Raleigh Pedestrian Safety Demonstration Project: Pedestrian Crash Analysis and Needs Assessment

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UNC Highway Safety Research Center

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Introduction

The main objective of the current project is to identify, prioritize and implement enforcement and educational strategies to help reduce pedestrian crashes in the State of North Carolina. Raleigh is one of four model cities in the overall Focus State project which aims to develop processes, actions, and sustainable strategies for pedestrian safety improvement to help reduce pedestrian crashes and injuries in North Carolina. Successful strategies will then be promoted to communities across the State. While the primary focus is on implementing and evaluating appropriate educational and enforcement countermeasures, comprehensive programs that incorporate education, enforcement, and engineering have the best chance of succeeding in reducing pedestrian trauma. Even encouraging more walking may reduce the individual risk of a collision, according to recent studies and practices in Europe (Fischer et al., 2010). The information developed in these processes can therefore certainly be used, and has been used, to identify areas where engineering improvements may be needed. Additionally, the information may facilitate the discussion of policies and practices, training, data quality, and other initiatives that might be improved to further help pedestrian safety and mobility in Raleigh as well as other communities in the State.

Raleigh, overall, has seen an upward trend in pedestrian crashes between 1997 and 2009, as indicated in Figure 1, which includes crashes that occurred in Public Vehicular Areas (PVAs). While this trend is likely related in part to the substantial population increase in the city, this project, the ongoing Pedestrian Planning process, and the NCDOT Department of Bicycle and Pedestrian Division focus on reducing pedestrian crashes can be instrumental in reversing this upward trend. In particular, 2007 had a large increase in crash numbers.

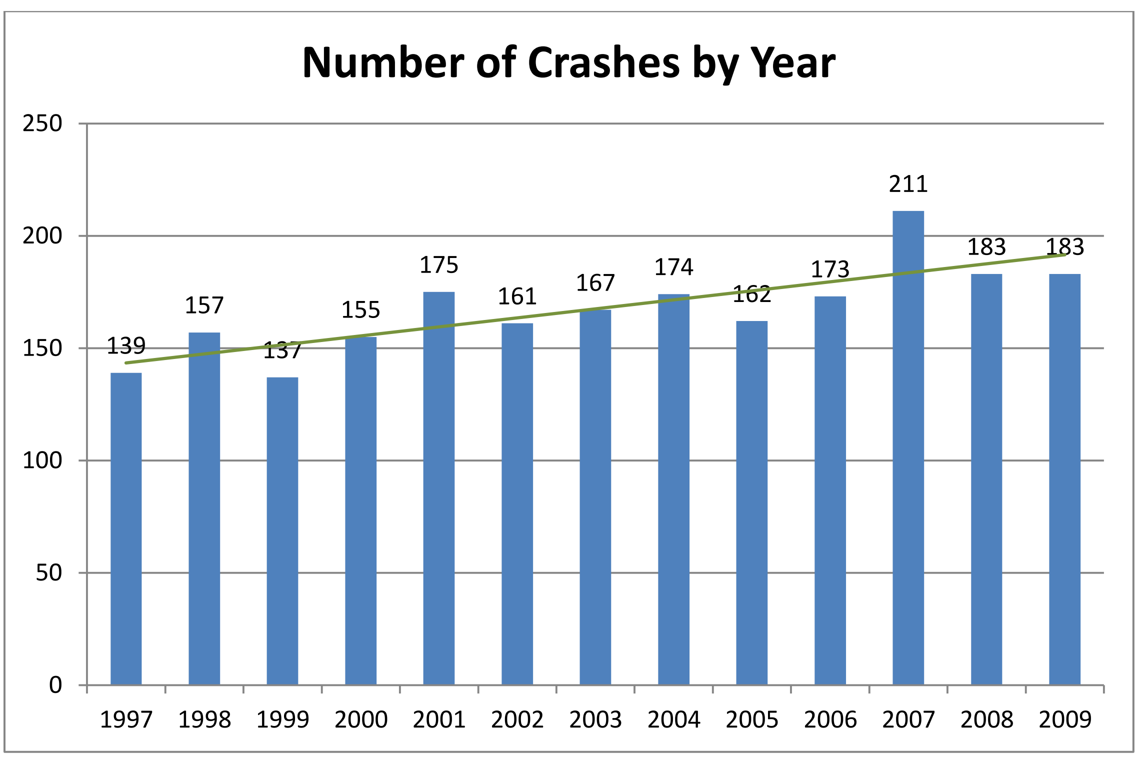


Figure 1: Pedestrian Crash Trends in Raleigh, NC, 1997-2009.

Purpose

The purpose of this document is to provide an overview of pedestrian crash problems and trends as identified through a preliminary analysis of available data from 2004 – 2010 (though 2010 data is in some instances not available) and to help set priorities for addressing pedestrian safety problem in Raleigh, NC.

Data Sources and Methods

The data used for analyses were obtained from the City of Raleigh Office of Transportation Planning. The Chair of the Raleigh Bicycle and Pedestrian Advisory Commission geocoded pedestrian crashes for the City based on crash location data provided by NCDOT. Crashes that were reported to have occurred in Public Vehicular Areas (PVAs) such as parking lots and other off-roadway areas not maintained by the State or City were excluded from the data by the City prior to geo-coding the pedestrian crash locations, as the city cannot undertake infrastructure improvements on property not owned by the City of Raleigh or the State of North Carolina.

HSRC had also provided the City of Raleigh data on typed pedestrian crashes for the years 2004-2008, and has since completed crash analyses of 2009 crashes which were merged with the spatial data. Based on these data for the years 2004-2009, which included review of every reported pedestrian (and bicycle crash), 1086 reported pedestrian crashes occurred in the City of Raleigh on both City and State-owned streets and in PVAs , while only 767 occurred on City and State-owned streets alone (excluding the PVA crashes). Figure 2 shows the distribution of crashes by location type when all reported pedestrian crashes are included, and when crashes reported to occur on PVA's are excluded. Most of the excluded PVA crashes occurred in **non-roadway** areas such as parking lots and driveways, but they may sometimes occur on private roads.

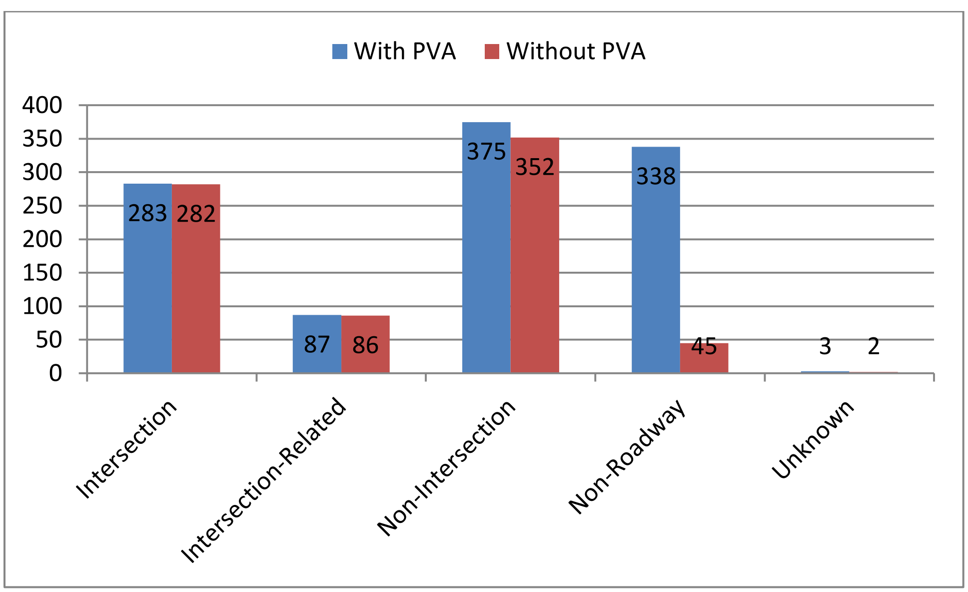


Figure 2: Pedestrian Crash Numbers with and without PVA Crash Data Included, 2004-2009.

The analyses contained in this report utilized the data provided by the City, which excluded PVA crashes, which make up nearly 30% of reported pedestrian crashes. It is also likely that the crashes reported from PVAs are only a fraction of the total crashes occurring in such areas. While the city cannot directly make improvements in PVAs, cities can influence the design and safety of PVAs through parking lot design guidelines, ordinances, communications with property owners, lighting, enhanced security, and other measures, as well as through educational efforts targeting both drivers and pedestrians. Strategies to mitigate crashes in PVAs could be considered based on the large number of such reported crashes and even larger number of likely crashes, as well as part of over-all efforts to create a safe pedestrian environment from door-to-door. Figure 3 provides a clear representation of how many more crashes occurred in PVAs yearly and highlights the importance of identifying measures to address crashes occurring in PVAs as well as on roadways in a comprehensive way.

As mentioned, HSRC provided the crash typed data for 2004-2009 crashes. Crash typing refers to the process by which the sequence of events and participating actions leading to a pedestrian/motor vehicle crash are identified and is conducted using the Pedestrian and Bicycle Crash Analysis Tool (PBCAT) (Harkey, et al. 2006). As the 2010 pedestrian crashes for the City of Raleigh have not yet been reviewed and crash typed, only preliminary crash data from 2010 from NCDOT has been included in these analyses, and is subject to change as the data are refined. In summary, spatial data will in most cases include pedestrian crashes from 2004 to 2010, but in some cases, which are specifically noted in the text, the spatial data will <u>not</u> include 2010 crash data, as it is not yet available in complete form. To recap:

- Spatial Data includes data from 2004 -2010 (n=924, excludes crashes reported to have occurred on PVAs).
- Characteristics Data (Alcohol-Involvement, Day of the Week, Crash Location, etc.): Includes data from 2004-2009, excluding crashes reported from PVAs and may include data from 2010 if it is available (n=767).

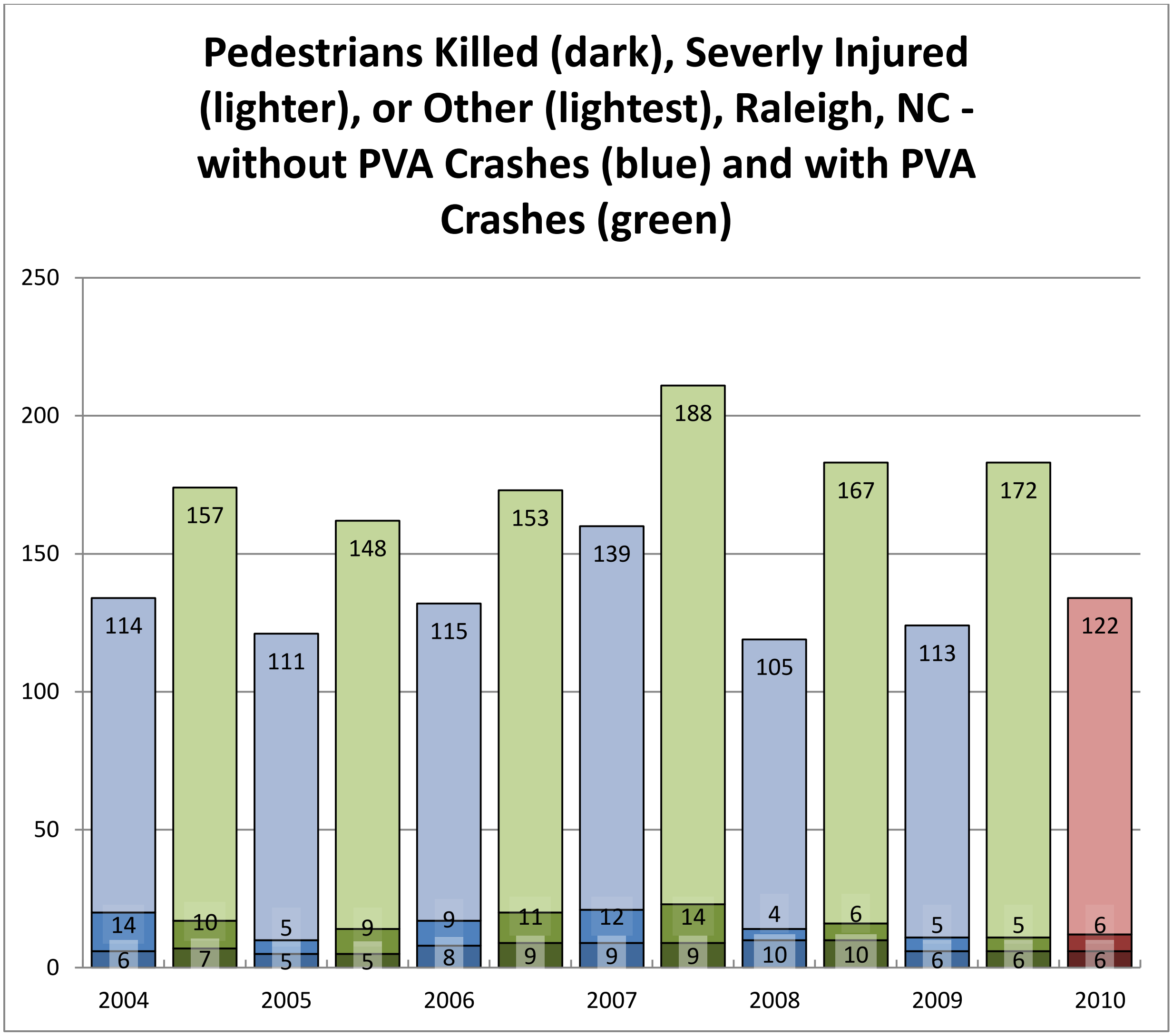


Figure 3: Pedestrians Killed, Severely Injured, and Other with and without PVA Crashes Included, 2004-2010.

Following the geocoding procedure, HSRC checked a subset of the crashes using ArcGIS and Google Earth to ensure accuracy. With pedestrian crash data from 2004 to 2010, HSRC created kernel and dot density maps using ArcGIS. If the preliminary 2010 pedestrian crash data was incomplete, it was omitted from the analysis.

Although occasionally more than one pedestrian is involved in the same crash, the database on which these analyses are based counts each crash one time to avoid over-representing crashes at locations or in other factors. Thus, in tables and data summarizing pedestrian-related factors, only the first pedestrian struck in the crash – the one used to type the crash – is accounted for.

The HSRC performed a number of spatial analyses of pedestrian crashes. In simple dot maps, multiple crashes might occur at the same location or close enough that the actual density of crashes cannot be easily observed or quantified. Various types of density analyses including by population and by area were also performed. By exploring the spatial distribution and characteristics of pedestrian crashes, specific zones where large numbers of crashes have occurred or specific types of factors are concentrated, suggest areas where countermeasures could have a substantial positive impact. Kernel density analysis is useful in examining broad areas where crashes may be more concentrated as opposed to other areas of the City, as it is not limited by artificial geographic boundaries; only by the edges of the map and or where crashes occurred. Kernel density also has some limitations as it searches in planar space for nearby crashes as opposed to along the street network, where roadway crashes, at least, should be concentrated. Although crash concentrations along a roadway network can be identified using a network based analysis, we have found in other studies that kernel density analysis, and other types of general spatial analyses readily available in the ArcGIS software, provide similar results to some more intensive procedures and are useful for identifying general areas or neighborhoods of crash concentration. (Note that some of the earlier maps shown also utilized kernel density analysis.)

Pedestrian Crash Facts

Using exposure measures, such as counts of pedestrians, may help to target countermeasures toward locations where the risk of individual collisions or severe crashes are highest. It should be noted, however, that any pedestrian collision may be severe, particularly if older pedestrians or young children, or higher speeds are involved. Any safety efforts should take all crashes as well as areas with high crash rates into consideration. Unfortunately, exposure measures often do not exist at all, making an analysis of pedestrian activity and areas of high pedestrian concentration difficult. Boarding and alighting data from Capital Area Transit (see Figure 30) is used in this analysis as a surrogate measure.

Educational, engineering, and enforcement measures are crucial to developing an overall safety culture, engendering respect for and compliance with traffic laws, and reducing the severity and incidence of not only pedestrian crashes, but all crashes. Understanding where, when, how, why, and who is involved in pedestrian collisions can help target appropriate countermeasures to the areas and populations where they are most needed. The following figures and tables highlight some of the characteristics of pedestrian collisions in Raleigh over a recent seven year period. Figure 4 displays clusters of crashes in Raleigh, using data from 2004-2010, while Figure 5 presents a closer more detailed view of crashes in downtown Raleigh.

Kernel Density of Pedestrian Crashes,
Raleigh, NC

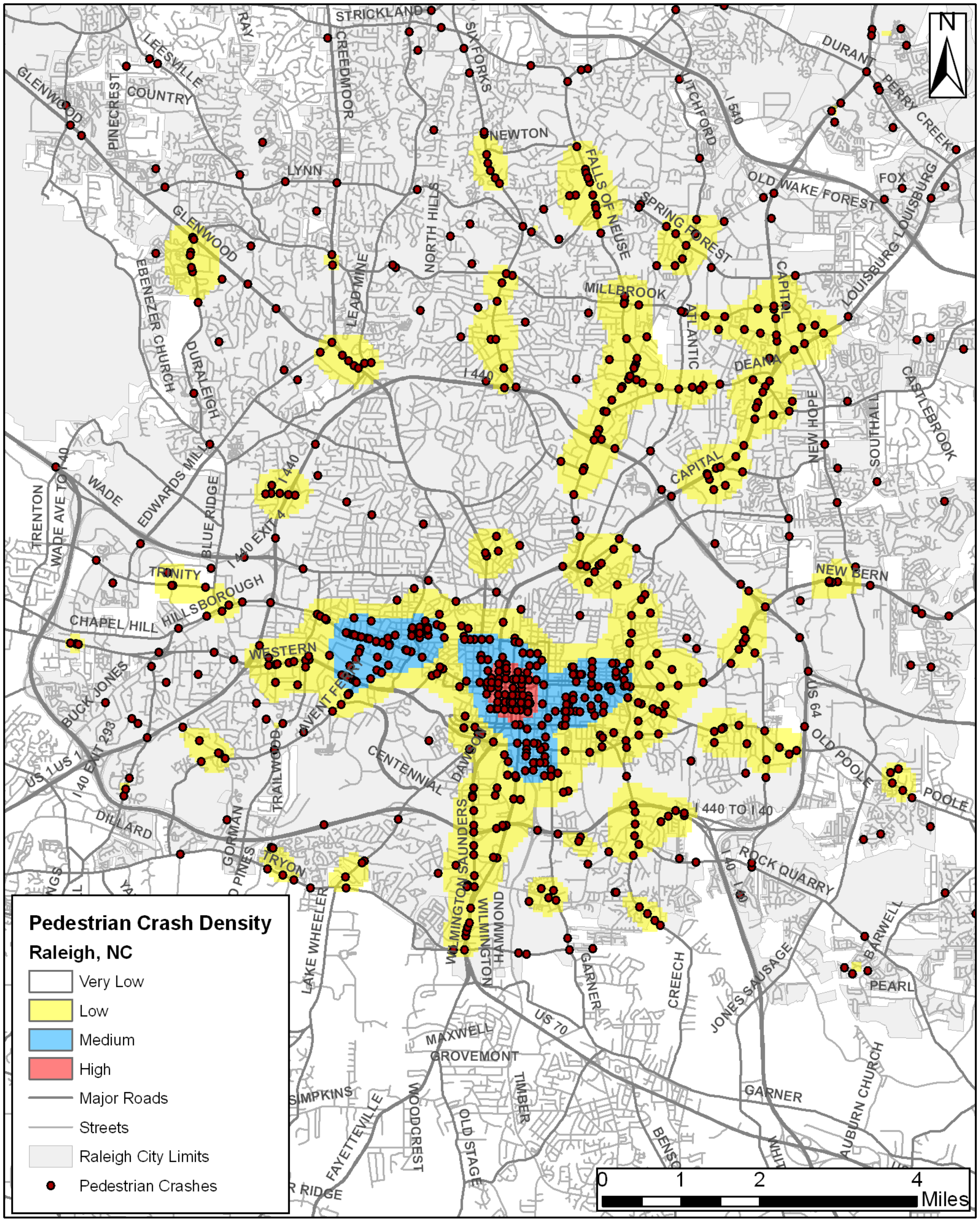


Figure 4: Pedestrian Crash Density, 2004-2010.

Kernel Density of Pedestrian Crashes,
Raleigh, NC

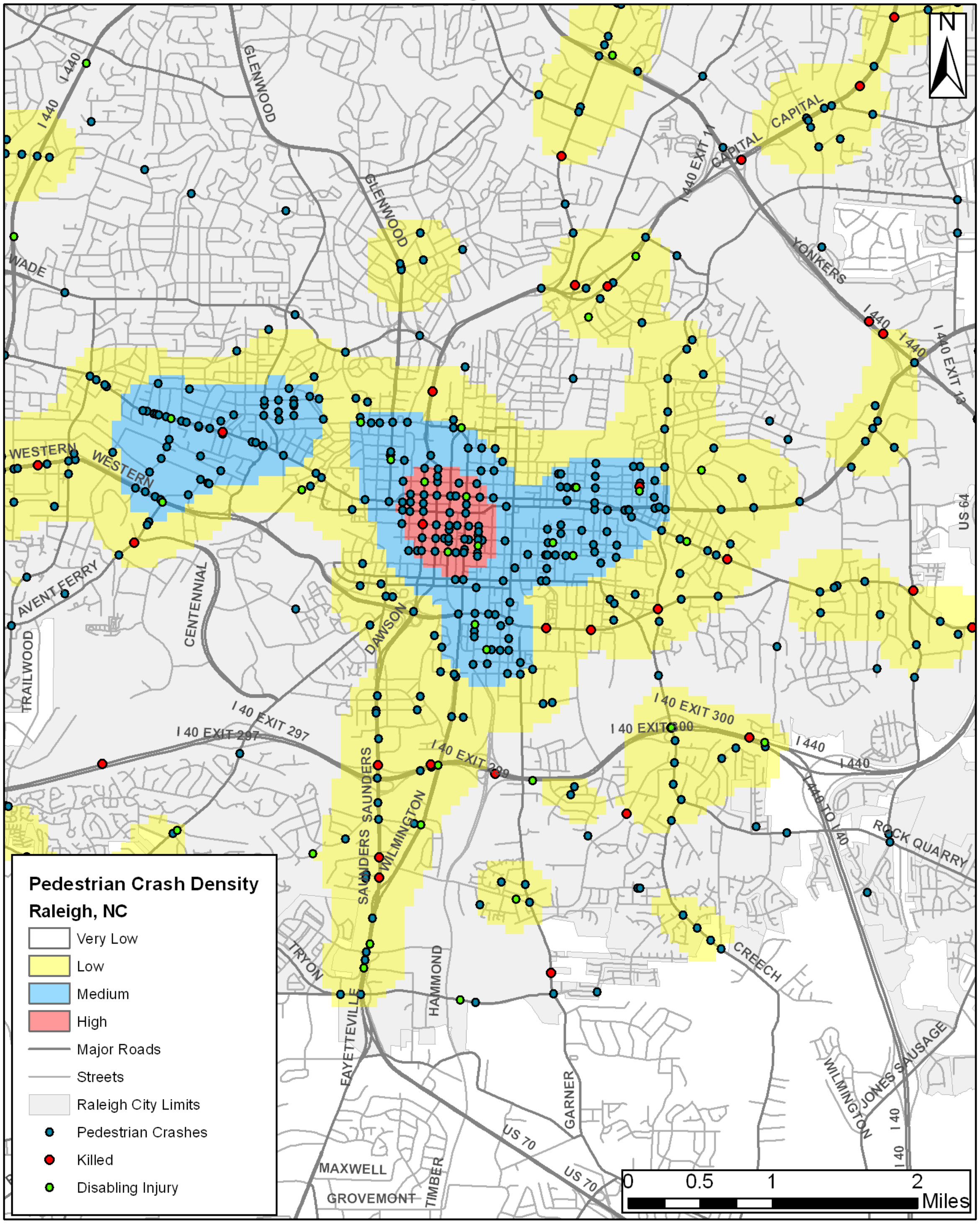


Figure 5: Pedestrian Crash Density near Downtown, 2004-2010.

Crash Severity

While the overall distribution of pedestrian crashes in Raleigh is helpful, examining crashes resulting in pedestrian deaths or serious injuries can further refine one's understanding of the pedestrian safety issue in Raleigh. In terms of crash severity, the NCDOT Standardized Crash Cost Estimates for North Carolina memorandum was used to weight the crashes (NCDOT 2008). The following table (Table 1) provides the estimates.

Table 1: NCDOT Standardized Crash Cost Estimates (2008).

Crash Type	Cost per Crash (2008 Dollars)
Fatal Crash	4,400,000
A Injury Crash	250,000
B Injury Crash	74,000
C Injury Crash	36,000
Property Damage only Crash	5,000

These costs were linked to the shapefile for pedestrian crashes in ArcGIS 9.3 and the kernel density tool was used to map the distribution of pedestrian crashes using the costs as weighting factors. Figure 6 displays this information. In particular, those areas highlighted when crashes are weighted by severity include the Falls of Neuse Road, Poole Road, Western Boulevard, Wilmington Street, and S. Saunders Street corridors, as well as Interstate 40 and others. Such information may be useful in attempting to prioritize among the many areas of general crash concentration. Figure 7, based on spatial analysis of the locations of fatal and A-type injuries, presents findings similar to, but not as comprehensive as, the map incorporating all severities of crashes. Those areas where more severe crashes occurred are clearly highlighted and include Falls of Neuse Road, Capital Boulevard, Wilmington Street, and Interstate 40.

Pedestrian Crash Density by Severity,
Raleigh, NC

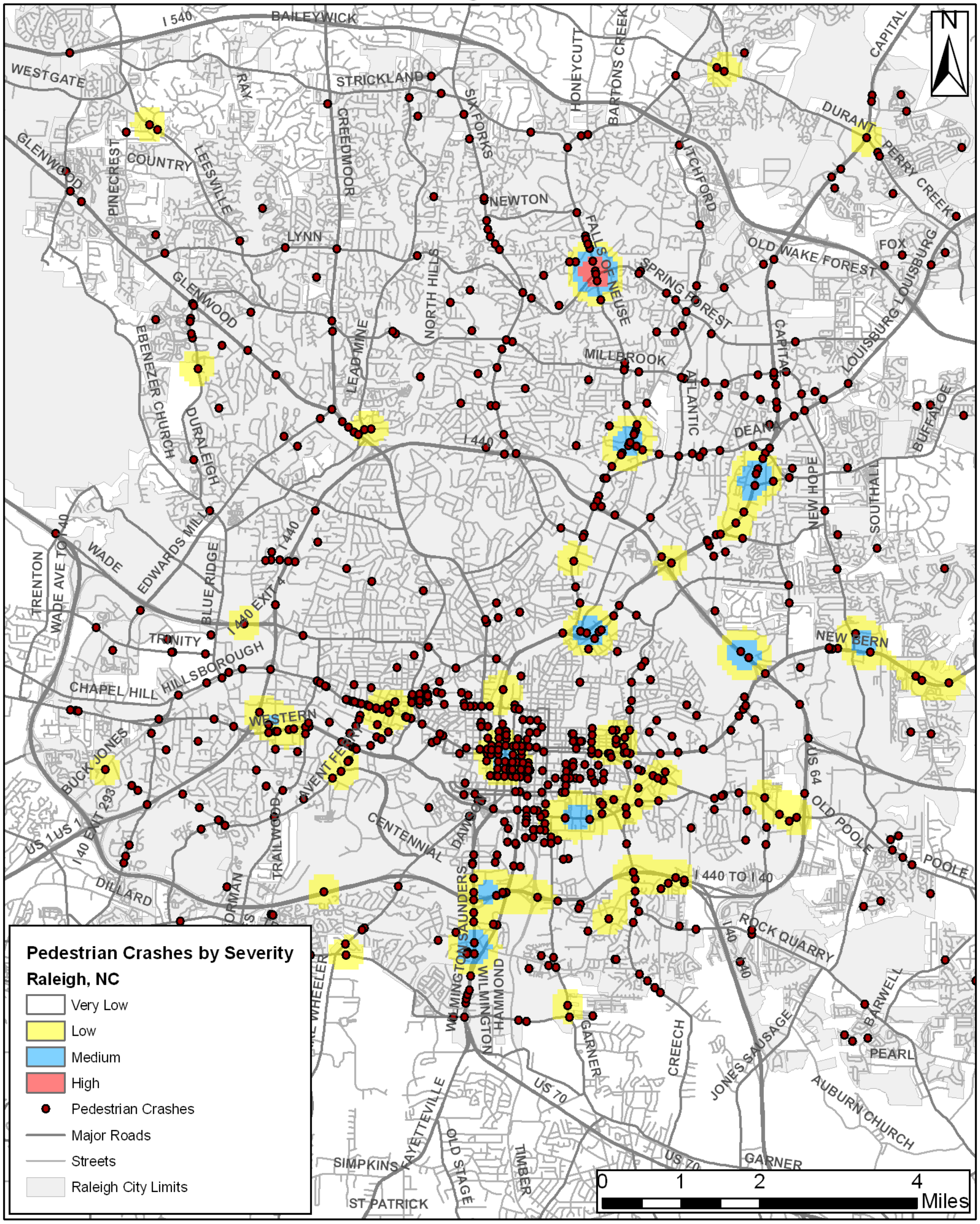


Figure 6: Pedestrian Crashed by Severity, Raleigh, NC, 2004-2010.

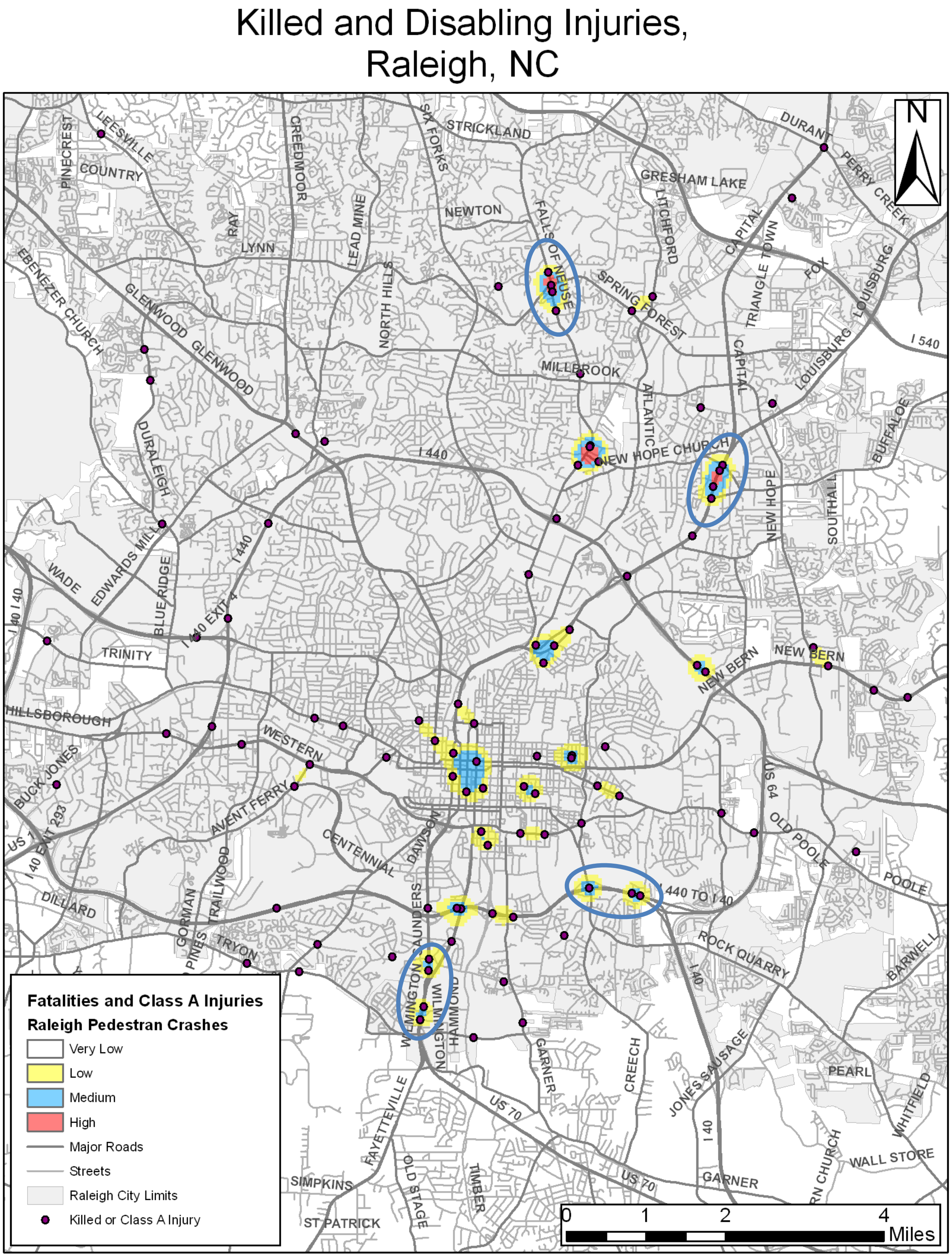


Figure 7: Killed and Disabling Injuries, Raleigh, NC, 2004-2010.

Traffic Control

Fifty-nine percent of collisions were reported to have occurred at locations with no traffic controls present, while 28 percent were reported to have occurred at locations with Stop and Go traffic signals and 10 percent at locations with Stop signs. Due to the lack of availability of these data from 2010, only data from 2004-2009 were taken into account in determining the traffic control present at the crash location. Small numbers and percentages occurred at locations with various other types of traffic control, with 5 (one percent) of collisions reported at locations with human traffic control in operation.

Temporal Factors

Crashes tend to fluctuate by month from year to year, but typically the autumn months (September, October, and November) have somewhat higher numbers of crashes. During this seven-year period, the autumn months accounted for slightly more than 31 percent of crashes with proportionally fewer in other seasons (Figure 8). The months of October, November, and December are also the highest crash months Statewide from 2004 to 2008, accounting for 28.5% of all crashes per year (NCDOT 2010). Year-to-year variability in crash proportions by month may reflect weather, special events, or other conditions that affect exposure to collisions as well as just chance variation. Crash data for North Carolina is only available through 2008, though Figure 8 includes crash data from Raleigh through 2010.

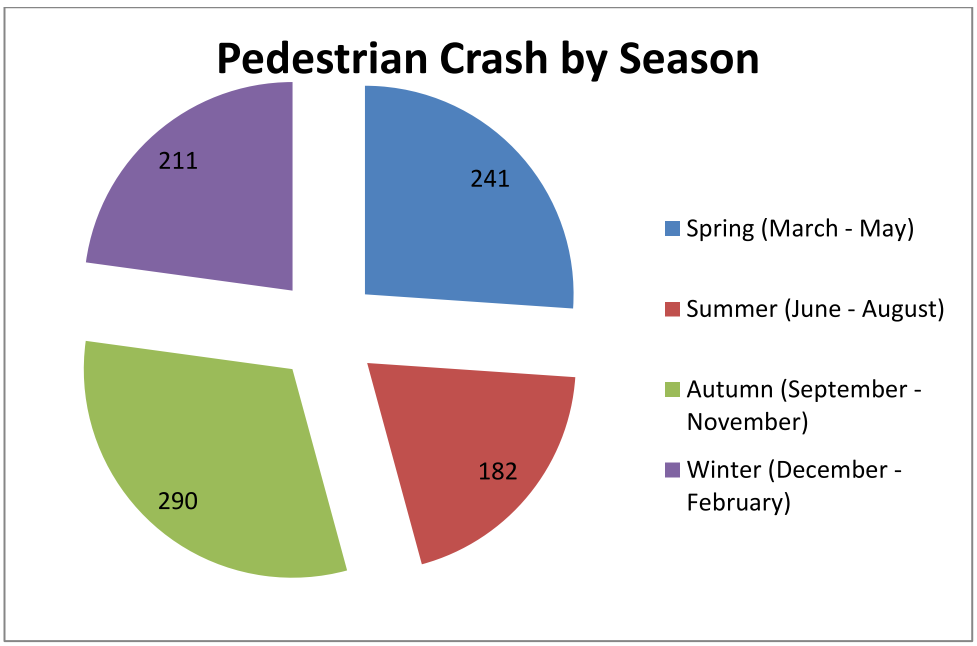


Figure 8. Pedestrian Crashes by Season of the Year, 2004-2010.

There are year-to-year fluctuations in crashes by day of the week, but on average, pedestrian crashes have been very evenly distributed across days of the week with all days except Sunday accounting for about 15 percent; Fridays have accounted for slightly more than other days at 17 percent, while Tuesdays have accounted for 16 percent. Sunday, on average the lowest crash day across the state, has similarly accounted for about 8 percent in Raleigh.

In terms of the light conditions at the time of the crash, most crashes occurred during daylight hours at 59 percent, most likely as a result of higher walking volumes during daylight hours, while 26 percent of crashes occurred on lighted roadways during dark hours. Approximately 9 percent of crashes occurred on unlighted roadways.

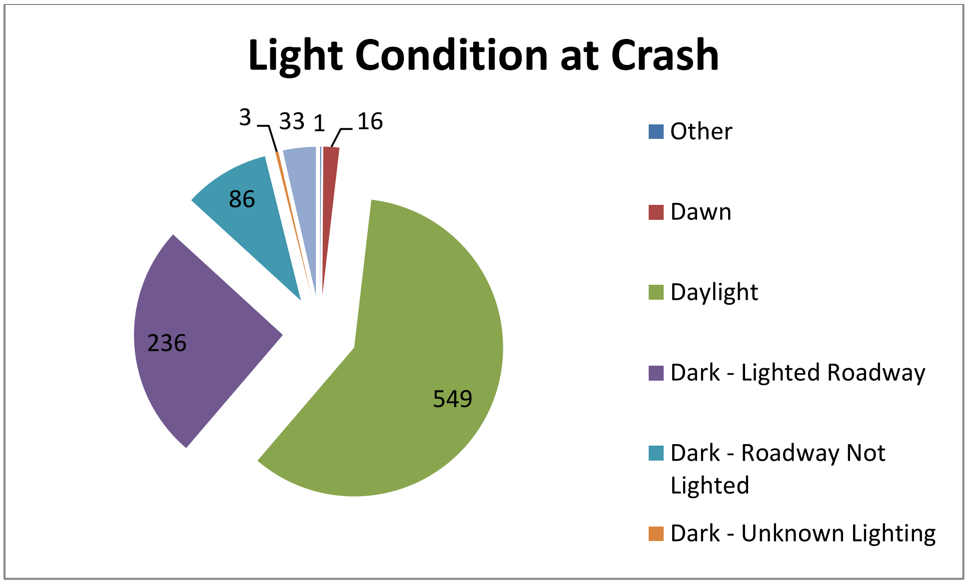


Figure 9. Raleigh Pedestrian Crashes by Light Condition, 2004-2010.

The following map (Figure 10) provides some insight into where crashes are occurring. In particular, the downtown area and certain corridors, including the Saunders, Capital, and Old Wake Forest arterials, exhibit crash problems during both daylight and dark hours. A map of crashes occurring during daylight hours has not been included here, as it mirrors the overall crash density for the City of Raleigh. For crashes occurring during hours of darkness, concentrations of crashes are clearly visible and seem to be clustered along certain corridors.

Pedestrian Crashes in Dark Conditions, Raleigh, NC

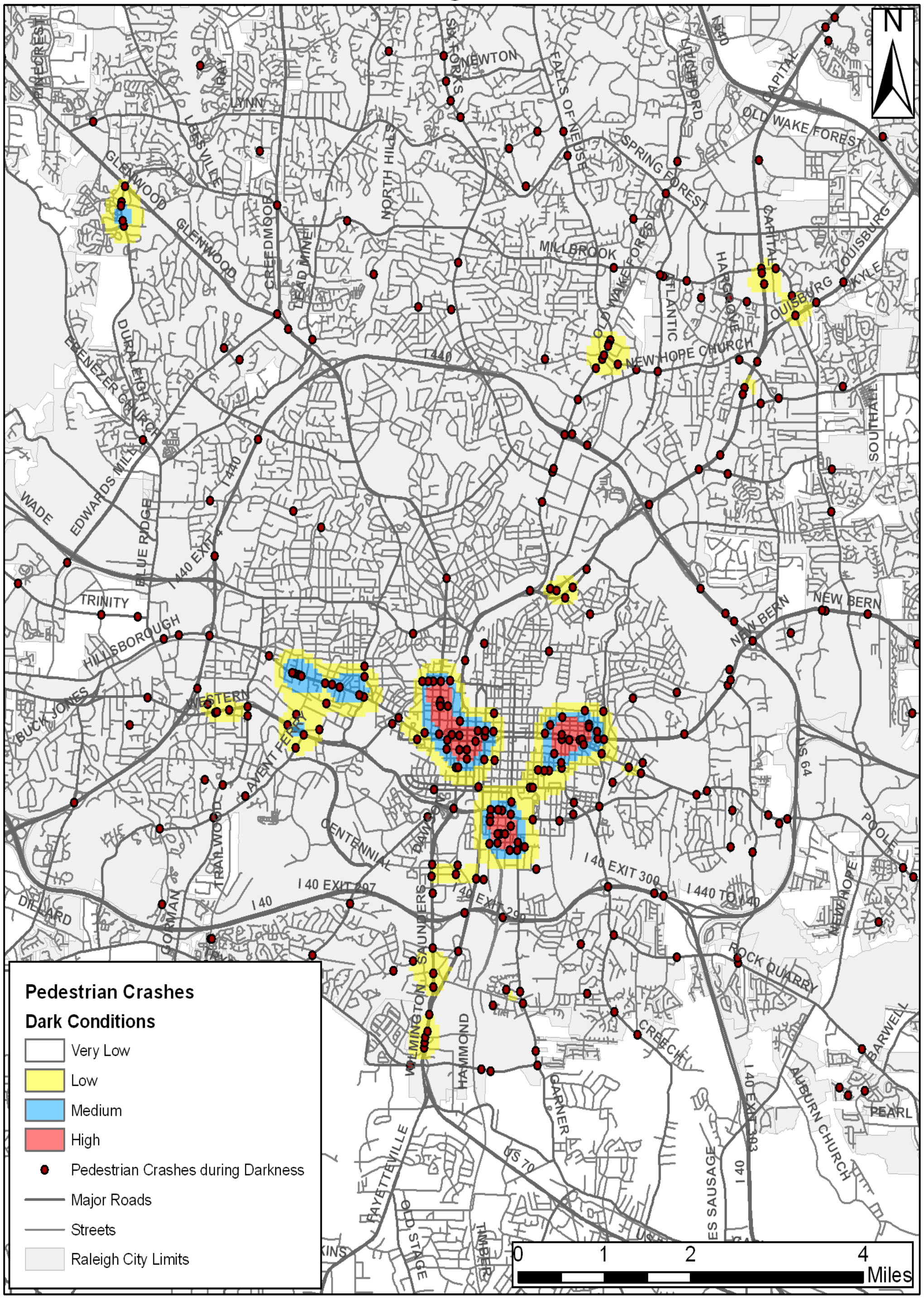


Figure 10. Pedestrian Crashes under Dark or Low- Light Conditions, 2004-2010.

The peak in pedestrian collisions occurs during the afternoon hours to evening hours, especially from 3 to 6 PM (24 percent), while pedestrian crashes remain high between 1 and 9 PM (Figure 11). The six hours from 3 to 9 PM together account for 41 percent of daily crashes on average. The mid-day period from noon to 3 PM accounts for another 15 percent. Late night hours from midnight to 6 AM account for 9 percent of pedestrian collisions, but 18 percent of fatalities, in keeping with higher night-time fatality rates.

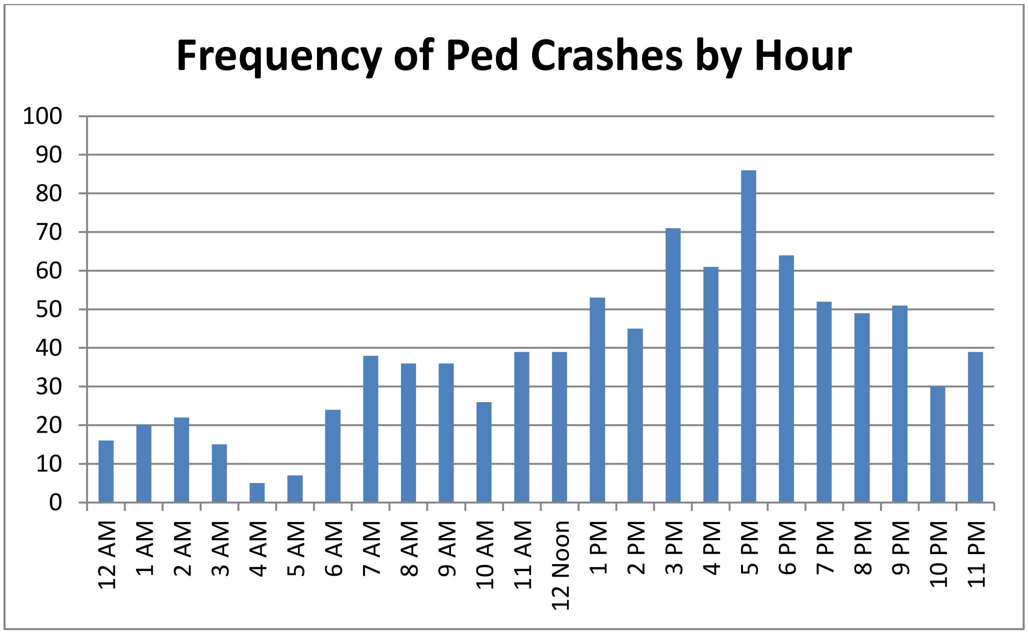


Figure 11. Pedestrian Crashes by Hour of Day, 2004-2010.

Pedestrian Characteristics

As mentioned in the introduction, crashes occurring in PVAs constitute a substantial number of total crashes in the City of Raleigh. Specifically, a total of 46 pedestrians were killed and 56 seriously injured in Raleigh (within the City limits) from 2004-2009 **including PVA crash data.**

Age

Crash proportions for different age groups fluctuate over the years. (Note that age groups span different numbers of years.) Young adults and teenagers, including 11 to 29 year olds account for 42% of pedestrians involved in any crash over the period. Adults aged 40 to 59 years, comprised 26% of crash-involved pedestrians over this entire time period. Older pedestrians have a somewhat lower representation in collisions with only 7%, while children 10 years and younger also only account for 7% of total crashes. As data from 2010 is available, this analysis includes data from 2004-2010, but does not include PVA crashes. Figure 12 displays this information.

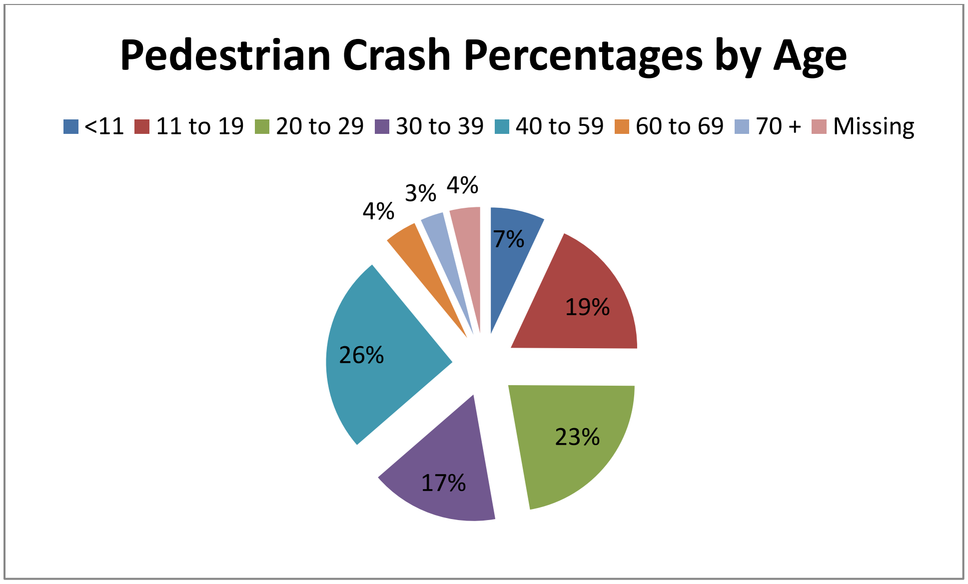


Figure 12: Pedestrian Crash Percentages by Age, 2004-2010.

In general, older pedestrians and very young children may be more vulnerable to severe injuries or fatalities in a crash. As illustrated in Figure 13, adults 70 and older have the combined highest proportions of fatalities and serious injuries for those involved in a pedestrian crash. The youngest children also have a higher rate of disabling and fatal injuries than older children who were struck.

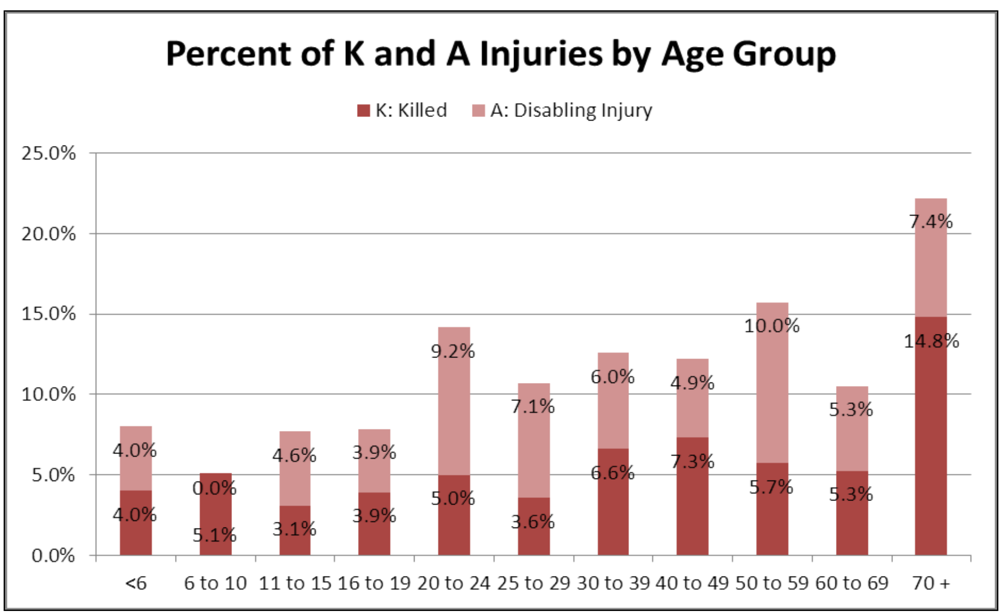


Figure 13. Severe Injury Proportions by Age Group, 2004-2010.

Overall however, adults between the ages of 30 and 59 have suffered the highest rates of fatalities among those involved in a pedestrian crash in Raleigh, when adults 70 and over are not taken into account. As will be indicated later, nighttime and alcohol-involved crashes may have an influence on adult crashes.

In terms of the location of pedestrian crashes by age, the following maps present the kernel density analysis of crashes by children under the age of 16 and adults of the age of 65. For pedestrian crashes involving children under the age of 16, the density of crashes is skewed toward the southeast of downtown as well as in the northeast of the city, while pedestrian crashes for adults over the age of 65 are clustered in one instance to the west of downtown.

Pedestrian Crashes Age 15 and Younger
Raleigh, NC

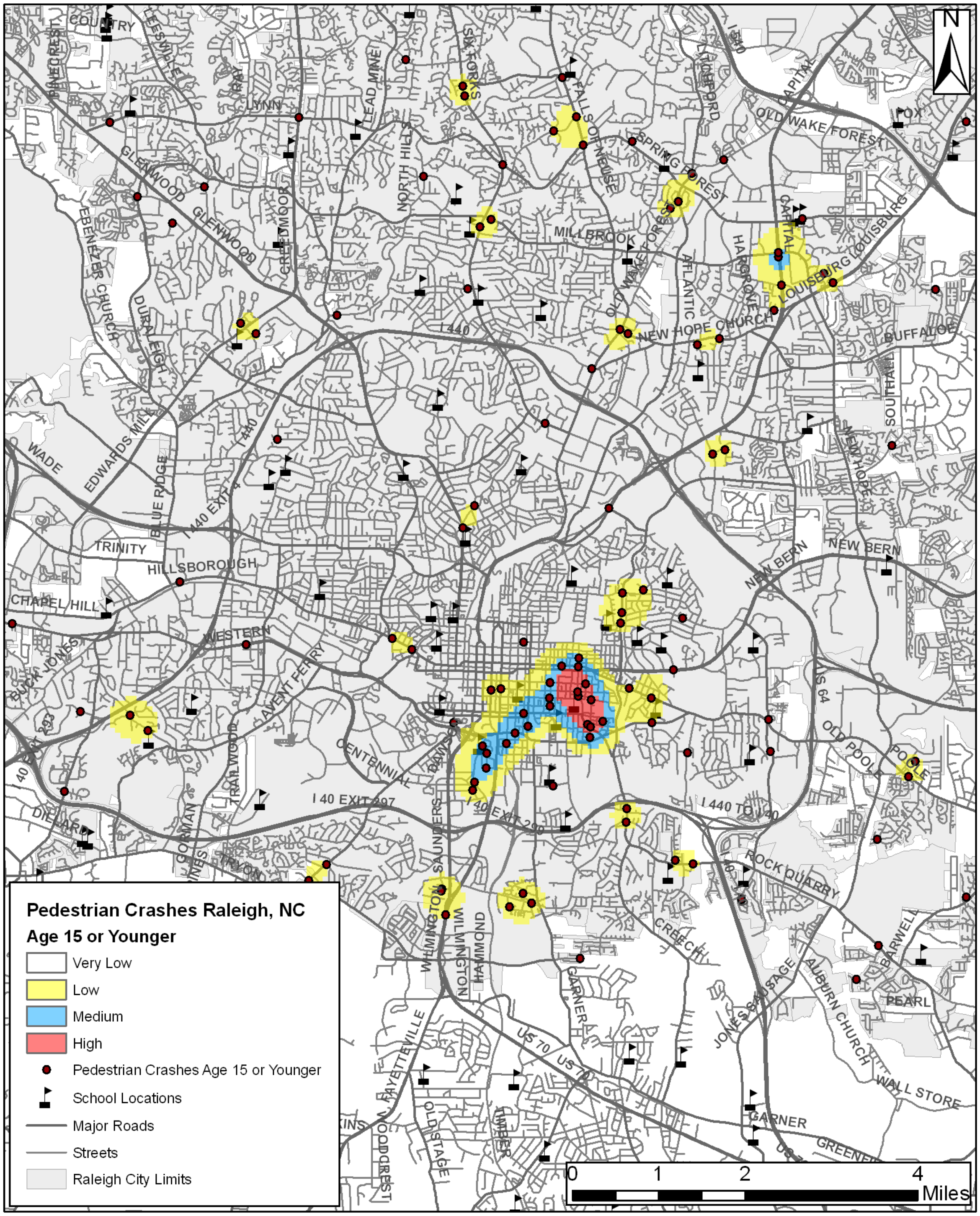


Figure 14: Child Pedestrian Crashes and School Locations, 2004-2010.

Pedestrian Crashes for Individuals Age 65 and Older, Raleigh, NC

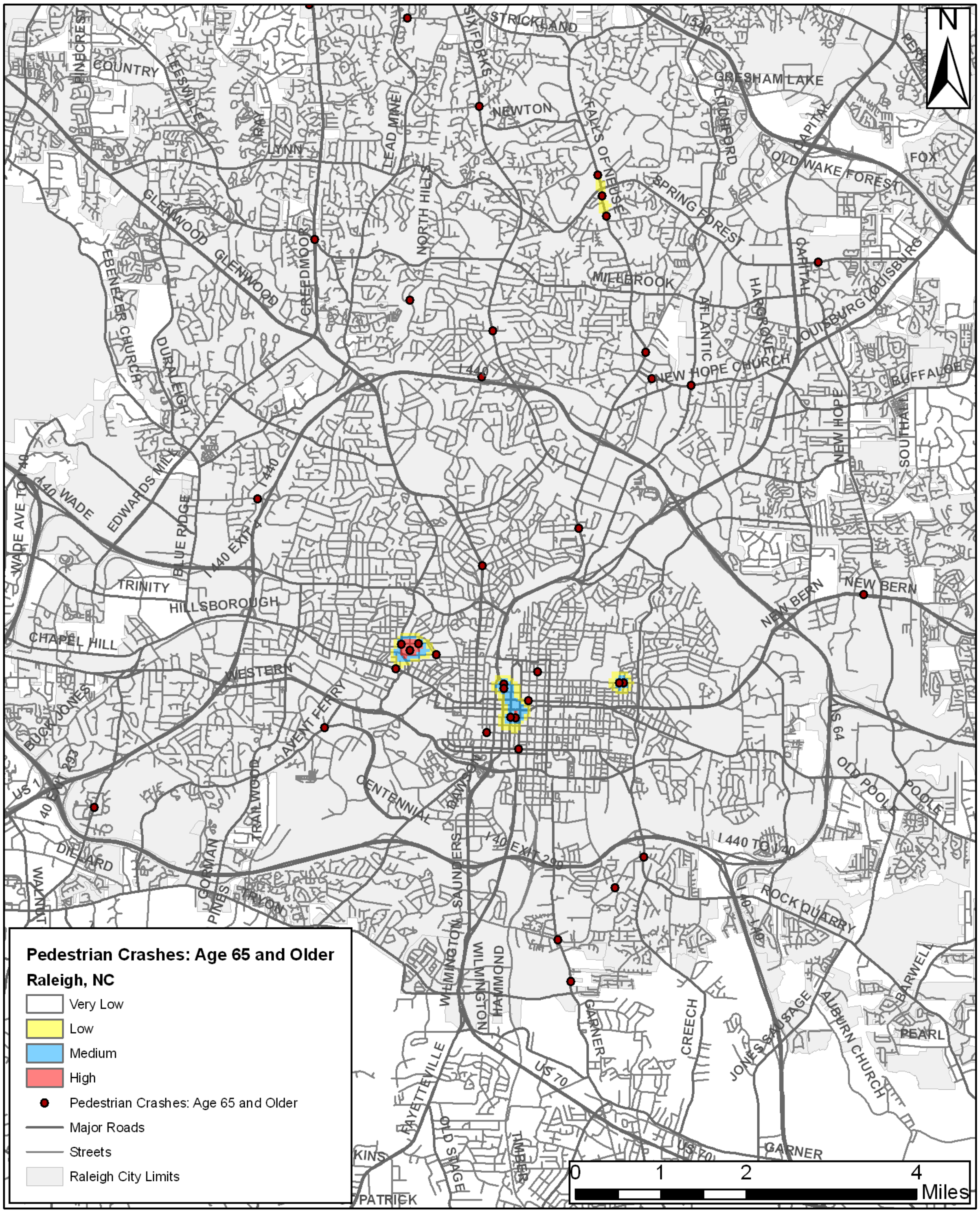


Figure 15: Pedestrian Crashes involving Older Adults, 2004-2010.

Demographics

Blacks/African Americans account for almost half (46 percent) of pedestrians involved in Raleigh collisions for 2004-2010. By comparison, Blacks accounted for approximately 29 percent of Raleigh's population (2010 Census). Hispanics accounted for 11 percent of pedestrians in collisions according to police-crash report data, while Hispanics (all races) accounted for about 11 percent of Raleigh's population in the year 2010. For Whites, roughly 39% of pedestrian crashes involved white people, while they constitute more than 57% of population in Raleigh. Figure 16 displays this information.

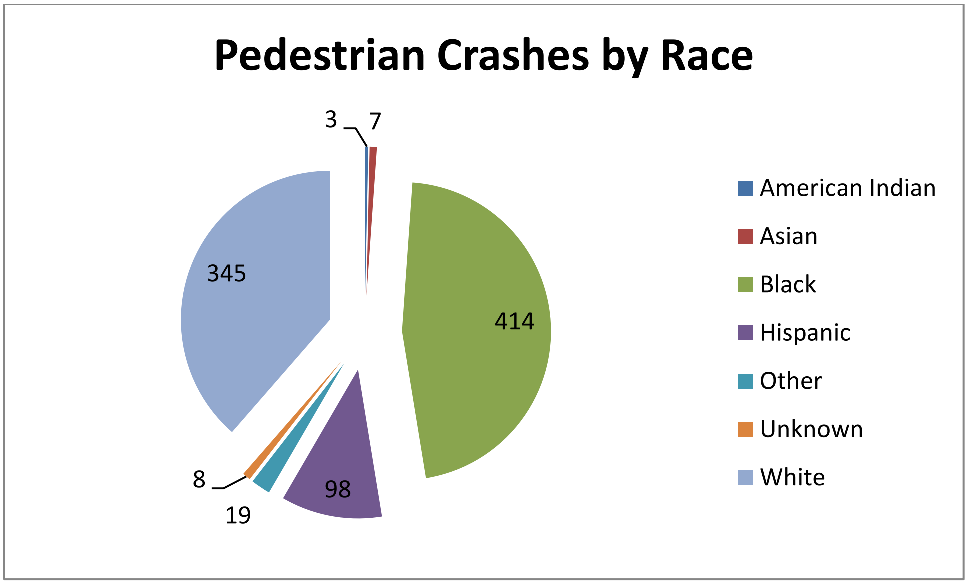


Figure 16: Pedestrian Crashes by Race, 2004-2010.

The reporting and capturing of these groups is different on police crash reports than for the Census, though population numbers from the 2010 Census should be relatively up-to-date. The following maps provide an idea of where crashes are located in Raleigh by race.

While pedestrian crashes involving both Whites and African Americans are widely dispersed across the City of Raleigh, a slight skew to the east of downtown exists for African Americans (see Figure 17). For pedestrian crashes involving whites, however, the skew exists to the west of downtown (see Figure 18). Pedestrian crashes involving Hispanics are less widely dispersed in Raleigh and clear clusters can be identified in the map. Hotspots in downtown and along Old Wake Forest and New Hope Church roads are particularly noteworthy, while Western Boulevard and Wilmington Road are also high crash areas for Hispanic pedestrians (see Figure 19).

African American Pedestrian Crashes, Raleigh, NC

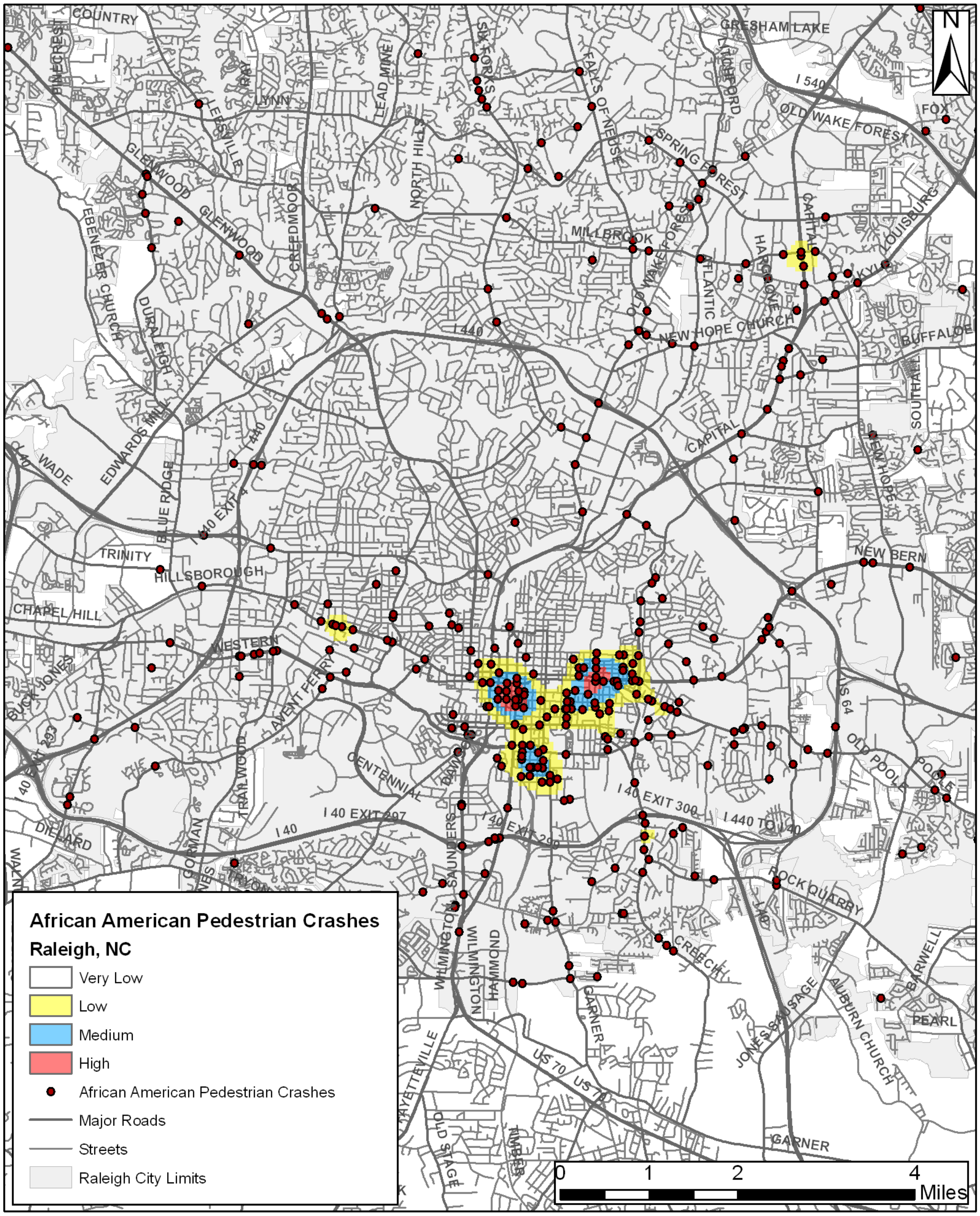


Figure 17: African American Pedestrian Crashes, 2004-2010.

White Pedestrian Crashes,
Raleigh, NC

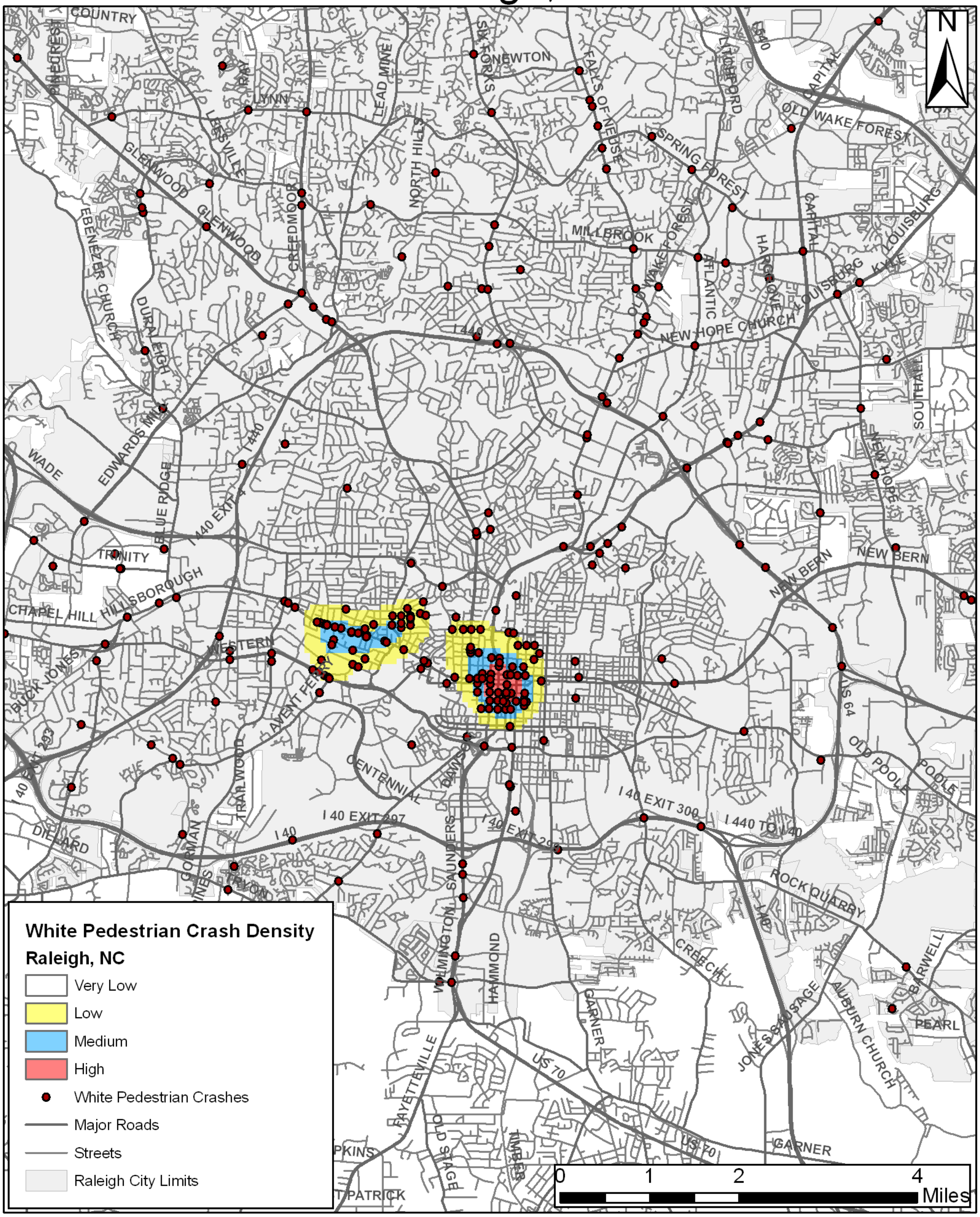


Figure 18: White Pedestrian Crashes, 2004-2010.

Hispanic Pedestrian Crashes, Raleigh, NC

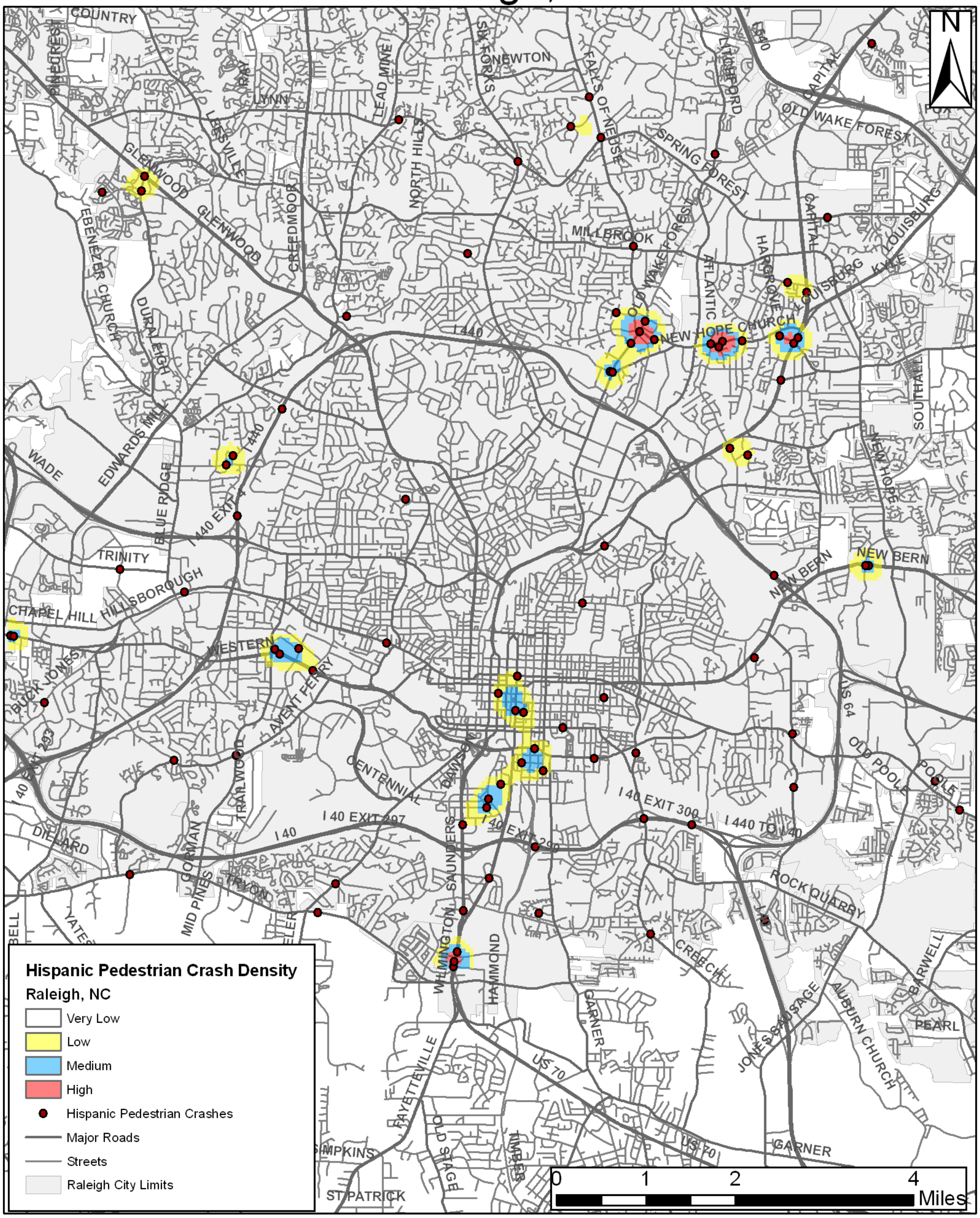


Figure 19: Hispanic Pedestrian Crashes, 2004-2010.

Sex

Males account for about 59 percent of pedestrians in crashes in Raleigh, but a slightly lower percentage than for the State as a whole (which is 61 percent, data not shown).

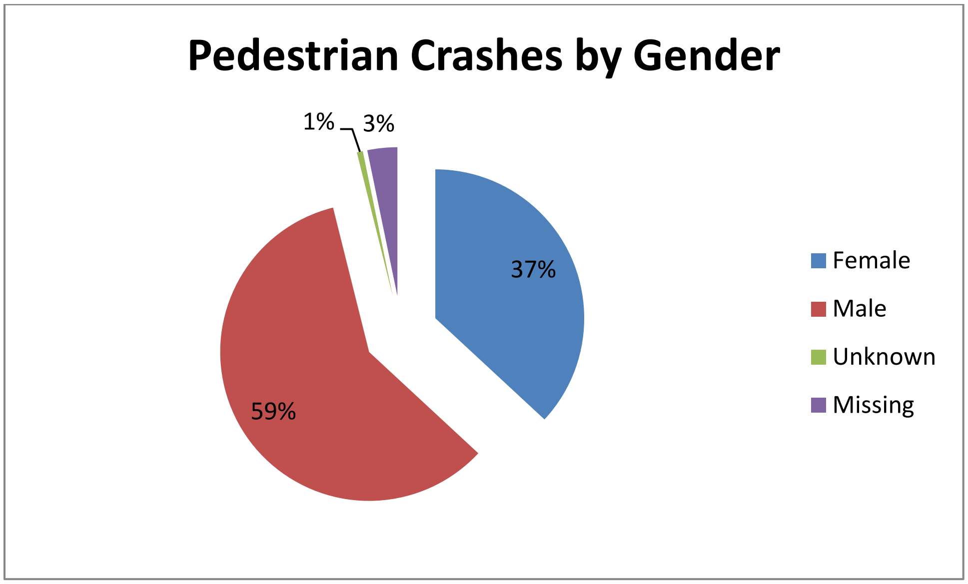


Figure 20: Pedestrian Crashes by Gender, 2004-2010.

Females account for 37 percent of pedestrians in crashes, while roughly 4 percent of crashes did not have information with regard to gender. No clear pattern in pedestrian crashes emerges, though male pedestrian crashes are clustered in greater numbers to the east of downtown Raleigh.

Alcohol Involvement

Alcohol indicators suggest that alcohol use by the pedestrian was noted in slightly less than 13 percent of crashes on average, and alcohol use by either the pedestrian or driver or both may be a factor in more than 15 percent of pedestrian crashes in Raleigh, though this analysis only takes data from 2004 to 2009 into account, due to the lack of available data from 2010. It is important to note that detection or suspicion of alcohol use prior to the collision does not necessarily indicate impairment.

The reported crash data do not suggest that Raleigh has a worse problem than the rest of the State, which reports alcohol use by one or both parties in about 14 percent of crashes on average over this period. It is not known whether police officers usually indicate alcohol use if it is suspected for pedestrians or how much variation there is by jurisdiction in reporting of alcohol use by either party. Twenty-three fatalities (53 percent of the total) apparently involved either driver or pedestrian use of alcohol, so alcohol use is clearly over-represented in fatal collisions. For pedestrians only, 21 fatalities involved alcohol, equaling 49 percent of pedestrian fatalities. Again, data from 2004-2009 were used to determine these figures.

The following map (Figure 21) details the locations of alcohol-involved pedestrian crashes and clearly indicates that certain corridors, including Wilmington, Hillsborough, Old Wake Forest Road, as well as Capital, have issues with alcohol-related crashes.

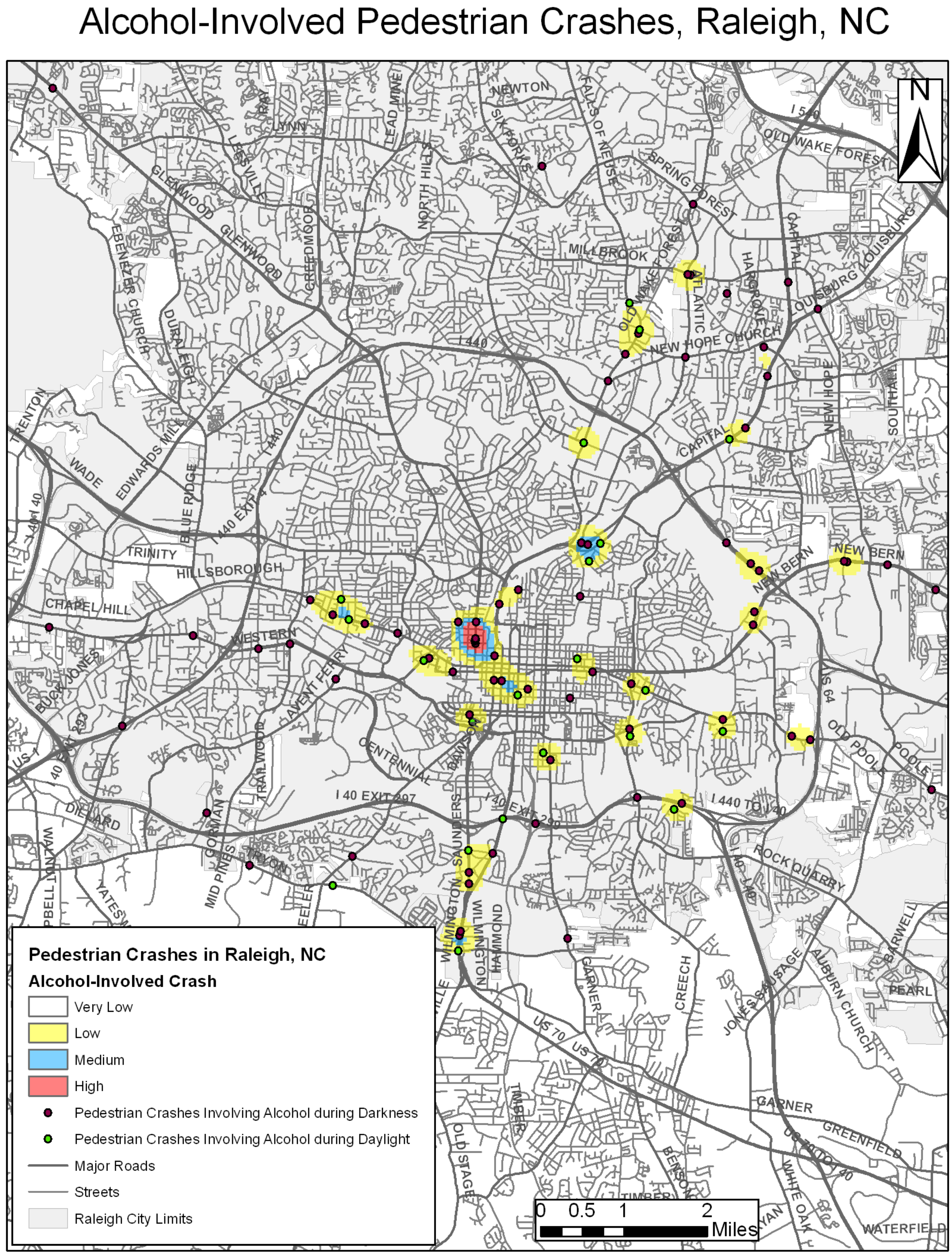


Figure 21: Alcohol-Involved Pedestrian Crashes, 2004-2009.

Weekday versus Weekend

The spatial patterns for crashes occurring on weekdays roughly mirrors the overall crash density for the City of Raleigh. As the spatial patterns do not yield any new information on the distribution of crashes in Raleigh, the weekday crash map has not been included in this section.

Downtown is highlighted as an area of concentrated pedestrian crashes during the week, while the area along Hillsborough Street near the campus of North Carolina State University is also characterized by a high density of pedestrian crashes. Other weekday pedestrian crashes are spread throughout the city, but seem to occur along major collectors and arterials as opposed to local roads. Weekday crashes constitute 76 percent of all crashes in Raleigh. Figure 22 presents the proportions of crashes by weekday and weekend. Data from 2004-2009 relating to the day of the crash was used for these maps, due to the lack of available 2010 data.

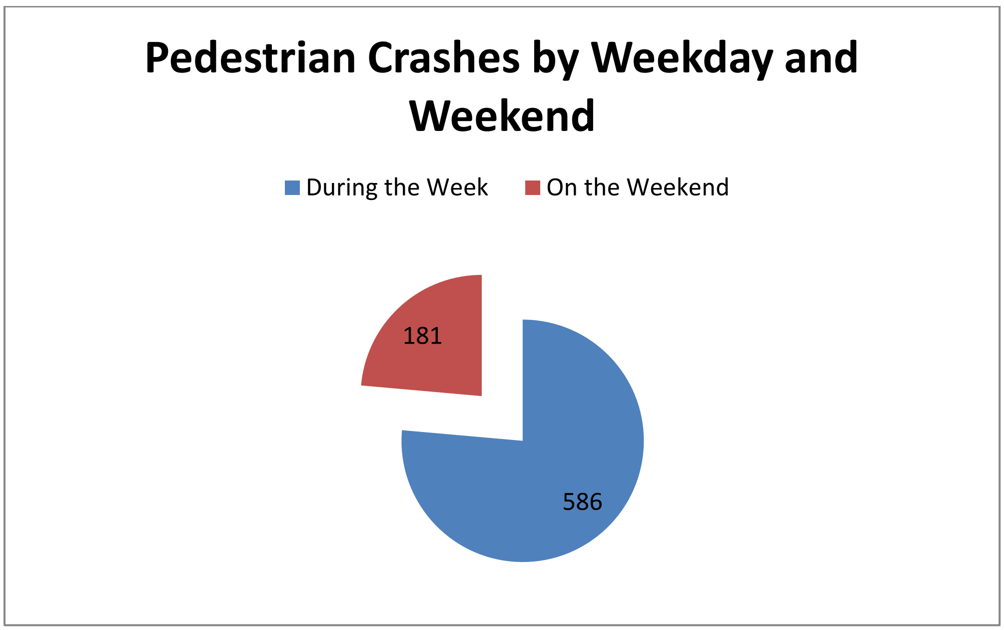


Figure 22: Pedestrian Crashes by Weekday and Weekend, Raleigh, NC, 2004-2009.

For weekend crashes, which constitute 24 percent of all crashes, corridors and hotspots can easily be identified. There are substantially fewer crashes occurring directly downtown, with high crash densities directly to the northwest, west, southeast, and east of Raleigh's downtown. The following map (Figure 23) provides insight into the spatial pattern of weekend crashes. These locations are also hotspots for alcohol-related crashes (Figure 21) and could be areas for pedestrian education with regard to safe walking at night.

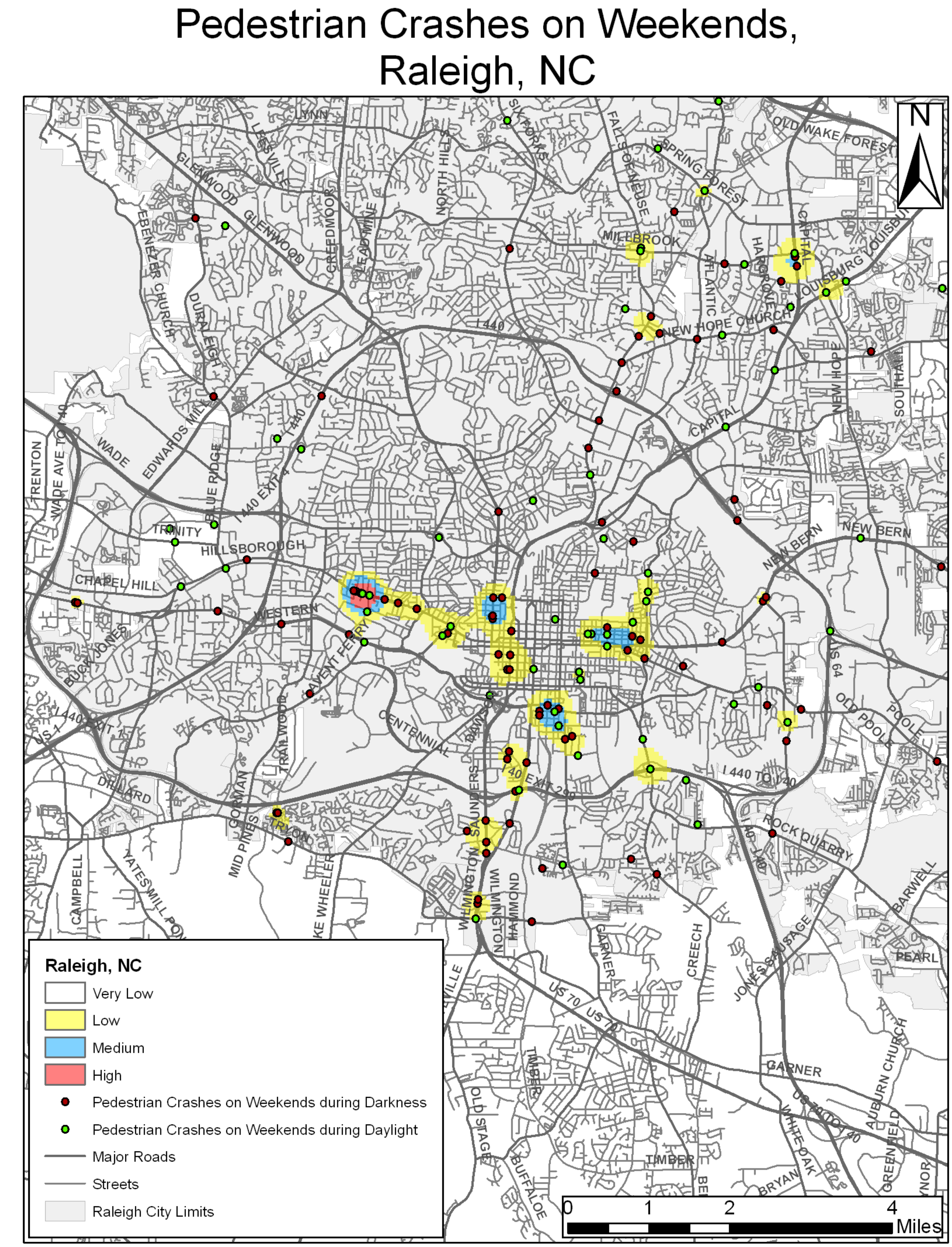


Figure 23: Weekend Crashes, 2004-2009.

Crash Types and Location

Crash Types

All types of crashes are observed in Raleigh with many types accounting for relatively small numbers. For ease in interpretation, a few of the specific crash types are grouped into related types (denoted by *) in the list of top crash types below.

In descending order, the most common types of crashes observed in Raleigh **without including crashes occurring in PVAs** were:

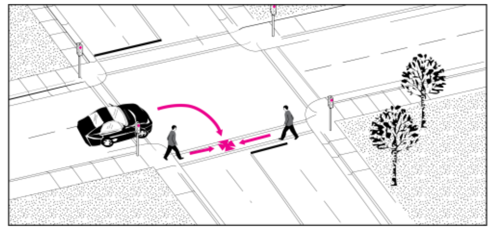
Table 2: Most Common Crash Types, Raleigh, NC, 2004-2009.

Crash Type	Frequency	Percent
Pedestrian Failed to Yield	194	26%
Dart-Out and Dash *	110	15%
Motorist Left Turn *	67	9%
Motorist Failed to Yield	50	7%
Motorist Right Turn *	28	4%
Backing Vehicle - Roadway	20	3%
Walking in Roadway	19	3%
Vehicle-Vehicle / Object	18	2%
Walking Along Roadway With Traffic - From Behind	17	2%
Left Turn - Opposite Direction	16	2%
Standing in Roadway	15	2%
Motor Vehicle Loss of Control	15	2%
Trapped	12	2%
Dispute-Related	12	2%
Multiple Threat	12	2%
Total	605	80%

The 15 types of crashes above accounted for 80 percent of all pedestrian collisions in Raleigh. These and other related crash types should be the primary focus of countermeasures to reduce crashes.

The most frequent crash type involved pedestrians crossing a roadway and apparently failing to yield right-of-way (**Pedestrian Failure to Yield**, 26 percent). From the data, it is clear that more than one half (56 percent) of these crashes occurred at mid-block locations in Raleigh, or at locations where obvious or implied cross walks are unlikely to exist. Pedestrians may have failed to detect an adequate gap in traffic or underestimated the speed of approaching vehicles. These types of crashes may occur at locations with large distances between signalized crossings. Another 27 percent occurred at intersections, with an additional 17 percent deemed to be related to / within 50 feet of an intersection. Pedestrians may be walking against signal indications, attempting to cross where pedestrian signals may be lacking, failing to use push-buttons for a pedestrian Walk indication, or attempting to cross away from the crosswalk area (the 10 percent related to intersection). Overall, this crash type resulted in **twenty fatalities** with 13 of these fatalities occurring at midblock locations.

Of the 110 pedestrian crashes located crash typed as **Dart-out** or **Dash** crashes (15%), a majority occurred at midblock locations (66%). Also, 40 percent of Dart-out and Dash crashes involved children under the age of 16. Dash implies that the pedestrian suddenly entered or ran into the roadway while dart-out means that the pedestrian came suddenly from behind an object, vehicle, or building that obscured the pedestrian from view until the last moment. These crashes occurred with the greatest frequency during daylight hours (61%) and resulted in **seven fatalities.** Countermeasures would include slowing vehicle speeds on neighborhood streets, near schools, parks, and other areas where people are likely to walk, particularly children; examining sight-distance issues (dart-outs); and behavioral interventions that target this behavior.



Other crashes that occur with some frequency involve motorist turning maneuvers. The **Motorist Left Turn** (9%) and **Motorist Right Turn** (4%) crash types, which aggregate related categories together, resulted in **zero fatalities** and one serious injury in Raleigh. Left turn movement pedestrian and motor vehicles crashes occur in situations when a motorist turns across the path of pedestrians walking in the same or opposite direction as the motorist (before the turn), while right turn movement crashes occur at signalized and stop-controlled locations and involve motorists making right turns across parallel or perpendicular path pedestrians. A frequent scenario includes motorists looking to the left for a gap in traffic and pulling out for a right turn without detecting pedestrians crossing from the right or on a parallel path. Motorist Left and Right Turn crashes occurred overwhelmingly during daylight hours (73% and 89%, respectively) and at intersections (85% and 89%, respectively). The pedestrians struck at non-intersection locations were usually in a travel lane trying to cross the street when hit by motorists turning out of or into driveways. A variety of engineering (such as signal phasing and timing, including Leading Pedestrian Intervals, protected left turn phase; no right turn when pedestrians are present; signs; pavement markings; and curb radii reductions) and educational measures could be used to target this crash type. The low number of fatalities and injuries is indicative that this problem is less severe than other types of crashes as vehicles have slowed for turns. However, if vehicles do not yield to pedestrians when turning, pedestrians may develop the perception that there is no safe time to cross at an intersection and choose to cross at midblock locations instead. This choice could result in more dangerous crossings against higher speed traffic at midblock locations. By improving interactions through enforcement and other measures at intersections, pedestrians may choose to cross at safer locations, which could bring about a more widespread beneficial effect.

The **Motorist Failed to Yield** (7%) crash type accounted for **one fatality** and one serious injury in Raleigh from 2004 until 2009. This type of crash occurred mostly during daylight hours (80%) and at intersections locations (76%). Countermeasures include assessing the need for crossings that are suitably treated for the roadway type and crossing lines of desire (origins and destinations), perhaps additional lighting in areas of night-time crashes, and educating pedestrians to cross where there is lighting and to cross where gaps are provided by signals or to wait for suitable gaps in traffic. Speeding could also be a factor in these types of crashes, affecting pedestrians' ability to identify a safe gap.

The remaining crash types accounted for 3% or less of total crashes occurring in Raleigh between 2004 and 2009. **Backing Vehicle – Roadway** type crashes resulted in **one fatality** over the years examined in this analysis and occurred predominantly during daylight hours (80%), while **Walking in Roadway** (3%) and **Vehicle-Vehicle/Object** (2%) crash types caused **one** and **three fatalities**, respectively. Educational countermeasures for both drivers and pedestrians to increase awareness and looking behaviors could have an effect on these crash types.

Walking Along Roadway with Traffic - From Behind crashes accounted for nearly two percent of Raleigh crashes; when all walking along roadway types are combined, the proportion is nearly five percent. Only two of 17 crashes (~12 percent) in this category involved the use of alcohol on the part of the pedestrian. These types of crashes may be mitigated most readily by providing space for pedestrians to walk away from the path of motor vehicles. The space may include of sidewalks, paths, or paved shoulders, dependent on the context or area type. Seventy-three percent of all Walking Along Roadway crashes occurred under dark conditions, with a significant portion (13 percent) involving alcohol on the part of the pedestrian. **One fatality** (3 percent of this type) resulted. Behavioral countermeasures therefore include enhancement and promotion of pedestrian conspicuity through both roadway lighting and personal devices (lights and retroreflective gear), promoting walking facing traffic and moving off the traveled way when cars approach, and for the longer term, providing space to walk, whether sidewalks, paths, or paved shoulders).

Other crash types not addressed above resulted in significant numbers of fatalities. In particular, three instances of **Crossing an Expressway** resulted in fatalities, while two **Lying in Roadway** crashes ended in fatalities. The following maps provide information with regard to the most common crash types found to occur in Raleigh between 2004 and 2009. Data from 2010 has not yet been crash typed and is therefore not included here. Figure 24 illustrates the spatial distribution of Pedestrian Failed to Yield crashes, while Figure 25 presents the locations of Dart-out and Dash crashes. Figure 26 captures those intersections with high numbers of Motorist Right Turn and Left Turn pedestrian crashes.

Crash Type: Pedestrian Failed to Yield, Raleigh, NC

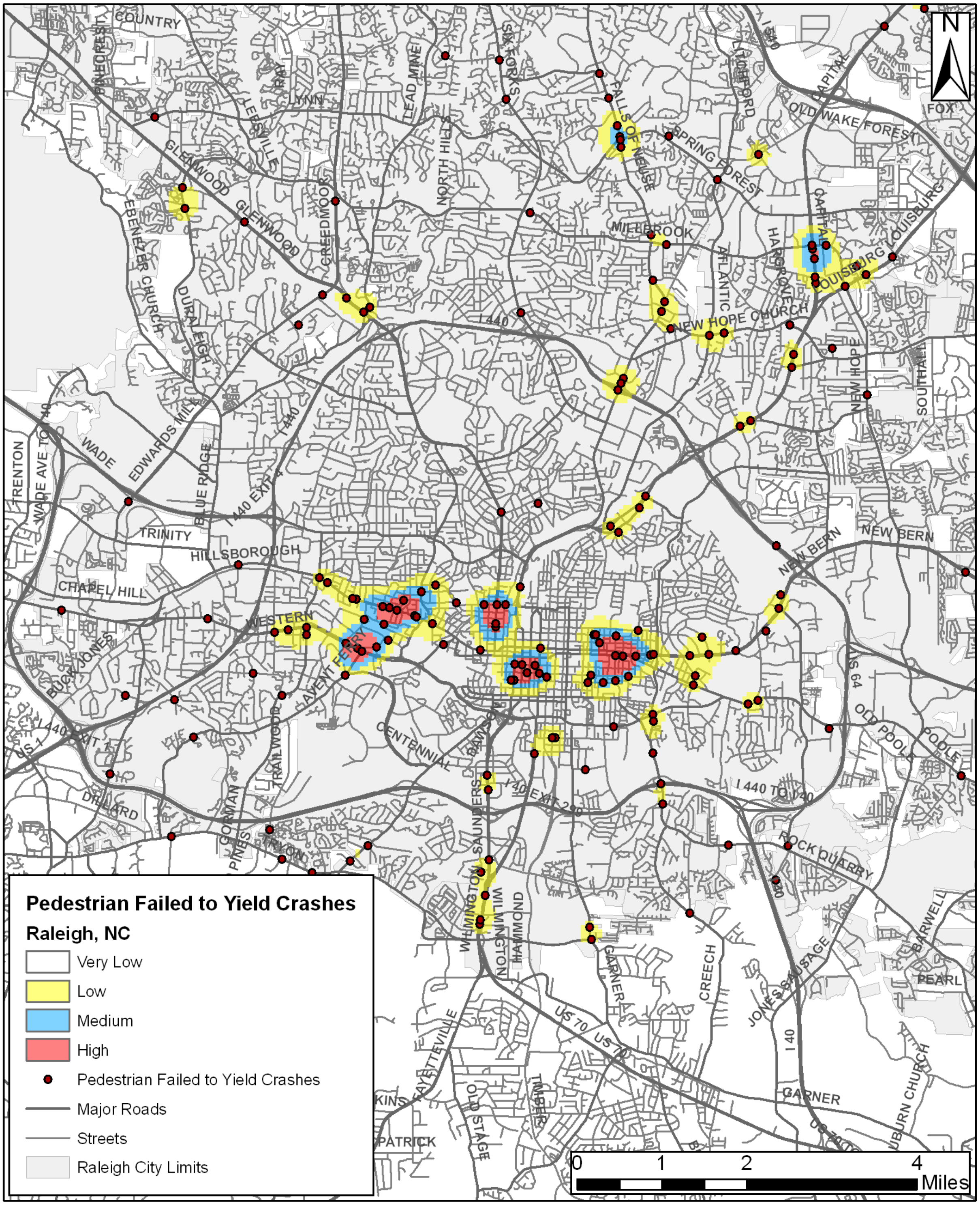


Figure 24: Pedestrian Failed to Yield Crash Density, 2004-2009.

Crash Type: Dart-Out and Dash Pedestrian Crashes, Raleigh, NC

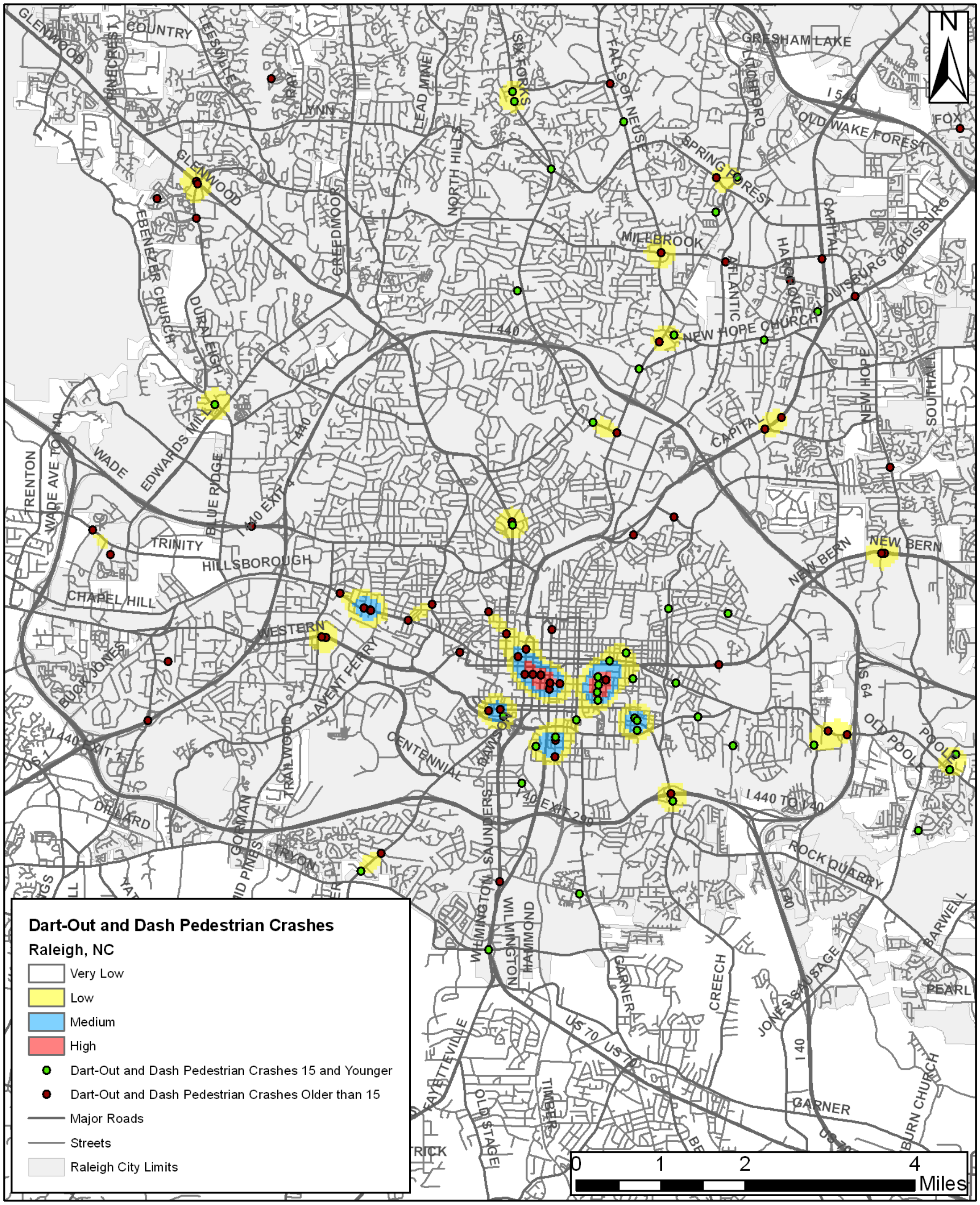


Figure 25: Dart-Out and Dash Crash Density, 2004-2009.

Crash Type: Motorist Right or Left Turn Pedestrian Crashes, Raleigh, NC

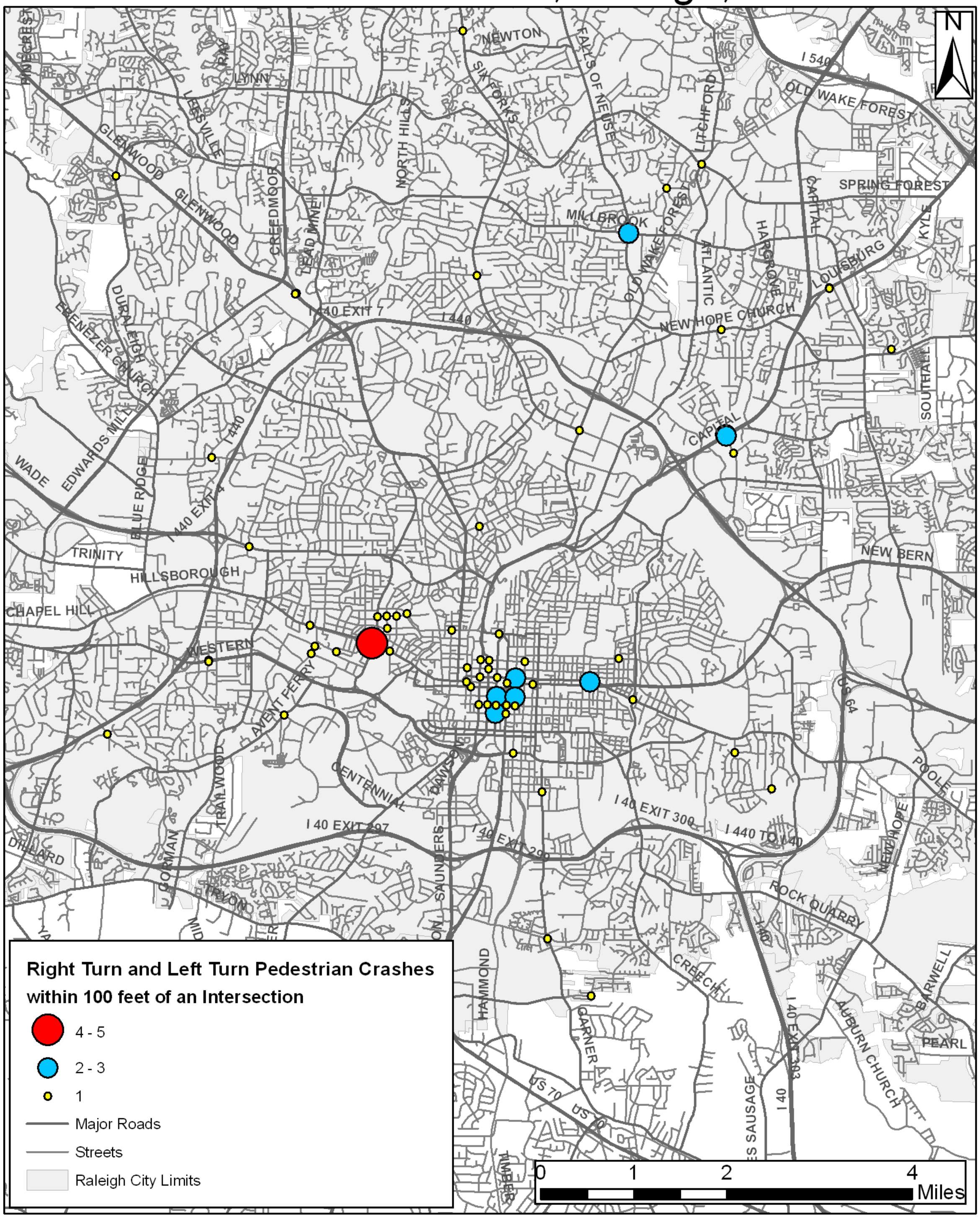


Figure 26: Intersections with High Numbers of Right and Left Turn Pedestrian Crashes, Raleigh, NC, 2004-2009.

Intersection versus Midblock

In terms of the location of pedestrian crashes for the years 2004-2009 (the only data available), 37 percent of crashes occurred at an intersection, though a further 11 percent of crashes were defined as intersection-related. As such, roughly 48 percent of crashes occurred at or near intersections. For crashes occurring away from intersections, roughly 46 percent were defined as such, while slightly less than 6 percent of crashes occurred away from the roadway (PVAs not included). Slightly more than 1 percent of pedestrian fatal crashes occurred at or near intersections, while roughly 2 percent of disabling injuries occurred at or near intersections. Non-intersection locations accounted for 4.2 percent and 3.9 percent of pedestrian fatalities and disabling injuries, respectively.

The following map (Figure 27) illustrates those intersections that have one crash or more occurring within a 100 foot buffer of the intersection. As this map uses a buffer around each intersection, instead of the "Crash Location" field of the attribute table, the map includes information for crashes from 2010. Seven intersections were identified with five or more pedestrian collisions within 100 feet from 2004-2010. Ten more intersections were identified with four collisions (see Table 3). These intersections could warrant further investigation of geometrics, operational parameters, pedestrian amenities, and behavioral issues. If these intersections overlap with those focus/hotspot areas identified in the Pedestrian Plan process for Raleigh, this analysis will provide further information to support infrastructure investments for pedestrians around these intersections. We can also further explore the characteristics of the crashes that occurred at each location for more information. For example, Figure 26 indicates that a number of these intersections are marked by crashes involving motorists turning across the path of pedestrians.

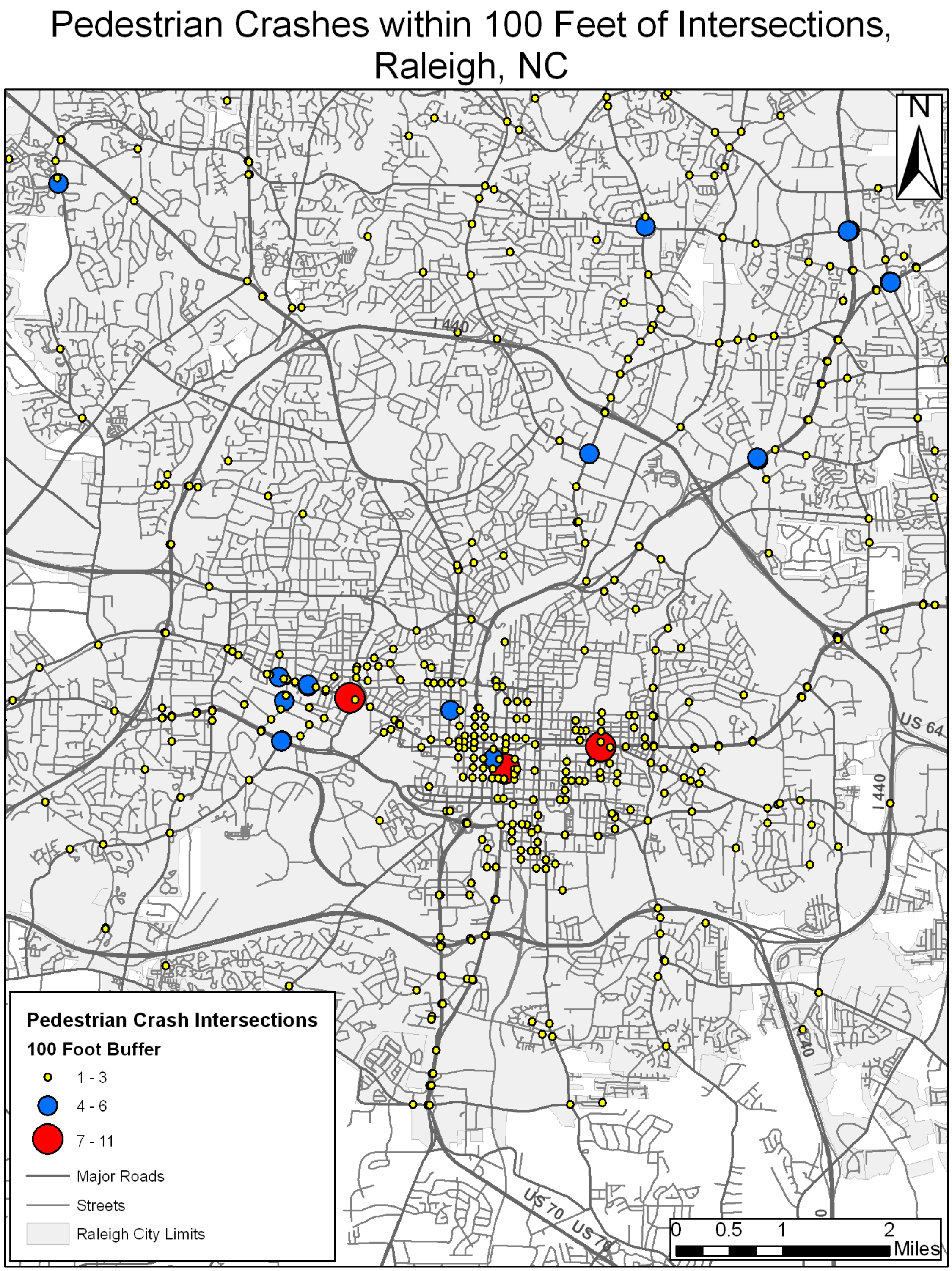


Figure 27: Intersections with Pedestrian Collisions within 100 feet of Center, 2004-2010.

Table 3. Intersections with 4 or More Related Pedestrian Collisions within 100 feet of Center.

Intersection Name	Crashes
Hillsborough and Enterprise	11
Martin and Wilmington	7
New Bern and Tarboro	7
Dixie and Hillsborough	6
Friendly and Hillsborough	6
Hargett and Salisbury	6
Brentwood and Capital	5
Avent Ferry and Western	4
Capital and Millbrook	4
Dan Allen and Thurman	4
Delta Lake and Duraleigh	4
Falls Of Neuse and Millbrook	4
Gardner and Hillsborough	4
Glenwood and North	4
Louisburg and New Hope	4
Morrill and Western	4
Six Forks and Wake Forest	4

An analysis of midblock crashes is presented in the following map (Figure 28). It is clear from the spatial distribution of crashes that certain corridors have a midblock crash problem, most notably Hillsborough Street, Falls of Neuse/Old Wake Forest Road, New Bern Avenue, and Capital Boulevard. These corridors could merit conducting roadway audits and site-specific analyses to determine whether infrastructure, access, roadway operations, or behavioral issues such as failure to yield, speeding, or crossing at night without lights are associated with these areas of higher than average midblock crashes.

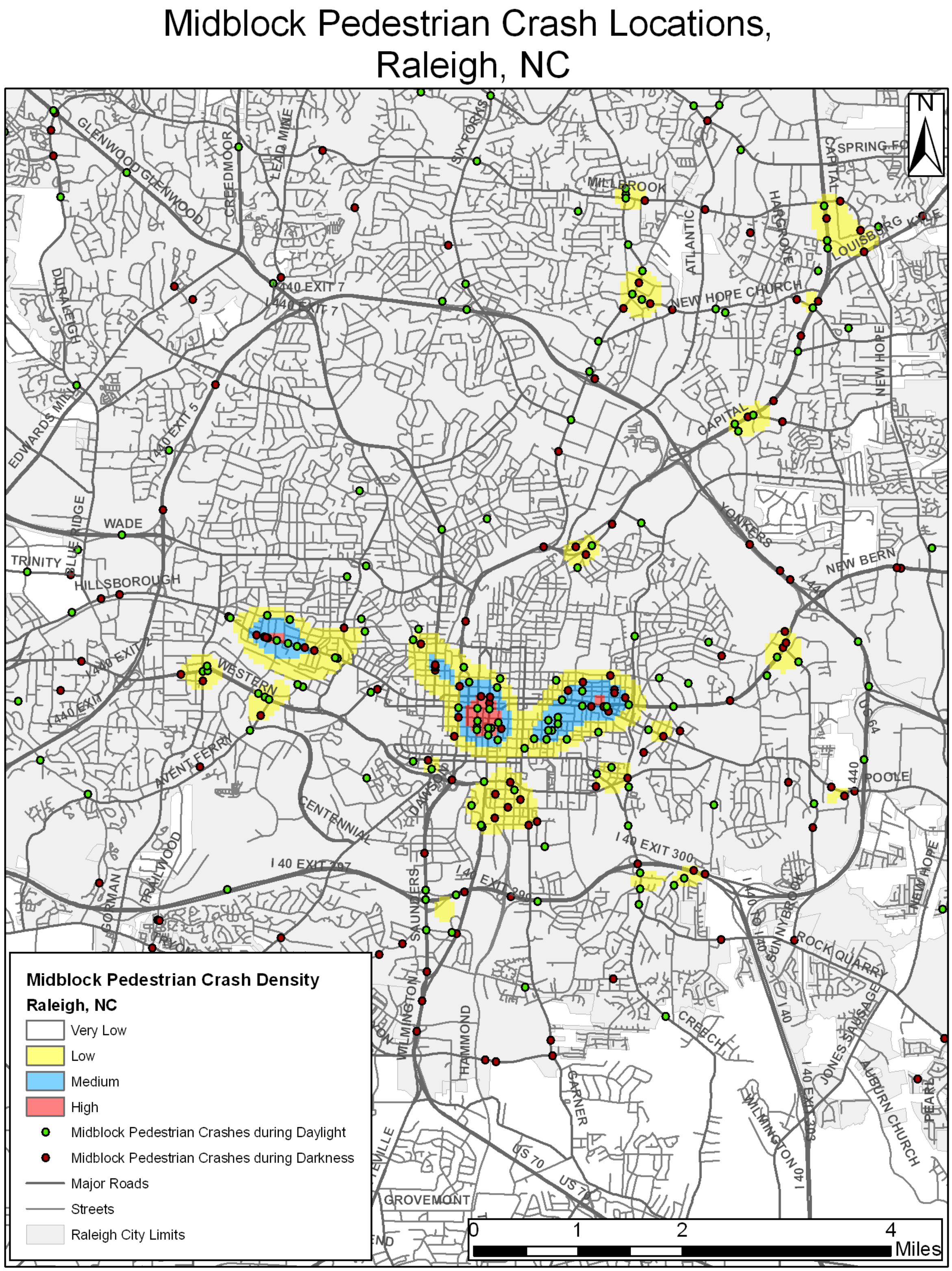


Figure 28. High Density Zones for Midblock Pedestrian Crashes, Raleigh, 2004-09.

Crashes Near Transit

Analyses also identified bus stops where multiple crashes had occurred within 200 feet. These crashes were not necessarily associated with accessing the transit stop or transit stop operations, but could reflect conditions around the transit stop. Figure 29 shows the top locations in terms of crash frequency. Again, these locations may be sites for further investigation, or could be part of a corridor-wide analysis of conditions focusing on safety and access to transit stops among other conditions. Table 4 lists those stops with three or more crashes occurring within 200 feet of the stop.

Boarding and alighting data from Capital Area Transit (CAT) also yielded some interesting information. Most transit riders are also pedestrians at some point of the commute and as pedestrian volume data is unavailable for Raleigh, the boarding and alighting data serves as an imperfect measure of areas where pedestrian activity is high. By overlaying the boarding and alighting data on the kernel density analysis of pedestrian crashes in Raleigh, a pattern emerges, indicating that pedestrian crashes are often located in close proximity to transit stops. Figure 30 displays the pedestrian crash density overlaid with boarding and alighting data.

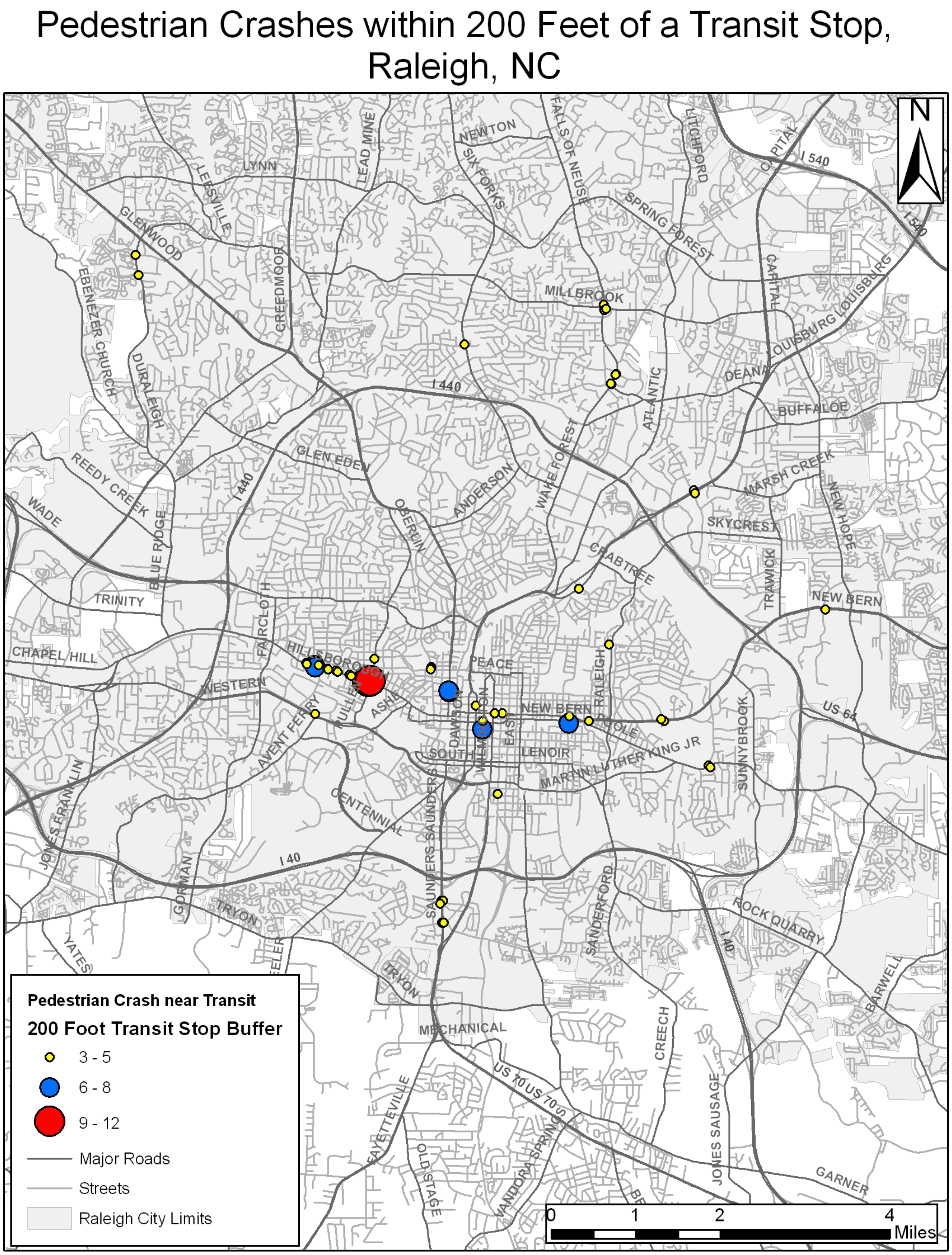


Figure 29. Transit Stops with Pedestrian Collisions within 200 Feet of Stop, 2004-2010.

Table 4. Bus stops with 3+ Pedestrian Crashes within 200 feet of Stop (complete listing available).

Stop Name	Crashes
Hillsborough St & Enterprise	12
Hillsborough St & Dixie	7
New Bern & Tarboro	7
Glenwood Ave & North	6
Salisbury & Hargett	6
Brentwood & Capital	5
Falls Of Neuse & Millbrook	5
Western & Avent Ferry	5
Hillsborough St & Gardner	4
Duraleigh & Delta Lake	4
Hillsborough St & Dan Allen	4
Falls Of Neuse & Millbrook	4
Oberlin & Stafford	4
Capital & Fenton	3
Morgan & Salisbury	3
Wake Forest & Hardimont	3
Wake Forest & Ollie	3
Glascock & Raleigh	3
Hillsborough St & Horne	3
Hillsborough St & Brooks Ave	3
Duraleigh & Pleasant Valley	3
Saunders & Carolina Pines	3
Saunders & Ileagnes	3
Peace & Saint Marys St	3
Northbrook & Six Forks	3
Hillsborough St & Daisey	3
New Bern & Poole	3
New Bern & Clarendon Crescent	3
Edenton & Tarboro	3
Edenton & Blount	3
Wilmington & Edenton	3
Blount & Lee	3
Poole & Ashford	3
Saunders & Carolina Pines	3
Mcdowell & Jones	3
New Bern & Corporation	3

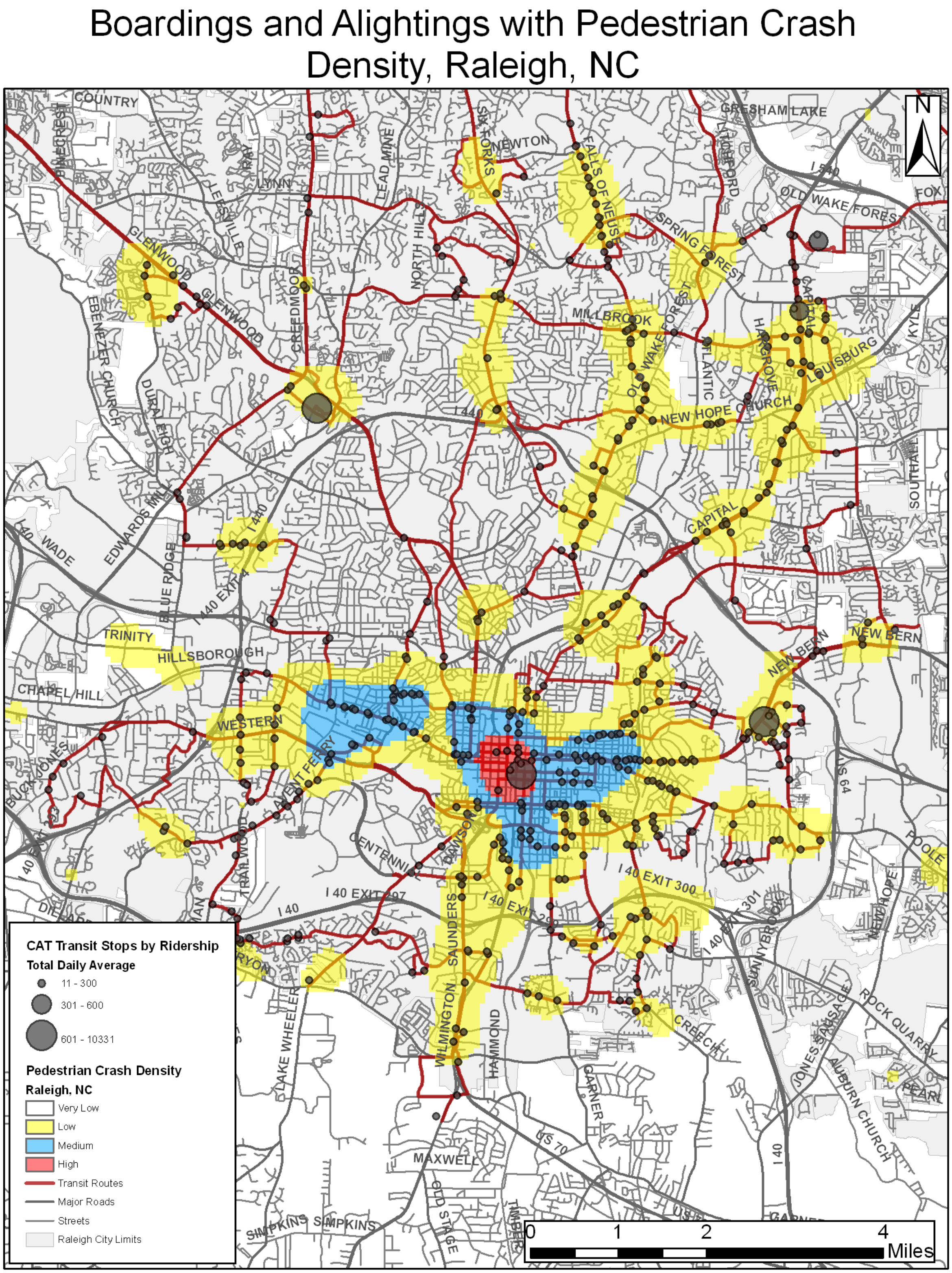


Figure 30: CAT Boardings and Alightings with Pedestrian Crash Density, 2004-2010.

High Crash Corridors

Another method used to identify locations with high midblock crash issues is to identify entire corridors or roadway sections that have a high frequency or a high crash rate per mile.

Since sections with higher crashes may reflect similar problems along an entire corridor, even if higher numbers of crashes haven't yet occurred along the entire corridor, it may be more prudent and proactive to focus attention corridor-wide. Corridors or entire roads that had the highest rates of pedestrian crashes are shown in Table 5. Roads with high counts of pedestrian crashes, 2004-2010. These corridors could reflect a wide variety of issues warranting further investigation, including long block lengths, lack of crosswalks, wide crossing distances, or large pedestrian volumes. These high crash corridors could also be the focus of countermeasure efforts in order to have a significant impact on pedestrian safety in the City.

Table 5. Roads with high counts of pedestrian crashes, 2004-2010.

Crash Corridor	Length of Street in Miles	Number of Crashes	Rate/Mile
Tarboro	0.65	8	12.33
Salisbury	1.34	12	8.94
Hillsborough St	6.28	45	7.17
Blount	2.84	19	6.68
Davie	1.65	11	6.65
Edenton	1.59	10	6.29
Martin	1.81	11	6.08
Mcdowell	1.66	9	5.43
Wake Forest	3.85	16	4.16
Saunders	4.38	16	3.65
Duraleigh	2.98	10	3.35
Poole	4.26	11	2.58
Rock Quarry	5.41	13	2.40
Falls Of Neuse	8.95	21	2.35
Wilmington	7.55	17	2.25
Tryon	4.54	10	2.20
New Bern	11.87	25	2.11
Raleigh	3.84	8	2.09
Atlantic	4.74	9	1.90
Capital	18.51	34	1.84
Six Forks	7.67	14	1.83
Western	8.96	15	1.67
Millbrook	7.88	9	1.14
Glenwood Ave	25.95	21	0.81
I-440	30.77	19	0.62
I-40	27.22	11	0.40

Crashes Near Schools

Using buffer zones around schools, we also identified schools where crashes involving school-aged children (under 15 years) occurred within ¼ mile of school boundaries (Figure 31). Presumably these crashes could involve school-related travel, although we did not select by time of day, day of week or other factors. Even so, only one school was identified that had more than two child pedestrian crashes within ¼ mile (Table 6). At present, we do not know what these results suggest about safety of neighborhood routes to most schools versus numbers of children walking to school.

Pedestrian Crashes Under the Age of 16
Near Schools, Raleigh, NC

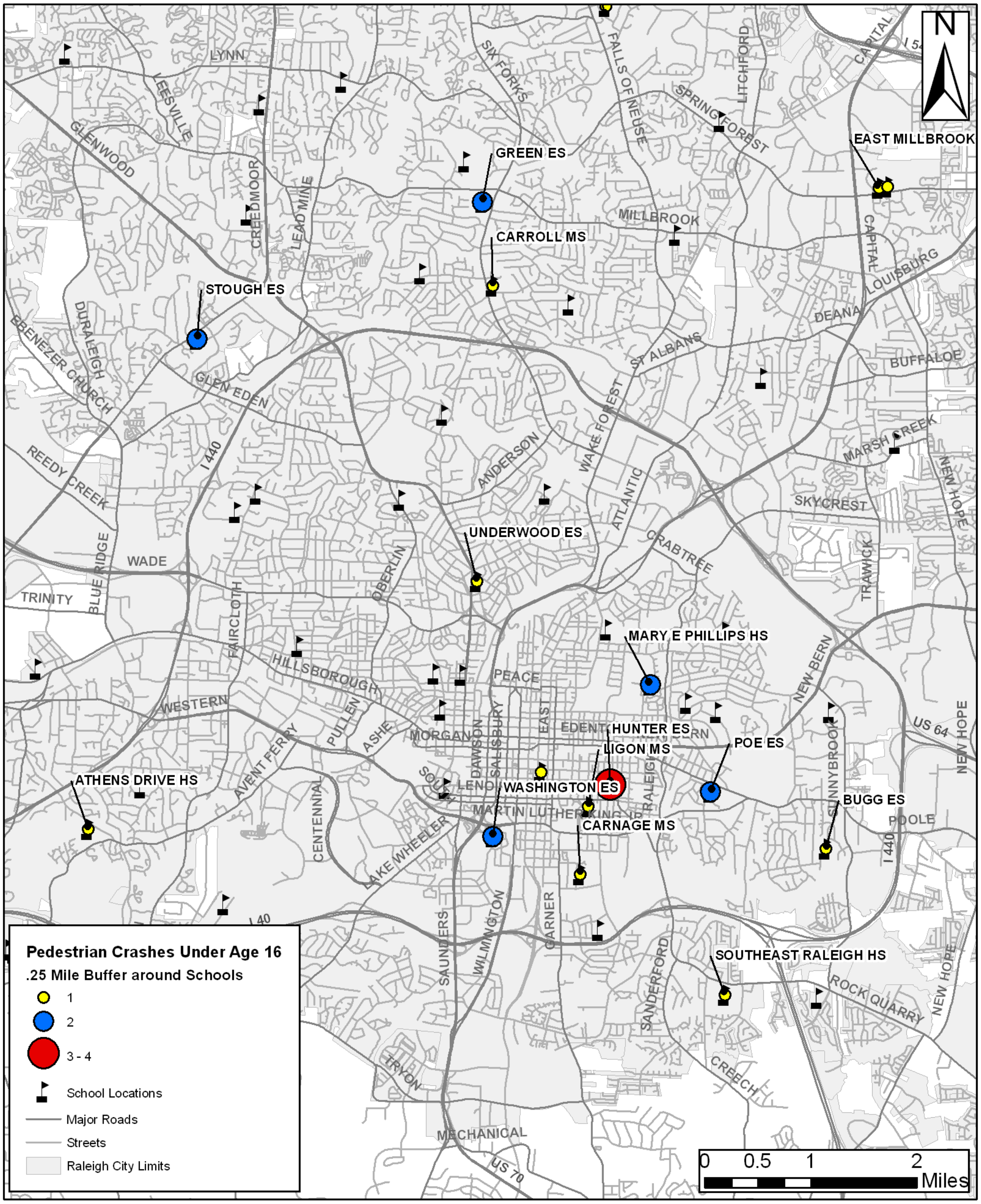


Figure 31. Pedestrian Crashes Under the Age of 16 Near Schools, 2004-2010.

Table 6. Schools with School-Aged Child (5 to 15 years) Pedestrian Crashes within ¼ Mile of School Boundary. 2004-2010.

School Name	Number of Crashes
Hunter ES	4
Mary E Phillips HS	2
Washington ES	2
Stough ES	2
Green ES	2
Poe ES	2
Athens Drive HS	1
Ligon MS	1
Carnage MS	1
Carroll MS	1
East Millbrook MS	1
Bugg ES	1
Southeast Raleigh HS	1
North Ridge ES	1
Moore Sq Museum MS	1
Underwood ES	1
Spring Forest Road Modular Site	1
North Forest Pines Drive ES	1
Forest Pines Drive ES	1

Speed

Travel speed profoundly affects the severity of injuries to pedestrians, but quality data on pre-crash travel speeds are unavailable. However, the relationship between speed and serious or fatal injury is clear in Raleigh, with crashes on roadways with higher speed limits more often resulting in fatal and disabling type injuries (Figure 32).

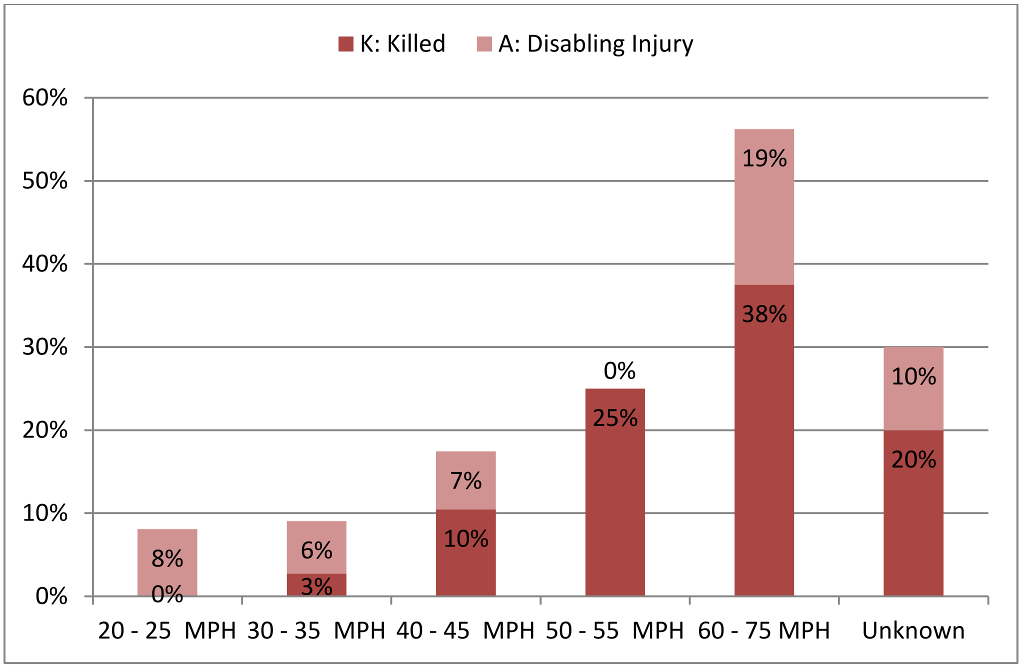


Figure 32: Percent of Killed or Seriously Injured (A-Type) by Speed Limit, 2004-2010.

The City of Raleigh could conduct speed studies on identified corridors to better understand the speeding issue in the city.

Other

Further analysis will be conducted with respect to the Wolfline using boarding and alighting data as well as kernel density analysis of crashes. Parking-related crashes may also be examined and analyzed in the future.

Summary of Data Analysis Findings and Issues

- Crashes have fluctuated over the past seven years and no definitive trend can be determined, though 2007 saw the highest number of pedestrian crashes in one year at 160. However, a clear upward trend can be discerned in terms of crash numbers from 1997-2009, data that include PVA crashes.
- Crashes occurring in Public Vehicular Areas (PVAs) are not included in this analysis, but do constitute a large portion of crashes that occurred in Raleigh from 2004-2009 (see Figure 3).
- The times between 3:00 and 7:00 had the highest crash totals by hour of the day. A majority (59 percent) of crashes occurred during daylight hours. However, 41 percent occurred during dark or low light hours with 26 percent of occurring at night on lighted roadways. Crashes are also higher during the fall months as daylight hours are waning.
- Certain corridors, including Falls of Neuse Road, Capital Boulevard, South Saunders Street, and Wilmington Street, have clear concentrations of fatal and A-type crashes, as indicated in Figure 7.
- Children under the age of 16 accounted for 129 of those struck in reported collisions (14 percent of the total) over the 2004 to 2010 time period. Children five and under accounted for slightly less than three percent. By comparison to another large urban area, pedestrians up to age 15

comprised 13 percent of those struck in the City of Charlotte. Adults 65 and older accounted for 4.5 percent of the total pedestrian crashes in Raleigh, and 4.2 percent in Charlotte.

- The crash problems as characterized by reported collision data suggest that adults of all ages are most involved in collisions, but particularly young adults (16 to 29) who accounted for 36 percent of all pedestrian collisions, with adults 30 to 59 comprising 39 percent and adults ages 60 and up accounting for less than four percent.
- Fatalities occurred with greater frequency for those pedestrians aged 70 or older, though the age group between 30 and 59 also accounted for 13.9% of fatalities. Children under the age of 16 accounted for 12.2 percent of the total fatalities.
- Persons of black or African American heritage accounted for slightly less than half (46 percent) of the Raleigh area pedestrian collisions, though they only account for 29 percent of Raleigh's overall population. Persons identifying as Hispanic accounted for about 11 percent, with whites accounting for roughly 39 percent and Asian and other groups accounting for two percent.
- Males of all ages accounted for about 59 percent of pedestrians involved.
- Weekday crashes account for 76 percent of all crashes.
- A variety of roadway and off-roadway crash types were observed with a majority of fatalities occurring in collisions where the pedestrian was crossing a roadway and was struck by a through vehicle (16 fatalities) or dashed or darted into the roadway (seven fatalities). Other fatalities occurred under more obscured conditions where the pedestrian was in the roadway but other factors are unknown, or under unusual circumstances (such as prior crashes). Alcohol use was also over-represented among fatal crashes with 19 fatalities recorded.
- Crashes overall are fairly evenly divided by location type (midblock or intersection), though crashes that occurred in PVAs were not included in this analysis. Fatalities, however, are more concentrated at non-intersection locations (75 percent of those killed, although only 47 percent of collisions occurred at such locations). Fatalities are also over-represented on higher speed limit roadways of 50+ mph (63 percent of fatalities).
- High crash intersections among other high crash areas, could be candidate sites for roadway safety audits and may warrant special enforcement activities as well as engineering and other measures. Motorists making turns without yielding to pedestrians at intersections are a frequent crash type that may affect where pedestrians choose to cross. Leading Pedestrian Intervals (LPI) could be a good way to mitigate the motorist turning crash problem.
- Areas with concentrations of midblock crashes were also identified where additional roadway and behavioral assessments could occur. Motorists often fail to yield to pedestrians when turning in and out at driveways and pedestrians often fail to yield or choose a safe gap when crossing at midblock locations. Specific roadways with high numbers of pedestrian midblock collisions were identified. These corridors could be the focus of additional safety audits, analysis, and identification of appropriate engineering, enforcement and educational countermeasures.
- Transit stops with pedestrian crashes occurring nearby were also identified. Both mid-block and transit areas could represent segments with inadequate infrastructure and access, operational issues, as well as potential behavioral issues such as speeding, failure to yield, or lack of conspicuity at night. Further site assessments are warranted and these may in turn help to identify appropriate countermeasures such as enforcement or targeted educational measures, along with potential engineering remedies.
- High crash corridors were also identified in this analysis and include Hillsborough Street, Capital Boulevard, New Bern Avenue, Glenwood Avenue, and Falls of Neuse Road. Tarboro Road, Salisbury Street, Hillsborough Street, and Blount Street have the highest pedestrian crash rate per mile of roadway.

- Schools were also identified with crashes for school-age children (15 and under). Hunter Elementary School, Mary Phillips Elementary School, Washington Elementary School, Stough Elementary School, Green Elementary School, and Poe Elementary School all had two or more crashes within ¼ mile of the school itself.

A variety of spatial analyses show that crashes appear to be concentrated downtown, and in some areas west and east sides of Raleigh. Outside of the downtown core, crashes are especially clustered along arterial roads and transit corridors. Within I-440 crashes seem to occur with greater frequency away from major roads, which reflects the assumption that more people are walking in and close to the downtown area.

Discussion

The development and examination of crash data is an important first step in developing a plan to address pedestrian safety problems in the City of Raleigh and prioritizing pedestrian safety measures (Zegeer, Sandt, Scully, et al., 2008). Overall crash issues were described in tables and figures analyzing the pedestrian safety issues City-wide and including demographics, pedestrian and driver behaviors, and location and environmental factors associated with crashes. Some of these factors may be useful for targeting countermeasures City-wide including enforcement, education, lighting, and other issues. In particular, the analysis of race, age, time of day, and gender can influence the development of educational messages and aid in targeting those populations that are most at risk. In addition, some of the issues that have been revealed in this analysis may be useful when reviewing and developing plans, development guidance, and other policies as well as inter-departmental and inter-agency cooperative efforts. In particular, this analysis can supplement the ongoing Pedestrian Plan development process in Raleigh.

Further examination of crash types may also help to identify areas of concern for particular types of problems that might be addressed by comprehensive countermeasures. For example, Pedestrian Failed to Yield or Vehicle Turning collisions could be examined to determine where and why pedestrians are struck while crossing the roadway. Are there gaps or a lack of facilities or space to walk, or are other issues present? For night-time collisions, are there gaps in lighting resulting in dark zones, poor maintenance of lighting, or roadways or segments where no lighting exists but may be needed. An educational campaign incorporating messages regarding conspicuity of pedestrians could be especially effective in mitigating nighttime crashes.

High crash areas at various scales and areas with different types of crash issues were also identified through a variety of spatial analyses. Intersections and corridors with high counts of pedestrian crashes as well as transit stops with pedestrian safety issues were identified. Such locations may also be targeted for further assessment of more location-specific (intersection, corridor, transit stop) crash problems. Once specific locations are identified, more detailed examination of crash factors may be incorporated into on-site assessments of roadway geometry and operations, and observations of pedestrian-motorist interactions such as in roadway safety audits. See Nabors et al. (2007) for more information on conducting roadway safety audits and prompt lists for focusing on pedestrian issues. In addition, more detailed examinations could incorporate neighborhood population, built environment characteristics, and infrastructure buildout in conjunction with traffic crash and demographic factors.

Such analyses should aid efforts to develop and target enforcement and educational countermeasures as well as policy and engineering treatments to the specific problems and target audiences in each area.

Tools such as PEDSAFE (Harkey and Zegeer, 2004), Countermeasures That Work (NHTSA, 2010; 6th edition due shortly), the NCHRP Guide for Reducing Collisions Involving Pedestrians (Zegeer, Stutts, Huang, et al., 2004), NCHRP Report 622, Effectiveness of Behavioral Highway Safety Countermeasures (Presseur, Williams, Nichols, Tison, and Chaudhary, 2008), and other references provide help in identification of potentially suitable countermeasures. ***All countermeasures and locations should be thoroughly assessed by qualified traffic safety officials before implementation.*** By adding some of the identified locations to the Pedestrian Plan site identification process in Raleigh, existing resources and ongoing initiatives can be leveraged to create a comprehensive program to enhance pedestrian safety in the city.

Analyses have not yet incorporated pedestrian or motor vehicle volumes or other exposure measures, apart from the boardings and alightings analysis of Capital Area Transit. Although the analyses reported on herein do not account for relative risk or crash rates per individual, identifying areas with significant numbers of pedestrian collisions is still a valid way to prioritize where both engineering and behavioral improvements might be focused to help bring down numbers of crashes, especially when supplemented by additional information gleaned from site visits and roadway audits to assess specific problems. Finally, in developing a safety action plan, it should be considered that crash data suffer from inaccuracies and incomplete reporting (Zegeer, et al. 2008). Although it seems as if every effort has been made to code the crashes in the analysis database correctly with respect to type and location, these fields and the other reported crash factors undoubtedly contain some errors. In addition, pedestrian falls and mishaps due to maintenance issues or other factors are not reported in State crash data. It is also the case that crashes may increase at one location and decrease at others, even if nothing is done. This is a well-documented statistical phenomenon known as regression toward the mean. Thus, in an effort to be more proactive, one might identify areas with similar issues to those with current crash problems and treat them in a similar fashion. City-wide improvements such as measures to slow vehicle speeds, improve visibility, and lighting crossing amenities and others may also be undertaken (Zegeer et al 2006, pp 13-17).

Other Data Issues

The HSRC team has checked a subset of the pedestrian crash ArcGIS shapefile that were provided by the City of Raleigh and found no geocoding errors, though errors may still be present in the data. An intersection file was created for Raleigh for this project, which is available from HSRC upon request.

Next Steps

These data analyses will be combined with additional contextual information and observations from City staff and stakeholders to identify high crash target areas and will hopefully inform the Pedestrian Plan process. These target areas will be further examined through field visits and additional analysis. With stakeholder input, analysis data, and site visit observations in place, a targeted pedestrian safety action plan will be developed. Additionally, this analysis will affect the focus and coordination of a unified pedestrian safety educational campaign for the Triangle region. This action plan will be reviewed by a wide variety of Raleigh stakeholders and revised with their input and will serve as the basis for the project intervention and evaluation efforts for the subsequent 3 years in conjunction with the ongoing Pedestrian Plan efforts of the Toole Design Group. This document should be regularly updated as new issues and opportunities arise.

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