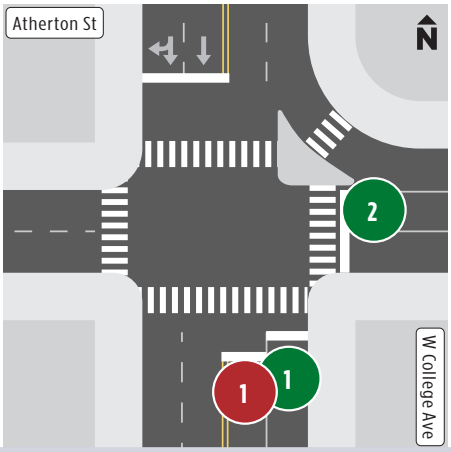


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Vehicle Conflicts with Bicycle

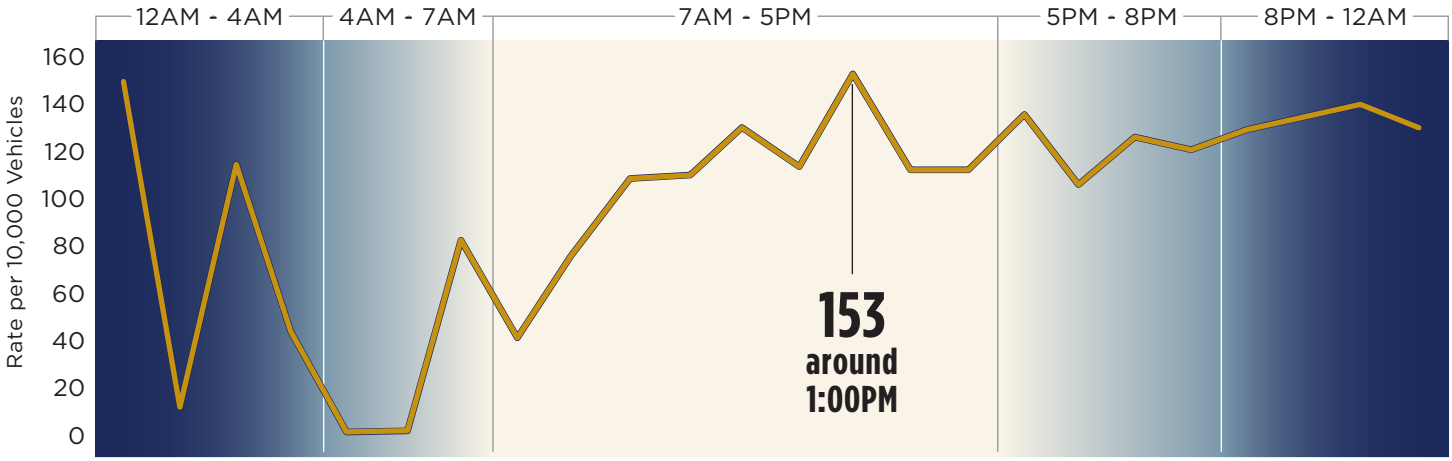


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn | Through | Right Turn

57% | 28% | 15%

Pedestrian vs. Bicycle

98% | 2%

Intersection Volume

24% Pedestrian

<1% Bicycle

76% Vehicle

Key Takeaways

- 6% Confirmed conflict rate
- Nearly half of critical events involve westbound left turning vehicles and pedestrians in the southside crosswalk
- Nearly three-in-four pedestrians involved in a critical event are in the southside crosswalk

pennsylvania DEPARTMENT OF TRANSPORTATION

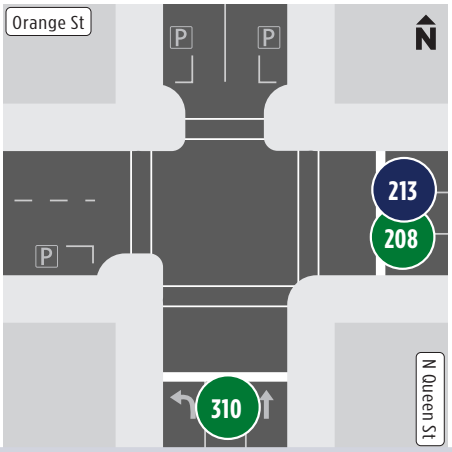
INTERSECTION FACT SHEET

N Queen St & Orange St — Lancaster

URBAN

Number of Critical Events by Maneuver Type

Vehicle Conflicts with Pedestrian

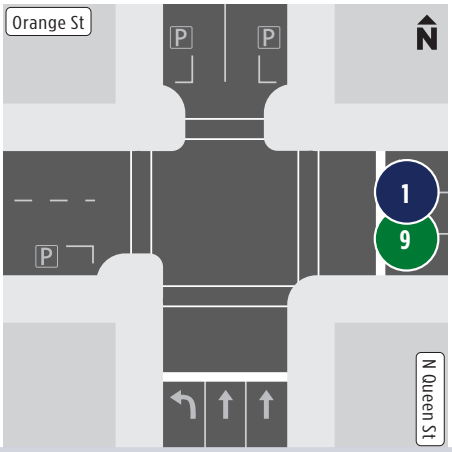


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Vehicle Conflicts with Bicycle

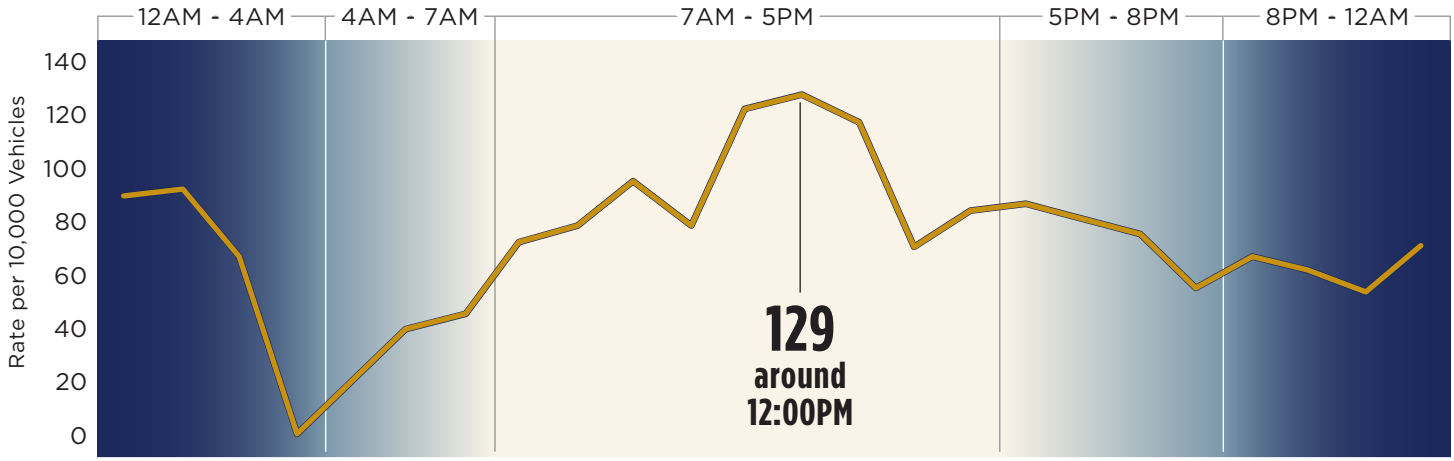


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn | Through | Right Turn

Pedestrian vs. Bicycle

Intersection Volume

23% Pedestrian

<1% Bicycle

76% Vehicle

Key Takeaways

- 4% Confirmed conflict rate
- More than half of pedestrians involved in critical events are in the northside crosswalk
- Nearly three-in-four critical events involve a through vehicle

pennsylvania DEPARTMENT OF TRANSPORTATION

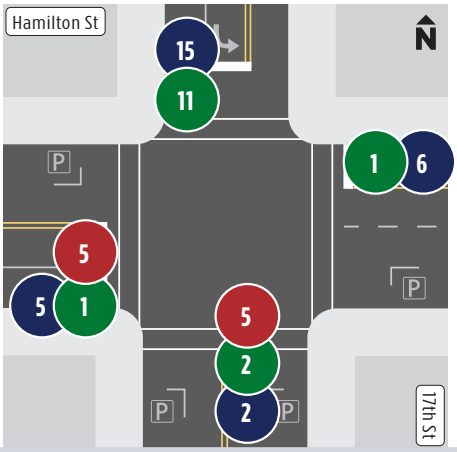
INTERSECTION FACT SHEET

SUBURBAN

Hamilton St & 17th St — Allentown

Number of Critical Events by Maneuver Type

Vehicle Conflicts with Pedestrian

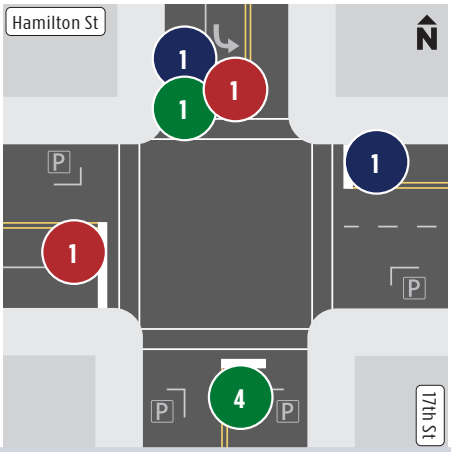


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Vehicle Conflicts with Bicycle

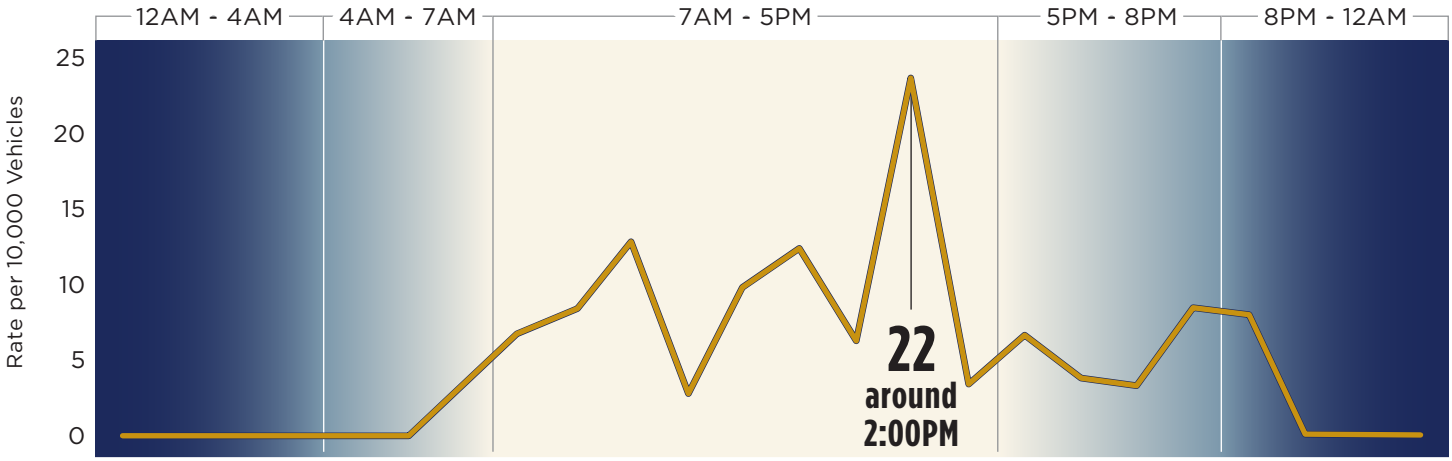


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn | Through | Right Turn

16%	34%	50%

Pedestrian vs. Bicycle

86%	14%

Intersection Volume

2% Pedestrian

<1% Bicycle

98% Vehicle

Key Takeaways

- 9% Confirmed conflict rate
- Half of critical events involve a right turning vehicle
- Nearly half of critical events involve a southbound vehicle

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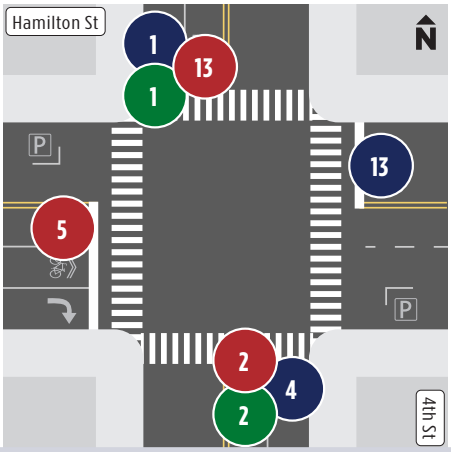
INTERSECTION FACT SHEET

SUBURBAN

Hamilton St & 4th St — Allentown

Number of Critical Events by Maneuver Type

Vehicle Conflicts with Pedestrian

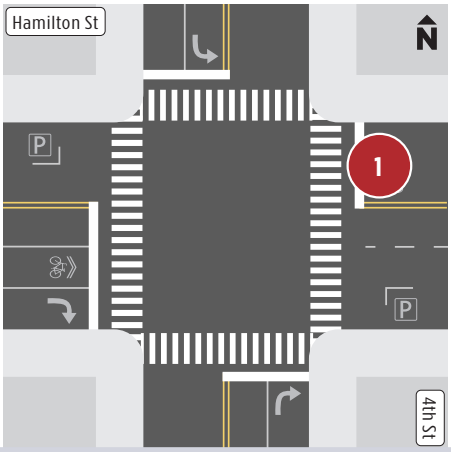


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Vehicle Conflicts with Bicycle

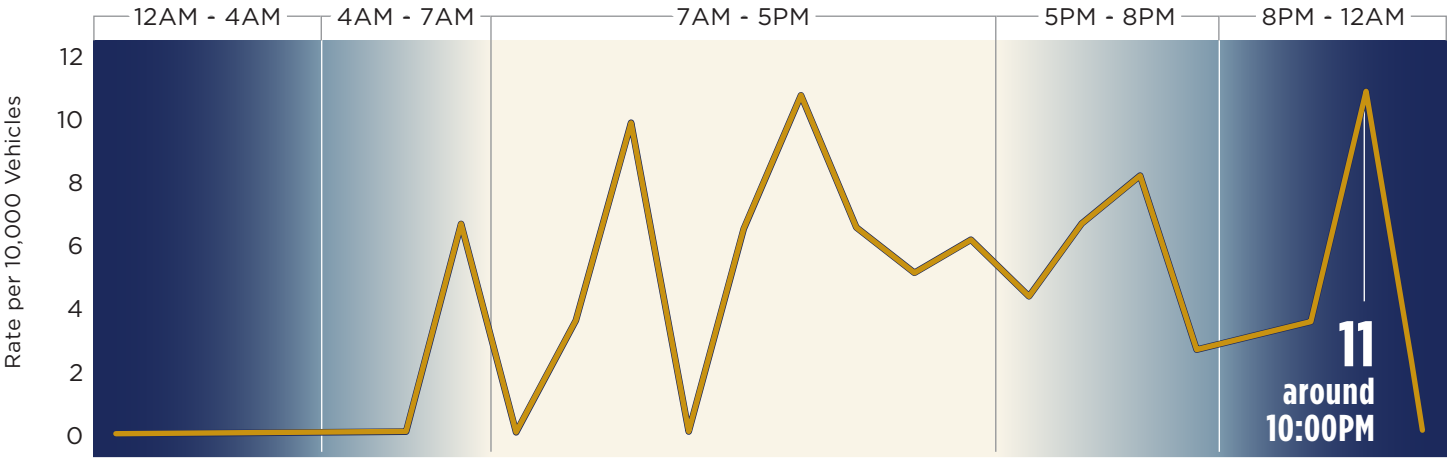


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn **Through** **Right Turn**

47%	12%	42%

Pedestrian vs. Bicycle

98%	2%

Intersection Volume

1% Pedestrian

<1% Bicycle

98% Vehicle

Key Takeaways

- 5% Confirmed conflict rate
- Three-in-four pedestrians involved in a critical event are in the northside crosswalk
- Southbound left turning and westbound right turning vehicles are involved in more than half of critical events

pennsylvania
DEPARTMENT OF TRANSPORTATION

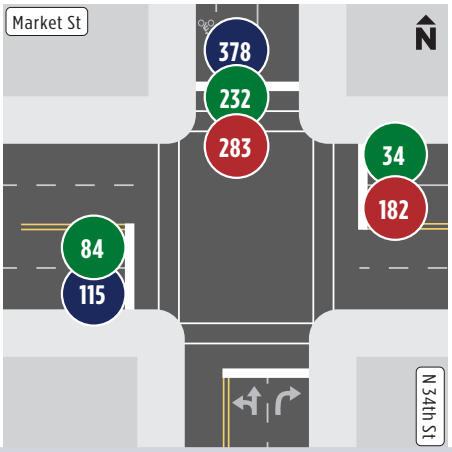
INTERSECTION FACT SHEET

Market St & 34th St — Philadelphia

COLLEGE

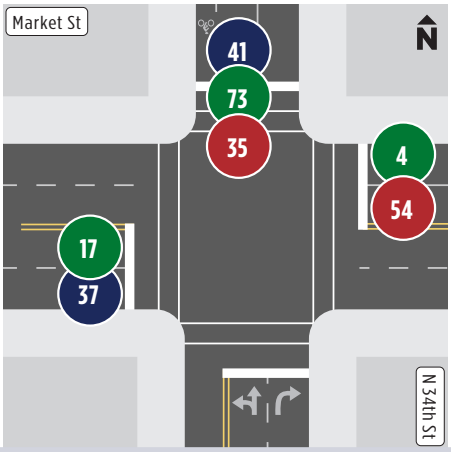
Number of Critical Events by Maneuver Type

Vehicle Conflicts with Pedestrian



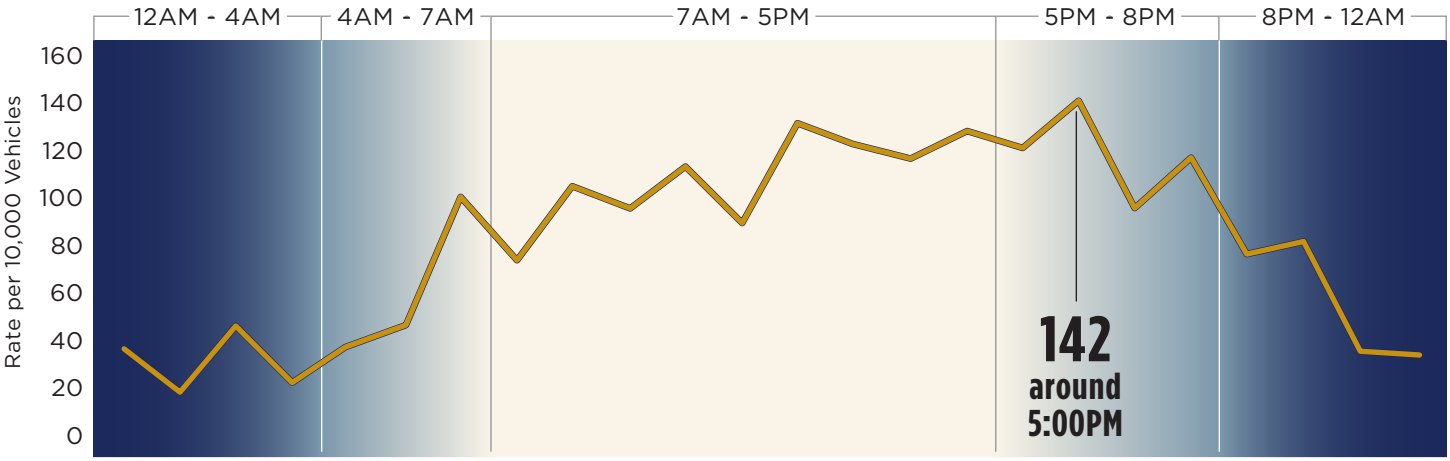
Vehicle Left Turn
Vehicle Through
Vehicle Right Turn

Vehicle Conflicts with Bicycle



Vehicle Left Turn
Vehicle Through
Vehicle Right Turn

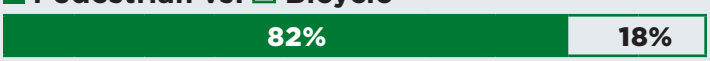
Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn | Through | Right Turn

Pedestrian vs. Bicycle



Intersection Volume

16% Pedestrian

1% Bicycle

82% Vehicle

Key Takeaways

- 8% Confirmed conflict rate
- Bicyclists are overrepresented in critical events
- Relatively even distribution of critical events across all vehicle movement types compared to other sites in the study

pennsylvania DEPARTMENT OF TRANSPORTATION

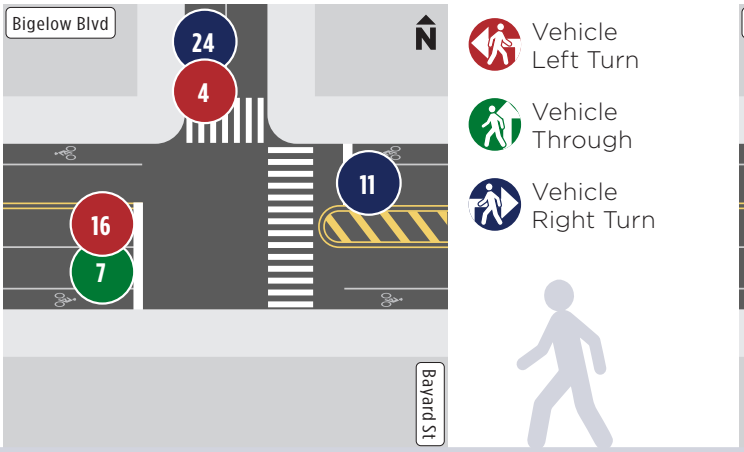
INTERSECTION FACT SHEET

Bigelow Blvd & Bayard St — Pittsburgh (before)

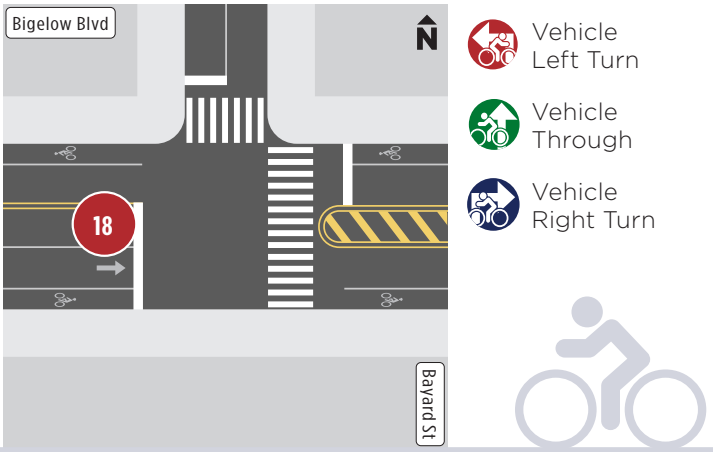
COLLEGE

Number of Critical Events by Maneuver Type

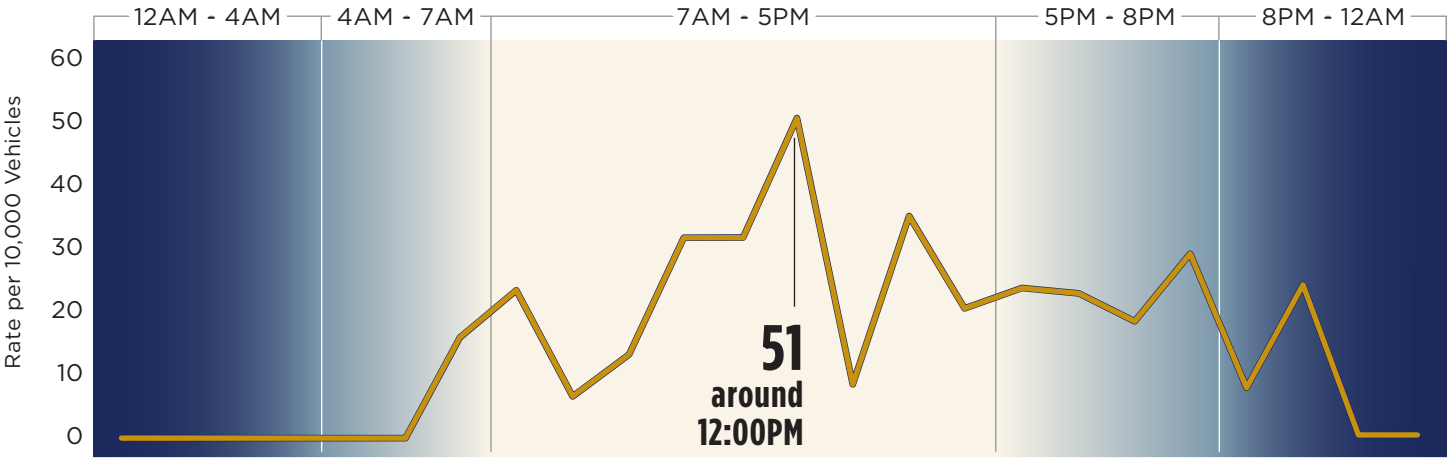
Vehicle Conflicts with Pedestrian



Vehicle Conflicts with Bicycle



Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn **Through** **Right Turn**

32%	15%	53%

Pedestrian vs. Bicycle

74%	26%

Intersection Volume

2% Pedestrian

<1% Bicycle

98% Vehicle

Key Takeaways

- 3% Confirmed conflict rate
- More than half of pedestrians involved in critical events are in northside crosswalk
- Bicyclist-involved critical events are dominated by interactions between eastbound left turning vehicles and westbound right turning bicyclists

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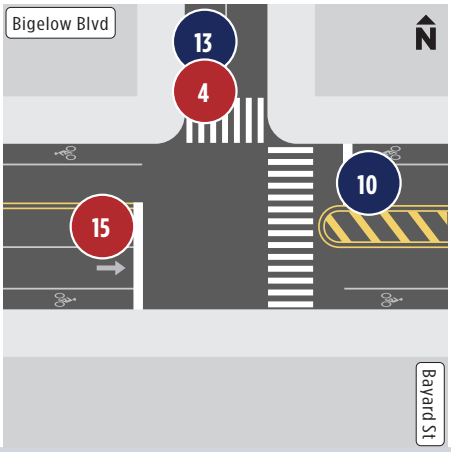
INTERSECTION FACT SHEET

COLLEGE

Bigelow/Bayard - After (No Snow)

Number of Critical Events by Maneuver Type

Vehicle Conflicts with Pedestrian

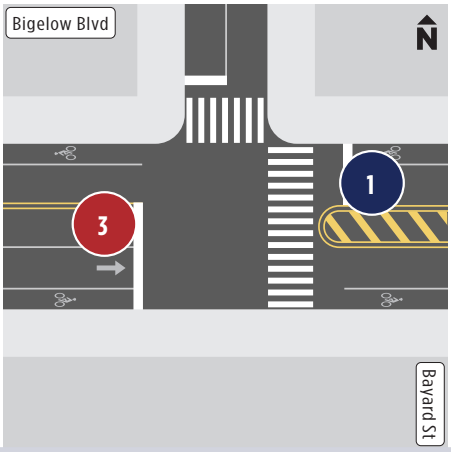


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Vehicle Conflicts with Bicycle

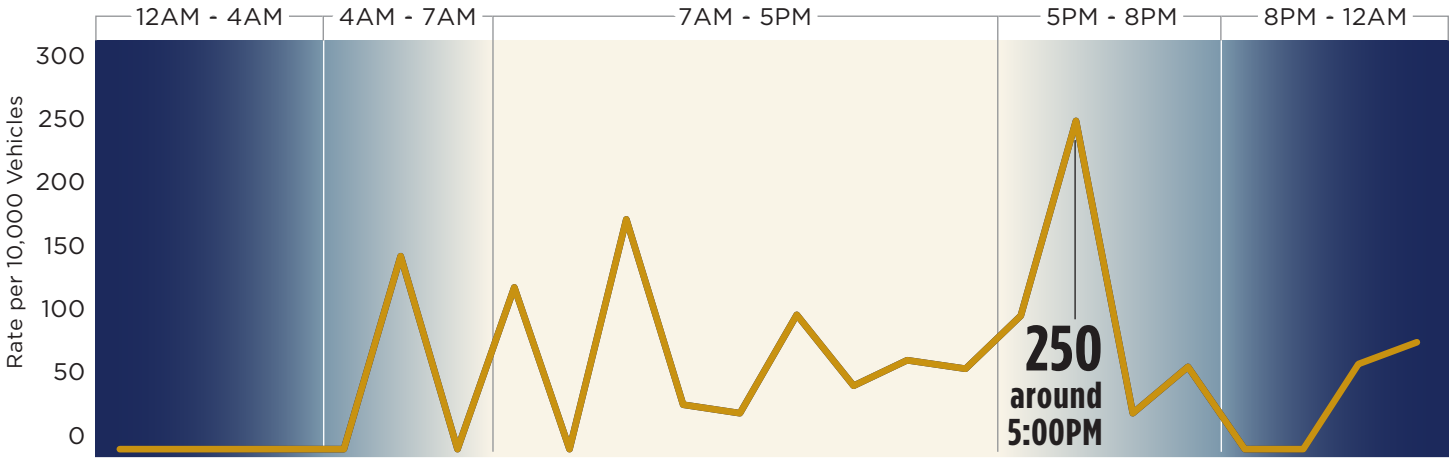


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn **Through** **Right Turn**

48%	0%	52%

Pedestrian vs. Bicycle

90%	10%

Intersection Volume

19% Pedestrian

1% Bicycle

80% Vehicle

Key Takeaways

- 1% Confirmed conflict rate
- 85% of critical events are involved with northside crosswalk
- Bicyclist-involved critical events are dominated by interactions between eastbound left turning vehicles and westbound right turning bicyclists

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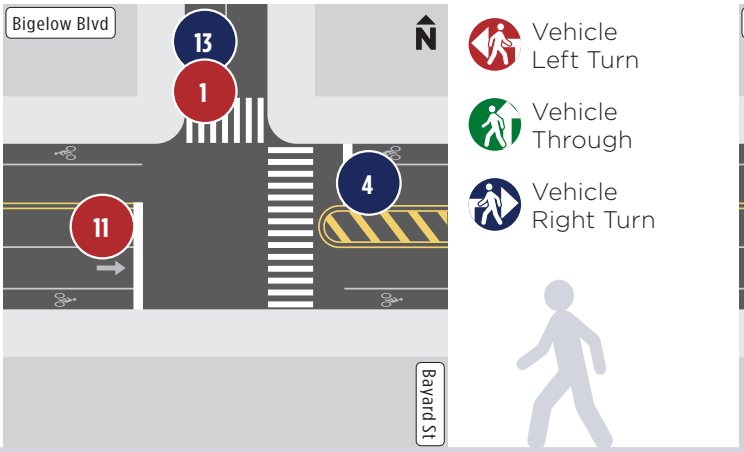
INTERSECTION FACT SHEET

Bigelow/Bayard - After (With Snow)

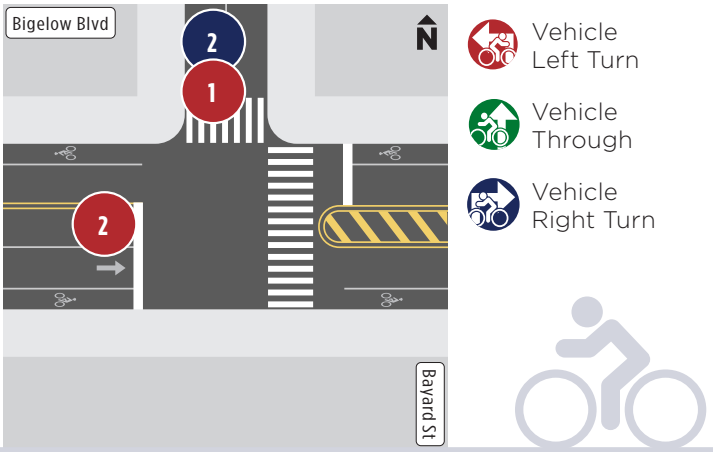
COLLEGE

Number of Critical Events by Maneuver Type

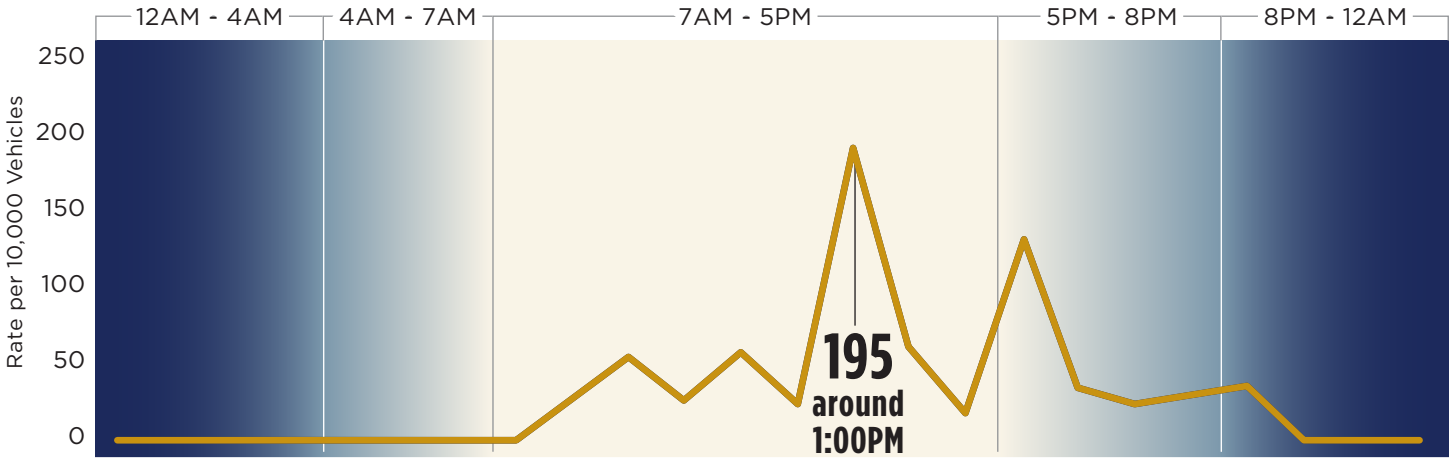
Vehicle Conflicts with Pedestrian



Vehicle Conflicts with Bicycle

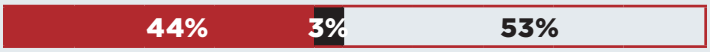


Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn | Through | Right Turn



Pedestrian vs. Bicycle

Intersection Volume

19% Pedestrian

1% Bicycle

80% Vehicle

Key Takeaways

- 1% Confirmed conflict rate
- 77% of critical events are involved with northside crosswalk
- Bicyclist-involved critical events are dominated by interactions between eastbound left turning vehicles and westbound right turning bicyclists

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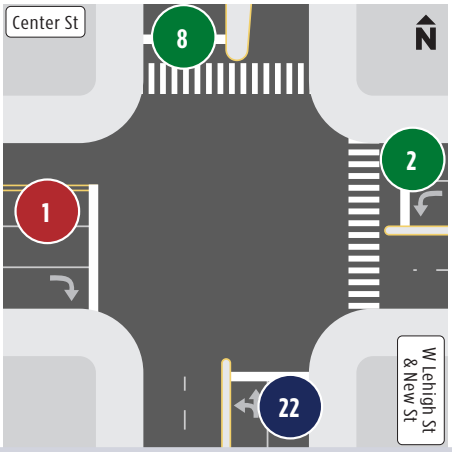
INTERSECTION FACT SHEET

Center St/W Lehigh St & New St Bethlehem (before)

URBAN

Number of Critical Events by Maneuver Type

Vehicle Conflicts with Pedestrian

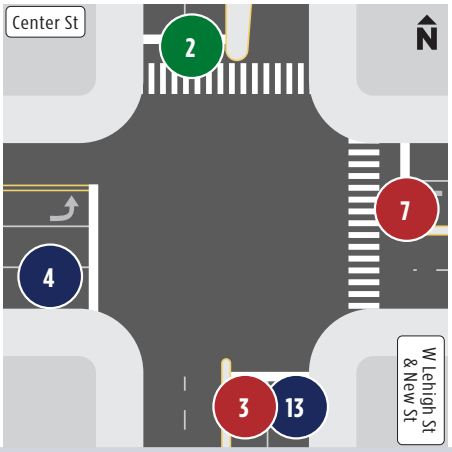


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Vehicle Conflicts with Bicycle

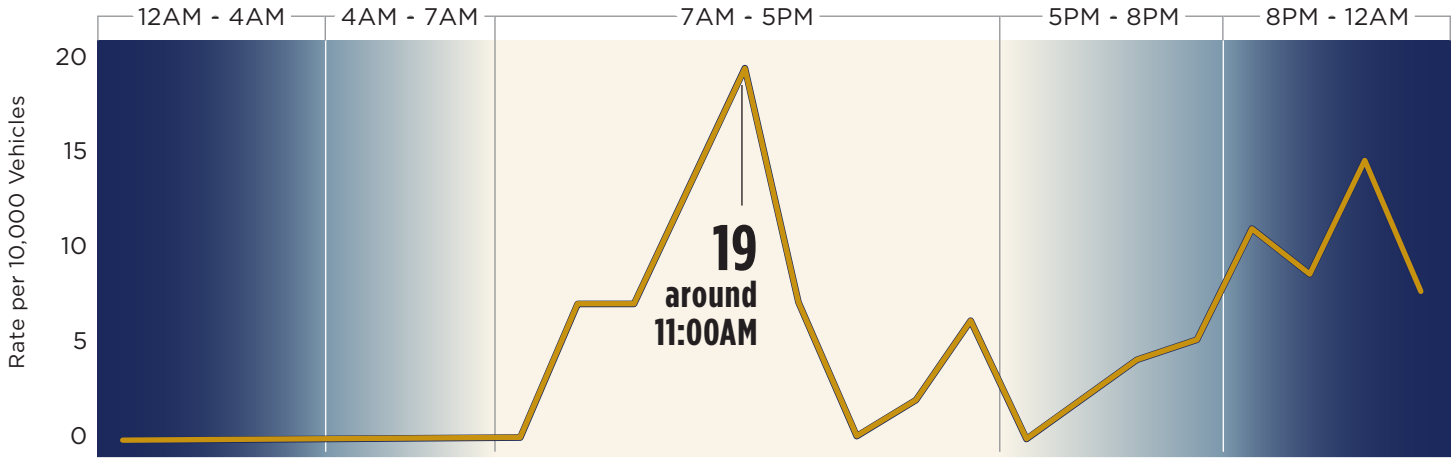


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn | Through | Right Turn

3%	34%	63%

Pedestrian vs. Bicycle

53%	47%

Intersection Volume

2% Pedestrian

1% Bicycle

97% Vehicle

Key Takeaways

- 5% Confirmed conflict rate
- More than half of critical events involve northbound right turning vehicles
- Relatively high proportion of users involved in critical events are bicyclists likely due to the influence of the trail

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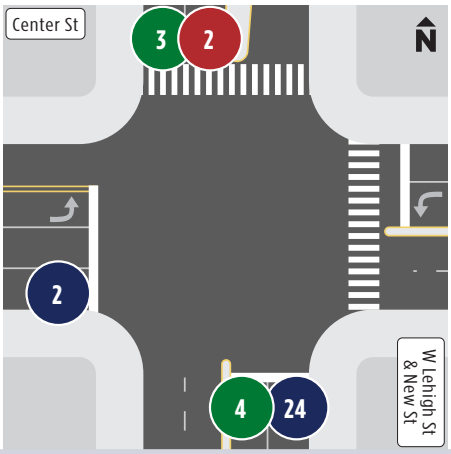
INTERSECTION FACT SHEET

Center St/W Lehigh St & New St Bethlehem (after)

URBAN

Number of Critical Events by Maneuver Type

Vehicle Conflicts with Pedestrian

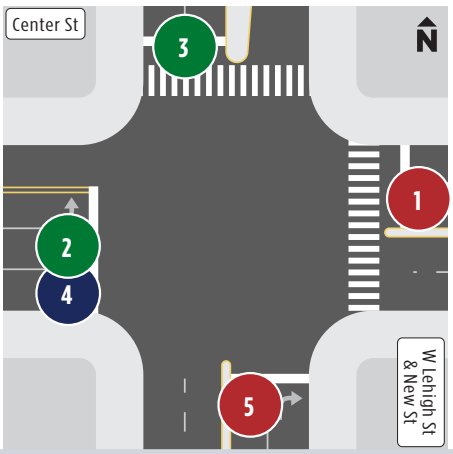


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Vehicle Conflicts with Bicycle

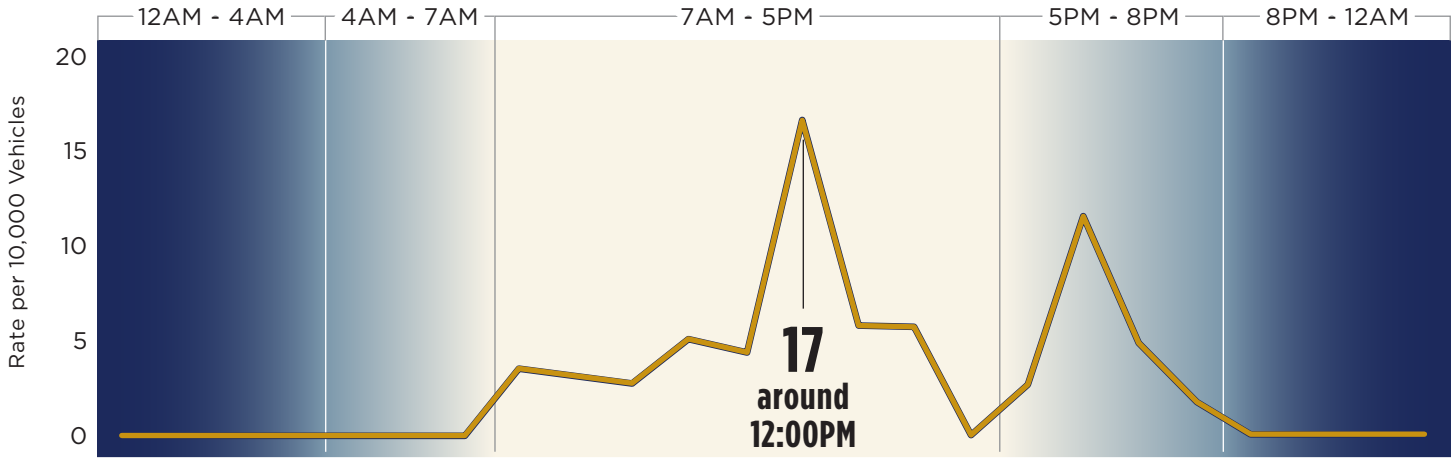


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn | Through | Right Turn

8%	18%	74%

Pedestrian vs. Bicycle

67%	33%

Intersection Volume

1% Pedestrian

<1% Bicycle

98% Vehicle

Key Takeaways

- 2% Confirmed conflict rate
- Count of critical events compared to before period remained relatively stable, but proportion of conflicts involving northbound right turning vehicles reduced 10 percentage points

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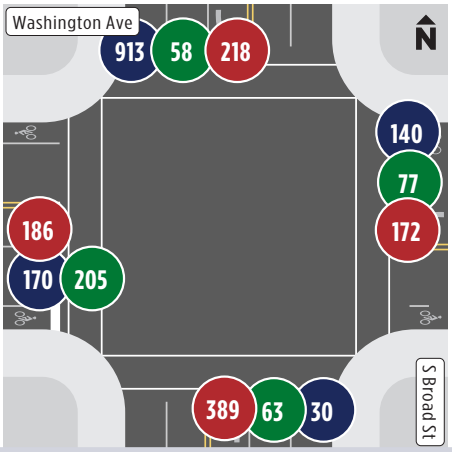
INTERSECTION FACT SHEET

S Broad St & Washington Ave — Philadelphia

URBAN

Number of Critical Events by Maneuver Type

Vehicle Conflicts with Pedestrian

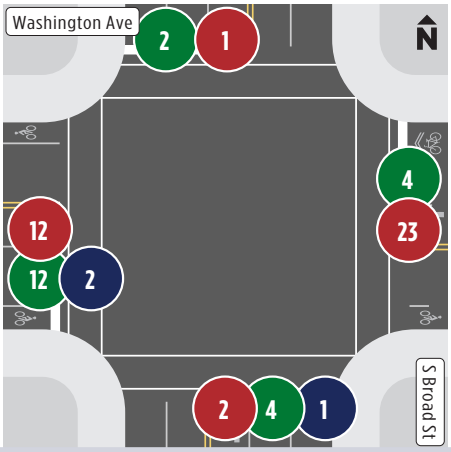


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Vehicle Conflicts with Bicycle

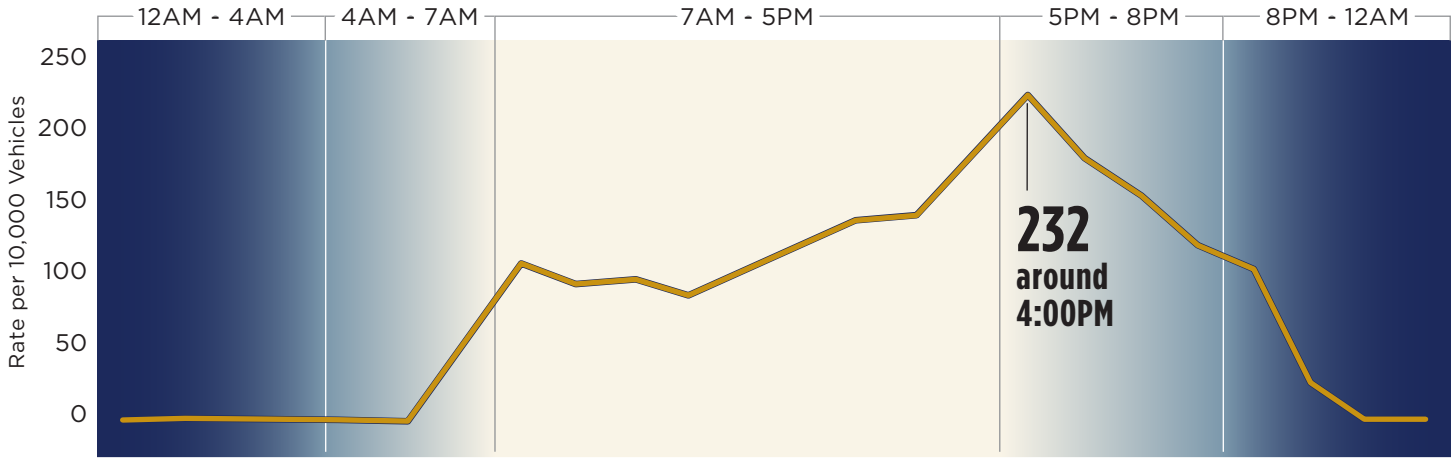


Vehicle Left Turn

Vehicle Through

Vehicle Right Turn

Pedestrian Critical Event Rate by Time of Day



Critical Event Demographics

Left Turn | Through | Right Turn

37% | 16% | 47%

Pedestrian vs. Bicycle

97% | 3%

Intersection Volume

11% Pedestrian

1% Bicycle

88% Vehicle

Key Takeaways

- 28% Confirmed conflict rate, significantly higher than other sites in this study
- More than half of critical events involved pedestrians in the westside crosswalk
- Roughly one-in-three motor vehicles involved in a critical event was making a southbound right turn