"Pedestrian and Bicycle Safety Analysis"

Prepared for

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Executive Summary

In research sponsored by the Delaware Center for Transportation and DelDOT, traffic crashes involving injuries to pedestrian or bicyclists between the years of 2012 and 2016 were studied. Tabulations and maps of related factors were produced and reviewed as a starting point and are discussed here and in the body of the report.

Data that could be useful to determine pedestrian and bicyclist activity levels were investigated so as to better understand the number of accidents that occur, the relative safety of current locations, the level of interaction between pedestrians, cyclists, and motor vehicles, and what might be appropriate safety measures. Approaches to estimating risk and exposure, and pedestrian activity were researched and available data for Delaware was investigated and related to observed crashes.

This report includes numerous maps as an approach to isolating hot spots that could lead to mitigation projects. For instance in the City of Wilmington there are a few street blocks that have more crashes. Mapping can also show where crashes are occurring at a lower rate than expected, and in such areas, further investigation may provide some insight for safety initiatives.

In the five year period data set there were 222 pedestrian crashes in Kent (14%), 1241 in New Castle (77%), 139 in Sussex (9%). Of these, 133 resulted in fatal injuries.

Distributions for pedestrian fatality crashes are very different than those for non-fatal crashes. Rather than clusters as seen in municipalities, fatalities are strung across major arteries where there is high volume, high speed, and multiple lanes. In particular, the corridors Route 40, Kirkwood Highway (Route 2), and Concord Pike in New Castle County, Route 13 through City of Dover, and in Sussex County near Rehoboth, on Route 1. About 2/3rds of crashes involving pedestrians occurred between intersections rather than at intersections.

For crashes involving fatal pedestrian injuries, pedestrian contributing factors included “In Roadway Improperly” (30%), “Not Visible” (25%), “Dart/Dash” (24%), and “Failure to Yield Right of Way” (15%). For these pedestrian fatalities, the pedestrian was determined to be DUI/impaired/emotionally disturbed in about 40% of the crashes, with the driver in this condition 9% of the time. This can be contrasted with non-fatal pedestrian crashes, where the pedestrian exhibited impairment 10% of the time and driver 3%.

For crashes involving non-fatal pedestrian injuries, leading contributing actions by the pedestrian were “In the Roadway Improperly” (12%), “Dart/Dash (16.8%), “Not Visible” (5.7%), and “Failure to Yield Right of Way” (5.5). Vehicle drivers’ contributing actions were mostly “Failed to yield right of way” (18%) or other contributing action (18%). There are a number of “Dart-Dash” and “Failure to Yield Right of Way “contributions within the City of Wilmington, City of Dover, and Route 1 leading to the beaches.

For pedestrian crashes, weather is a possible factor in less than 15% of the time, surface condition about 15%. Close to 60% of pedestrian injuries are at night, and about 80% of the pedestrian fatalities were at night.

Crashes are more clustered around locations where there are many destinations that are near concentrations of housing units, where there is usually more pedestrian activity. From the location of the crash it is usually not possible to determine the origin or destination of the pedestrian and there was no evidence found of crashes being in the neighborhood of particular types of destinations (i.e. retail, recreation, convenience stores, etc.). In 2017, the standard crash report was updated to include the origin and the destination of the pedestrian. An examination of the data in regards to origin and destination by DelDOT after this change, data indicated less than 20% of the records provided useful data and over half of the crashes were missing this origin and destination data. Additional training on capturing this information was suggested.

For all crashes studied, about 62% occurred in municipalities with 34% occurring in the City of Wilmington.

In the five years (2012 to 2016), there were 114 crashes involving bicyclists in Kent (18%), 399 in New Castle (64%), and 111 in Sussex (18%). There were 13 total bicyclist fatalities. Contributing Action by the cyclist for non-fatal crashes were mostly “Wrong-way riding” (18%), “Failure to Obey Traffic Signs” (10%), and “Failure to Yield Right of Way” (9%), with about a third of crashes indicating no improper action by the cyclist. “Driver Inattention” (13%), “Failure to Yield Right of Way” (11%), and “Operating vehicle in an Erratic or Dangerous Manner” (5.4) were leading contributing factors for drivers of motor vehicles.

Surface conditions (dry 90%) and weather (not raining 90%) were usually not factors with bicycle crashes and 76% of crashes were in daylight. There were only 13 bicyclist fatalities but 10 of those were at night.

Only 1% of bicyclist non-fatal crashes indicated impairment by the cyclist. However 3 in 13 of the fatalities indicated cyclist impairment and 2 of 13 indicated driver impairment.

Age distributions of pedestrian injuries are fairly balanced with no particular age group standing out. For pedestrian fatalities there are a bit more in the 30 to 59 year old categories. The 10 to 20 year old group for bicyclists see the most injuries followed by the 20 to 30 year old grouping as would be expected since bicyclists are generally younger.

In general, with most crashes there will be some mistake or contributing action. For instance, drivers sometimes go to fast or follow too close. Pedestrians may not wear visible clothing or may cross mid street rather than walk uncomfortable distances to intersections and pedestrian crossing facilities. In some cases such as with multi-lane high speed corridors, the situation is particularly unforgiving. Identifying the nature of those mistakes is helpful but ultimately it is a problem of the interaction with vehicles and pedestrians and bicyclists, and that interaction can be characterized in terms of the number of pedestrians, the number and speed of vehicles, features of transportation facilities, and neighboring land uses. To address that interaction, DelDOT and law enforcement and government agencies in Delaware have continued to promote educational programs, and safety initiatives to promote safe practices and travel. There are a numerous pedestrian and cyclist infrastructure projects such as on Route 40 and Route 13 corridors. Millions of dollars have been dedicated to additional pedestrian signals, lighting, sidewalks and other infrastructure, particularly in the last 10 years.

Without understanding the level of activity of walking or biking in an area, it is difficult to fully understand the safety of an area or the risk for a particular individual on a particular trip. Risk is typically defined as the number of crashes divided by the exposure. Exposure is a number associated with the activity level of a behavior and captures the amount of opportunity for an event to happen. Just because an area has many crashes does not mean it is relatively unsafe for an individual making a particular trip. More pedestrian crashes happen where more people are walking. Improving an area for walking may even result in more crashes if activity levels increase, though from the individual walker's perspective, the areas could be less risky.

Crash rates have often been developed purely by dividing crashes by population and coming up with a per capita rate per 100,000. As different areas have different activity levels, comparison using population based estimates are often not appropriate and can be misleading. .

Estimating the risk for pedestrians or cyclists for any corridor or small area or making judgements when viewing crashes that are particularly numerous in an area requires appropriate measures of exposure which are generally unavailable in Delaware except perhaps in areas with comprehensive pedestrian or cyclist counts. There are various ways exposure could be specified, such as with counts, number of trips, number of miles traveled or number of hours spent traveling.

Determination of risk depends on exposure and determination of exposure is needed for:

- Development of safety performance measures
- Identifying high-risk subareas
- Examination of high risk facilities
- Prioritization of projects
- Evaluating the effectiveness of safety countermeasures

FHWA has produced studies and guidelines on the development of risk and exposure estimates, have compiled data and studies of risk factors, and have documented several approaches and analytical methods to produce risk estimates for pedestrian and bicycle travel. There is considerable research into the factors that can be used to model the number of walk or bike trips that will result in a particular locale. Analytic methods to estimate exposure measures are in three main areas: site counts, demand estimation models; and travel surveys.

Detailed survey information and site counts were not available for this project. To illustrate a view of analysis that would take into account exposure, an estimate of pedestrian activity at the traffic zone level was developed. Zone to zone trip tables were obtained, crashes were allocated to zones, zone to zone trip distances were estimated using housing clusters and destination clusters. Data on the percentage of walking trips depending on trip distance were applied to obtain an exposure estimate for pedestrian activity that could be related to the number of crashes observed, and was superior to using population density. Areas with high pedestrian activity but relatively low number of crashes included urban areas like Newark and Center City Wilmington. Areas where there was relatively high number of crashes in relation to lower pedestrian activity, were identified in corridors like Route 40 and Kirkwood Highway, which is consistent with crashes increasing with increasing speed and multilane facilities. First attempts of looking at crashes in Wilmington relative to exposure appeared to allow for the identification of areas that are less safe than others.

A recommended next step would be to refine pedestrian and bicycle activity estimates and measures of exposure, together with developing a more detailed understanding of the level of service provided by paths between origins and destinations. A high resolution study of travel as necessary for examination of pedestrian and bike safety is increasingly more possible as DelDOT in recent years has developed travel demand forecasting at the tax parcel level, detailed housing and destination data is becoming available, and higher resolution travel network specifications are being developed. Better estimates of pedestrian and bike activity would also support other efforts such as the planning of multi-modal facilities. However, use of analytical methods to identify specific unsafe facilities are limited in most suburban areas due to the rarity of crashes.

Factors Related to Pedestrian and Bicycle Crashes

Five years of crash report data from 2012 thru 2016 were made available for study. Data included 624 crashes involving bicycles and 1602 crashes involving pedestrians. The data includes location, time of day, primary contributing factors, lighting, surface condition, weather, information about vehicles involved, age and condition of drivers/walkers, road type, and other data. This chapter tabulates data from that review.

County Tabulations

Below are tabulations of crashes by year and county for those crashes involving pedestrians. Rates do not fluctuate from year to year beyond what would be expected from random variation. Most striking is that when calculating a rate based on population of counties, New Castle County is close to 2 times the rate for Kent County, and about 3-1/2 times more than for Sussex. The conclusion from this is that the counties are significantly different, not that New Castle County is necessarily more dangerous than the other counties. The reverse could be true. In order to compare the relative safety there must be some estimate of the exposure that needs to be taken into account. For instance, New Castle County is expected to have considerably more walk activity than the other counties. This is discussed in detail in a later chapter in this report. Estimates shown there indicate that New Castle County is expected to see about 6 times the number of walk trips than Kent and close to 4 times for Sussex. For bike trips, New Castle County is expected to have close to 4 times as many as Kent and about 25 percent more than Sussex. Such estimates then greatly affect the interpretation of the tables presented here and on the next page.

Figure 1, Pedestrian Crashes By Year By County

	2012	2013	2014	2015	2016	Total	Rate Based on Population
Kent	33	36	55	53	45	222	24.3 per 100,000 persons per year
New Castle	260	246	235	238	262	1241	43.5 per 100,000 persons per year
Sussex	28	27	34	21	29	139	12.2 per 100,000 persons per year
Total	321	309	324	312	336	1602	32.7 per 100,000 persons per year

Source: DelDOT Crash Analysis Reporting System

Figure 2, Pedestrian Non-Fatal Crashes By Year By County

	2012	2013	2014	2015	2016	Total	Rate Based on Population
Kent	29	35	46	48	39	197	21.5 per 100,000 persons per year
New Castle	237	228	219	212	244	1140	40 per 100,000 persons per year
Sussex	27	24	33	19	29	132	11.6 per 100,000 persons per year
Total	293	287	298	279	312	1469	30 per 100,000 persons per year

Source: DelDOT Crash Analysis Reporting System

Figure 3, Pedestrian Fatal Crashes By Year By County

	2012	2013	2014	2015	2016	Total	Rate Based on Population
Kent	4	1	9	5	6	25	2.7. per 100,000 persons per year
New Castle	23	18	16	26	18	101	3.5 per 100,000 persons per year
Sussex	1	3	1	2	0	7	0.6 per 100,000 persons per year
Total	28	22	26	33	24	133	2.7 per 100,000 persons per year

Source: DelDOT Crash Analysis Reporting System

Below are similar tabulations for crashes involving bicyclists. The rates based on population in this case are more similar but again, comparisons depend on exposure to the activity.

Figure 4,Bicycle Crashes By Year By County

	2012	2013	2014	2015	2016	Total	Rate Based on Population
Kent	27	16	23	26	22	114	12 per 100,000 per year
New Castle	68	89	85	82	75	399	14 per 100,000 per year
Sussex	33	14	21	21	22	111	10 per 100,000 per year
Total	128	119	129	129	119	624	13 per 100,000 per year

Source: DelDOT Crash Analysis Reporting System

Figure 5, Bicycle Non-Fatal Crashes By Year By County

	2012	2013	2014	2015	2016	Total
Kent	25	16	23	25	20	109
New Castle	67	89	83	82	75	396
Sussex	32	14	20	19	21	106
Total	124	119	126	126	116	611

Source: DelDOT Crash Analysis Reporting System

Figure 6, Bicycle Fatal Crashes By Year By County

	2012	2013	2014	2015	2016	Total	Rate Based on Population
Kent	2	0	0	1	2	5	0.5 per 100,000 per year
New Castle	1	0	2	0	0	3	0.1 per 100,000 per year
Sussex	1	0	1	2	1	5	0.4 per 100,000 per year
Total	4	0	3	3	3	13	0.2 per 100,000 per year

Source: DelDOT Crash Analysis Reporting System

Crashes Involving Pedestrians

The next pages tabulate various factors noted in crash reports about crashes involving pedestrians and bicyclists. There are 3 data items in the reports that can assist with understanding what led to an crash-- the Primary Contributing Circumstance of the crash, the Primary Contributing Action by the Pedestrian, and the Primary Contributing Action by the Driver of a vehicle in the crash. These three are tabulated below. The Primary Contributing Action by the Pedestrian is useful to examine the pedestrian's role. In several cases, the values of these could be Other or Unknown in which case further examination of the report narrative is necessary. The Primary Contributing Action by the Driver indicates failure to yield right of way 18% of the time. More information can be obtained about the action of the driver with the Primary Contributing Circumstance in figure 9, in particular showing the role of driver inattention.

Figure 7, Pedestrian Non-Fatal Injury, Contributing Action by Pedestrian

	Frequency	Percent
Disabled Vehicle Related	16	1.1
Wrong-Way Riding or Walking	31	2.1
Entering/Exiting Parked/Standing Vehicle	38	2.6
Inattentive (Talking, Eating, Etc.)	50	3.4
Failure to Obey Traffic Signs, Signals, or Officer	53	3.6
Failure to Yield Right-Of-Way	81	5.5
Not Visible (Dark Clothing, No Lighting, Etc.)	84	5.7
Other	94	6.3
In Roadway Improperly	180	12.1
Unknown	191	13
Dart/Dash	249	16.8
No Improper Action	419	28.2
Total	1486	100

Source: DelDOT Crash Analysis Reporting System

Figure 8, Pedestrian Fatal Injury, Primary Contributing Action by Driver

	Number	Percent
Driver inattention, distraction, or fatigue	1	0.9
Driving under the influence	1	0.9
Failed to yield right of way	21	18.1
Other	21	18.1
Pedestrian Contributing Action	68	58.6
Unknown	4	3.4
Total	116	100

Source: DelDOT Crash Analysis Reporting System

Figure 9, Pedestrian Non-Fatal Injury, Primary Contributing Circumstance Driver

	Number	Percent
Failed to yield right of way	1	0.1
Speeding	1	0.1
Wrong side or wrong way	1	0.1
Following too close	2	0.1
Improper passing	3	0.2
Made improper turn	4	0.3
Mechanical defects	4	0.3
Other improper driving	4	0.3
Roadway circumstances - debris, holes, etc.	5	0.3
Passed Stop Sign	6	0.4
Driving in an aggressive manner	10	0.7
Driving under the influence	16	1.1
Other environmental - weather, glare	17	1.2
Disregard Traffic Signal	23	1.6
Improper backing	30	2.1
Driving in a careless or reckless manner	85	5.9
Failed to yield right of way	102	7.1
Driver inattention, distraction, or fatigue	162	11.3
Unknown	261	18.1
Other	294	20.4
Pedestrian Contributing Action	409	28.4
Total	1440	100

Source: DelDOT Crash Analysis Reporting System

As shown in figure 10, The leading contributing factor in fatal crashes is “In Road Improperly,” followed by “Not Visible,” and “Dart/Dash,” which is in line with figures that say that for pedestrian fatality crashes 81 % are at night and 40% involve being under the influence of drugs or alcohol (or emotional disturbance).

Figure 10, Pedestrian Fatality, Contributing Action by Pedestrian

	Frequency	Percent
Disabled Vehicle Related	1	0.9
Failure to Obey Traffic Signs, Signals, or Officer	1	0.9
Inattentive (Talking, Eating, Etc.)	1	0.9
Entering/Exiting Parked/Standing Vehicle	2	1.7
Other	2	1.7
Wrong-Way Riding or Walking	2	1.7
No Improper Action	3	2.6
Unknown	5	4.3
Failure to Yield Right-Of-Way	15	12.9
Dart/Dash	24	20.7
Not Visible (Dark Clothing, No Lighting, Etc.)	25	21.6
In Roadway Improperly	35	30.2
Total	116	100

Source: DelDOT Crash Analysis Reporting System

Tabulations for the Contributing Action by the Driver are shown below. In the case of crashes involving a pedestrian non-fatal injury, around 40% of the time the driver did no contributing action. For fatal crashes, 80% of the time there is no contributing action by the driver. The big difference is that 78% of the time the driver had no contributing action.

Figure 11, Pedestrian Non-Fatal Injury, Contributing Action by Driver of Vehicle

	Frequency	Percent
Followed too closely	1	0.1
Disregard other road markings	2	0.1
Disregard other traffic sign	3	0.2
Exceeded authorized speed limit	3	0.2
Improper Passing	3	0.2
Ran Stop Sign	3	0.2
Wrong side or wrong way	3	0.2
Made an improper turn	4	0.3
Driving too fast for condition	7	0.5
Failure to keep in proper lane	7	0.5
Swerving or avoiding	8	0.5
Ran off roadway	9	0.6
Ran Red Light	10	0.7
Improper backing	28	1.9
Failed to yield right of way	102	6.9
Other Contributing Action	124	8.3
Operating vehicle in erratic, dangerous manner	146	9.8
Unknown	385	26
No Contributing Action	638	42.9
Total	1486	100

Source: DelDOT Crash Analysis Reporting System

Figure 12, Pedestrian Fatality, Contributing Action by Driver

	Frequency	Percent
Operating vehicle in erratic or dangerous manner	1	0.9
Ran off roadway	1	0.9
Exceeded authorized speed limit	2	1.7
Swerving or avoiding	2	1.7
Other Contributing Action	6	5.2
Unknown	13	11.2
No Contributing Action	91	78.4
Total	116	100

Source: DelDOT Crash Analysis Reporting System

The condition of the pedestrian and driver of vehicles involved is also included in the crash reports and is provided below. A figure that stands out is that 42 percent of the fatalities are in cases where the pedestrian is impaired. For Non-Fatal crashes this is lower at around 10%.

Figure 13, Condition of Pedestrian

For non-fatal	Frequency	Percent
Apparently Normal	1156	78%
DUI/impaired/disturbed	142	10%
Unknown/missing	161	11%

For fatal	Frequency	Percent
Apparently Normal	26	22%
DUI/impaired/disturbed	49	42%
Unknown/missing	40	34%

Source: DelDOT Crash Analysis Reporting System

Figure 14, Condition of Driver, Pedestrian Crashes

For non-fatal	Frequency	Percent
Apparently Normal	1019	69%
DUI/impaired/disturbed	52	3%
Unknown/missing	415	28%

For fatal	Frequency	Percent
Apparently Normal	92	79%
DUI/impaired/disturbed	10	9%
Unknown/missing	14	12%

When examining age distributions of pedestrian injuries percentages are fairly balanced.

Figure 15 Age Distribution for Pedestrian Crashes

Age	Count	Percentage
Under 9	134	8.58
10 to 19	268	17.16
20 to 29	369	23.62
30 to 39	223	14.28
40 to 49	213	13.64
50 to 59	185	11.84
60 to 69	102	6.53
70 up	68	4.35

Source: DelDOT Crash Analysis Reporting System

Figure 16 Age Distributions for Pedestrian Fatalities

Age	Count	Percentage
Under 9	0	0.00
10 to 19	21	16.41
20 to 29	12	9.38
30 to 39	26	20.31
40 to 49	26	20.31
50 to 59	23	17.97
60 to 69	9	7.03
70 up	11	8.59

Source: DelDOT Crash Analysis Reporting System

Figure 17, Gender in Pedestrian Crashes

Gender			
For non-fatal		Number	Percent
	Female	582	40
	Male	864	60
For fatalities			
	Female	35	30
	Male	81	70

Figure 18, Gender in Bicycle Crashes

Gender			
For non-fatal		Number	Percent
	Female	105	17
	Male	508	83
For fatalities			
	Female	4	31
	Male	9	69

Source: DelDOT Crash Analysis Reporting System

For pedestrian crashes, weather is predominantly clear and surface conditions dry. However darkness is related to more crashes, particularly for fatalities.

Figure 19, Crashes and weather

WEATHER			
For non-fatal		Number	Percent
	Clear/cloudy	1304	88
	Raining/snowing/fog	157	10
For fatalities			
	Clear/cloudy	100	86
	Raining/snowing/fog	14	12

Source: DelDOT Crash Analysis Reporting System

Figure 20, Crashes and Surface Condition

SURFACE			
For non-fatal		Number	Percent
	Dry	1220	82
	Wet/ice/snow	238	16
For fatalities			
	Dry	96	83
	Wet/ice/snow	18	15

Source: DelDOT Crash Analysis Reporting System

Figure 21, Crashes and Lighting

LIGHT			
For non-fatal		Number	Percent
	Daylight	852	57
	Dusk/dawn	65	4
	Dark	538	36
For fatalities			
	Daylight	19	16
	Dusk/dawn	2	2
	Dark	94	81

Source: DelDOT Crash Analysis Reporting System

Figure 22, Pedestrian Fatality and Injury Crashes by time of day

Hour of Day	Fatality Frequency	Fatality Percent	Injury Frequency	Injury Percent
0	8	6.9	37	2.5
1	9	7.8	27	1.8
2	4	3.4	17	1.1
3	3	2.6	7	0.5
4	5	4.3	5	0.3
5	3	2.6	10	0.7
6	2	1.7	29	2
7	1	0.9	59	4
8	3	2.6	56	3.8
9	1	0.9	44	3
10	0	0	48	3.2
11	2	1.7	54	3.6
12	2	1.7	65	4.4
13	2	1.7	68	4.6
14	2	1.7	80	5.4
15	2	1.7	103	6.9
16	2	1.7	114	7.7
17	7	6	124	8.3
18	11	9.5	141	9.5
19	10	8.6	125	8.4
20	12	10.3	112	7.5
21	16	13.8	70	4.7
22	5	4.3	52	3.5
23	4	3.4	39	2.6
Total	116	100	1486	100

Source: DelDOT Crash Analysis Reporting System

It is interesting to view more closely the causes of pedestrian crashes when no improper action is taken by the pedestrian.

Figure 23 Primary Contributing Circumstance for Crashes Involving Pedestrians Where Pedestrian Makes No Improper Action

	Percentage of Crashes
Improper backing	3.1
Driving under the influence	3.3
Disregard Traffic Signal	3.8
Driving in a careless or reckless manner	10.2
Failed to yield right of way	13.7
Unknown	22.5
Driver inattention, distraction, or fatigue	25.4

Source: DelDOT Crash Analysis Reporting System

Crashes Involving Bicyclists

As shown in figure 24 below, over 60% of the time, the bicyclist may have avoided a non-fatal injury. For those crashes involving a fatality, though there were only 13 crashes in the time period, it would seem many of these were also avoidable by the bicyclist.

Figure 24, Bicyclist Non-Fatal Injury, Contributing Action by Cyclist

	Frequency	Percent
Improper Passing	5	0.8
Improper Turn/Merge	13	2.1
Inattentive	14	2.3
Not Visible	15	2.5
Dart/Dash	28	4.6
In Roadway Improperly	42	6.9
Other	42	6.9
Unknown	47	7.7
Failure to Yield Right-Of-Way	57	9.3
Failure to Obey Traffic Signs,	62	10.1
Wrong-Way Riding or Walking	109	17.8
No Improper Action	177	29
Total	611	100

Source: DelDOT Crash Analysis Reporting System

Figure 25, Bicyclist Fatality, Contributing Action by Cyclist

	Frequency	Percent
Failure to Yield Right-Of-Way	1	7.7
Improper Turn/Merge	1	7.7
In Roadway Improperly	1	7.7
Wrong-Way Riding or Walking	1	7.7
Failure to Obey Traffic Signs,	2	15.4
Not Visible	2	15.4
Unknown	2	15.4
No Improper Action	3	23.1
Total	13	100

Source: DelDOT Crash Analysis Reporting System

Figure 26, Bicyclist Injury, Contributing Action by Driver of Vehicle

	Frequency	Percent
Disregard other road markings	1	0.2
Exceeded authorized speed limit	1	0.2
Ran Red Light	2	0.3
Swerving or avoiding	2	0.3
Ran Stop Sign	3	0.5
Failure to keep in proper lane	4	0.7
Improper Passing	4	0.7
Disregard other traffic sign	6	1
Made an improper turn	7	1.1
Other Contributing Action	30	4.9
Operating vehicle in erratic or dangerous manner	33	5.4
Failed to yield right of way	68	11.1
Unknown	141	23.1
No Contributing Action	309	50.6
Total	611	100

Source: DelDOT Crash Analysis Reporting System

Figure 27, Bicyclist Fatality, Contributing Action by Driver

	Frequency	Percent
Exceeded authorized speed limit	1	7.7
Failed to yield right of way	1	7.7
Wrong side or wrong way	1	7.7
Operating vehicle in an erratic or dangerous fashion	2	15.4
Unknown	2	15.4
No Contributing Action	6	46.2
Total	13	100

Source: DelDOT Crash Analysis Reporting System

Figure 28, Bicyclist Fatality, Primary Contributing Circumstance

	Frequency	Percent
Disregard Traffic Signal	1	7.7
Driving in a careless or reckless manner	1	7.7
Failed to yield right of way	1	7.7
Improper lane change	1	7.7
Other	1	7.7
Pedestrian	1	7.7
Wrong side or wrong way	3	23.1
Driving under the influence	4	30.8
Total	13	100

Source: DelDOT Crash Analysis Reporting System

Figure 29 Bicycle Non-Fatal Injury, Primary Contributing Circumstance,

	Frequency	Percent
Roadway circumstances - debris, holes, etc.	1	0.2
Speeding	1	0.2
Driving in an aggressive manner	2	0.3
Following too close	3	0.5
Mechanical defects	3	0.5
Improper lane change	4	0.7
Other environmental circumstances	4	0.7
Driving under the influence	7	1.1
Improper passing	8	1.3
Made improper turn	8	1.3
Other improper driving	12	2
Driving in a careless or reckless manner	17	2.8
Passed Stop Sign	17	2.8
Disregard Traffic Signal	24	3.9
Bicyclist Contributing Action	37	6.1
Wrong side or wrong way	54	8.8
Driver inattention, distraction, or fatigue	78	12.8
Unknown	78	12.8
Failed to yield right of way	116	19
Other	137	22.4
Total	611	100

Source: DelDOT Crash Analysis Reporting System

While there were only 9 fatal bicycle crashes in the data for years 2012 to 2016, a third of the crashes involved impairment of the cyclist or driver.

Figure 30, Cyclist Condition

CYCLYST CONDITION			
For bicycle non-fatal		Frequency	Percentage
	Apparently Normal	540	88
	DUI/impaired/disturbed	24	4
For bicycle fatal			
	Apparently Normal	6	67
	DUI/impaired/disturbed	3	33

Source: DelDOT Crash Analysis Reporting System

Weather and surface conditions are usually good in cyclist crashes. Darkness could be a factor in about 20% of bicycle non-fatal crashes. For bicyclist fatalities, 10 out of 13 crashes were in darkness.

Figure 31, Driver Condition

DRIVER CONDITION			
For bicycle non-fatal		Frequency	Percentage
	Apparently Normal	458	75
	DUI/impaired/disturbed	6	1
For bicycle fatal			
	Apparently Normal	8	80
	DUI/impaired/disturbed	2	20

Source: DelDOT Crash Analysis Reporting System

Figure 32, Weather and bicycle crashes

WEATHER			
For bicycle non-fatal		Frequency	Percentage
	Not raining	573	93
	Raining	27	5
For bicycle fatal			
	Not raining	13	100
	Raining	0	0

Source: DelDOT Crash Analysis Reporting System

Figure 33, Surface Condition and Bicycle Crashes

SURFACE	Column1	Column2	Column3
For bicycle non-fatal		Frequency	Percentage
	Dry	551	90
	Wet/ice/snow	52	9
For bicycle fatal			
	Dry	13	100
	Wet/ice/snow	0	0

Source: DelDOT Crash Analysis Reporting System

Figure 34, Lighting and Bicycle Crashes

LIGHT			
For bicycle non-fatal		Frequency	Percentage
	Daylight	446	76
	Dusk/Dawn	25	4
	Dark	116	19
For bicycle fatal			
	Daylight	2	15
	Dusk/Dawn	1	7.5
	Dark	10	77

Source: DelDOT Crash Analysis Reporting System

Examining bicycle crashes by time of day, 68% of fatalities were between the hours of 7pm and 2am. For crashes involving bicycle non-fatality injuries, there is more of a spread throughout the day.

Figure 35, Bicycle Fatality and Injury Crashes by time of day

Hour Of Day	Fatality Frequency	Fatality Percent	Injury Frequency	Injury Percent
0	0	0	2	0.3
1	0	0	4	0.7
2	3	23.1	2	0.3
3	0	0	1	0.2
4	1	7.7	0	0
5	0	0	3	0.5
6	0	0	9	1.5
7	0	0	21	3.4
8	0	0	34	5.6
9	0	0	20	3.3
10	1	7.7	30	4.9
11	0	0	37	6.1
12	0	0	43	7
13	0	0	32	5.2
14	0	0	35	5.7
15	0	0	50	8.2
16	0	0	53	8.7
17	1	7.7	58	9.5
18	0	0	53	8.7
19	2	15.4	45	7.4
20	3	23.1	41	6.7
21	1	7.7	22	3.6
22	0	0	7	1.1
23	1	7.7	9	1.5
Total	13	100	611	100

Figure 36 Primary Contributing Circumstance for Crashes Involving Bicyclists Where Bicyclist Takes No Improper Action

	Percentage of Crashes
Driver inattention, distraction, or fatigue	27.2
Failed to yield right of way	25.6
Unknown	16.1
Other	9.4
Driving in a careless or reckless manner	5
Passed Stop Sign	3.3
Improper Passing	2.8
Disregard Traffic Signal	2.2
Driving under the influence	2.2

Source: DelDOT Crash Analysis Reporting System

Figure 37 below shows the age distribution of bicyclist injuries. The distribution is fairly spread out but of course bicyclists are generally younger which is reflected.

Figure 37 Age Distribution of Bicycle Injuries

Age	Count	Percentage
Under 9	39	6.22
10 to 19	194	30.94
20 to 29	153	24.40
30 to 39	51	8.13
40 to 49	64	10.21
50 to 59	68	10.85
60 to 69	48	7.66
70 up	10	1.59

Source: DelDOT Crash Analysis Reporting System

Environmental Factors and Mapping Views

Having examined possible causal factors in the previous chapter, this chapter moves toward an understanding of the spatial context of crashes, looking at land use and the travel network.

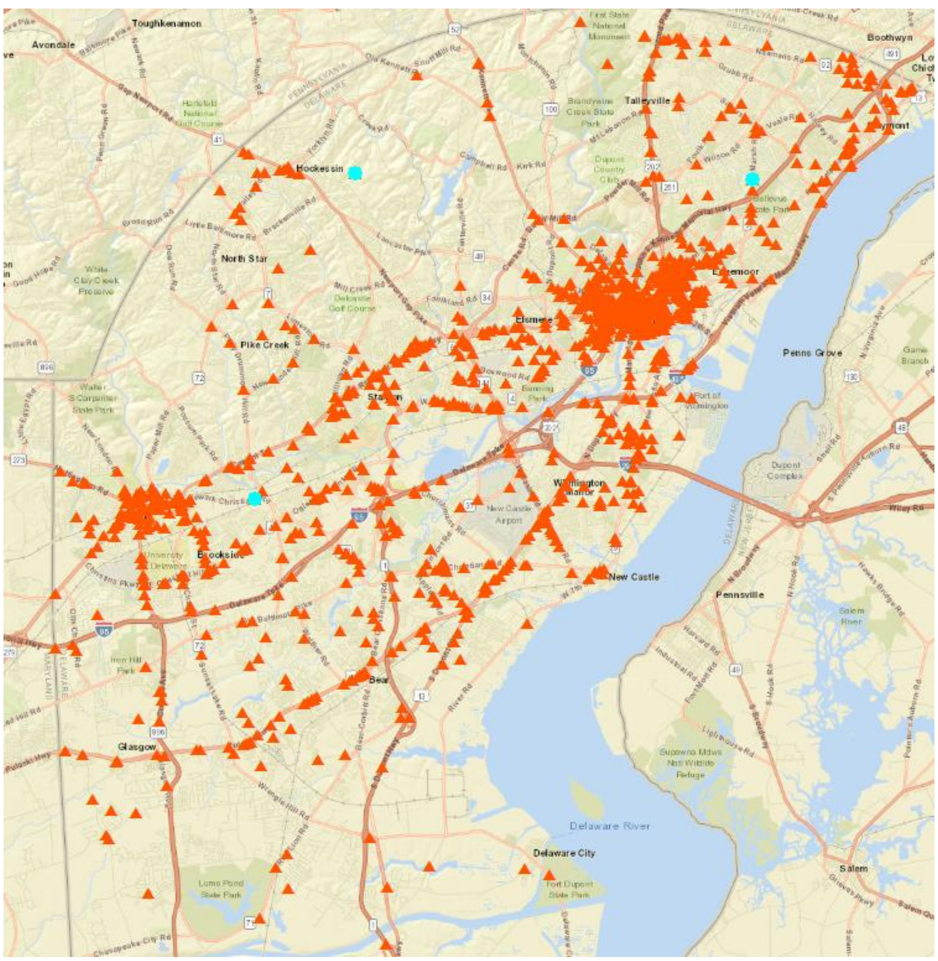
Clusters of Crashes Seen in Municipalities

When first mapping the data it is quite obvious that crashes are clustered around municipalities:

- 1372 of the 2226 crashes from 2012 to 2016 are in municipalities
- 759 (34%) are within Wilmington
- 171 (8%) are in Newark
- 202 are in Dover
- 240 are in other municipalities

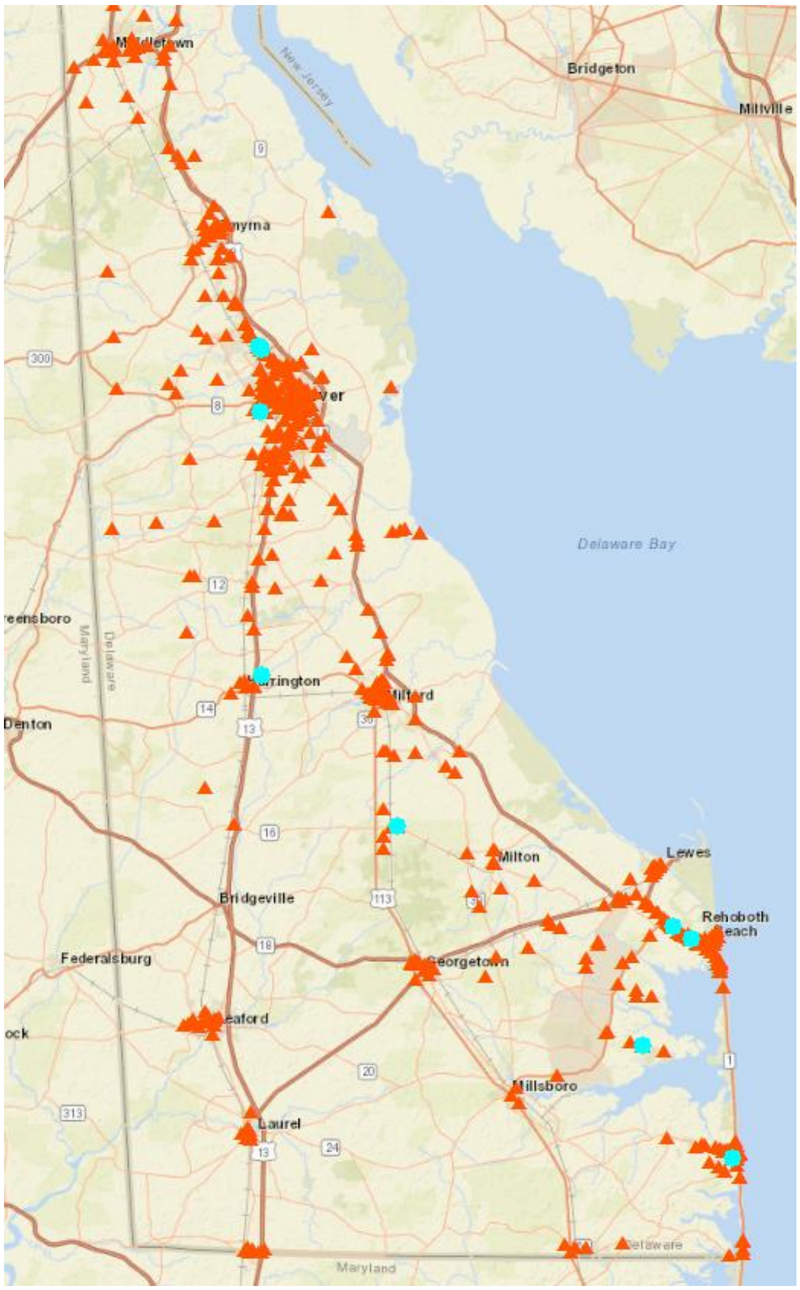
Figures 38 and 39 below demonstrate this as do other views that are presented.

Figure 38, Crashes Involving Pedestrians and Bicyclists, Northern Delaware 2012 thru 2016



Source: DelDOT Crash Analysis Reporting System

Figure 39, Crashes Involving Pedestrians and Bicyclists, Southern Delaware 2012 thru 2016



Source: DelDOT Crash Analysis Reporting System

Views of Crashes

Contributing factors were tabulated in the previous section. Figures 40 thru 45 provide a map view and include pedestrian contributing action.

The pedestrian location distribution in Wilmington is about a third at intersections, a third midblock, and about 25% on the sidewalk.

Figure 40 Crash Pedestrian Location for the City of Wilmington (%)

Location	Percentage
Sidewalk	25
Travel Lane	22
Intersection Marked Crosswalk	16
Shoulder/roadside	12
Intersection unmarked crosswalk	10
Intersection other	5

Source: DelDOT Crash Analysis Reporting System

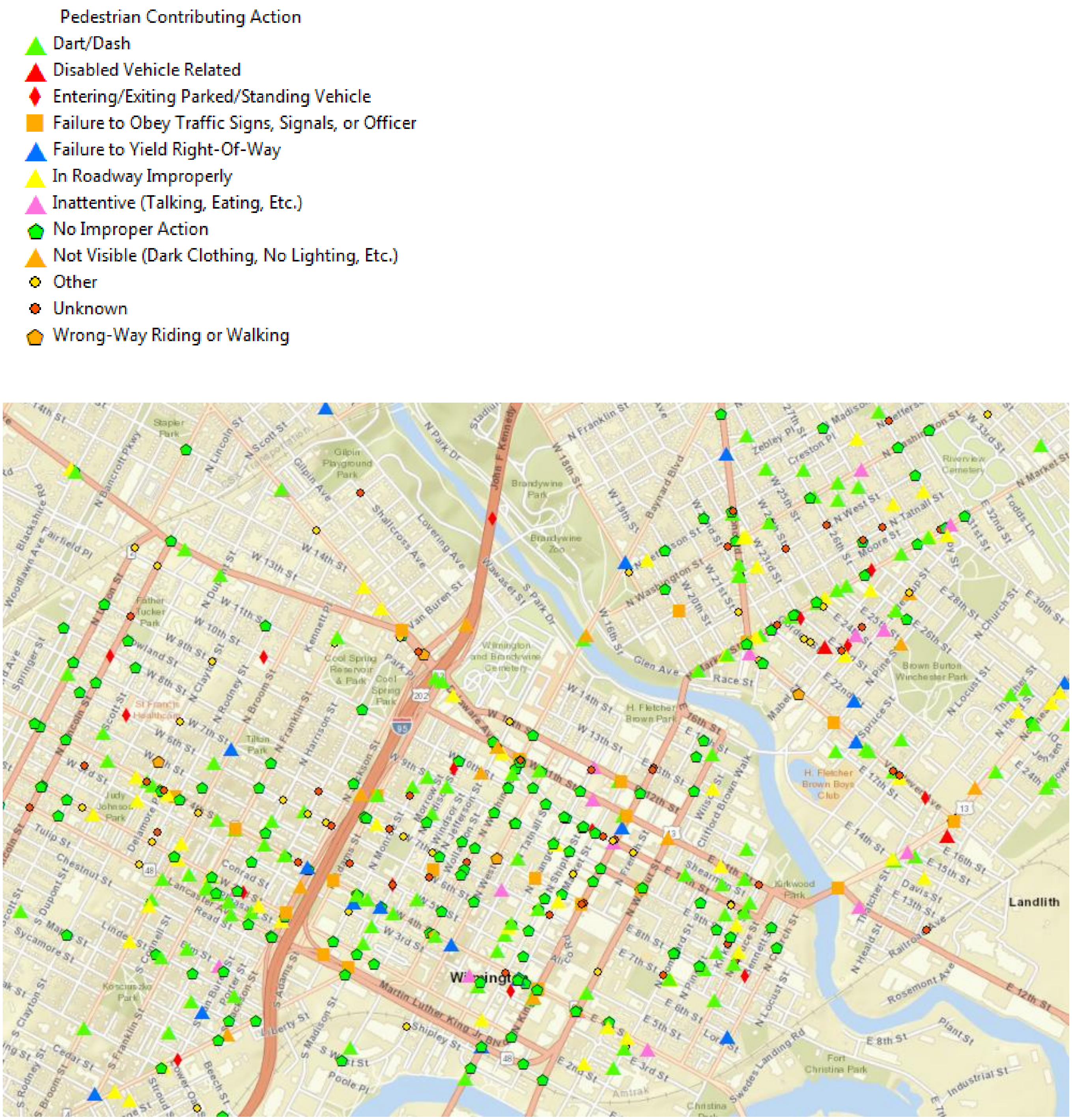
Crashes in the travel lane were mostly related to Dart/Dash, in the road improperly, or failure to yield right of way.

Figure 41, Pedestrian Contributing Action for the City of Wilmington

Action	
No Improper Action	31
Dart/Dash	22
Unknown	11
In roadway improperly	10
Other	7
Failure to obey signs	4
Inattentive	3
Not visible	3

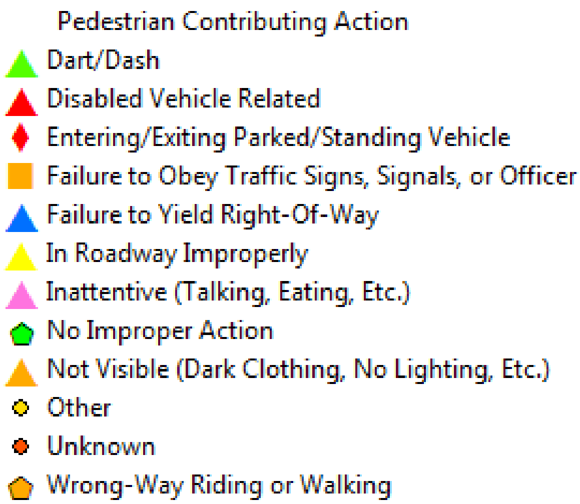
Source: DelDOT Crash Analysis Reporting System

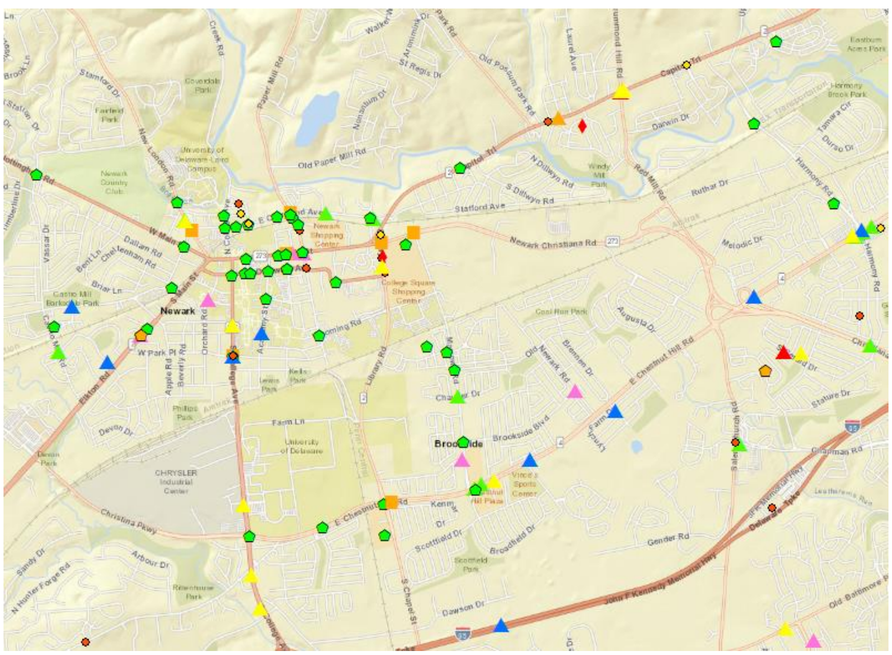
Figure 42, Crashes Involving Pedestrians, Pedestrian Contributing Actions Years 2012 thru 2016



Source: DelDOT Crash Analysis Reporting System

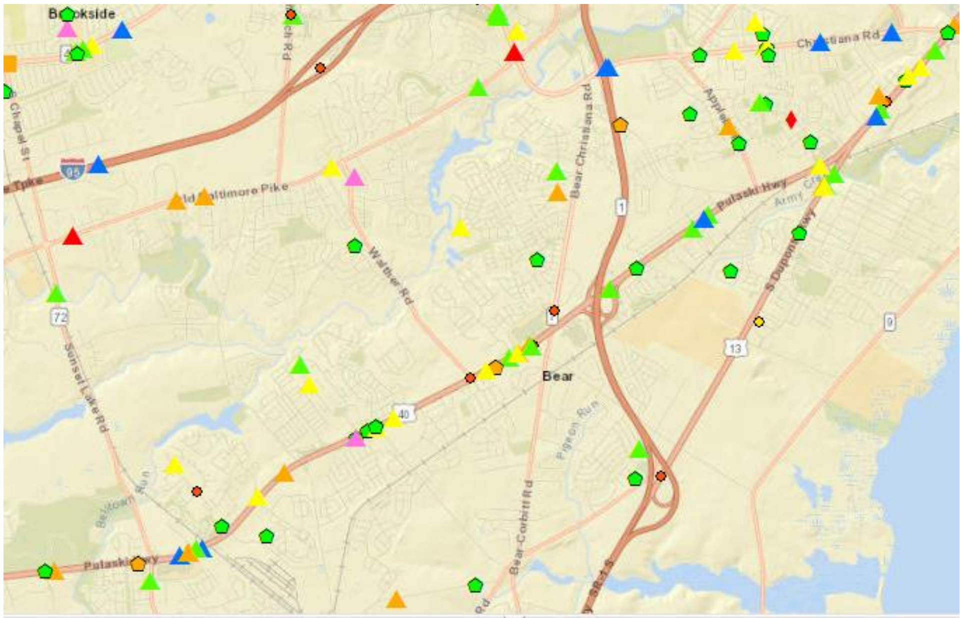
Figure 43, Crashes Involving Pedestrians, Pedestrian Contributing Actions Years 2012 thru 2016, City of Newark





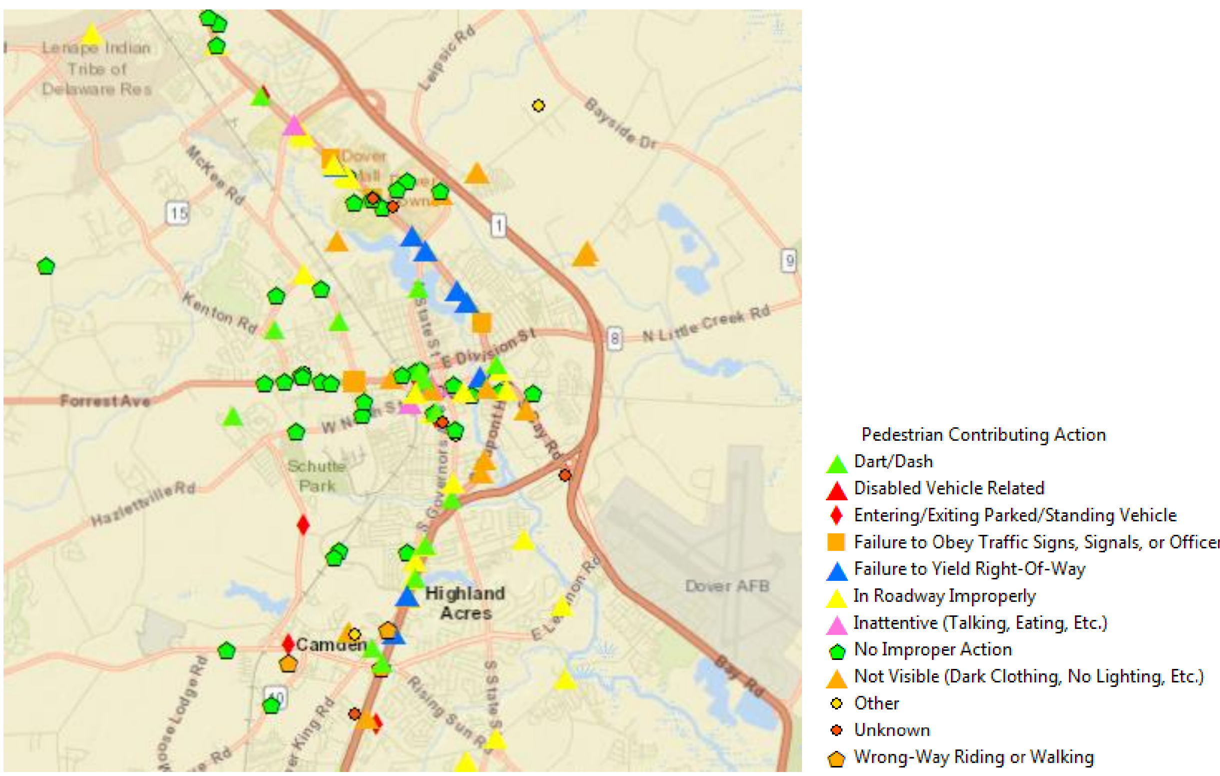
Source: DelDOT Crash Analysis Reporting System

Figure 44, Crashes Involving Pedestrians, Pedestrian Contributing Actions Years 2012 thru 2016 Route 40



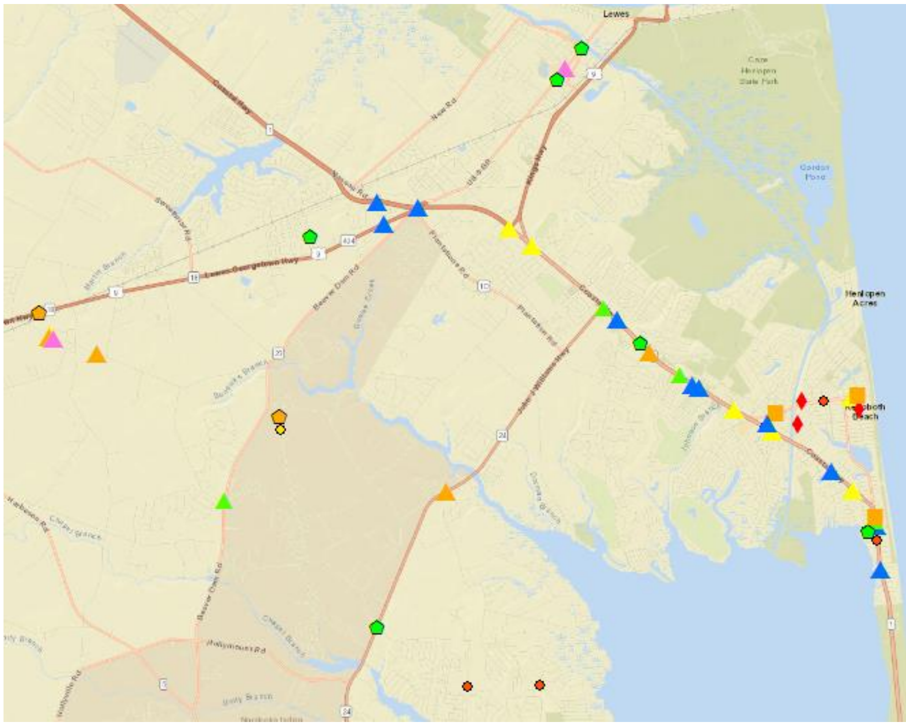
Source: DelDOT Crash Analysis Reporting System

Figure 45, Crashes Involving Pedestrians, Pedestrian Contributing Actions Years 2012 thru 2016 Dover Area



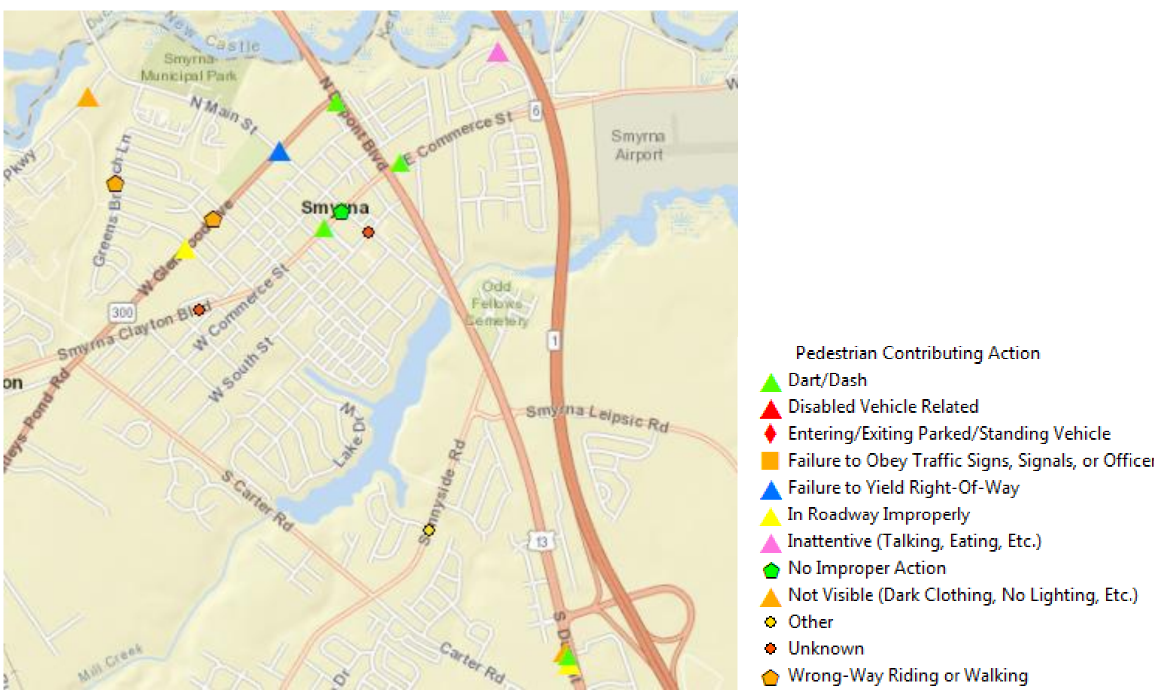
Source: DelDOT Crash Analysis Reporting System

Figure 46, Crashes Involving Pedestrians, Pedestrian Contributing Actions Years 2012 thru 2016 Route 1 near beaches



Source: DelDOT Crash Analysis Reporting System

Figure 47, Crashes Involving Pedestrians, Pedestrian Contributing Actions Years 2012 thru 2016 Smyrna Area

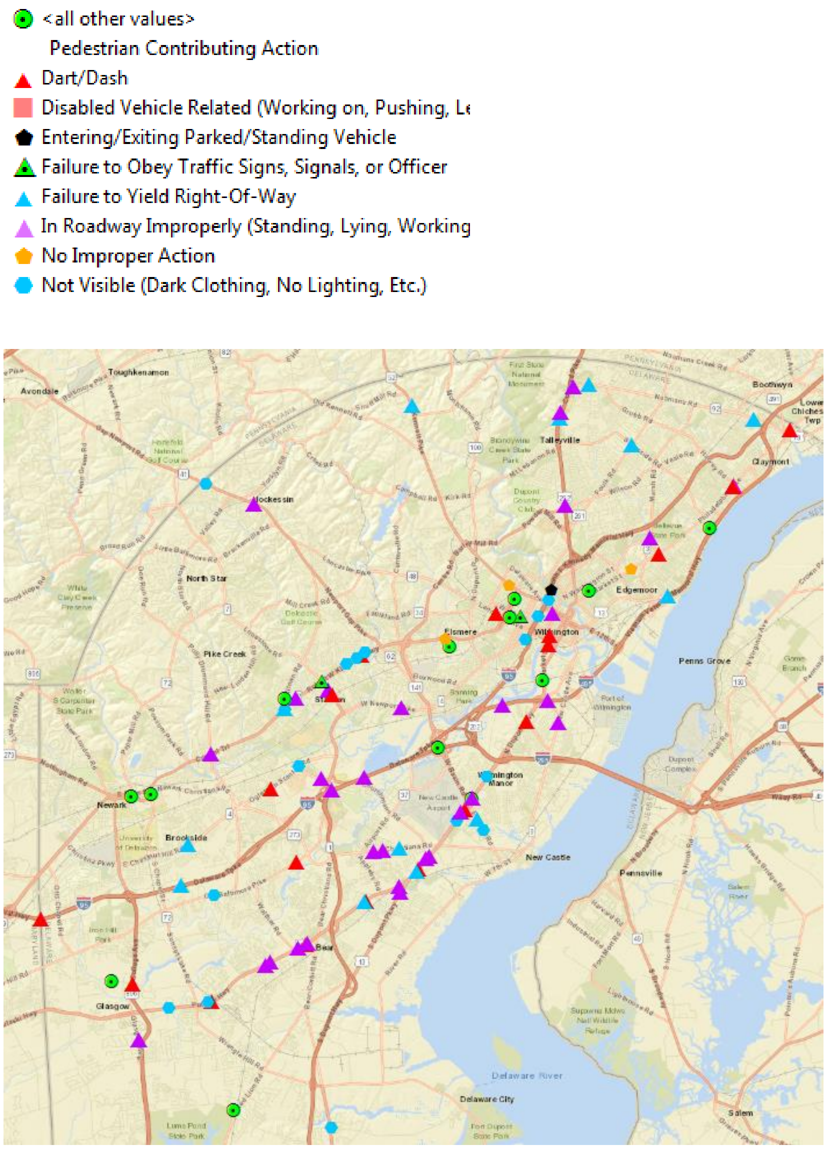


Source: DelDOT Crash Analysis Reporting System

Pedestrian Fatalities

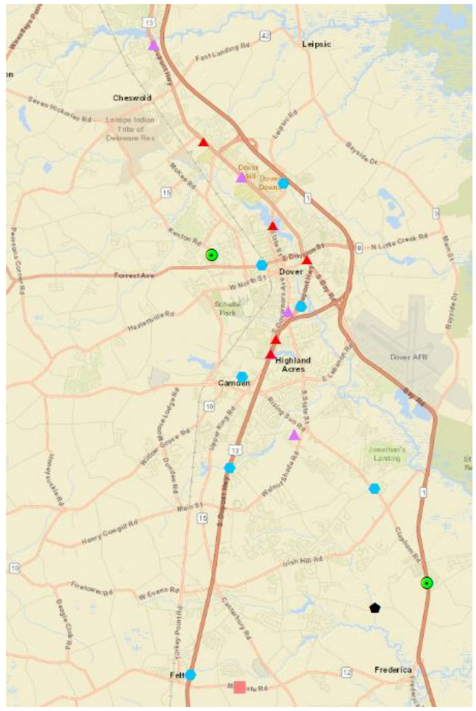
Distributions of pedestrian fatalities are very different than those for non-fatal crashes. Rather than clusters as seen in municipalities, they are strung across major arteries and are a testament to the effects of high volume, high speed, and multiple lane highways. In particular, Route 40, Kirkwood Highway (Rt 2), Concord Pike, Rt 1 near Rehoboth, and Route 13. Contributing Actions are primarily "Dart/Dash", "Failure to yield right of way", and "In the Road Improperly". About 2/3 are along roadways between intersections. About 50% involve impaired pedestrian or driver.

Figure 48, Pedestrian Crashes Involving Fatalities in Northern New Castle County



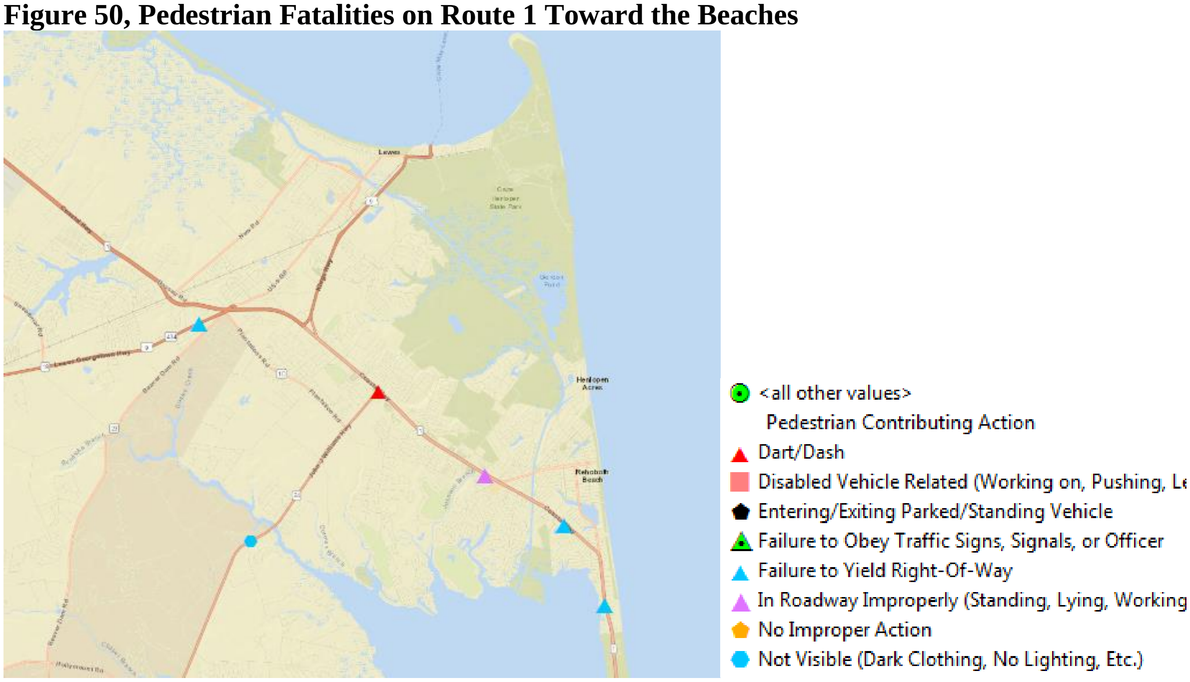
Source: DelDOT Crash Analysis Reporting System

Figure 49, Pedestrian Fatalities in the Dover Area



Source: DelDOT Crash Analysis Reporting System

Figure 50, Pedestrian Fatalities on Route 1 Toward the Beaches



Source: DelDOT Crash Analysis Reporting System

Crashes Relative to Housing Units and Destinations

Crashes were mapped with housing unit locations as shown in figures 51 and 52. It is clear that there are many areas throughout Delaware that have large numbers of housing units but no crashes. As we are focusing on walking and biking, two modes that involve smaller trip distances, crashes are seen to cluster around destinations in proximity. CADSR developed and maintains a statewide destination layer that shows and categorizes destinations of all types. Maps with crashes overlaid on destinations are shown in figures 53 and 54. There is an obvious spatial correlation as expected.

Figure 51, Crashes (purple diamonds) overlaid on Housing Units (red dots)

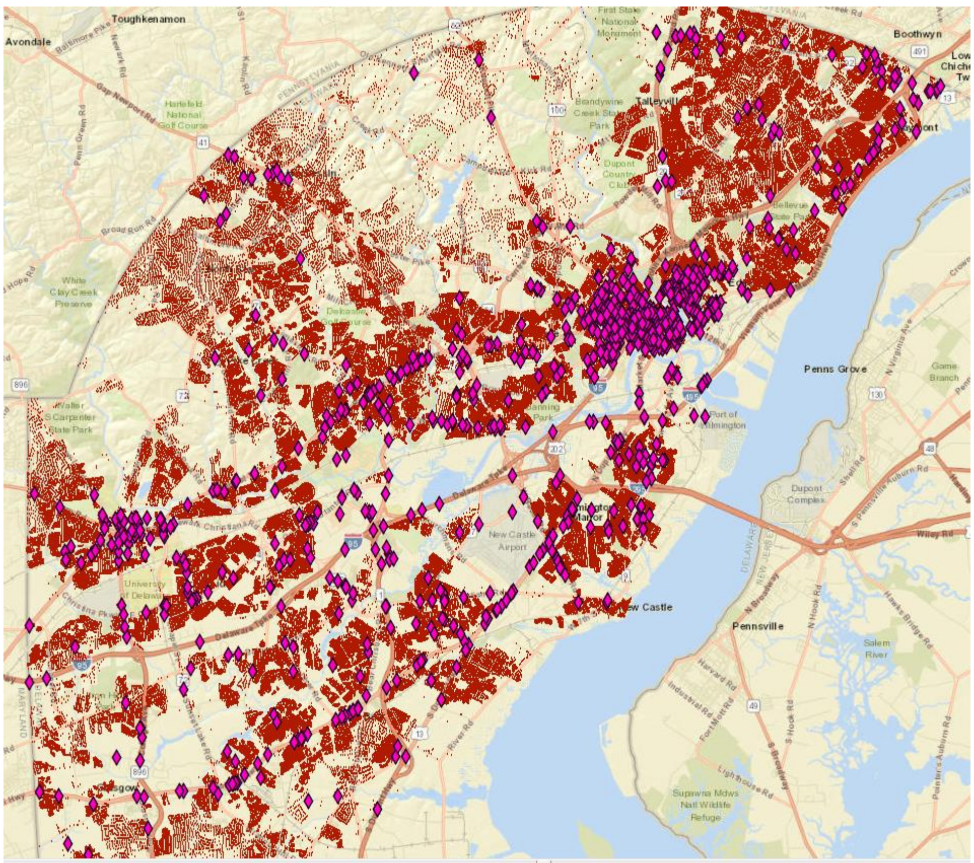
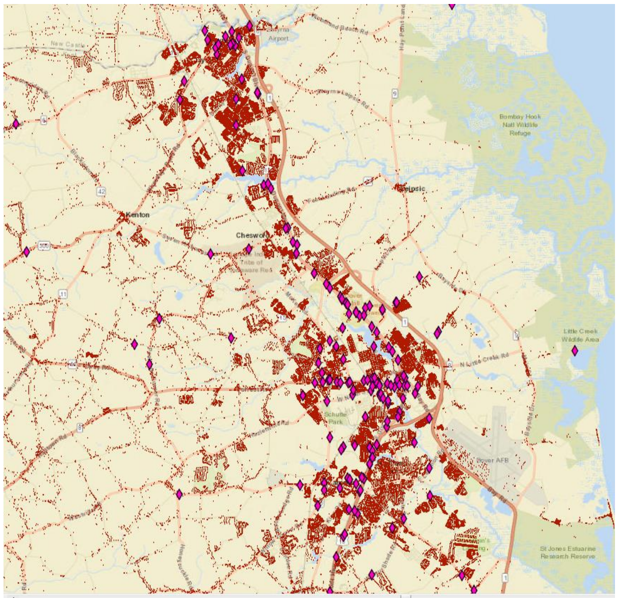


Figure 52, Crashes (purple diamonds) overlaid on Housing Units (red dots)



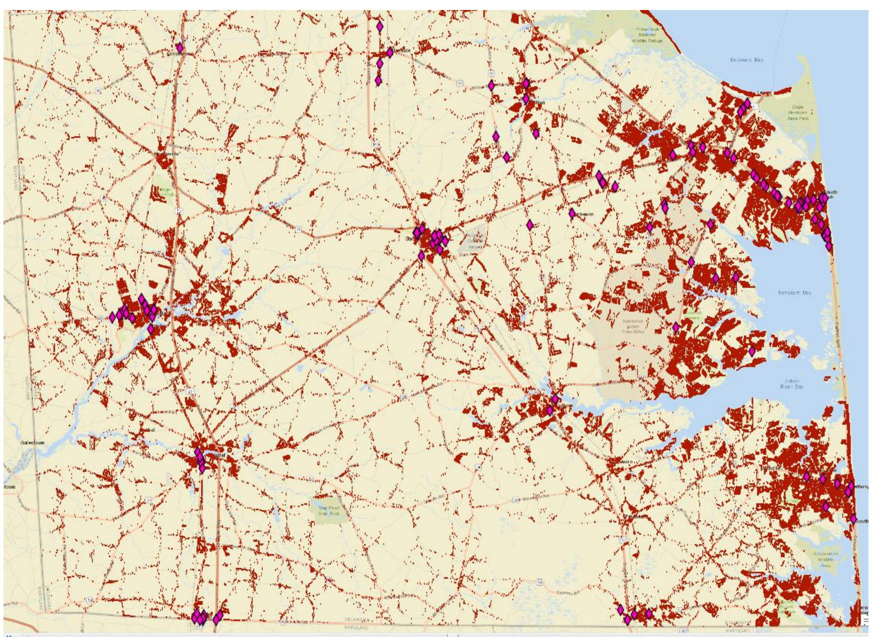
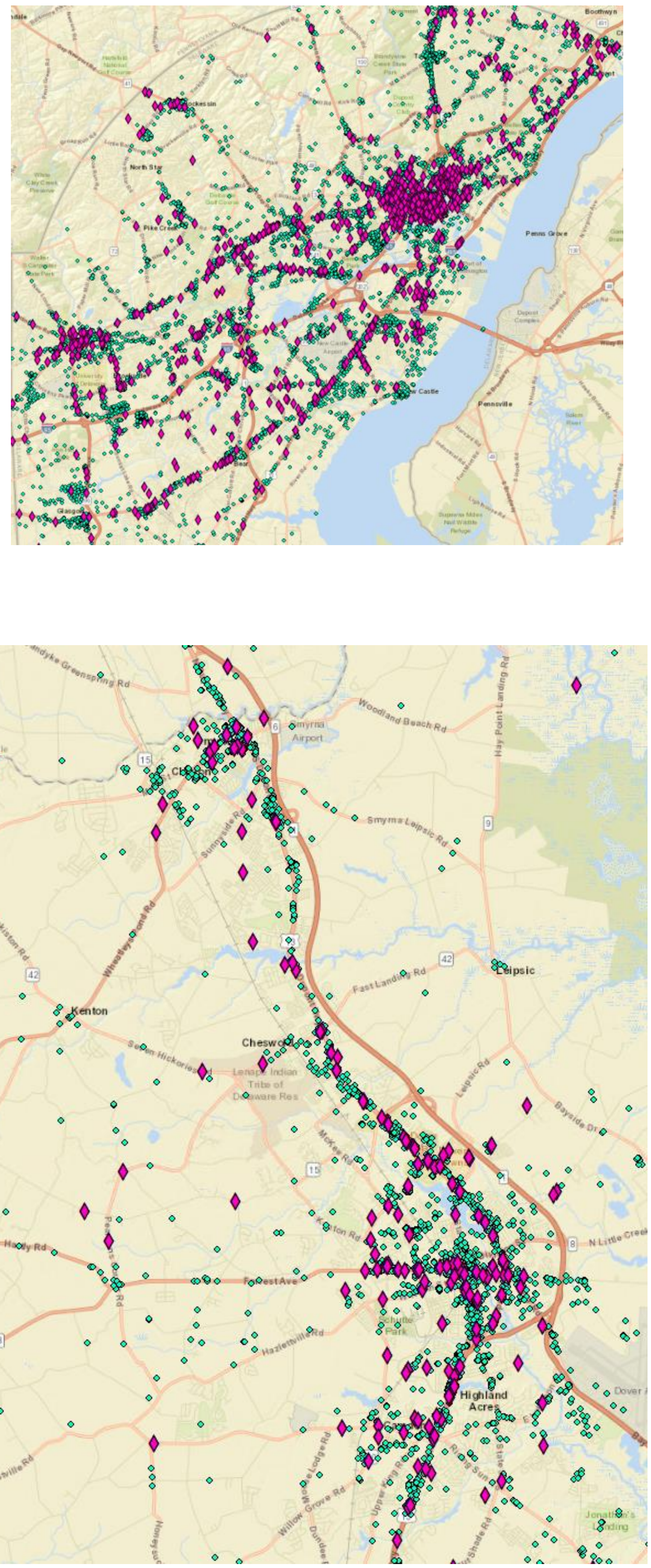
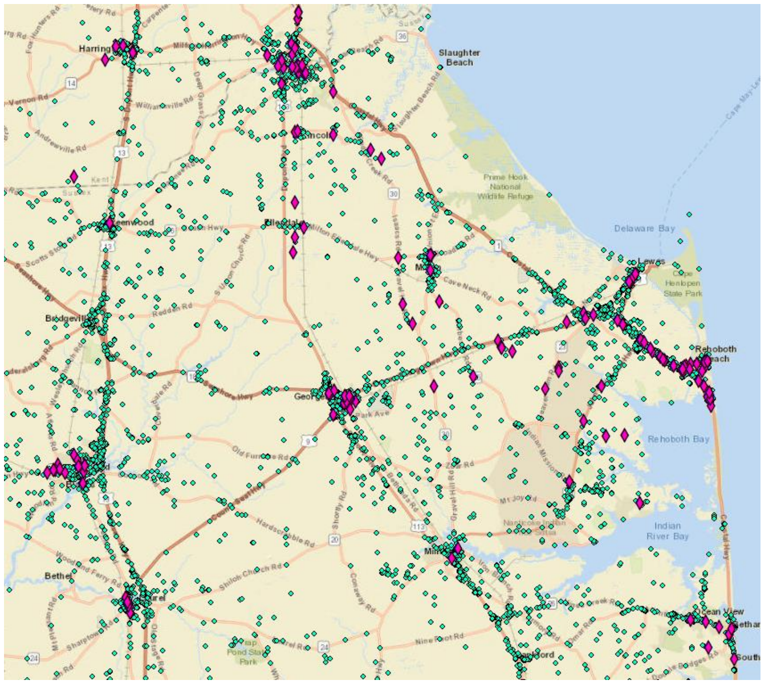


Figure 53, Crashes (purple diamonds) overlaid on Destinations (green dots)



Source: DelDOT Crash Analysis Reporting System

Figure 54, Crashes (purple diamonds) overlaid on Destinations (green dots)



Source: DelDOT Crash Analysis Reporting System

With the relationship to destinations, there is an interest in whether a certain number of destinations or a certain category of destination might show a tendency toward more crashes. To investigate this, the number and type of destination within a half mile of each crash (along the walking/road network) were tabulated. 72% of the crashes were within a five minute walk of 10 destinations, the median is 30 destinations. Figure 53 below compares the distribution of destination types between those near crashes and the statewide distribution. There is a similar distribution, perhaps a bit more Services and Finance influenced by the large number of destinations in Wilmington.

Where travelers are going and where they are coming from are not typical data items in a crash report. As most crashes are in areas with 10 destinations within a 5 minute walk, it would be difficult at any resolution tying a person at risk with a particular activity, for instance convenience store stops or recreational. Figure 54 below shows the distribution of the closest destination type to the crashes, and with a few differences the distribution is fairly similar to the statewide distribution of destinations types within a 5 minute walk. In 2017, the standard crash report was updated to include the origin and the destination of the pedestrian. An examination of the data in regards to origin and destination by DelDOT after this change for 2017 data indicated less than 20% of the records provided useful data and over half of the crashes were missing this origin and destination data. Additional training on capturing this information was suggested.

Figure 55, Comparison of number of crashes by destination type with statewide destination mix

TYPE	% of crashes	% statewide
Services	31	21
Finance	13	9
Retail	11	14
Eat Out	8	7
Community	6	5
Medical	4	8
Beauty	3	2
Short Stop	3	3
Contractor	2	4
Education	2	3
Store Basics	2	3
Wholesale	2	2
Place of Worship	1	1
Housing	1	1
Child Care	1	1
Recreation	1	2

Figure 56, Distribution of closest types of destination to crashes

TYPE	Crashes	%
Services	313	14.1
Retail	299	13.4
Eat Out	281	12.6
Community	186	8.4
Short Stop	152	6.8
Place of Worship	118	5.3
Education	100	4.5
Finance	4.2	4.2
Medical	88	4
Store Basics	87	3.9
Child Care	48	2.2
Beauty	31	1.4

Location Relative to the Transportation Network

Crash reports include the location of the crash relative to the transportation network and this is tabulated below. Pedestrian fatality crashes are shown to be more prevalent between intersections rather than at intersections, which is in line with fatalities being often related to speeds of traffic.

Figure 57, Location for Pedestrian Non-Fatal Injury

LOCATION	Number	Percentage
Intersection or Crossing	384	26
Sidewalk/path/nontraffic	266	18
Midblock	605	41
Driveway	18	1
Missing/unknown	198	13

Source: DelDOT Crash Analysis Reporting System

Figure 58, Location for Pedestrian Fatal Injury

LOCATION	Number	Percentage
Intersection or Crossing	20	17
Sidewalk/path/nontraffic	10	9
Midblock	74	64
Driveway	1	0.9
Missing/unknown	8	7

Source: DelDOT Crash Analysis Reporting System

Similarly, the functional class of neighboring roads for fatalities are more prevalent on Principal Arterials.

Figure 59, Functional Class of Roadway for Pedestrian Non-Fatal Injury

Functional Class for Roadway	Number	Percentage
Local	187	13
Minor collector	74	5
Minor Arterial	350	24
Major Collector	283	19
Principal Arterial	164	11
Missing	416	28

Source: DelDOT Crash Analysis Reporting System

Figure 60, Functional Class of Roadway for Pedestrian Fatal Injury

Functional Class for Roadway	Number	Percentage
Local	6	5
Minor collector	4	4
Minor Arterial	15	13
Major Collector	6	5
Principal Arterial	25	22
Missing	56	50

Source: DelDOT Crash Analysis Reporting System

Locations for bicyclist crashes are tabulated below. Crashes tend to occur midblock rather than at intersections.

Figure 61, Location for Bicyclist Non-Fatal Injury

LOCATION	Number	Percentage
Intersection or Crossing	164	26
Sidewalk/path/nontraffic	82	13
Travel way/roadside	351	57

Source: DelDOT Crash Analysis Reporting System

Figure 62, Location for Bicyclist Fatal Injury

LOCATION	Number	Percentage
Intersection or Crossing	3	23
Travel way/roadside	10	74

Source: DelDOT Crash Analysis Reporting System

Figure 63, Functional Class of Roadway for Bicyclist Non-Fatal Injury

FUNCTIONAL CLASS OF ROADWAY	Number	Percentage
Local	84	14
Minor collector	14	2
Minor Arterial	151	25
Major Collector	136	22
Principal Arterial	86	14.1

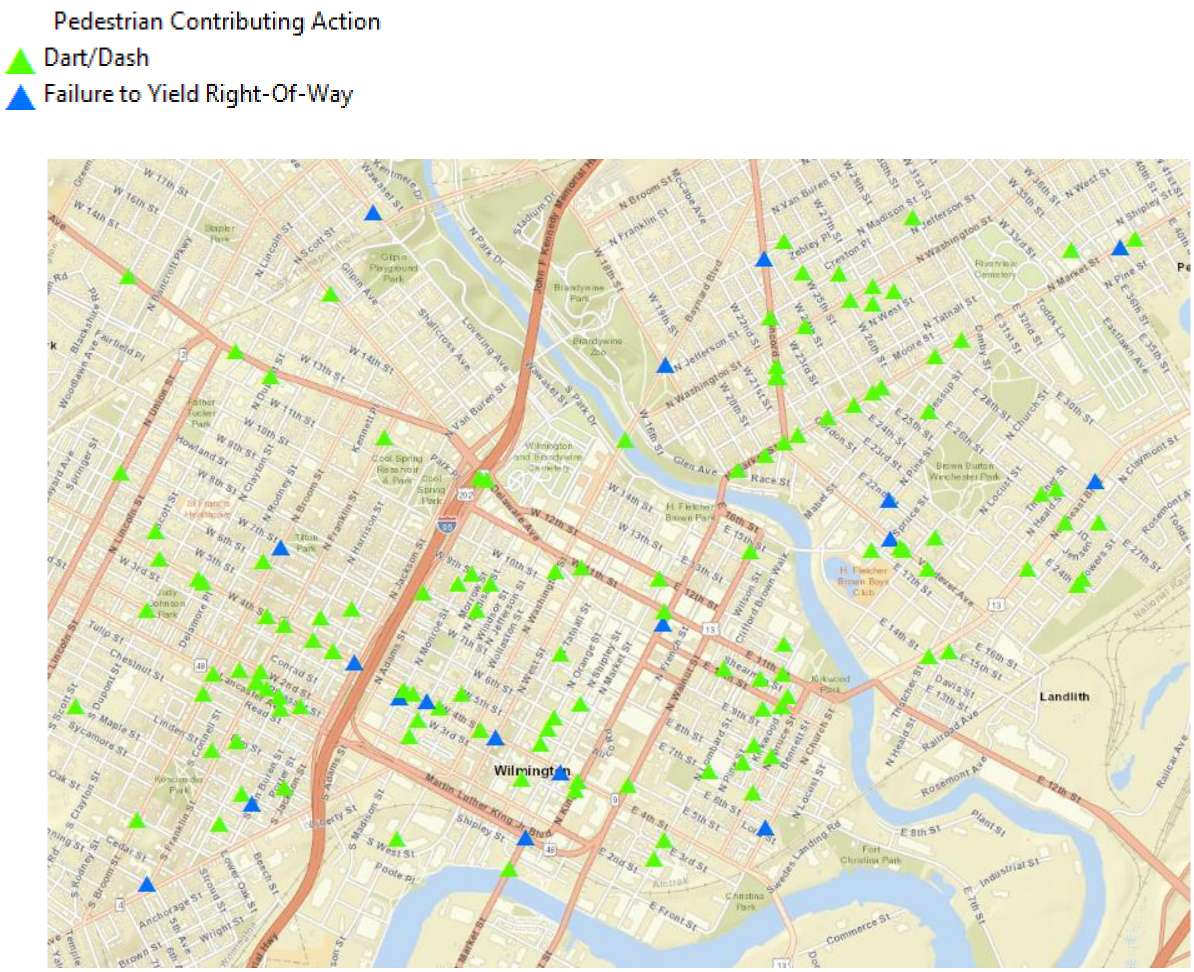
Source: DelDOT Crash Analysis Reporting System

Pedestrian dart dash and failure to yield right of way

There has been particular interest in Dart and Dash. Dart and Dash includes situations where the pedestrian failed to stop or slow down before attempting to cross a road. Often this is a behavior endangering child pedestrians. In other cases it often references where pedestrians attempt to cross multi-lane highways away from the intersection crossings. This behavior is similar to "failure to yield right of way" in crash reports, so discussion in this section includes pedestrians not yielding right of way.

The largest cluster of these crashes are in the City of Wilmington as shown in figure 62. Strings of these crashes are found particularly on 4rth Street and North Market which are high density city row house areas with cars parked on both sides.

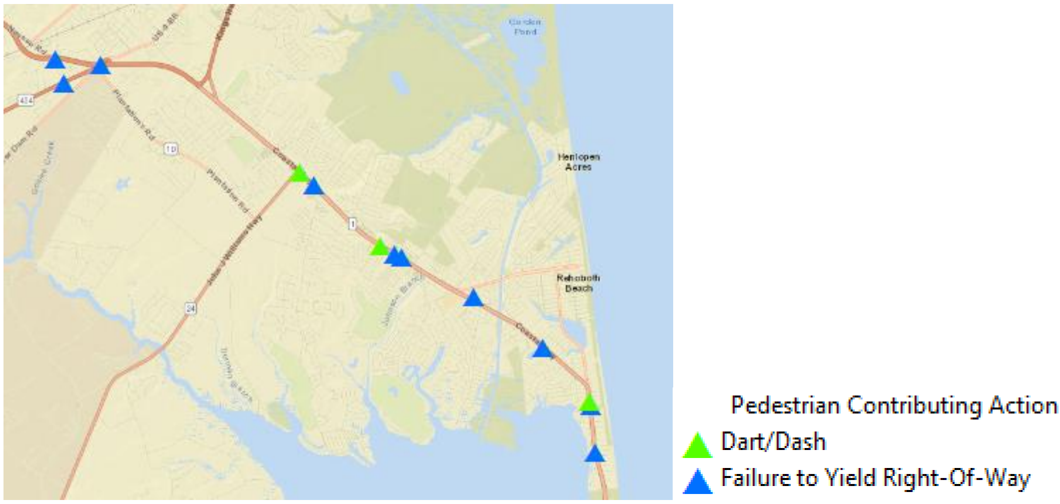
Figure 64, "Dart and Dash" and "Failure to Yield Right of Way" in the City of Wilmington Crash data from years 2012 to 2016



Source: DelDOT Crash Analysis Reporting System

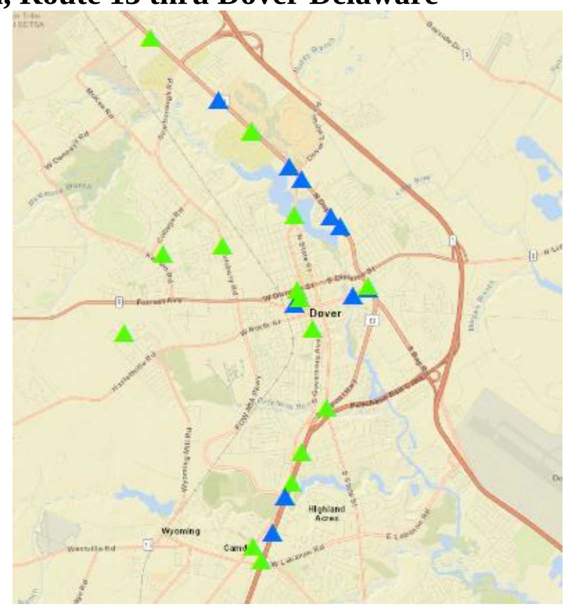
To a much lesser extent, crashes can be found on major multi-lane roads which are particularly dangerous, since speeds are much higher and traffic volume higher. Examples are Route 1 coming into the beaches, Route 13 through Dover, portions of Route 40, East Chestnut Hill Road, in north Delaware, in municipalities and major roads. Figure 63 below shows northern New Castle County with a large cluster in the City of Wilmington.

Figure 65, Dart and Dash, Route 1 near Rehoboth Delaware



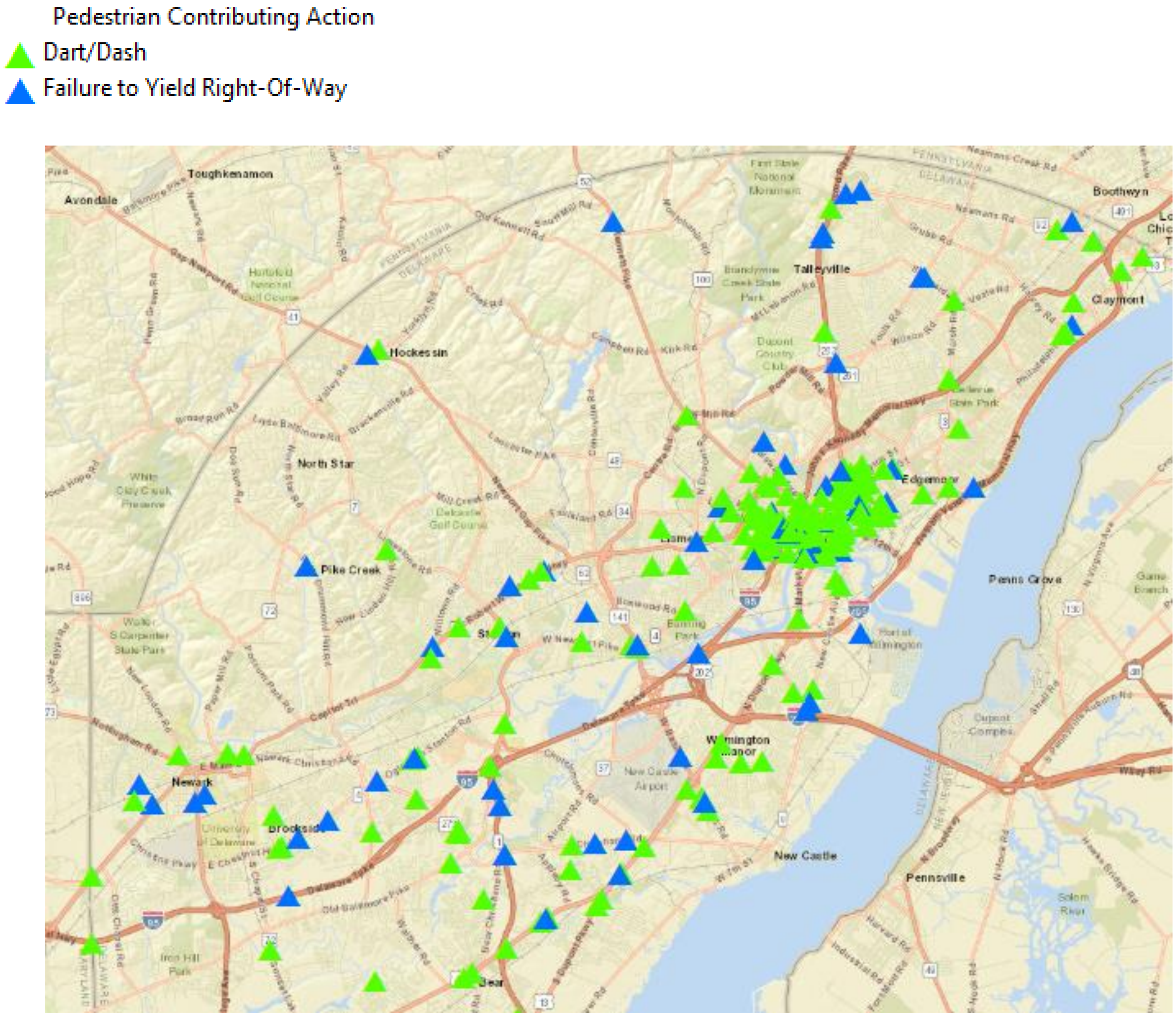
Source: DelDOT Crash Analysis Reporting System

Figure 66,Dart and Dash, Route 13 thru Dover Delaware



Source: DelDOT Crash Analysis Reporting System

Figure 67, Dart and Dash , Northern Delaware

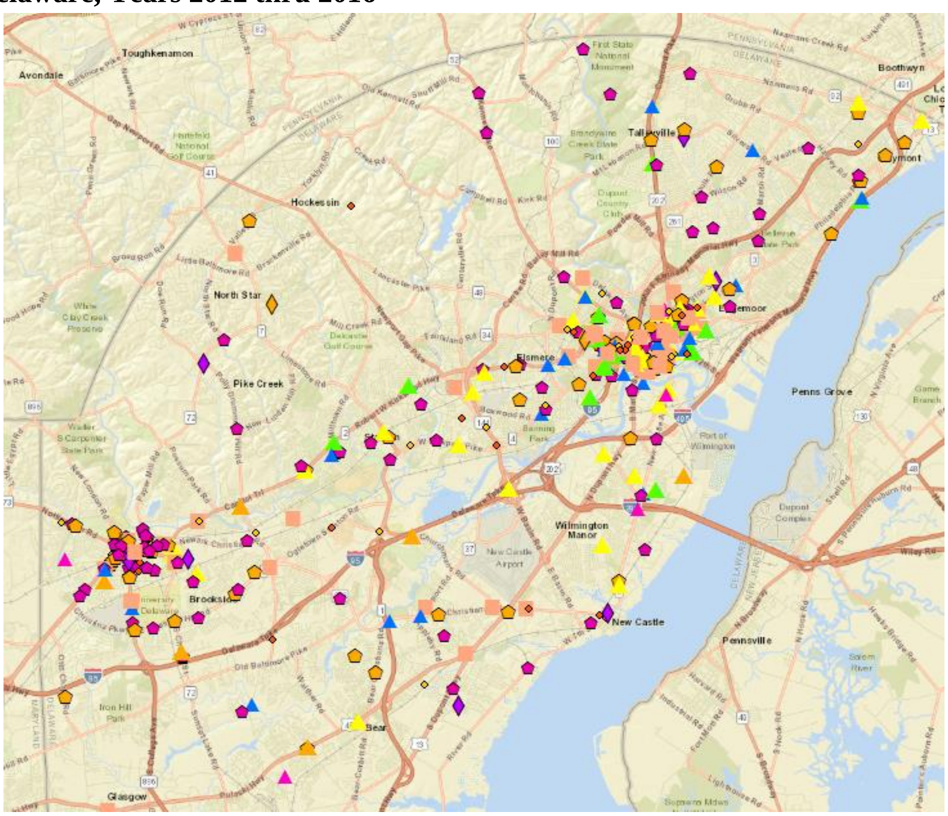


Source: DelDOT Crash Analysis Reporting System

View of Crashes Involving Bicyclists

Below are several views of crashes involving bicyclists. Clusters are found in Wilmington, Newark, Dover and the Beach area.

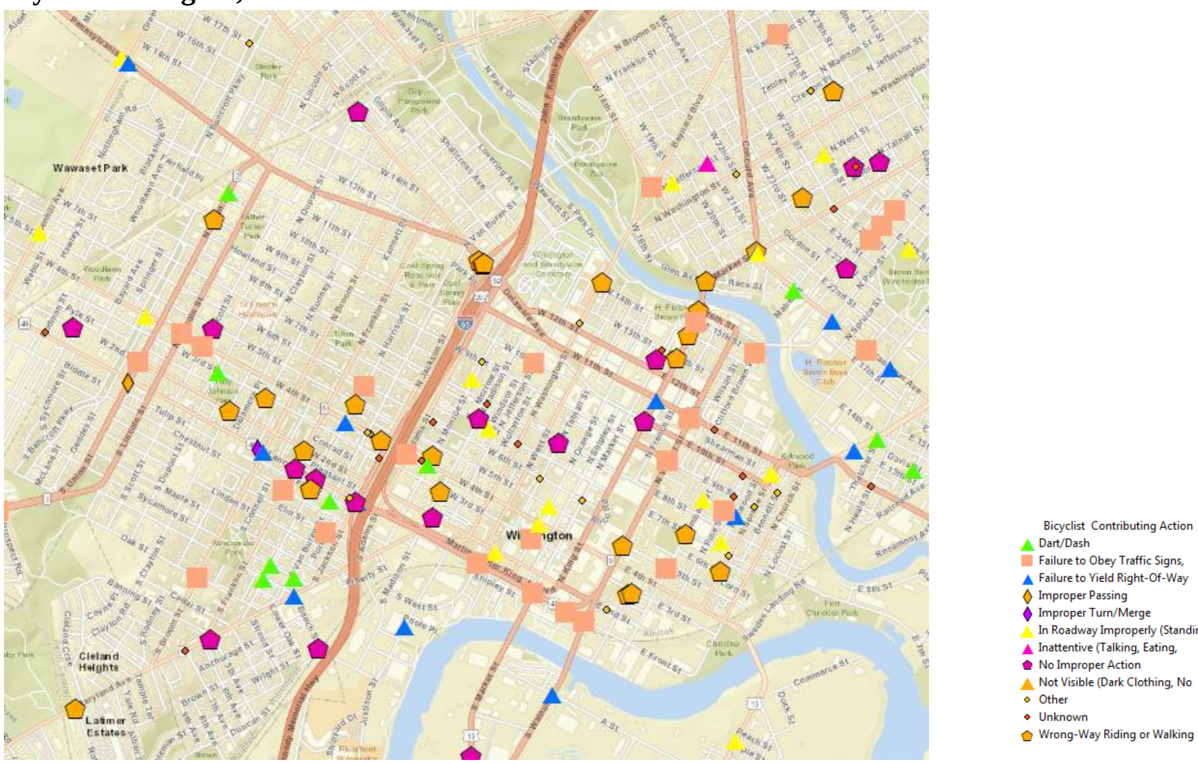
Figure 68, Bicyclist Contributing Action for Crashes Involving Bicycles Northern Delaware, Years 2012 thru 2016



Source: DelDOT Crash Analysis Reporting System

In the Wilmington area, about cyclist locations are about 40% are on the roadway or roadside, and about 40% are at intersections, with remaining locations being unknown, driveways or sidewalks. Predominant cyclist contributing actions are “Failure to Obey Traffic Signs at 19%, Wrong Way Riding (17%), Failure to Yield the Right of Way (9%), and Dart Dash (7%) with only 12% being assigned “No Improper Action.” Driver inattention or distraction was cited as a primary contributing circumstance in 12% of the cases.

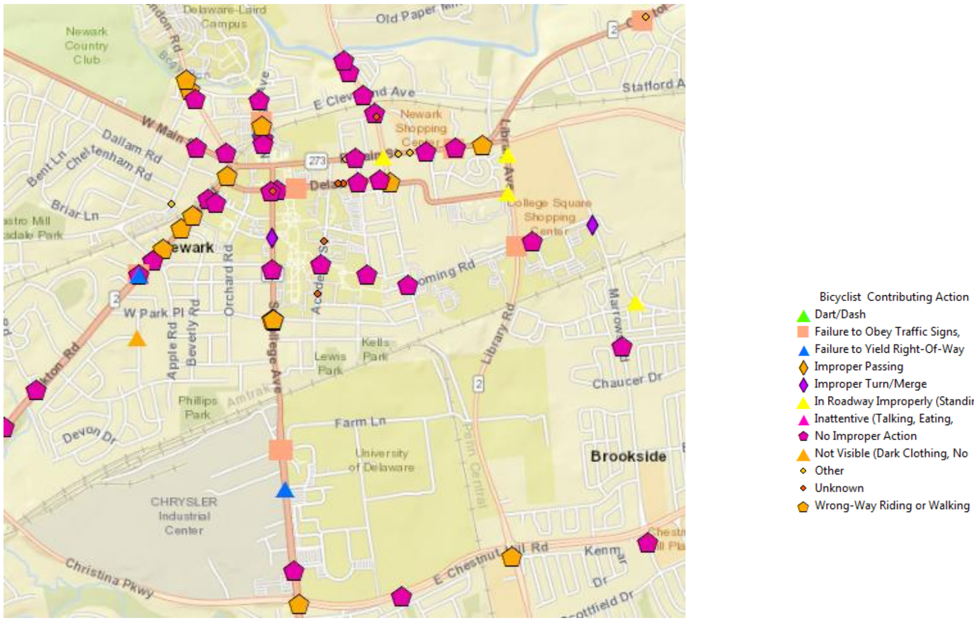
Figure 69, Bicyclist Contributing Action for Crashes Involving Bicycles City of Wilmington, Years 2012 thru 2016



Source: DelDOT Crash Analysis Reporting System

For the City of Newark, 26% locate the cyclist on a bicycle lane, 17% on sidewalks, 20% at intersections, and about 29% on the roadway or roadside. For crashes where the cyclist was in the bike lane, 38% of the time the cyclist was listed as proceeding in the wrong way. For driver of the vehicle contribution for crashes in the bike lane, a third were “Failed to Yield Right of Way”, and 10% were “Operating Vehicle in an Erratic or Dangerous Fashion”. With “No Improper Action” being assigned about 42% of the time, cyclists would be considered less responsible for crashes when compared to Wilmington. For Newark the largest contributing factor by the cyclist is “Wrong-Way Riding” at 21%, Failure to Obey Traffic Signs (9%) Failure to Yield Right of way (4%), In Roadway Improperly 4%. Interestingly, “Not Visible” was only cited in 1% of the cases. Driver of Vehicle contributing actions were primarily Failed to Yield the Right of Way at 19%, Inattentive Driving (10%) and there were several missing values.

Figure 70, Bicyclist Contributing Action for Crashes Involving Bicycles
City of Newark, Years 2012 thru 2016

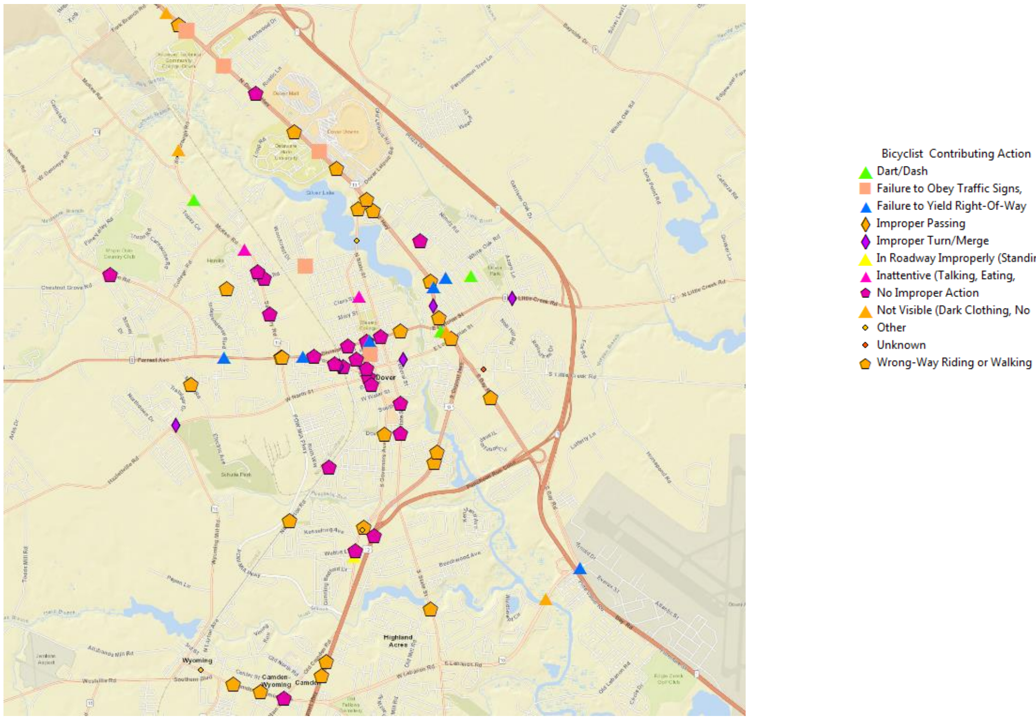


Source: DelDOT Crash Analysis Reporting System

For the City of Dover, cyclist crash locations were 15% in a bike lane, 16% in intersections, and 53% in the roadway or roadside. Contributing factors by the cyclist were Wrong-Way riding at 30%, Failure to yield right of way (10%), Failure to obey traffic signs (7%), improper turn/merge (6%) and Dart/Dash 4%. No improper action was listed for about 29% of the crashes. Driver of the vehicle contributing actions were mainly Failed to yield right of way 12% and operating vehicle in an erratic or dangerous manner 10%. For crashes in the bike lane 50% of the time the cyclist was Wrong Way Riding. 17% improper turn, 8% not visible.

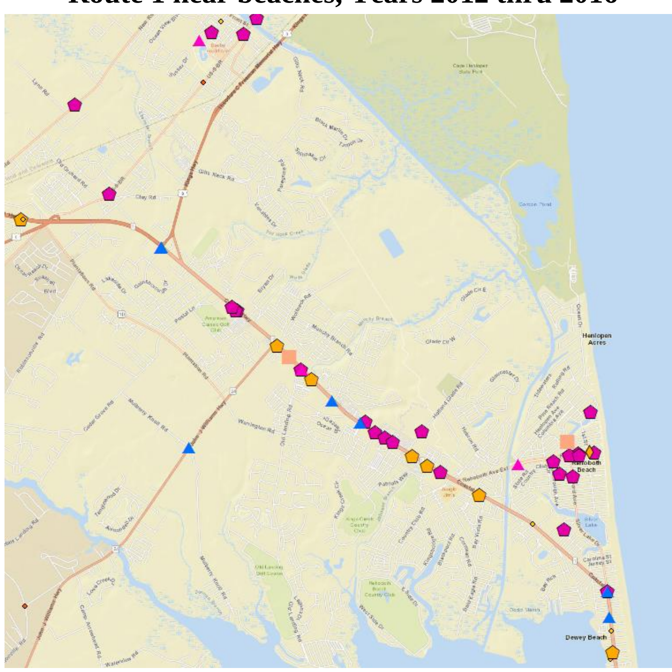
For the area near the beaches in Sussex County, location of the cyclist is at intersections about 15% of the time, on the travel lane or roadside (53%), and the bike lane (15%). Driver or cyclist inattention was listed as a primary contributing circumstance in about 26% of the cases. Contributing action by the cyclist were often Failure to yield right of way (13%) or Wrong Way Riding (13%) About half of the time “no Improper Action” was listed for the cyclist. For crashes in the bike lane 50% involved failure to yield right of way.

Figure 71, Bicyclist Contributing Action for Crashes Involving Bicycles
City of Dover, Years 2012 thru 2016



Source: DelDOT Crash Analysis Reporting System

Figure 72, Bicyclist Contributing Action for Crashes Involving Bicycles
Route 1 near beaches, Years 2012 thru 2016

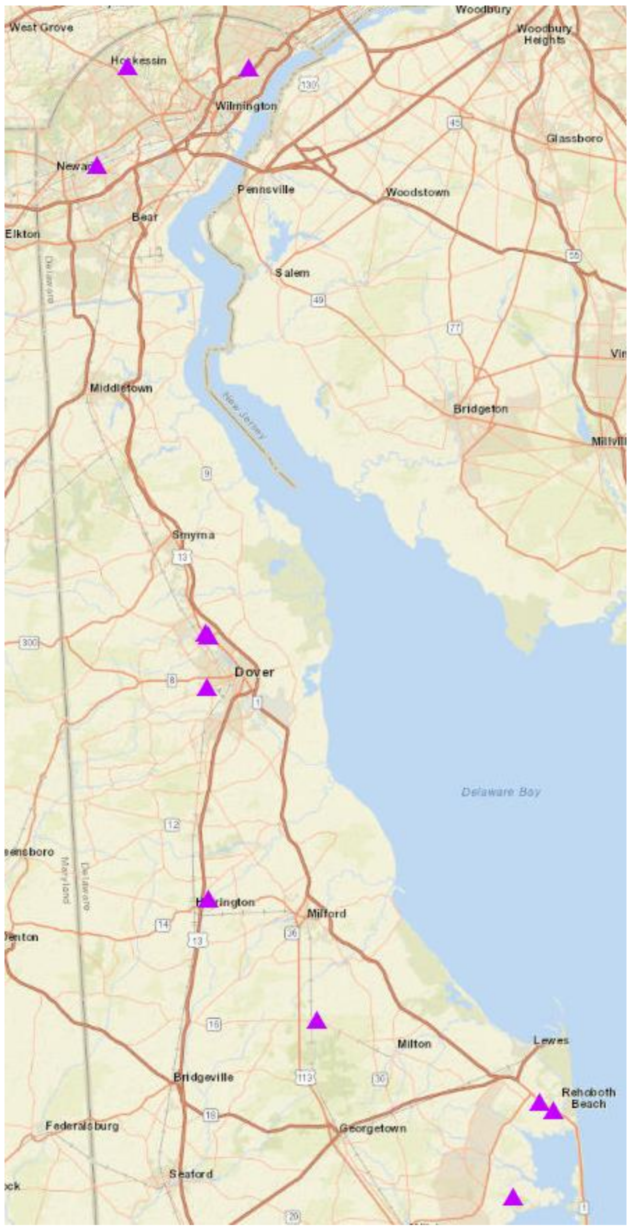


Source: DelDOT Crash Analysis Reporting System

Crashes involving Bicyclist Fatalities

As there were only 13 crashes involving bicyclist fatalities in the data for the years 2012 thru 2016, not much can be said. They were spread throughout the state and typically occurred on major roads. Ten of the thirteen occurred at night. Three involved impairment of the cyclist and 2 involved impairment of the driver.

Figure 73, Location of Crashes Involving Cyclist Fatalities



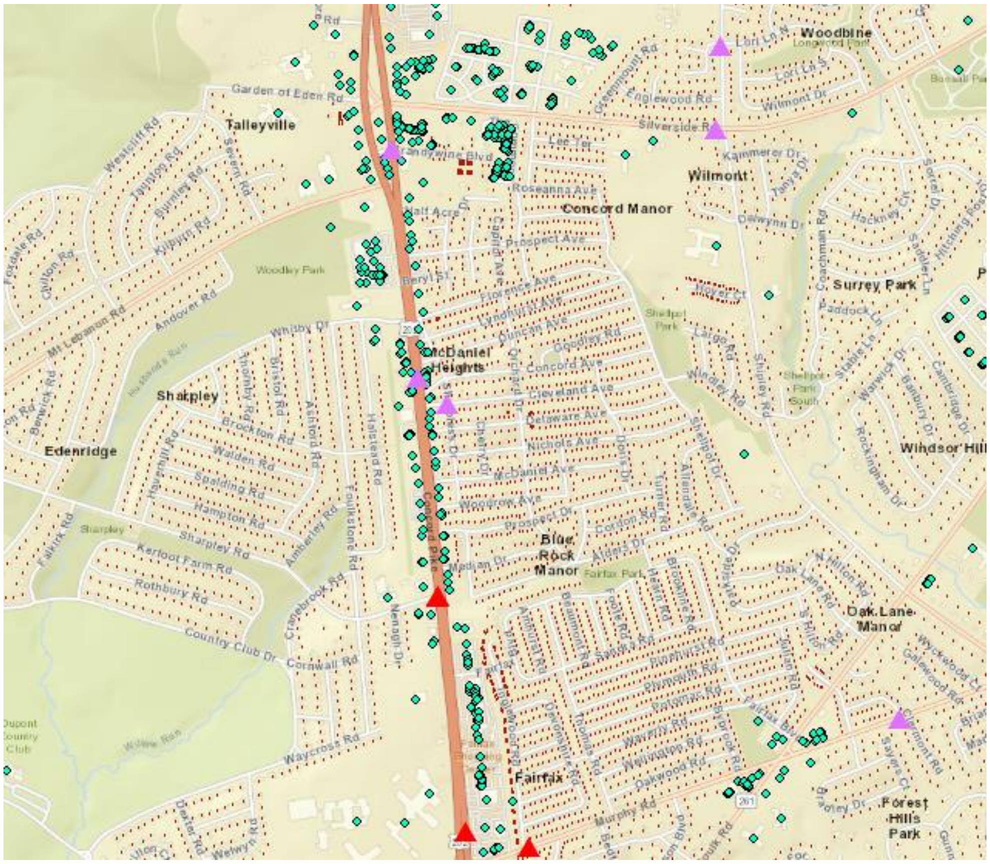
Source: DelDOT Crash Analysis Reporting System

Where there aren't crashes

So far, the focus has been on where crashes occur, but it may be instructive to examine areas where there were few or no crashes where they might be expected in areas where there are ample destinations and neighboring populations. In these views, housing units are symbolized as a small red dot and destinations are shown as green dots.

Figure 74, Concord Pike between Silverside Rd and Murphy Road:

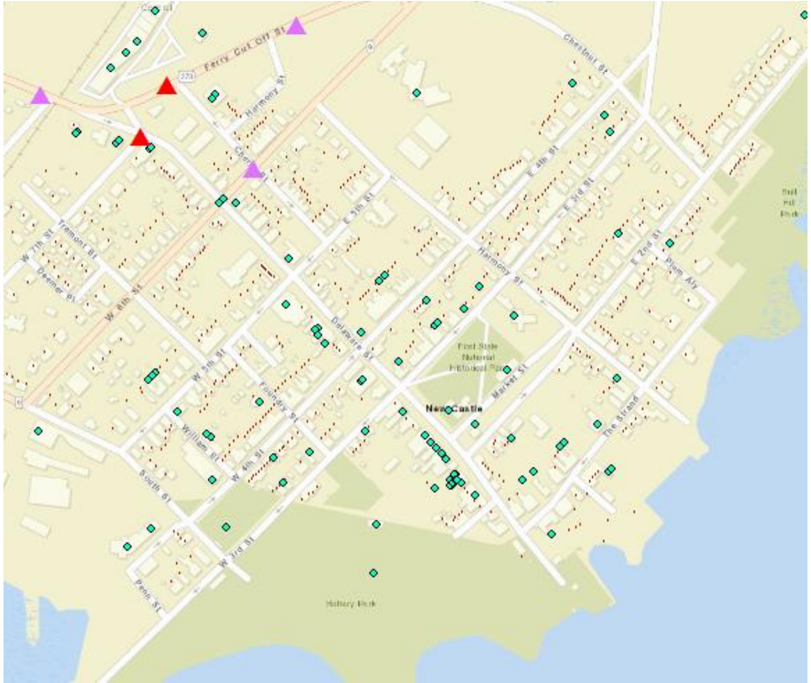
(Crash Involving Pedestrian is red triangle, Bicyclist is purple triangle. Destinations as green dots)



Source: DelDOT Crash Analysis Reporting System

Figure 75 Old New Castle,

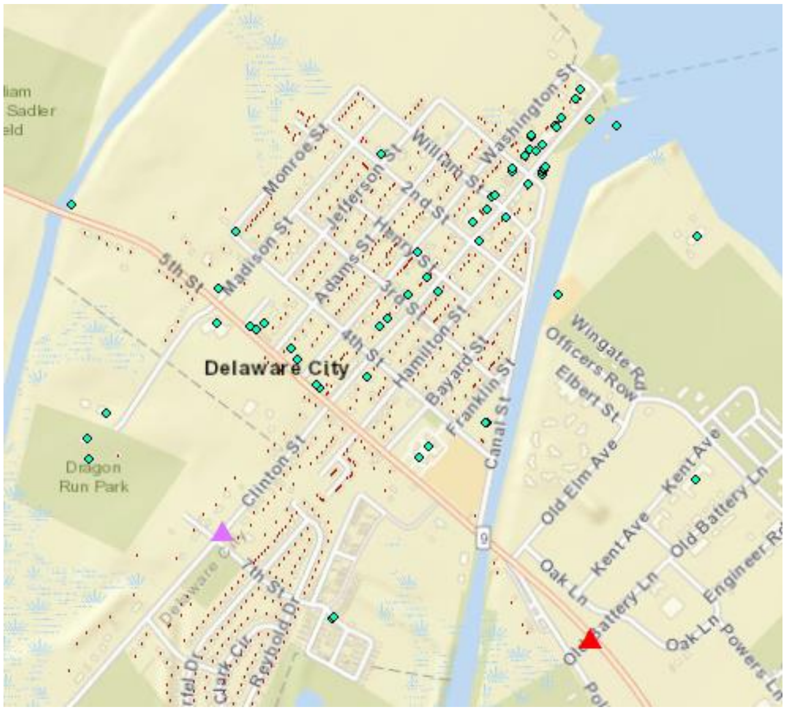
(Crash Involving Pedestrian is red triangle, Bicyclist is purple triangle. Destinations as green dots)



Source: DelDOT Crash Analysis Reporting System

Figure 76, Delaware City,

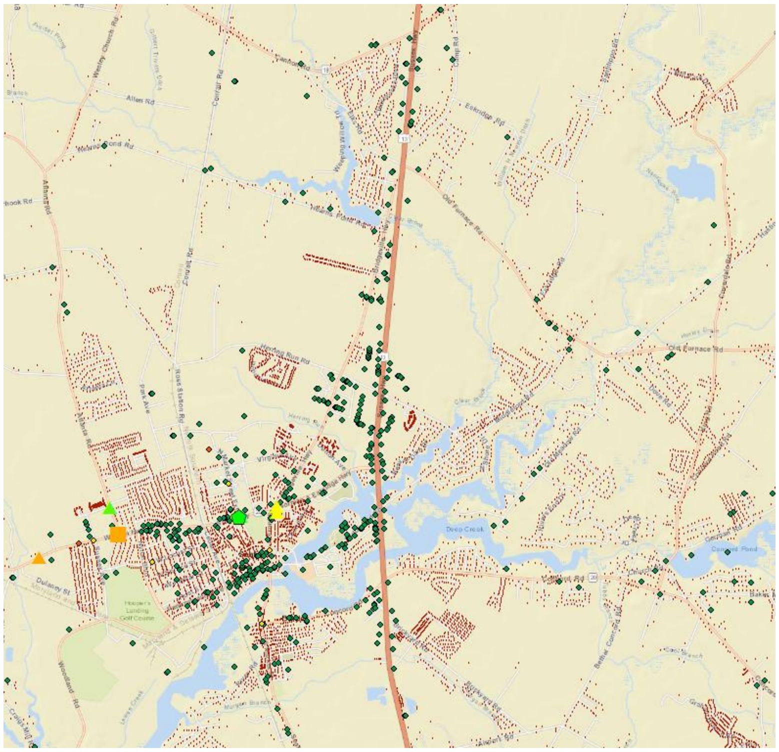
(Crash Involving Pedestrian is red triangle, Bicyclist is purple triangle. Destinations as green dots)



Source: DelDOT Crash Analysis Reporting System

Figure 77 Crashes in Seaford

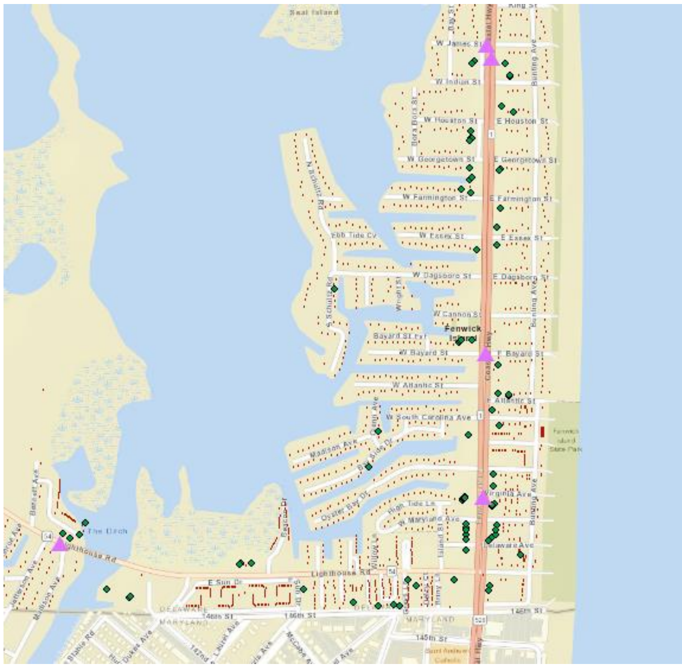
(Crash Involving Pedestrian is red triangle, Bicyclist is purple triangle. Destinations as green dots)



Source: DelDOT Crash Analysis Reporting System

Figure 78, Crashes in Fenwick Island

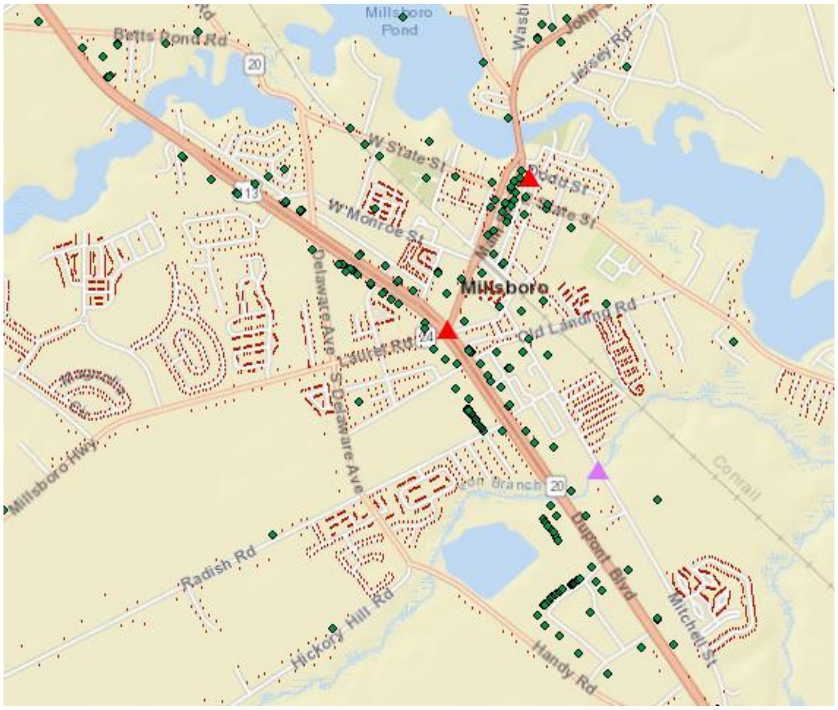
(Crash Involving Pedestrian is red triangle, Bicyclist is purple triangle. Destinations as green dots)



Source: DelDOT Crash Analysis Reporting System

Figure 79, Crashes in Millsboro

(Crash Involving Pedestrian is red triangle, Bicyclist is purple triangle. Destinations as green dots)



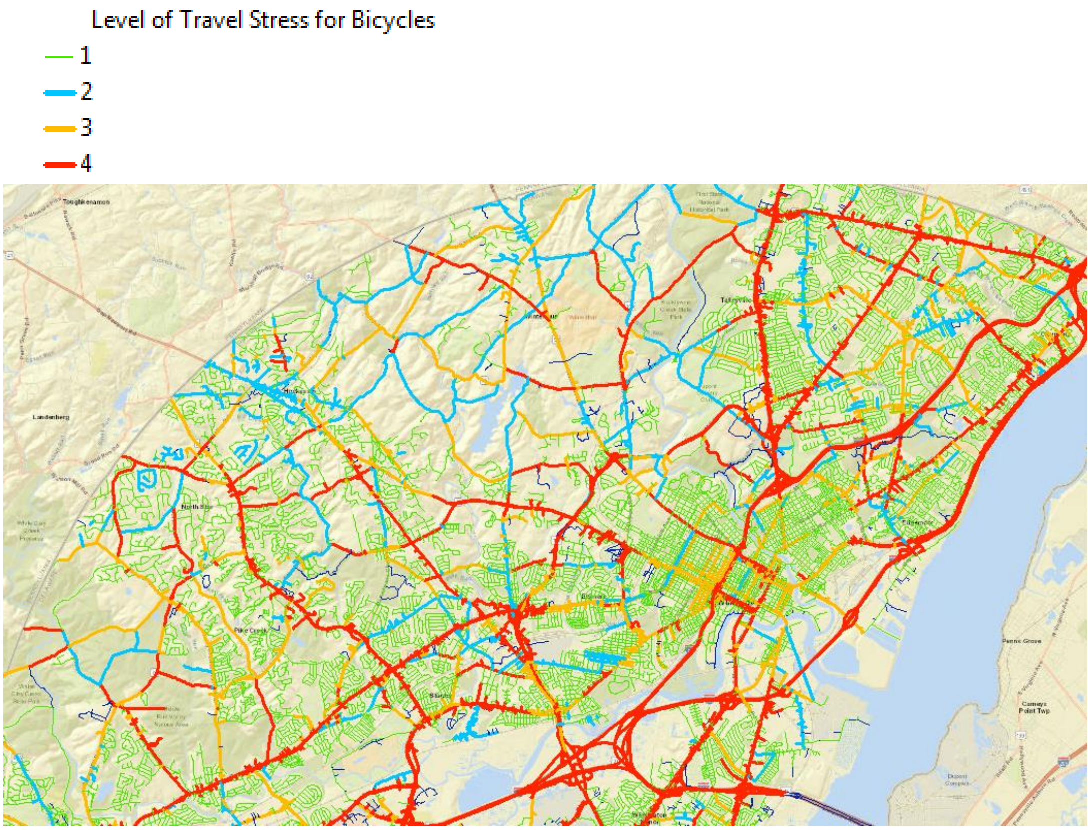
Source: DelDOT Crash Analysis Reporting System

Crashes Relative to Level of Service/Stress

Toward developing multimodal travel and improving facilities, efforts have begun toward developing level of service (LOS) or level of traffic stress (LTS) categorization for walking and bicycle travel. These classification are based on number of lanes, shoulder widths, trail and sidewalk availability, prevailing speeds, and other features of the transportation network. Portions of the travel way are ranked numerically where lower values are lower stress or comfort (perceived as safer). For instance, a dedicated trail, sidewalk, or subdivision street could be considered as a “1” where a multilane, no shoulder road with high traffic volumes and high speeds would be a “4.” Sometimes descriptors are attached to the ranking, for example for bikes a “1” would be Children cyclists, “2” would be Adult Cyclists, and “3” would be Advanced Cyclists.

An example is taken from a classification of bike routes that is a work in progress by DelDOT and WILMAPCO and example figure is below It is interesting to examine crashes relative to expected conditions.

Figure 80 , Level of Traffic Stress for Bicycles ,Northern New Castle County, As provide by WILMAPCO and DELDOT



The distribution of bicycle crashes relative to Bike LTS on the nearest road was examined. As the City of Wilmington and the City of Newark have almost half of the crashes, these high density urban areas are very different from areas in the rest of Delaware, and many of their roads were classified as “1,”, the distribution is about 10% higher for Level 1. To get a better estimate of the rest of the State, these downtown Newark and Wilmington crashes were removed from this rough estimate. Adult cyclists may find Wilmington and Newark roads less stressful as speeds are low, but these areas may warrant another classification. A suburban development street is considerably less stressful than a downtown road though in this particular classification system they each are classified the same. The distribution is shown in Figure 81 and from level of stress 2 to 4, percentages of bike crashes go up with stress classification. But this view has the same problem that any analysis has when dealing with numbers of crashes. It fails to account for the activity. More cycling could happen on level of stress “1” roads so regardless if they may be safer, they will still show more crashes if that is the case.

Figure 81, Travel way Level of Stress Distribution of Bicycle Crashes
New Castle County without downtown Wilmington and Newark

Level of Stress	Percent of Crashes
1	24%
2	11
3	30
4	40

Addressing the major missing component of crash analysis, the exposure, is the subject of the next chapter.

Estimating Exposure

Introduction

The probability of having an crash depends on the degree of walking or biking activity that occurs, and the opportunities for interaction with motor vehicles. Risk is generally defined as the number of crashes divided by some measure of exposure which captures the opportunity to be exposed to crashes. While 60% of the crashes involving pedestrians or cyclists appear in the municipalities it doesn't mean that towns are less safe for a particular individual, it could be that there is a large amount of walking and biking there, or a large amount of interaction with vehicles. If investments in an area are made to make a better and safer environment for walking and biking, the result could be that more crashes occur due to increased activity. At the scale of a State, a county, or at the small community level, the number of crashes may point to particular places that need attention or areas where investments may realize greater benefits but judgement as to how safe an area is, or how to prioritize countermeasures is relative and needs to include some measure of exposure. Measures could be:

- the number of hours spent traveling
- number of miles traveled
- the number of trips made
- a pedestrian or bicycle count

Predicting pedestrian and bicycle usage has many challenges. First from a data analysis and modeling perspective, crashes can be considered fairly rare events and since walking typically accounts for 2 to 4 percent of trips and bicycling 1% or less, getting sufficient data to analyze is always an issue. Analysis of walk and trips, particularly because of the small trip distances involved, requires a higher resolution description of populations, travel networks, land use, and origins and destinations than a usual traffic zone approach. This section reviews methods for estimating exposure. Literature is extensive in this area and has been summarized by many authors. The approach here is to select three guideline documents dealing with estimates of bicycling and pedestrian activity and measurement of risk, and then address specific approaches for Delaware.

An Example Exposure Measurement

Exposure based strictly on populations or housing units in an area could assist but, the character and activity levels and types of activity between various groups could be quite different.

Take, for example, the county based crash tabulation in figure 81. The rate based on the population was developed by taking the number of crashes, divided by 5 (5 years of data) and then dividing by the population in each county. A better estimate would be to take the estimated total walk and bike trips in each county and come up with a rate expressed as crashes per number of trips. The Delaware Travel Monitoring System is an ongoing travel study in Delaware that is sponsored by DelDOT and an estimate of daily weekday trips is available from that study. Estimates show that New Castle County is expected to see about 6 times the number of walk trips than Kent and close to 4 times for Sussex. For bike trips, New Castle County is expected to have close to 4 times as many as Kent and about 25 percent more than Sussex**.** For the sake of developing an estimate as an example, let us make the assumption that there are as many walk trips on weekends as weekdays. We will ignore the fact that trips will be of various different lengths in different counties (the longer the trip the long someone is exposed to traffic), ignore the varying road types and vehicle volume and speed conditions, and we will ignore the effect of trips by those under 18 since that wasn't included in our walk and bike trip estimates. We will simply divide the number of crashes by the number of trips. We will take the number of crashes averaged over 5 years and divide that by the daily estimate of trips multiplied by the number of days in a year. This produces a totally different estimate of crash rates.

Figure 82, Pedestrian Crashes By Year By County Based on Population

	2012	2013	2014	2015	2016	Total	Rate Based on Population
Kent	33	36	55	53	45	222	5.1 per 100,000 persons per year
New Castle	260	246	235	238	262	1241	8.7 per 100,000 persons per year
Sussex	28	27	34	21	29	139	2.4 per 100,000 persons per year
Total	321	309	324	312	336	1602	6.5 per 100,000 persons per year

Source: DelDOT Crash Analysis Reporting System

Figure 83, Estimated Daily Trips by County in Delaware
Source DTMS, 3 year average for 2015 thru 2017, Weekday trips, persons over 18

	Walk Trips	Bike Trips
Kent	25,766	2,521
New Castle	153,929	9,563
Sussex	40,116	7,580

Figure 84, Pedestrian crash rates based on number of trips by county

Kent	2.4 crashes per 100,000 trips per year
New Castle	2.2 crashes per 100,000 trips per year
Sussex	0.9 crashes per 100,000 trips per year
State	2.0 crashes per 100,000 trips per year

Figure 85, Total Bike Crashes by County between 2012 and 2016

Kent	114
New Castle	399
Sussex	111
Total	624

Source: DelDOT Crash Analysis Reporting System

Figure 86, Bicyclist crash rates based on number of trips by county

Kent	12 crashes per 100,000 trips per year
New Castle	11 crashes per 100,000 trips per year
Sussex	4 crashes per 100,000 trips per year
State	9 crashes per 100,000 trips per year

So from this data, when examining crashes per capita, New Castle County crash rates are close to twice that for Kent County. When looking at crashes per estimated trips, the crash rates are fairly similar.

Factors, challenges and methods for Estimating Bicycling and Walking for Planning NCHRP Report 770

"Estimating Bicycling and Walking for Planning and Project Development": A Guidebook, J. Richard Kumyak, Jerry Walters, mark Bradley, Kara M.Kockelman, Transportation Research Board Washington D. C. 2014

A highly informative and useful publication for estimating walk and bike activity is NCHRP Report 770 "Estimating Bicycling and Walking for Planning and Project Development" which lays out the main issues and methods for estimating bicycle and walking. Factors cited as effecting bicycling and walking include:

- Relationship between the build environment and travel network are important, demand depends on the number and variety of opportunities accessible within comfortable travel distance/time envelopes
- Acceptable trip distances vary by trip purpose
- The choice of walk, bike, and transit as modes are more likely with simple tours (single purpose, one stop)
- Natural environment is more important for non-motorized travelers, topography, climate, hours of daylight
- Personal safety
- Sociodemographic differences , like age, gender

Key challenges include:

- Operating at a spatial scale fine enough to articulate the factors and conditions affecting pedestrian and bicycle travel
- Accounting for the interplay between the built environment and the decision to walk or bike
- Accounting for the quality and accessibility of the bicycle and pedestrian travel networks.
- Representing mode and destination choices from the perspective of the individual traveler rather than spatial aggregations of household in traffic analysis zones
- Accounting for destination and mode as simultaneous choices
- Translating bicycle and pedestrian trip generation into trip flows and assignment to the travel network.

Whether to walk or bike is seen as a fairly complex set of highly location specific decisions involving multiple factors. Figures related to trip distance and purpose are included in the next couple pages.

Figure 87, Walk Trip Length in Miles, NCHRP Report 770

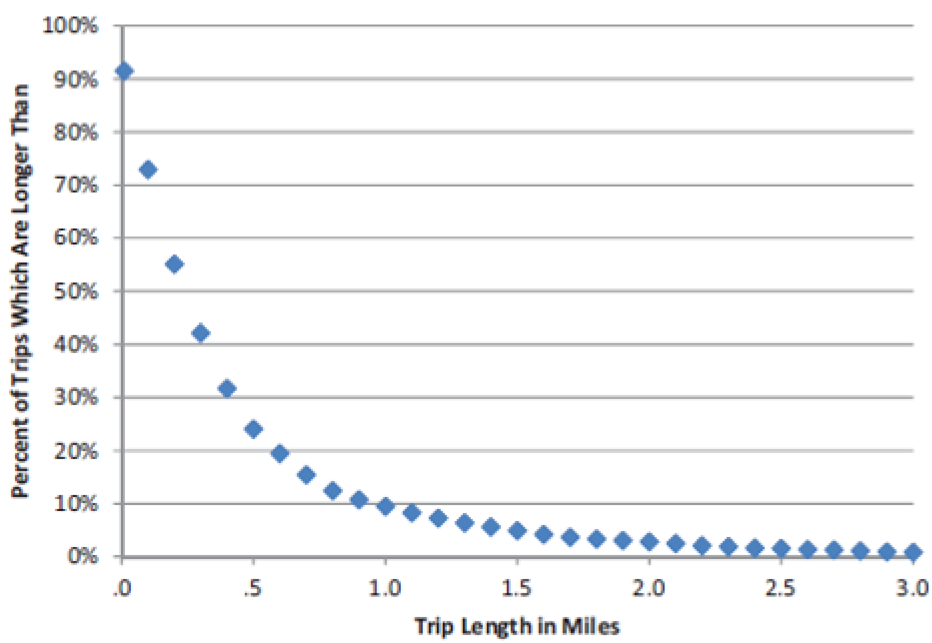


Figure 88, Walk Trips by Travel Time, NCHRP Report 770

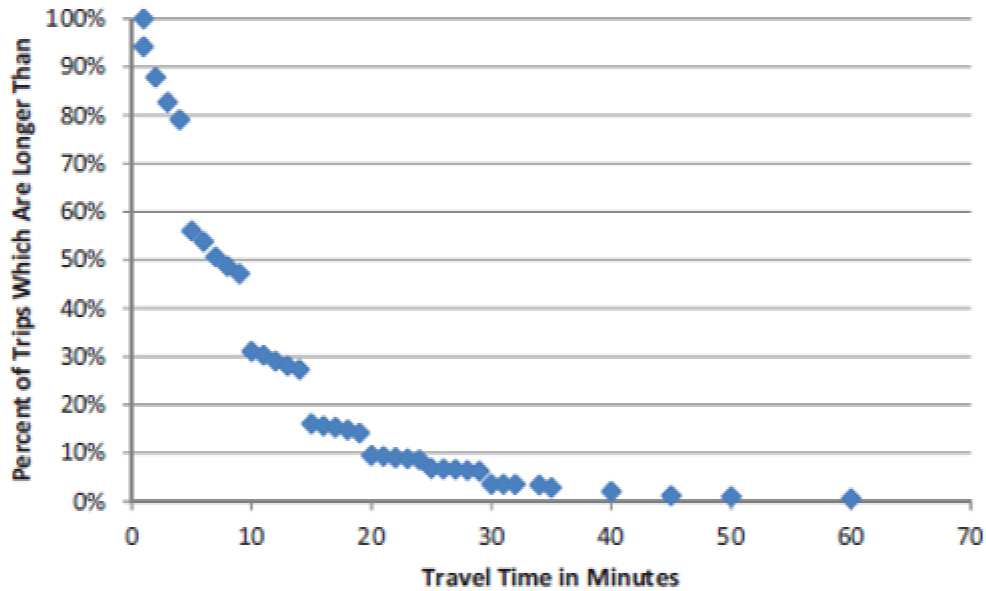


Figure 89, Bike Trips by Distance, NCHRP Report 770

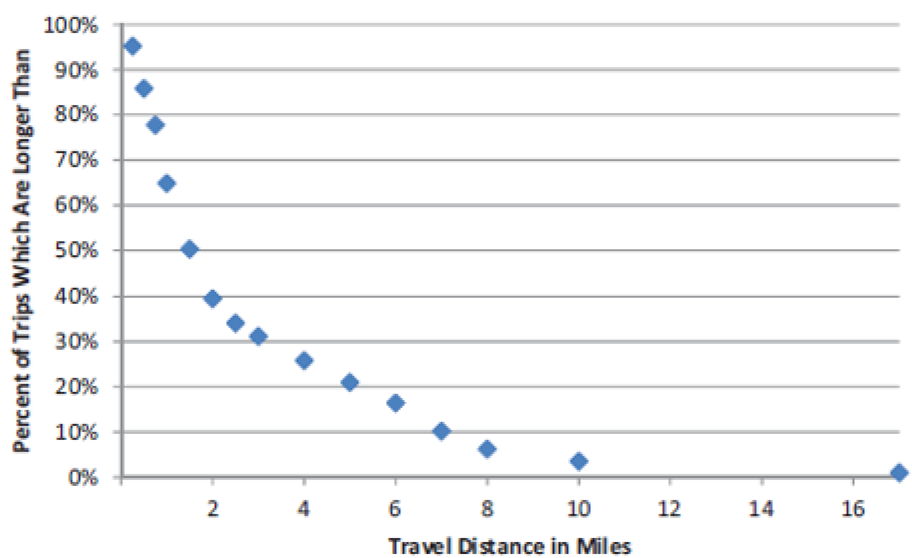
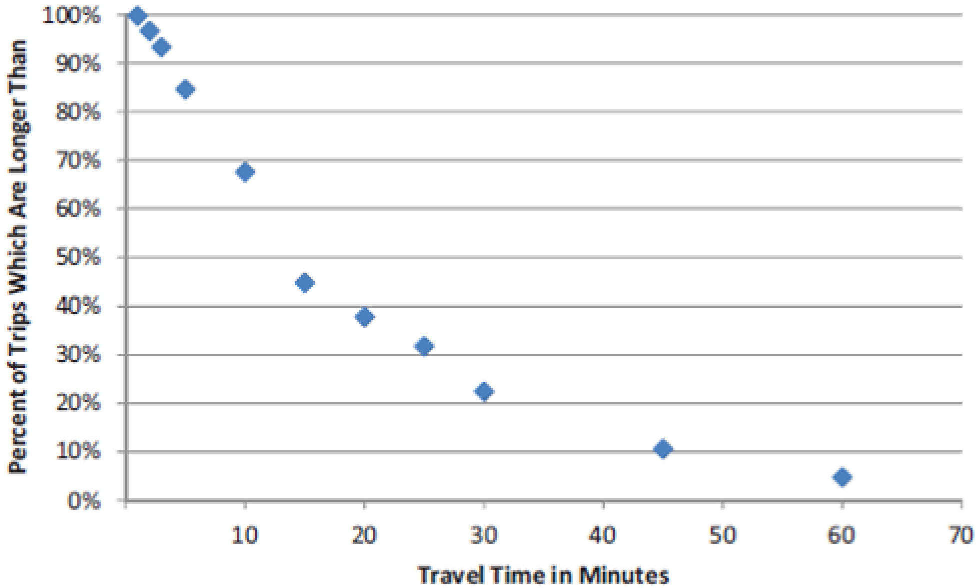
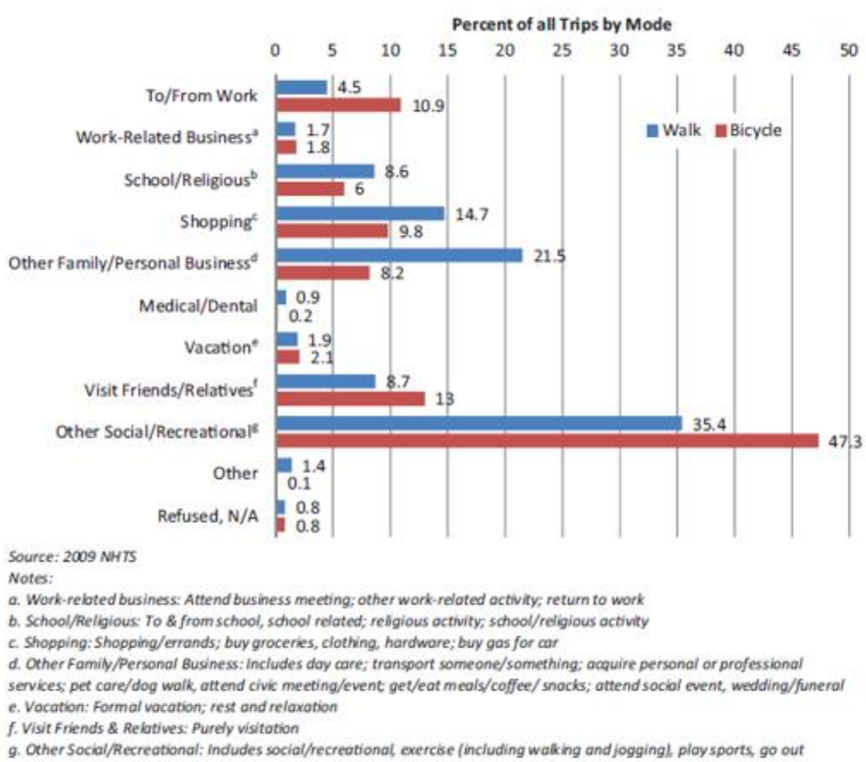


Figure 90, Bike Trips by Travel Time, NCHRP Report 770



NCHRP 770 also provides breakdowns by trip purpose as shown below.

Figure 91, Frequency of Walk and Bicycle Trips by Trip Purpose, NCHRP Report 770



Guide for Scalable risk Assessment methods for Pedestrians and Bicyclists
Publication FHWA-SA-18-032, July 2018 USDOT, FHA

The FHWA publication "Guide for Scalable Risk Assessment Methods" lays out eight sequential steps to develop risk values at various desired geographic scales, and provides information on analytical methods to estimate pedestrian and bicyclist exposure. The first step is to determine the use of risk values whether it is for safety performance measures, identifying high-risk sub areas, examination of high risk facilities, prioritization of projects, or evaluating the effectiveness of safety countermeasures. How measures are used will establish what information is needed and the scale of that information.

The second step, the selection of the risk values, suggests the geographic scale of the analysis. Figure 92 below shows scale categories from the FHWA report. The emergence of high resolution point based data for populations as for housing units, properties (tax parcels) and building specific origin and destination files would be an important class of data elements to also consider.

Figure 92, Scale Categories in the Risk Assessment Process as taken from FHWA-SA-18-032

Scale Group	Scale Category	Description	Examples
Facility-Specific	Point	Specific location where conflicting traffic streams cross, merge, or diverge.	• Single intersection or mid-block crossing • All crossings at an intersection • Conflict zone (e.g., merge area)
	Segment	Length of street or roadway between two points. Traffic volumes and physical characteristics generally remain the same along the length of a segment, although small variations may occur.	• Street segment between major intersections • Multiple street segments along a single facility, or on parallel facilities (e.g., corridor) • Street segment of defined length (e.g., one mile)
Areawide	Network	A mid-sized geographic area that includes an interconnected set of transportation facilities.	• Census tracts • Census block groups • Traffic analysis zones
	Regional	A large geographic area that includes all transportation facilities within a defined political boundary. Because of the large geographic size, land use at this scale can be heterogeneous within a defined area.	• City • County • Metropolitan Statistical Area • State

A risk definition is selected as an observed crash rate divided by the exposure, but also could be generated as “expected crashes” based on some statistical modeling. A definition might also be developed by a function of one or more risk indicators or factors.

The FHWA-SA-18-032 summarizes a selection matrix for exposure measures that is related to the scale of the analysis as shown in figure 93.

Figure 93, Selection Matrix for Exposure Measures From FHWA-SA-18-032

Category of Exposure Measure	Typical measures	Typical scale				Typical data sources
		Point	Segment	Network	Region	
Distance Traveled	Miles of travel	○	●	●	●	• Site counts or demand estimation models, multiplied by segment length • Sometimes travel surveys
	Miles crossed per entering vehicle	◐				
Time Traveled	Hours of travel	○	○	●	●	• Travel surveys • Sometimes site counts combined with crossing time or average travel speed data.
	Product of crossing time and vehicle volume	○	○			
Volume/ Count	Volume/count	●	●			• Site counts • Demand estimation models
	Product of pedestrian /bicyclist volumes and motor vehicle volumes	◐	◐			
Trips Made	Number of trips			●	●	• Travel surveys
Population	Number of people that walk or cycle on regular basis			●	●	• U.S. Census data products
	Percent of the population that walk or cycle on regular basis			●	●	

Legend: ○ = to a small extent; ◐ = to a moderate extent; ● = to a great extent.
Note: Each exposure measure will be for a defined time period that matches the risk definition.

Source: Partially adapted from Greene-Roesel et al., Estimating Pedestrian Accident Exposure: Protocol Report, March 2007.

The analytic method to estimate these measures are in three main areas:

- Site counts
- Demand Estimation Models
- Travel Surveys

Figure 94, Analytic Methods to Estimate Exposure

Analytic Method		Input Data Requirements	Technical Complexity	Popularity in Practice	Direct Usability	Accuracy
Site counts		○	○	●	●	○/◐/●
Demand Estimation Models	Direct demand models	◐	○/◐	●	◐	○/◐
	Regional TDM	◐/●	◐/●	○	○/◐/●	○/◐/●
	Trip generation and flow models	◐/●	◐/●	◐	●	◐/●
	GIS-based models	◐	◐	◐	●	◐/●
	Discrete choice models	◐/●	◐/●	◐	○	◐/●
	Simulation-based traffic models	●	●	○	●	●
	Data fusion	●	◐/●	○	●	◐/●
Travel surveys		○	○	●	●	○/◐/●

Legend: ○ = low suitability; ◐ = moderate suitability; ● = high suitability.

Note: For some categories, multiple ranges (e.g., ◐/●) are used since the corresponding criteria might vary significantly based on the specific characteristics of the model developed.

Figure 95,"Guide for Scalable Risk Assessment Methods" 8 Steps

Step 1, Determine uses of risk values
- A Safety performance measures
- B Network screening, area based
- C Network screening, facility based
- D Project prioritization
- E Countermeasure evaluation
- F Site Evaluation

Step 2, Select geographic scale
- Facility specific (C thru F above)
  - Point
  - Segment
- Area wide (A and B above)
  - Network
  - Regional

Step 3, Select risk definition
- Observed crash rate Risk = Observed crashes / exposure
- Expected crashes – Highway safety manual and other statistical models
- Additional risk indicators
  - Risk is numeric score or rating and does not estimate crashes
  - Compatible with FHWA Systemic Safety approach
  - Systemic safety: risk score based on combining pedestrian and bicyclist
    Exposure with other road and traffic variables (risk factors)

Step 4, Select exposure measure
- Distance traveled
- Time Traveled
- Volume/Count
- Trips Made
- Population

Step 5, Select analytical method to estimate exposure
- Facility Specific
- Area wide

Step 6, Use analytical method to estimate selected exposure measure
- Facility Specific – site counts, demand estimation models
- Area wide – travel surveys

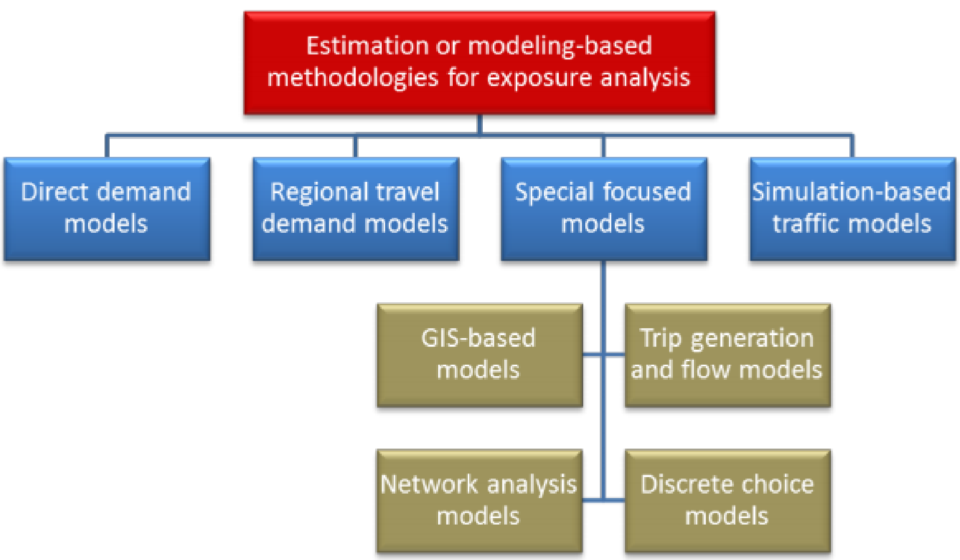
Step 7, Compile other required data

Step 8, Calculate risk values

Synthesis Of Methods For Estimating Pedestrian and Bicyclist Exposure To Risk At Areawide Levels And On Specific Transportation Facilities January 2017
UDDOT FHA Publication No. FHWA-SA-17-041

"SYNTHESIS OF METHODS FOR ESTIMATING PEDESTRIAN AND BICYCLIST EXPOSURE TO RISK AT AREAWIDE LEVELS AND ON SPECIFIC TRANSPORTATION FACILITIES" is an extensive resource that supports a data driven approach to identifying and mitigating safety problems. Goals of the report were to synthesize and document existing technical resources, develop risk assessment methods for practitioners, and promote the use of risk assessment methods through outreach, training and technical assistance. A wide range of exposure measures being used in practice are documented. Area wide and facility specific measures are addressed as are the inclusion of other risk factors related to demographics, land use and traffic characteristics. The report emphasizes the importance in scale in the exposure estimation process, scale levels being facility, corridor, network, and regional. Data sources for area wide exposure analysis are discussed such as the National Household Travel Survey, the American Community Survey, and the NHTSA Attitudes and Behavior Survey. The report also addresses direct measurement (counts) as well as discussion of modeling based methodologies for facility level exposure estimation.

Figure 96, Modeling Based Methodologies for Facility Level Exposure



Also included in the report are identification of risk factors that have been associated with crashes involving pedestrian and bicycle crashes and review of studies that have investigated those factors.

Approaches to Estimating Pedestrian Activity and Exposure in Delaware

The previous section referred to a few major publications describing the modeling of mode choice for walking and bicycling, and the estimation and use of exposure. There are of course many efforts across the country to estimate and model non-motorized travel, but the publication shows the important considerations of scale and estimate method selection. Analyzing and estimating walking and biking trips does not lend itself to a traditional wide area or traffic zone approach, as with most travel demand forecasting methods that have been used historically. The trip distances are small. With the continued advancement of geographical information systems (GIS) and the huge amount of data of all kinds being generated at the household, tax parcel, and building level, a clearer picture of non-motorized travel is possible and travel networks and interactions can be analyzed. Analytic methods to estimate exposure measures are in three main areas:

- Site Counts, pedestrian or bicycle counters at strategic positions relative to study area
- Travel Surveys, survey trip activity and mode split
- Demand Estimation Models, predict trip activity

This section discusses recent efforts to estimate walk and bicycle activity and possibilities for how exposure and therefore risk may be estimated for applications in Delaware. Delaware has a growing pedestrian and bicycle count program, though for this project counts were not readily available and project time would not have allowed for a detailed study.

High Resolution Travel Demand Forecasting Models

Pedestrian and bicycle activity estimates are most useful at high geographic resolution as typically interest is in the safety of specific transportation facilities or in expected usage of current or proposed facilities. These require:

- Housing unit or Tax Parcel Level based trip production. Instead of developing trip generation for large traffic zones, trip productions and attractions are estimated at the housing unit level.
- Models of trip production at the housing unit level.
- Destinations at the building or tax parcel level.
- Employment at the building or tax parcel level.
- Models of trip attraction
- Models that can distribute trips from origins to destinations at this high resolution
- Detailed multimodal routing network models that capture features that affect mode split such as sidewalks, bike facilities, level of stress, safety, speeds and volumes, signals, and crosswalks
- Detailed mode split models that take into account detailed features of the network.

DelDOT has made significant progress toward this type of high resolution approach through the development of a tax parcel based travel demand forecasting model which has been employed for small areas where data requirements could be met. High resolution destinations and employment files are gradually being developed, and categorization of destinations to reflect trip purpose. Routing network models are gradually improving and becoming more detailed. Distributing trips to various modes (car, bike, walk,) depends largely on distance and time curves, by purpose, by mode. Where actual pedestrian or bicycle counts on facilities are not available, a high resolution travel demand forecasting approach is expected to provide the detailed estimates needed for safety analysis and facility planning. Developing and implementing this approach to estimating exposure is beyond this project.

GIS Accessibility Models, CADSR Trip modeling that Includes Accessibility

Related to efforts to move to high resolution travel models, a study[*] sponsored by DelDOT, the Center for Applied Demography and Survey Research (CADSR) at the University of Delaware developed a multimodal trip generation model that included accessibility measures (Racca"Development of a Comprehensive Multi-Modal Accessibility Indexing System at the Tax Parcel Level",). CADSR has developed a statewide tax parcel based destination file which allows for various measures of accessibility to destinations. Data from the Delaware Travel Monitoring System (DTMS), the primary travel survey conducted by DelDOT, was processed and compiled for years 2012 thru 2015, and examined with accessibility measures. Travel survey data was used to develop trip generation models to discover in particular how accessibility factors may assist in explaining and predicting the propensity to walk or bike. Using maximum likelihood procedures four model equations were developed separately to predict "Total Trips," "Car Trips," "Walking Trips," and "Bike Trips" that an individual would take based on the demographic and land use information available from the DTMS survey.

For the model estimating number of walk trips, employment, number of available vehicles, and income were statistically significant factors. An employed person is seen as less likely to take a walk trip. Availability of a vehicle(s) makes walk trips less likely. Higher income groups tend to walk less though not uniformly so. The accessibility factor, "total destinations within a quarter mile", and the sidewalk density factor are both significant at the 95% confidence interval. Having more destinations within a quarter mile leads to more expected trips. The coefficient of the accessibility factor is not large, and the addition of a few destinations is not expected to largely effect the number of walk trips expected, but then again there are land use densities in some areas where 100's of destinations may be available within a quarter mile. Locations with a greater density of sidewalks also indicated a higher likelihood of pedestrian travel.

[*] Racca"Development of a Comprehensive Multi-Modal Accessibility Indexing System at the Tax Parcel Level".

The model equation for biking is similar to that for walking with a couple differences. Those employed and those with vehicles available tended to take fewer bike trips, but higher income groups indicated more likelihood of bike trips. One of the more interesting results was the coefficient for total destinations within a quarter mile. While for walking the effect of the number of destinations in the vicinity indicated more walk trips, for biking more destinations predicted less bike trips. Having a lot of places to go within a quarter of a mile and sidewalks should be a positive factor for walkers. The same is not likely for those with a bicycle unless there were widely available bike paths between the places of interest and the points of origin. Perhaps in the absence of bike paths, travel in areas with large numbers of destinations mostly accessed by automobiles could be seen as a discouragement for bike travel.

This model then produced a person based estimate for the number of walk trips in an area. If demographic variables for employment, available vehicles, income could be obtained or synthesized at small scale, it may be useful for estimating exposure at the community or facility level. Trips would still need to be allocated to destinations in order to perform road network allocations to provide expected volumes on roads and intersections.

Area wide Estimate based on the Delaware Travel Monitoring System (DTMS) Survey

The Delaware Trip Monitoring System (DTMS) Survey, as part of the Delaware Statewide Model Improvement Project, is an ongoing survey designed and conducted by the University of Delaware's (UD) Center for Applied Demography & Survey Research (CADSR). Since 1995, the survey has been utilized to gather information about the weekday travel behaviors and preferences of adults across the State. In a random process, respondents are selected and asked to list the origin, destination, time, and trip method (mode) of every trip made in the preceding day. Demographic data is compiled for each respondent and public opinion on transportation issues are also obtained. Since the start of the survey, there have been over 40,000 people surveyed, and over 120,000 trips have been documented. The DTMS is the primary data used in developing trip generation modeling. From that we can estimate trip purpose, trip lengths, travel modes, trip duration, trip distance, trip time of day, and several others. Demographic data is captured and origins and destination locations are captured.

In terms of exposure, the number of walk trips (week day for those 18 years or older) and bicycle trips can be estimated by State and by County as shown in an example in this report. Estimates at smaller levels, the traffic zone or census block group for instance, are not possible due to the small amount of trips (bicycling about 0.2% of trips, walking 4 to 7% of trips). DTMS is highly useful in the study of factors related to non-motorized travel.

Using Travel Demand Forecasting Data at the Traffic Zone Level to Estimate Exposure

For this project, a traffic zone based estimate for pedestrian trips was all that was available. This section demonstrates an estimate of exposure based on traffic zone estimates from DelDOT's travel demand forecasting model that can be compared with crash data. Certainly, trip estimates at the tax parcel level, combined with a detailed travel network that captures level of service and features of facilities at a high resolution could yield interesting results at the level where walking and biking occur, but traffic zone level estimates of total trips were available and may also be illustrative.

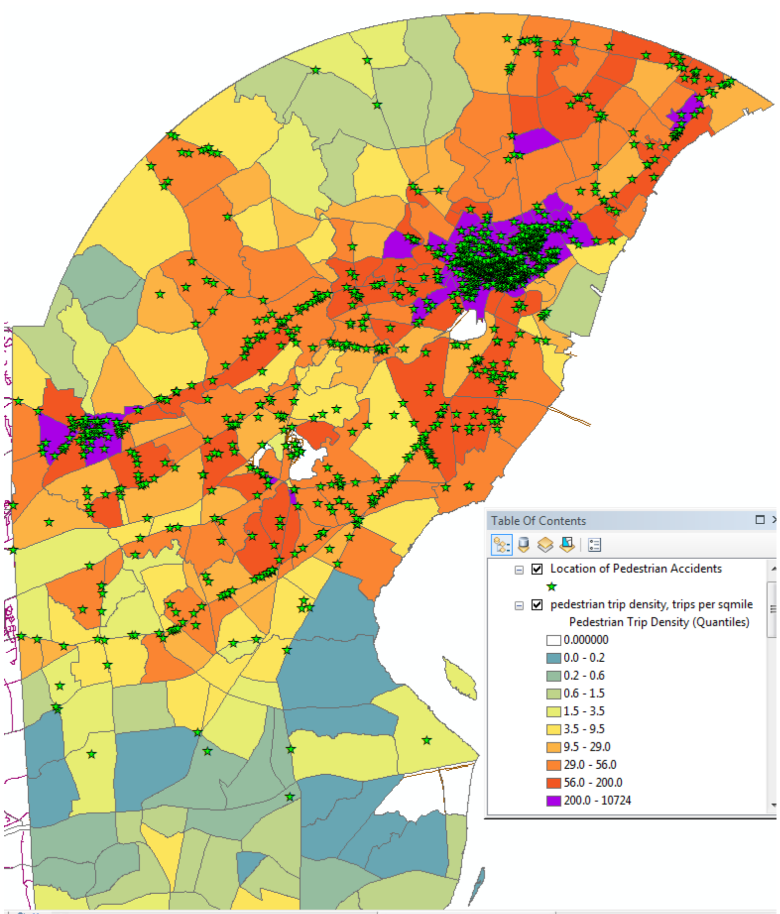
A spring of 2019 version of a zone to zone daily trip table was obtained from DelDOT for their peninsula wide model. In this model the Delmarva Peninsula is divided into 975 traffic zones. The zone to zone trip table breaks trips down into various purpose but for the purpose of this exercise only total trips were considered and the analysis was focused on pedestrian trips and crashes. To estimate pedestrian trips tabulations of the expected percentage of those trips by pedestrians was estimated based on trip distance. Figure 97 estimates those percentages in a table used by planners in Delaware based on Delaware data.

Figure 97, Percentage of walking and bike trips expected based on trip distance

mile	per of walk	per of bike
0.1	77%	0%
0.2	50%	0%
0.3	36%	2%
0.4	27%	2%
0.5	21%	1%
0.6	17%	2%
0.7	14%	1%
0.8	11%	0%
0.9	10%	1%
1	8%	1%
1.25	5%	1%
1.5	4%	0%
2	2%	0%
3	1%	0%
4	0%	1%
5	0%	2%

This table was used to convert total trips to number of expected walking trips. The next step was to estimate a zone to zone distance. To improve the distance estimate relative to just taking the distances between centroids of traffic zones, first a center of mass for destinations within each zone was developed using a statewide destination file developed by CADSR at the address level. Next a statewide housing unit layer was used to locate a center of mass for residential properties. Then using network models, the estimated length of the path a pedestrian could take between these origin and destinations centers was generated. This resulted in a zone to zone distance estimate that was combined with figure 97 above to develop a zone to zone pedestrian total trip estimate. From that, the total the number of pedestrian trips generated in each zone was estimated through an aggregation over all zone destination records. Then to account for the varying size of traffic zones, total pedestrian trips were divided by the areas of the zones to obtain a pedestrian trip density, the estimated number of pedestrian trips per square mile. A thematic map of pedestrian trip density with four years of pedestrian crash locations is shown below. Clearly the amount and clustering of crashes is related to the pedestrian activity. One note here, population density will look similar to trip density for urban areas in particular where people work, shop, and live in the same area. Population density however misses the effects of destinations and people are of course traveling to destinations other that other residences. Numbers of trips is the appropriate focus to capture activity and exposure.

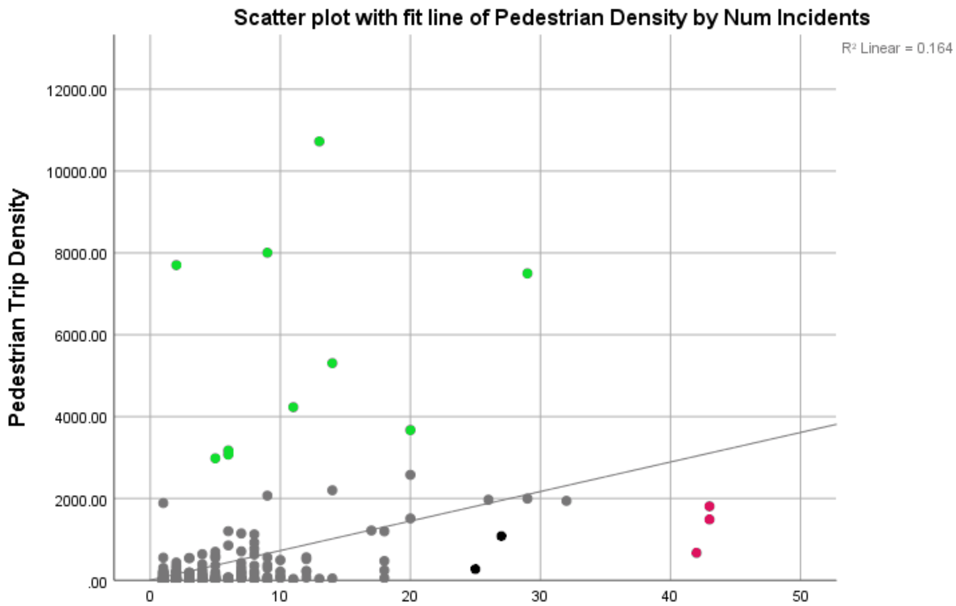
Figure 98, Pedestrian crash points overlaid on traffic zone based pedestrian trip density Northern Delaware

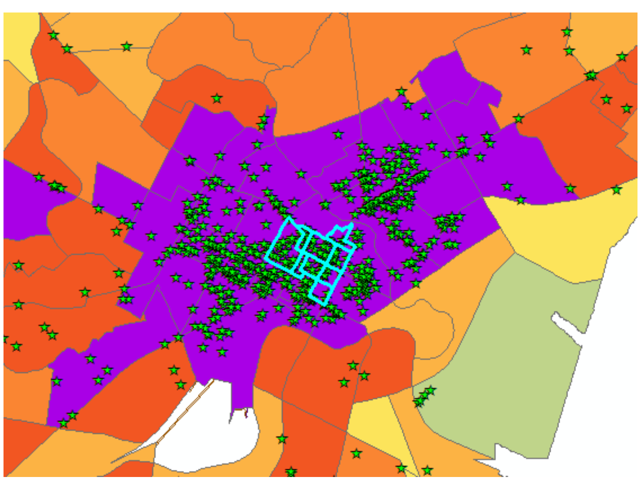


Source: DelDOT Travel Demand Forecasting Model and Source: DelDOT Crash Analysis Reporting System (2012-2016)

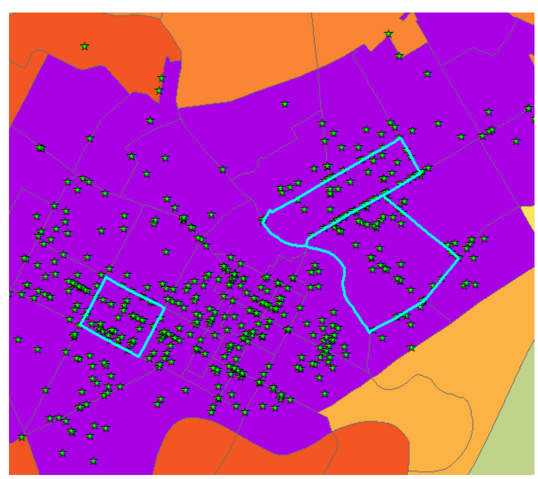
A scatterplot of zone pedestrian trip density versus number of crashes in the zone is provided below. Clearly there are different factors at work. The observations most deviating above a poorly fit line would be zones with the highest trip density and low number of crashes shown as green dots. These happen to be the contiguous zone in the City of Wilmington Central business district as highlighted in green in figure 100 . The high number of crashes with lower pedestrian trip density dots shown in red are also in Wilmington in particular along North market, Concord Ave, Vandever Ave, 4th St, and Lancaster Ave. These three “red dot” areas have large amounts of travel, generally see larger speeds than center city because they serve more as arteries, and all have on street parking.

Figure 99, Pedestrian Trip Density Versus Number of Crashes at the Traffic Zone Level





Green dot locations, Center City Wilmington



Red Dot Locations Center City Wilmington

The ratio of the counts of crashes to the zone pedestrian trip density would be a type of exposure estimate and could be ordered. Ordered in this way for zones with 5 or more crashes, the 20 crashes with smallest ratio, (the lowest number of crashes relative to trip density) are in Central Wilmington, central Dover and central Smyrna. The largest 20 occurrences of the ratio (larger number of crashes relative to pedestrian density) are primarily on major roads with 3 along Kirkwood Highway, 5 along Route 40, 2 on Old Baltimore Pike, 2 on Philadelphia Pike, and 2 on the stretch of Route 1 along the coming into along the beach area.

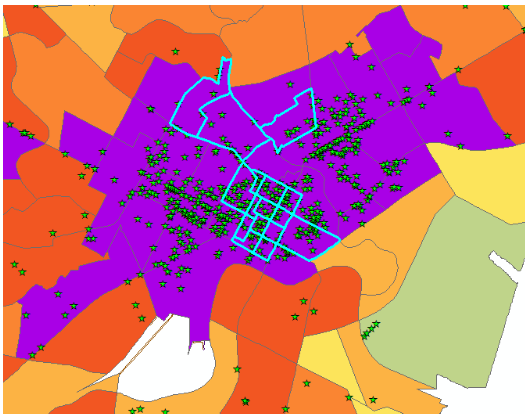


Figure 100, lower ratio of number of crashes to trip density, outlined in blue

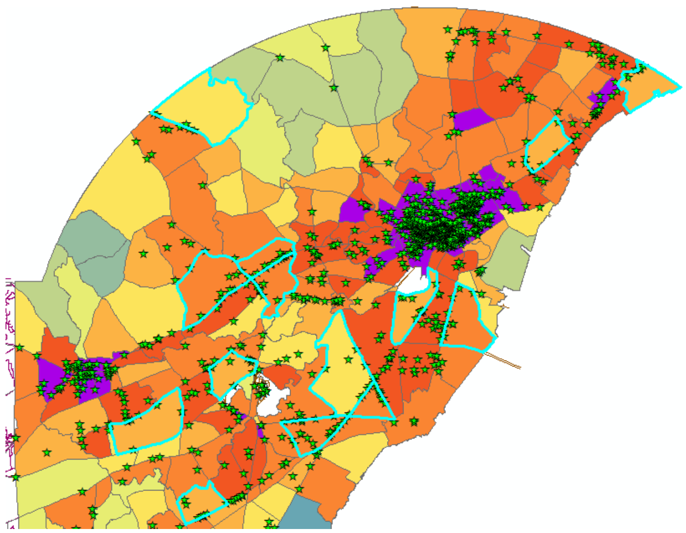
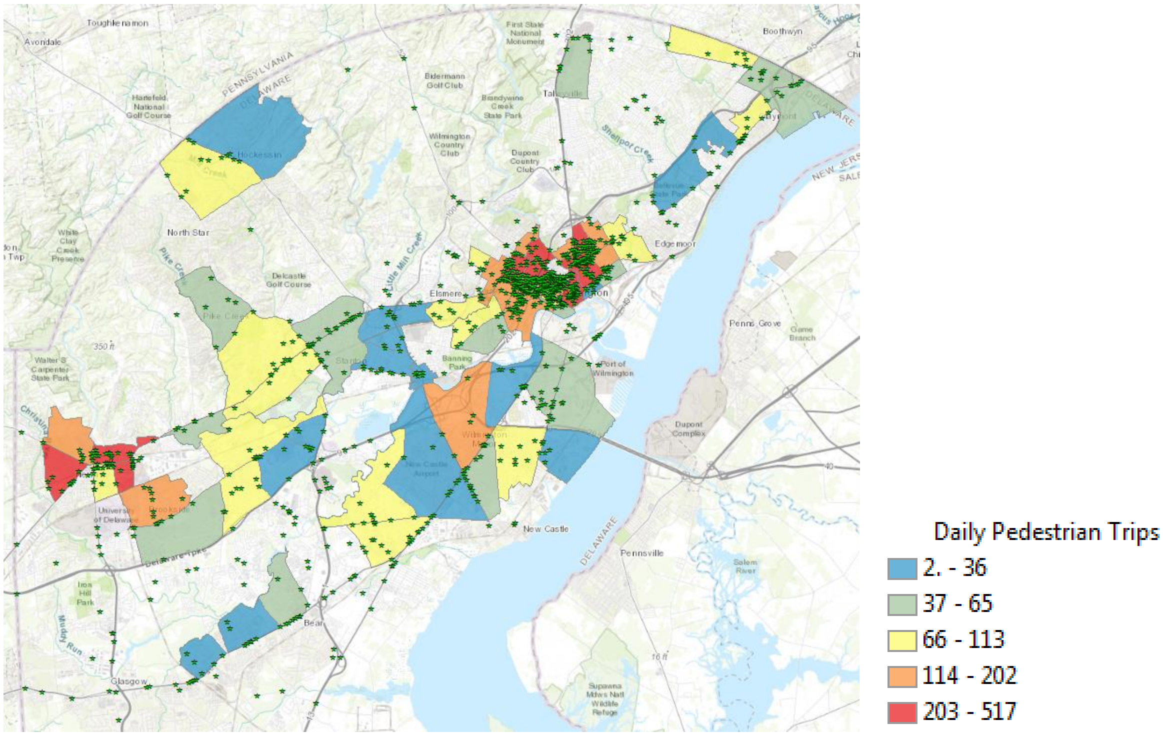


Figure 101, higher ratio of number of crashes to trip density , outlined in blue

It would be possible to refine this approach using trip generation at the tax parcel level and to better classify paths in regards to their safety or level of service. This rather quick and easy look at the traffic zone level does factor in pedestrian activity and assists in putting numbers of crashes in perspective and allow for a comparison of areas to hopefully highlight particularly unsafe areas.

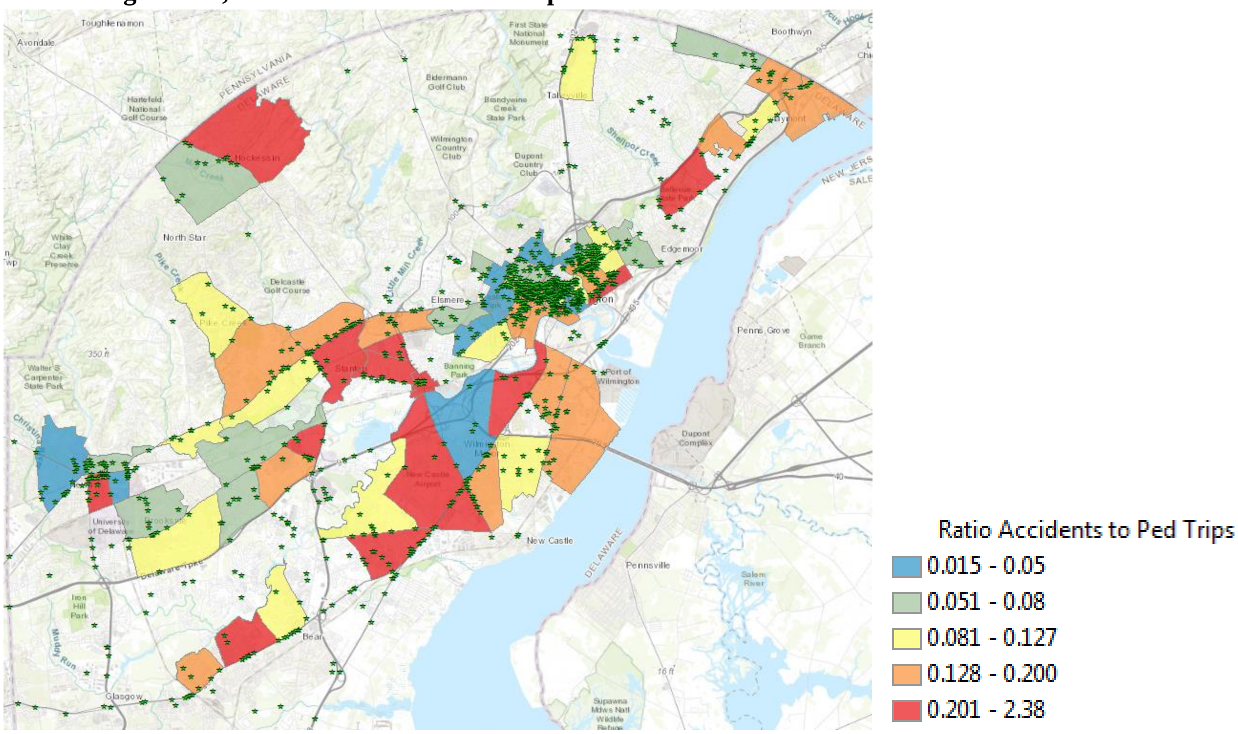
A trip density was used to account for the varying sizes of the traffic zones. It was suspected that using a trip density might tend to bias larger zones toward a higher ratio of crashes to exposure, so as a further experiment, total zone trips were examined and the ratio of number of crashes to total daily trips was viewed. The reasoning was that pedestrian trips would be near destinations and near crashes so using the total might be more appropriate. Figures of the results are on the next page for zones with 5 or more pedestrian crashes.

Figure 102, Daily Pedestrian Trips at the Traffic Zone Level (Crashes shown as green dots)



Source: DelDOT Travel Demand Forecasting Model and Source: DelDOT Crash Analysis Reporting System (2012-2016)

Figure 103, Ratio of Crashes to Ped Trips At the Traffic Zone Level



Pedestrian Activity Estimate on Roads Using Travel Demand Forecasting Data

Typically there is a desire to view the amount of pedestrian or bicycle activity with respect to specific facilities rather than a zone. Zone estimates are more appropriate for large areas, and when examining specific crash locations using zone data, issues arise. First of all, zone boundaries are usually formed by major roads so allocation of a crash to a particular zone can be difficult. A zone approach does not easily factor in facilities. Some zones may contain numerous facilities and destinations, while others, like suburban traffic zones can be comprised mostly of local roads with destinations mostly around the perimeter.

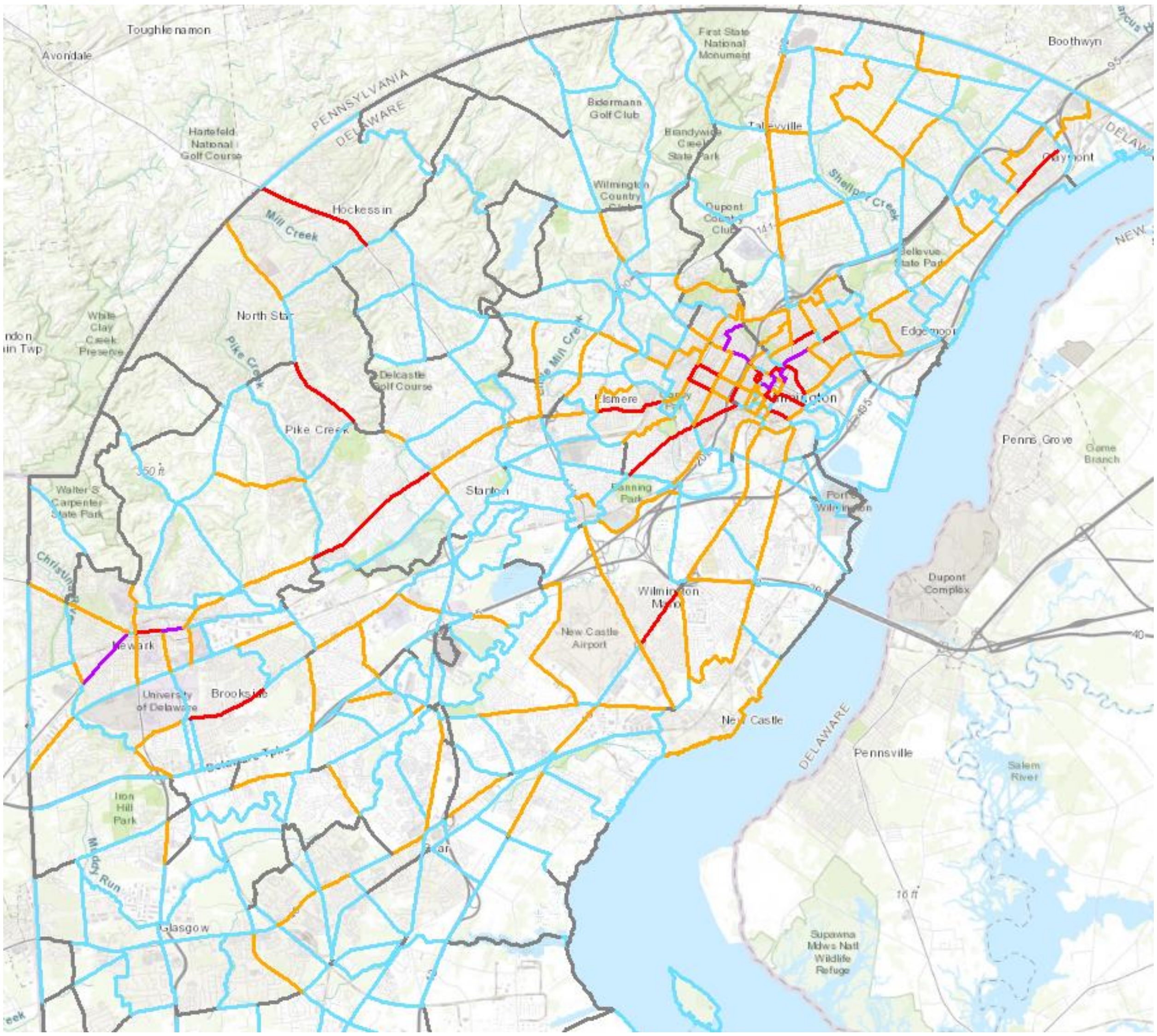
An attempt was made to develop an estimate of pedestrian trips on roadways using zone based trip data. To do this, the steps were:

- Obtain or derive a zone based pedestrian trip total, (Travel Demand Model)
- Associate building specific destinations with road segments
- Associate crashes with road segments
- Associate all zone boundary lines with roads they border. This creates multiple records for each zone.
- Allocate zone based pedestrian trips to border lines by the relative amounts of destinations on the borders roads.
- Sum all pedestrian trips for each road segment. The border road will be associated with pedestrian trips from zones on both sides.
- Sum all crashes on each road segment
- Create a crash rate by dividing crashes by pedestrian trips

Figure 104 shows estimates of daily pedestrian trips on road segments as derived from the traffic zone data in the way described.

By comparing the rates on each road this may provide a method to compare relative safety for pedestrians on roads. Figure 104 below shows rates for roads for the City of Wilmington. Figures 105 and 106 compare rates of other areas in New Castle County. Only road segments with 5 or more pedestrian crashes were considered and shown in these figures. One of the biggest issues of examining crashes at higher degrees of resolution, like at the road or intersection level is the lack of data which usually makes any type of statistical analysis impossible and conclusions less reliable.

Figure 104, Pedestrian Trips Per Day on Roads Estimated from Zone Data



Pedestrian Trip Per Day
- 0.00
- 0.01 - 20.00
- 20.01 - 100.00
- 100.01 - 200.00
- 200.01 - 382.88

Figure 105 Pedestrian Crash Rate Comparison for Road Segments with More Than 5 Crashes City of Wilmington

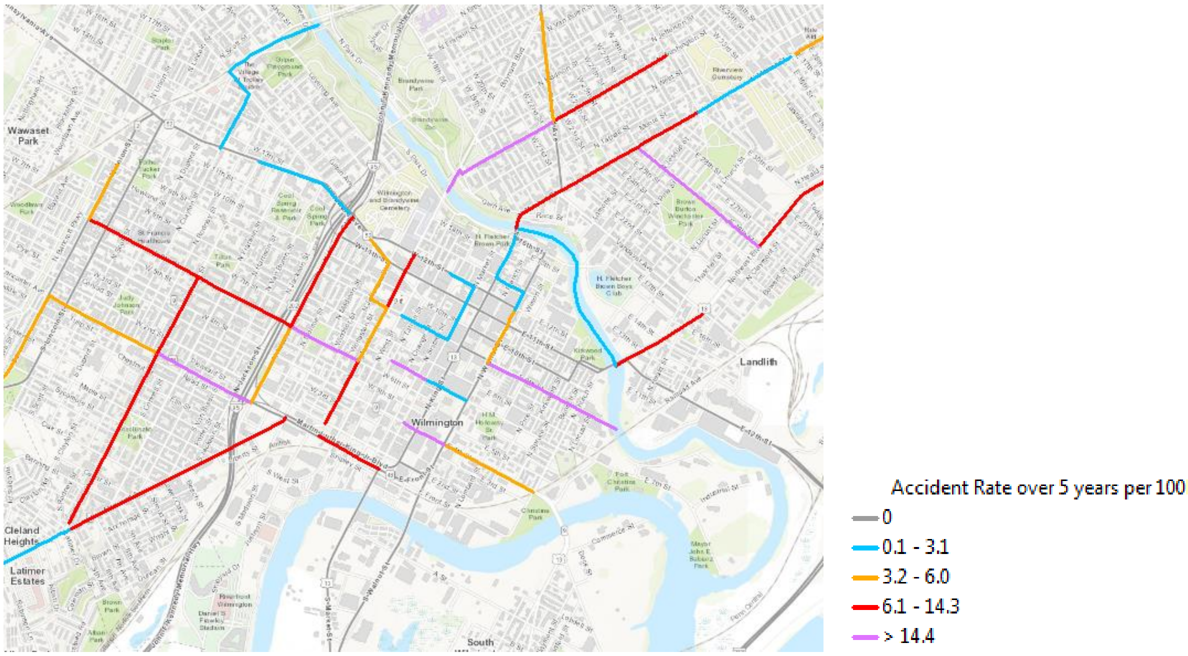
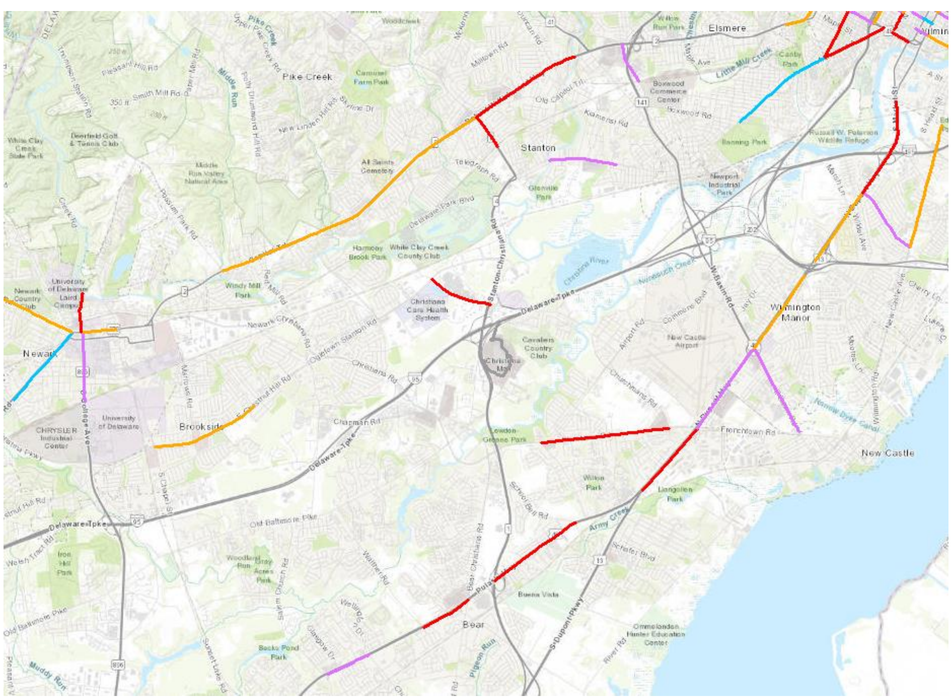


Figure 106 Pedestrian Crash Rate Comparison for Road Segments with More Than 5 Crashes Middle portions of New Castle County

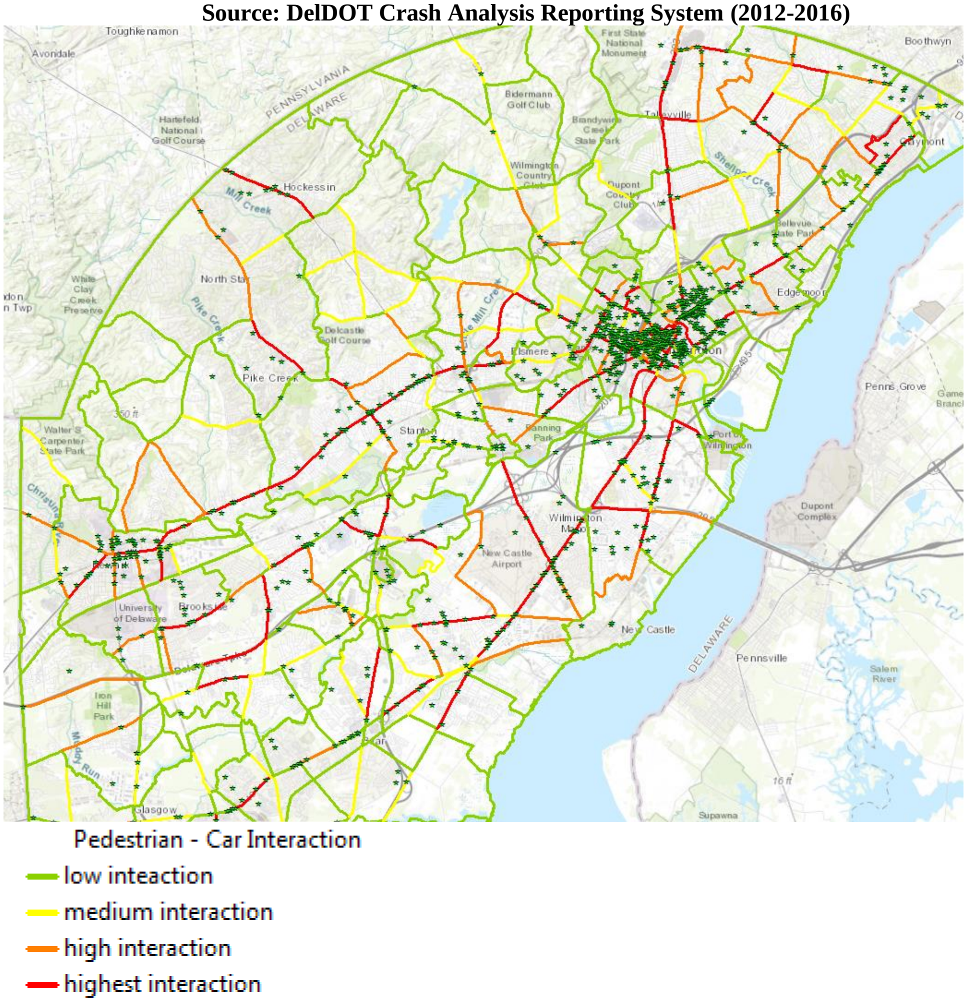


Interaction of Pedestrians and Traffic

The preceding pages viewed pedestrian activity estimates as they relate to location and number crashes. A related fuller picture that better addresses probabilities of a crash would be provided where expected pedestrian activity was related to the degree of interaction with traffic. That interaction is defined by traffic volume, speed, traffic control, lane width and other features of transportation facilities. Crashes happen where pedestrians interact with motor vehicles, and safety initiatives such as traffic calming, pedestrian signals, and sidewalks and other facilities are focused on improving that interaction.

Using the road based estimate of pedestrian trips as shown in the preceding section and using the Average Annual Daily Travel (AADT) counts estimate for roads as provided each year by DelDOT, a statistic was constructed for interaction by taking the product of pedestrian trips and AADT counts. A map of the result is shown in figure 107 and the resulting interaction statistic is highly correlated with crashes that occurred in the study period. A more refined statistic could then be used to examine where crashes are expected and where they are not, to provide additional information on where to focus efforts.

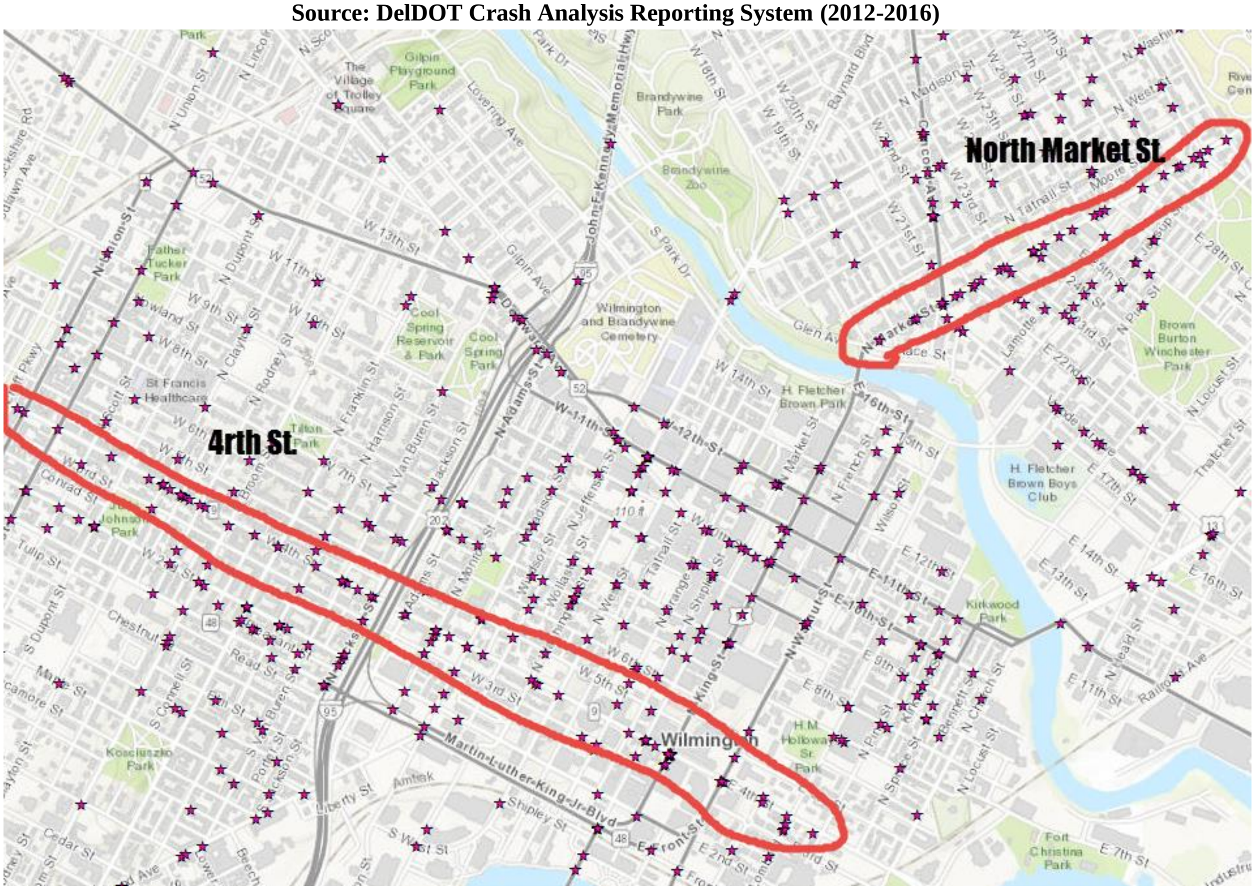
Figure 107, Crashes mapped with respect to pedestrian/vehicle interaction statistic
Source: DelDOT Crash Analysis Reporting System (2012-2016)



An Example of Using Exposure and Activity Estimates
City of Wilmington

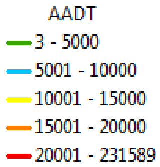
As an example, we could examine the area as shown in figure 108 of the City of Wilmington. This includes 599 pedestrian crashes for years 2012 through 2016 which is roughly 38% of the pedestrian crashes statewide. About 2% of the Wilmington pedestrian crashes involved fatalities which is less than a third of the percentage of fatalities statewide (7%) owing most likely to the relatively slower speeds in Wilmington. Looking at figure 108, two corridors stand out as having more accidents, 4rth Street and North Market (north of Brandywine River).

Figure 108, Example Area in Wilmington
Source: DelDOT Crash Analysis Reporting System (2012-2016)

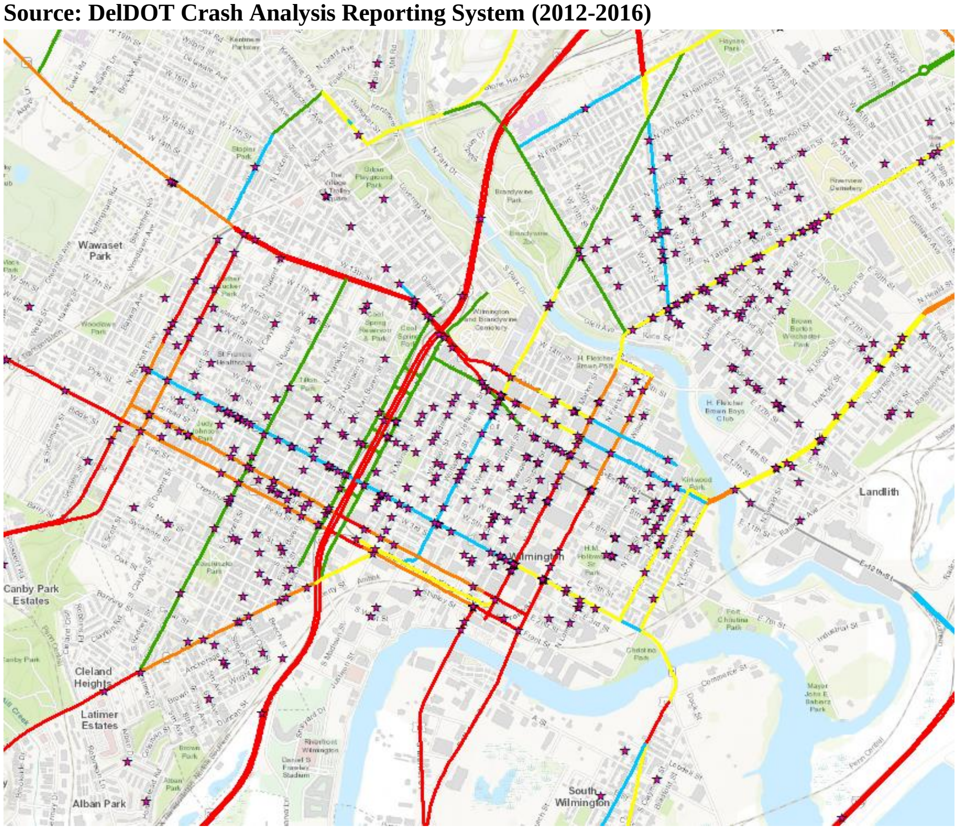


When viewing Annual Average Daily Traffic (AADT) counts as an indication of traffic volume, 4rth street and north market are relatively lower than other corridors such as North Walnut, North King, West 2nd and Lancaster Ave.

Figure 109 AADT in Wilmington Example



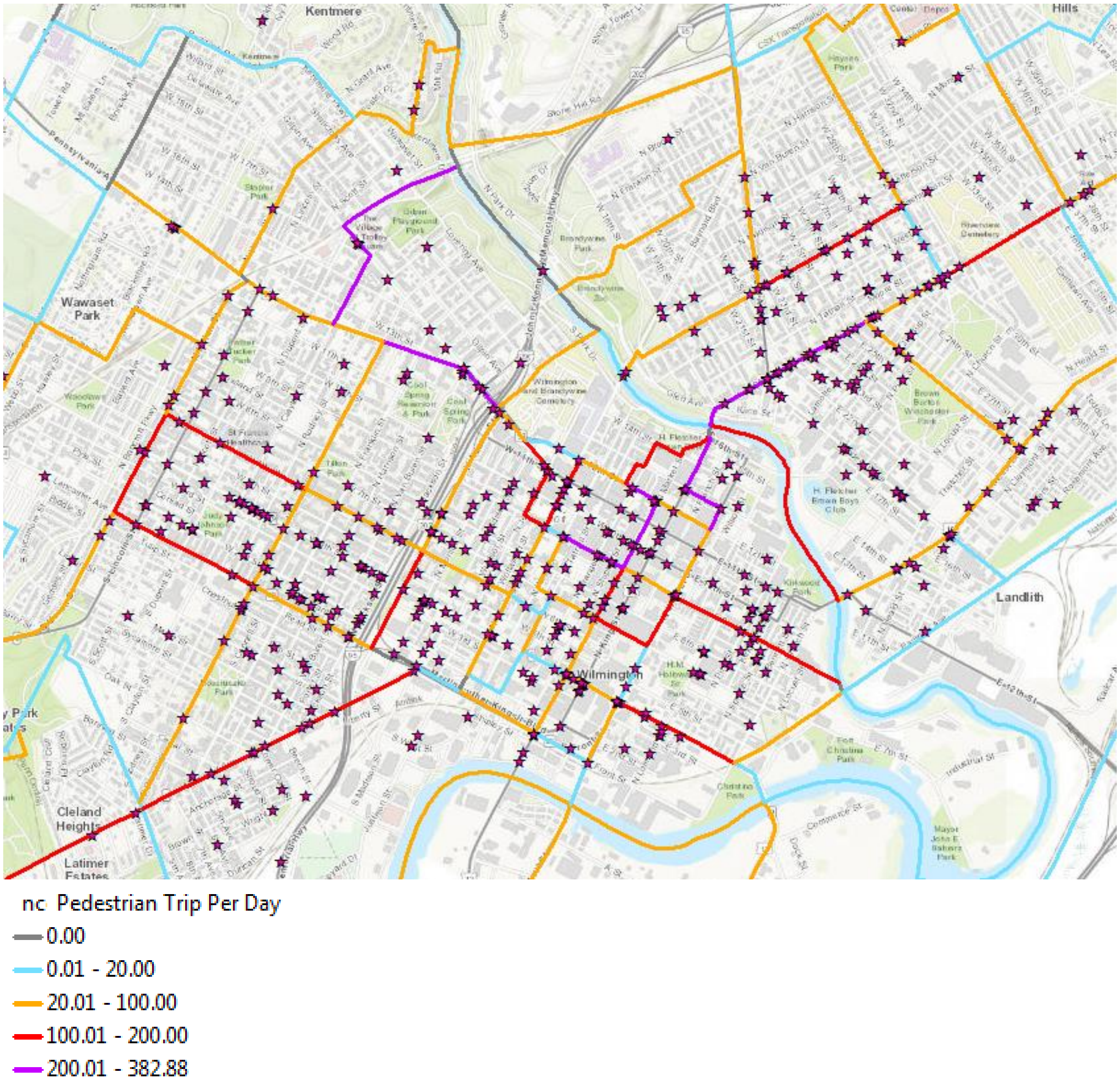
Source: DelDOT Crash Analysis Reporting System (2012-2016)



When examining the estimate of pedestrian trips per day though, North Market definitely stands out. While traffic volumes are less than some Wilmington corridors, pedestrian volume is expected to be higher.

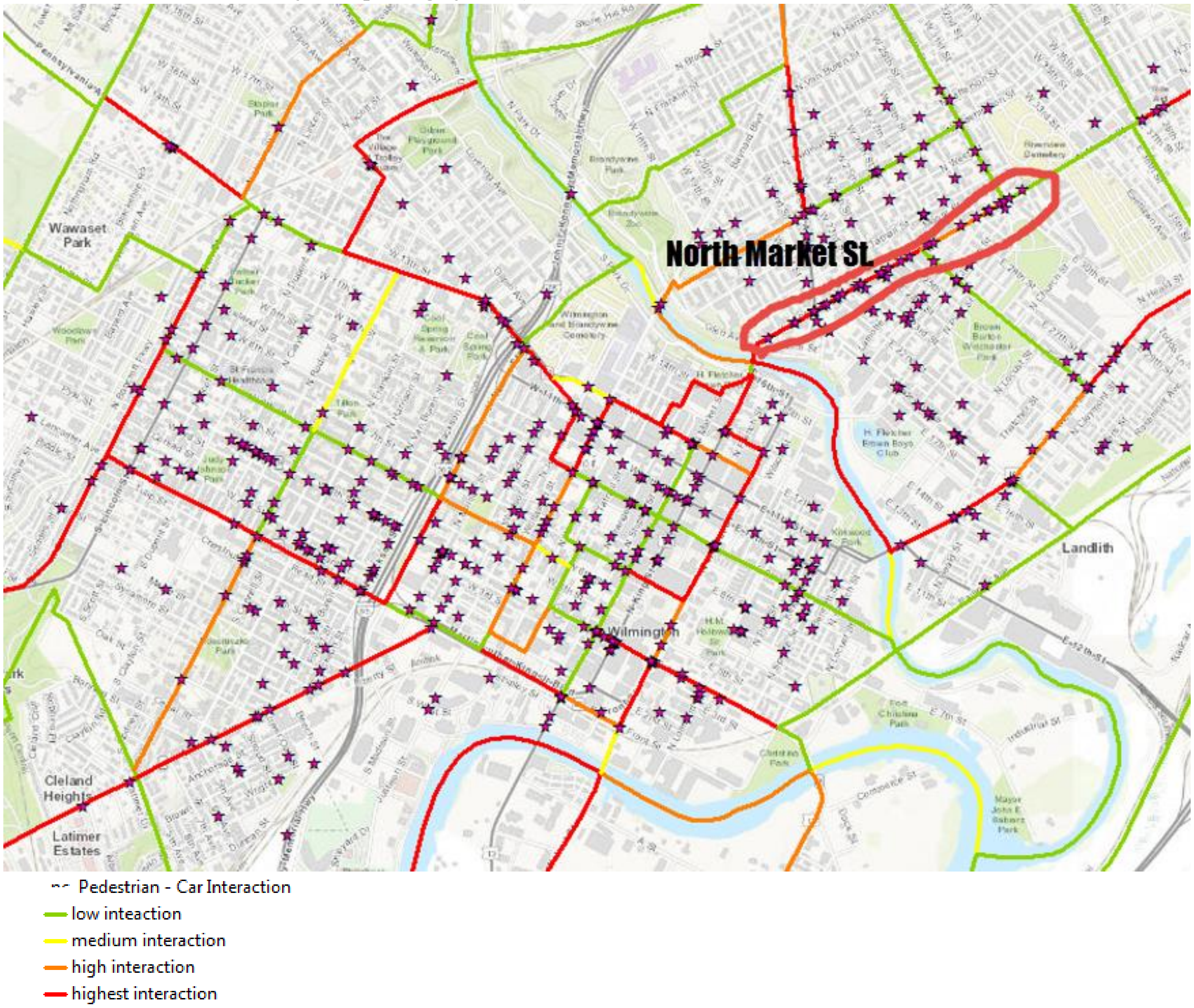
Figure 110 Pedestrian trips per day

Source: DelDOT Crash Analysis Reporting System (2012-2016)



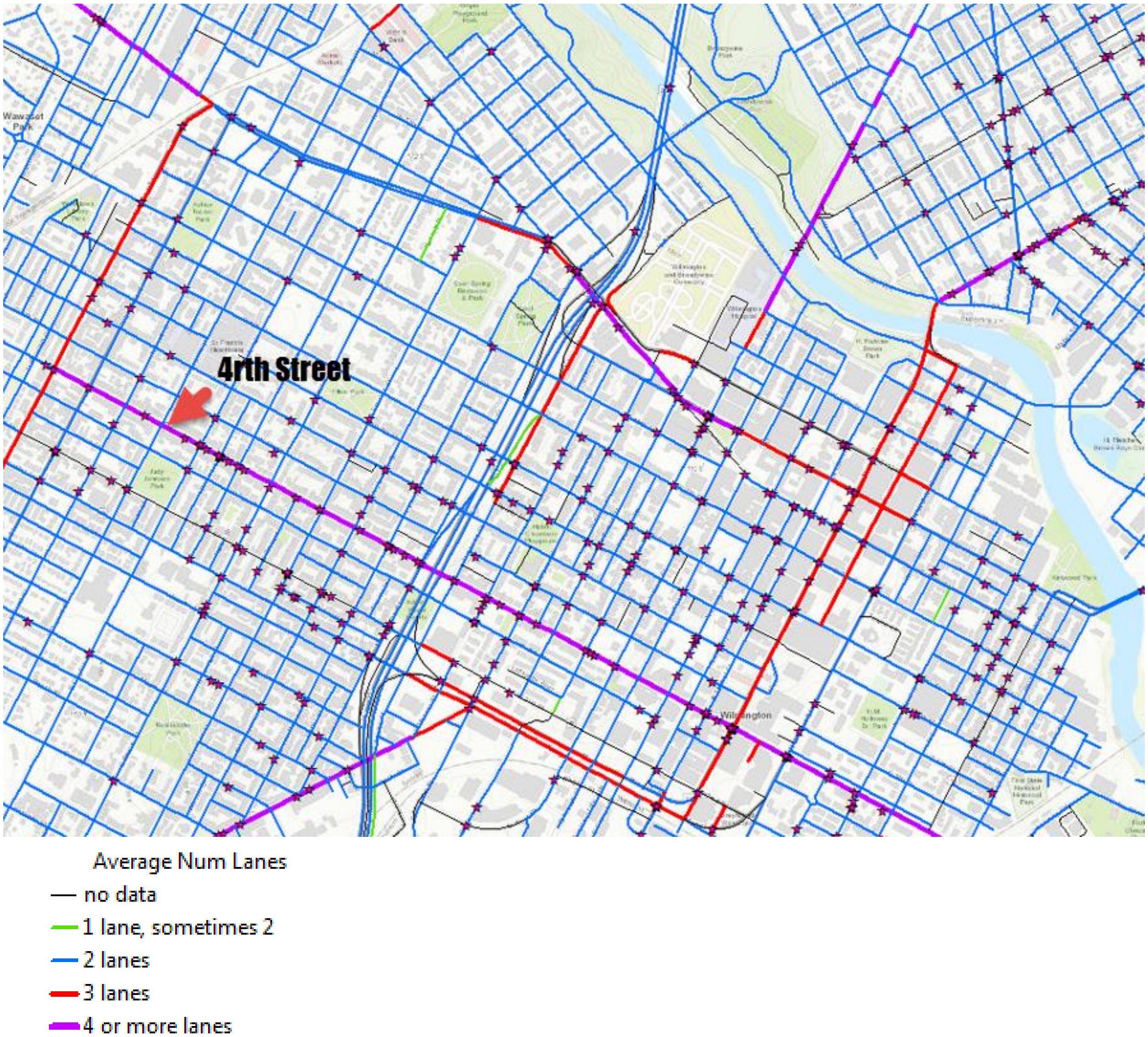
Combining the effects of traffic volume and pedestrian activity using the interaction statistic developed previously in this report produces a picture that visually correlates crashes where interaction is higher. In this view North Market Street shows a high interaction and a larger number of crashes. .

Figure 111, Crash locations with pedestrian-vehicle interaction estimate
Source: DelDOT Crash Analysis Reporting System (2012-2016)



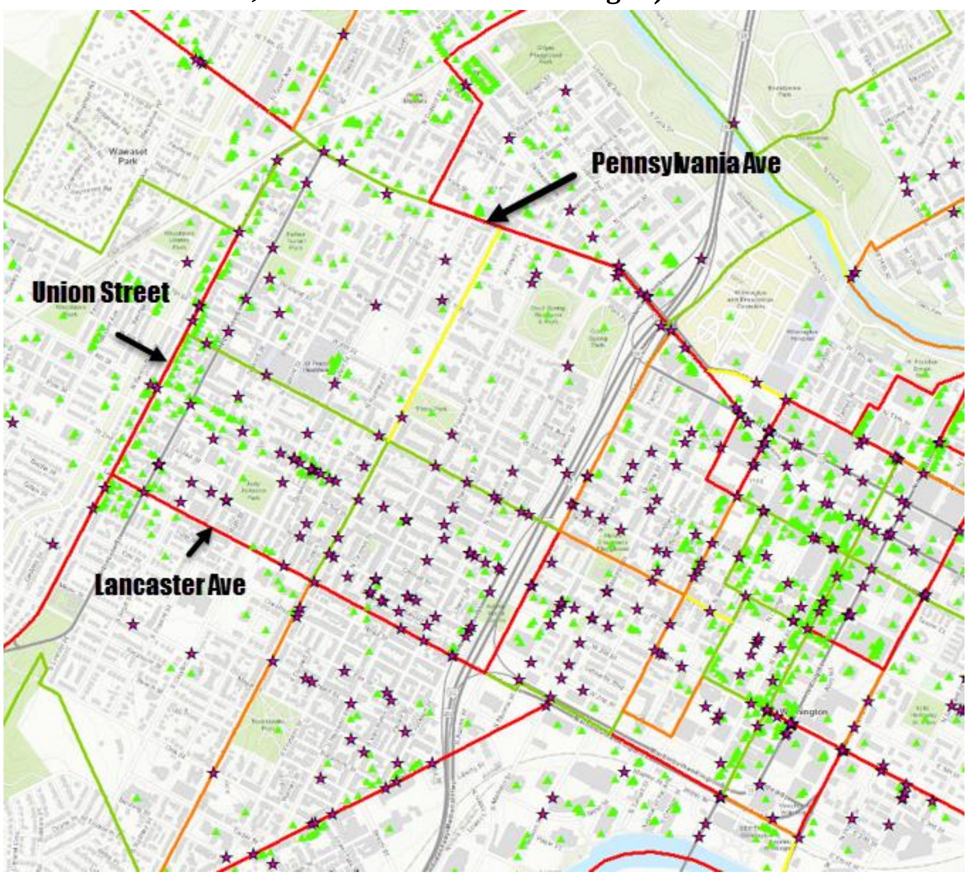
There are some roads in these figures that are not included, as the traffic zone based source data behind the estimates were not available, most notably for 4rth street and a few others. The area around 4rth street is densely populated and pedestrian activity is expected to be high. Other factors having to do with the configurations of land use and the roads and traffic speeds are expected to have a demonstrable effect. For example, 4rth Street is one of the few four lane roads (2 in each direction) in the city of Wilmington, and the data for Delaware shows a higher degree of difficulty for pedestrians crossing multi lane roads. North Market Street in addition to having high interaction with pedestrians and traffic also has tight on street parking on both sides.

Figure 112 , average number of lanes in Wilmington example. (crashes shown as stars)



Understanding safety using estimates of pedestrian activity and interaction with vehicles can be used in another way of course. Places where there is high interaction but a relatively low number of accidents could demonstrate features that promote greater safety. For example there are portions of Pennsylvania Avenue, Lancaster Ave, and Union Street that have very few accidents relative to what might be expected from estimates of pedestrian activity and vehicle interaction. Is it the flow direction of pedestrians, position in relation to destinations, or slightly different land uses? For instance, for Union Street, most of the destinations near populations are on one side of the road and perhaps people for the most part are not crossing Union Street. A view of crash locations, estimated interaction of pedestrians and vehicles, and locations of destinations is shown in figure 113. One thing that seems clear as a result of this research is that our current data on pedestrian activity, traffic flow, and land use are not yet at a sufficient high resolution to fully understand the crash data. This is gradually changing. Travel demand forecasting in Delaware is increasingly going to a tax parcel based level, mapping of land use, destinations, and pedestrian and bike facilities are at the path and facility level, and transportation performance measure are particularly larger and more detailed.

Figure 113 , Crashes, Destinations, and pedestrian-vehicle interaction in Wilmington (Crashes shown as stars, destinations shown as triangles)



Source: DelDOT Crash Analysis Reporting System (2012-2016)

Pedestrian - Car Interaction
low inteaction
medium interaction
high interaction
highest interaction

Conclusion and Recommendations

Factors related to pedestrian and bicycle crashes were examined and mapped using 5 years of data from 2012 to 2016. Tabulations and maps are provided in this report.

For crashes involving non-fatal pedestrian injuries, leading contributing actions by the pedestrian were "In the Roadway Improperly" (12%), "Dart/Dash (16.8%), "Not Visible" (5.7%), and "Failure to Yield Right of Way" (5.5). Roughly just under two thirds of the time (59%), pedestrians had some improper action contributing to the crashes.

Distributions for pedestrian fatality crashes however are very different than those for non-fatal crashes. Rather than clusters as seen in municipalities, fatalities are strung across major arteries where there is high volume, high speed, and multiple lanes. In particular, the corridors Route 40, Kirkwood Highway (Route 2), and Concord Pike in New Castle County, Route 13 through City of Dover, and in Sussex County near Rehoboth, on Route 1. For these pedestrian fatalities, the pedestrian was determined to be DUI/impaired/emotionally disturbed in about 40% of the crashes

In the five years (2012 to 2016), there were 114 crashes involving bicyclists in Kent (18%), 399 in New Castle (64%), and 111 in Sussex (18%). There were 13 total bicyclist fatalities. Contributing Action by the cyclist for non-fatal crashes were mostly "Wrong-way riding" (18%), "Failure to Obey Traffic Signs" (10%), and "Failure to Yield Right of Way" (9%), with about 29% indicating no improper action by the cyclist. "Driver Inattention" (13%), "Failure to Yield Right of Way" (11%), and "Operating vehicle in an Erratic or Dangerous Manner" (5.4) were leading contributing factors for drivers.

Given that more than half of pedestrian and bicyclist crashes involve some contributing action by the pedestrian or cyclist, perhaps publicity and education programs might be effective in promoting best practices and could address such things as visibility, traveling under the influence, adhering to traffic rules, and Dart/Dash.

Statistical analysis of pedestrian and bicycle crashes, particularly when attempting to relate safety to features of specific facilities is restricted due to a lack of data. With the several tens of millions of trips that occur each year in the State, crashes can be considered a rare event.

Crashes are most prevalent around destinations but no particular type of destinations in proximity were shown to be more prevalent in the data examined.

Examination, mapping, and tabulation of crash statistics as presented certainly provide useful information to understand how safety might be improved. However, without understanding the level of activity of walking of biking in an area, it is difficult to fully understand the safety of an area or the risk for a particular individual on a particular trip. Risk is typically defined as the number of crashes divided by the exposure. Exposure is a number associated with the activity level of a behavior and captures the amount of opportunity for an event to happen. Just because an area has many crashes does not mean it is relatively unsafe.

Estimating the risk for pedestrians or cyclists for any corridor or small area or making judgements when viewing crashes that are particularly numerous in an area requires appropriate measures of exposure which are generally unavailable in Delaware, except perhaps in areas with comprehensive pedestrian or cyclist counts.

The safety of an area or location cannot be fully understood by numbers of crashes or crash per capita statistics. The degree of pedestrian or bicycle activity, the exposure, needs to be taken into account. While around 60% of crashes occur within municipal boundaries, cities such as Newark and Wilmington are shown to be safer for an individual when one factors in the large amount of trips that occur.

Travel demand forecasting models employed by DelDOT have been refined for use at the tax parcel level, destination and employment data are being refined, and travel network models are becoming more detailed to reflect the built environment and travel way features. For small areas it is becoming more possible to model pedestrian and bicycle activity.

FHWA has produced studies and guidelines on the development of risk and exposure estimates, have compiled data and studies of risk factors, and have documented several approaches and analytical methods to produce risk estimates for pedestrian and bicycle travel. There is considerable research into the factors that can be used to model the number of walk or bike trips that will result in a particular locale.

An additional summary is provided in the Executive Summary of this report.

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