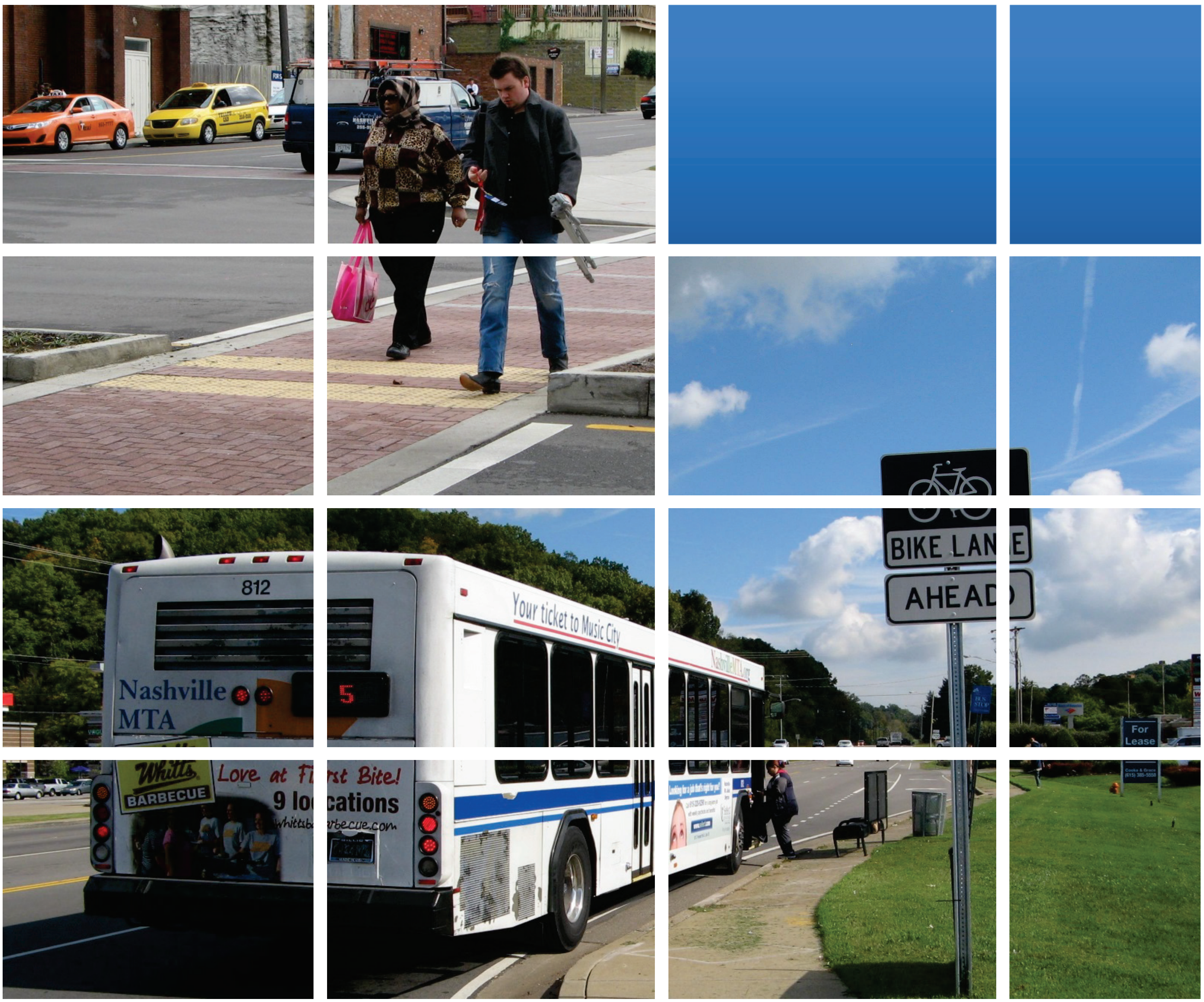
Pedestrian & Bicycle Safety Pilot Project

November 2014

Metro Nashville
PUBLIC WORKS



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1 Introduction

At some point nearly all trips involve an element of pedestrian access, be it walking from the parking space of a car to the storefront, getting to or from a bus stop, or running during lunch midday from the office. For many reasons people choose non-motorized modes as a means of transportation and/or for other purposes. Regardless of the reason or purpose, exposure to vehicular traffic possesses many safety risks to non-motorized travel. Over the last decade non-motorized travel within Metro Nashville has increased given a number of factors including an increased population, thriving tourist and entertainment destinations in the downtown, multiple greenways throughout the City, active transit lines, the addition of Nashville's B-Cycle program, and many more pedestrian and biking trip generators located along major roadways throughout Nashville. Because of these factors as well as many other conditions, pedestrians and bicyclists are more at risk than ever on the roadways, making their safety a top priority for Metro Nashville Public Works.

This report documents the development of a pilot pedestrian and bicycle safety improvement program for Metro Nashville Public Works. This program identified high hazard safety locations within Metro Nashville for both pedestrians and cyclists. Additionally, this pilot initiative included the development of a toolbox of pedestrian and bicycle safety countermeasures. This includes a range of cost-effective, easily-implementable countermeasures that can be employed in a short time frame to improve roadway safety for all transportation system users. In addition, the toolbox includes other countermeasures which may have application in the Metro Nashville area. These were not necessarily derived from the evaluation of crash locations as part of this study effort. Ultimately, the results of this pilot initiative will provide Metro Nashville Public Works with a methodology and process for addressing pedestrian and bicycle safety locations, and provide a range of cost-effective countermeasures for use in improving pedestrian and bicycle safety throughout Metro Nashville.

2 Data Analysis

2.1 Determining the Geographic Location of Crashes

The first step in the pilot process was to retrieve crash data for both pedestrian and bicycle crashes in Davidson County. A total of 1,233 pedestrian and bicycle crash records were provided by the Metro Nashville Police Department (MNPD) for the complete calendar years of 2010, 2011, and 2012 as well as a partial listing through May 2013. Of these crash records it was determined that 22 were duplicate crash records, resulting in 1,211 unique crash records for evaluation.

Using a geographic information system (GIS), a computer system that allows for the analysis spatial data, crash locations were geocoded. When data was provided, the crash reports were geocoded to a physical street address (e.g. 123 Main Street), with remaining crash locations being geocoded to intersecting cross streets (e.g. 21st Ave at Blair Blvd). The resulting effort yielded 1,199 crash records being successfully geocoded to either a physical street address or intersecting cross streets. Of the 12 unlocatable crashes, half were associated with an interstate and the remaining crashes did not contain adequate address information.

After the crash data was geocoded, crashes were divided into pedestrian crashes and bicycle crashes. Of the 1,199 crashes, 979 were pedestrian crashes and 220 were bicycle crashes, representing 82% and 18%, respectfully.

2.2 Determining High Crash Concentrations and High Crash Locations

Nashville's GIS street centerline file was used to assess pedestrian and bicycle crash concentrations. The following process was used independently for pedestrian crashes and bicycle crashes. Using GIS, the street centerline was first dissolved into one record file and then segmented (through an automated process) based on intersecting segments. The result allowed for streets to naturally break at every cross street opposed to how the street may have been digitized, or coded. The result of this process ended with the street centerline file having on average, all street segments .10 miles in length. From this, crash records were spatially joined to the corresponding roadway segment using a buffer analysis of within 50 feet of the segment. This process allowed for crash records to be placed along a segment and allowed for segments with multiple crashes to be documented by a join count, which is essentially the number of crashes documented at that location.

From this point, the segment was used to create an area which represented a high crash concentration. High crash segments were used to create a 50 foot buffer around the high crash segment. This buffer was then used to reselect the corresponding crash record for that high crash concentration area. For pedestrian crashes, 50 high crash concentrations were identified; this essentially designated locations with 4 or more pedestrian crashes within a tenth of a mile location as high pedestrian crash locations. Of these concentration areas, a total of 290 pedestrian crashes have occurred in these areas, representing 30% of all pedestrian crashes in Nashville during that time period. For bicycle crashes, 2 or more crashes were used for targeting high bicycle crash locations. A total of 25 high concentration locations were identified for bicycle crashes. Of these concentration areas, a total of 67 bicycle crashes occurred in these areas, representing 30% of all bicycle crashes in Nashville during that time period.

Tables 1 and 2 include the high crash locations for pedestrians and bicyclists, respectively. Locations have been named to identify the general area of the high crash connection area. To further help identify the crash concentration areas, Metro's subarea planning name has been added to illustrate geographic areas of these concentrations. From this table the corresponding individual crash records were pulled so that a more in-depth analysis of these concentration areas could be undertaken. Additionally, Figures 1 and 2 illustrate the high crash concentration areas for pedestrian crashes and bicycle crashes, respectively.

Table 1 Pedestrian High Crash Locations

Study Area	Subarea	Zone	Pedestrian Crashes In Zone
Broadway between 3rd Ave and 6th Ave	Downtown	1	17
West End Ave between 25th Ave and Louise Ave	Green Hills-Midtown	2	13
Nolensville Pike between Harding Place and Welshwood Dr	Southeast	3	10
Donelson Pike between Elm Hill Pike and Shacklett Dr	Donelson-Hermitage	4	9
Broadway between George E. Davis Blvd and 11th Ave	Downtown	5	9
Abbott Martin Road between Hillsboro Rd and Hillsboro Cr	Green Hills-Midtown	6	8
21st Ave between Children's Way and Pierce Ave	Green Hills-Midtown	7	8
2nd Ave N between Church Street and Broadway	Downtown	8	8
Gallatin Pike between Shepherd Hills Dr and Liberty Ln	Madison	9	8
Murfreesboro Pike between Bell Road and Rural Hill Rd	Antioch-Priest Lake	10	7
Harding Place between Tampa Dr and Linbar Dr	Southeast	11	7
21st Ave between 19th Ave South and Edgehill Ave	Green Hills-Midtown	12	12
Lafayette St between Charles Davis Blvd and Claiborne St	South Nashville	13	7
Charlotte Ave between 3rd Ave N and 5th Ave N	Downtown	14	7
Clarksville Pike between Buena Vista Pike and Cliff Dr	Bordeaux-Whites Creek	15	7
Gallatin Pike between Due West Ave and Berkley Dr	Madison	16	7
Thompson Lane between Bransford Ave and E Iris Dr	South Nashville	17	6
Rosa L Parks Blvd between Jefferson St and Monroe St	North Nashville	18	6
Lebanon Pike near Tyler Dr	Donelson-Hermitage	19	6
Dickerson Pike between Trinity Ln and Gatewood Ave	East Nashville	20	6
Gallatin Pike between Harrington Ave and south of Maple St	Madison	21	6
21st Ave and Blair Blvd	Green Hills-Midtown	22	5
Charlotte Ave between Lellyett St and Oceola Ave	West Nashville	23	5
Church St between 15th Ave N and 16th Ave N	Green Hills-Midtown	24	5
Gallatin Pike between Eastland Ave and Chickamauga Ave	East Nashville	25	5
Hillsboro Pike between Graybar Ln and Abbott Martin Rd	Green Hills-Midtown	26	5

Study Area	Subarea	Zone	Pedestrian Crashes In Zone
Bell Rd and Mt. View Rd	Antioch-Priest Lake	27	4
Bell Rd between Hickory Highlands Dr and Zelida Ave	Antioch-Priest Lake	28	4
US70 South and Old Hickory Blvd	Bellevue	29	4
Nolensville Pike and Paragon Mills Rd	Southeast	30	4
Franklin Pike between Gale Ln and Kirkwood Ave	Green Hills-Midtown	31	4
Murfreesboro Pike between Thompson Ln and Bowwood Ct	South Nashville	32	4
Charlotte Pike between River Rd and Davidson Rd	Bellevue	33	4
Division St between 19th Ave and Lyle Ave	Green Hills-Midtown	34	4
Church St between 18th Ave N and 19th Ave N	Green Hills-Midtown	35	4
Charlotte Ave between I-40/I-65 and 15th Ave N	North Nashville	36	4
Church St between 4th Ave N and Printer’s Alley	Downtown	37	4
Charlotte Ave and Rosa L Parks Ave	Downtown	38	4
5th Ave N and Union St	Downtown	39	4
Jefferson St between 26th Ave N and 28th Ave N	North Nashville	40	4
Jefferson St and Dr DB Todd Jr Blvd	North Nashville	41	4
Jefferson St between Rosa L Parks Blvd and 7th Ave N	North Nashville	42	4
Main St between Neill Ave and S 9th St	East Nashville	43	4
Gallatin Ave between Straightway Ave and Strouse Ave	East Nashville	44	4
Clarksville Pike between Hamilton Rd and Fairview Dr	Bordeaux-Whites Creek	45	4
Dickerson Pike between Broadmoor Dr and Oak Valley Dr	East Nashville	46	4
Gallatin Pike between Lakewood Dr and Walton Ln	Madison	47	4
Dickerson Pike between Briley Pkwy and Old Due West Ave	Parkwood-Union Hill	48	4
Gallatin Pike between Madison Blvd and Emmitt Ave	Madison	49	4
Gallatin Pike between Old Hickory Blvd and Maple St	Madison	50	4

Table 2 Bicycle High Crash Locations

Study Area	Subarea	Zone	Bicycle Crashes in Zone
Gallatin Ave between N 10th St and Calvin Ave	East Nashville	1	5
24^{th} Ave between Highland Ave and Pierce Ave and Highland Ave between 24^{th} Ave and 25^{th} Ave S	Green Hills-Midtown	2	4
8th Ave S between Broadway and Demonbreun St	Downtown	3	4
Broadway between 3rd Ave and 1st Ave	Downtown	4	4
Jefferson St between Warren St and Rosa L Parks Blvd	North Nashville	5	4
Harding Pike and White Bridge Road/Woodmont Blvd	West Nashville	6	3
Edgehill Ave between 16th Ave and 17th Ave	Green Hills-Midtown	7	3
21st Ave between Scarritt Pl and Division St	Green Hills-Midtown	8	3
Church St between 16th Ave N and I-40/I-65	Green Hills-Midtown	9	3
2nd Ave S between Demonbreun St and Peabody St	Downtown	10	3
21st Ave between Belcourt Ave and Dixie Pl	Green Hills-Midtown	11	3
Harding Pike between Woodlawn Dr and Cherokee Rd	Green Hills-Midtown	12	2
Murfreesboro Pike near Millwood Dr	South Nashville	13	2
Murfreesboro Pike at Elm Hill Pike	South Nashville	14	2
Charlotte Pike and White Bridge Road	West Nashville	15	2
20th Ave N and State St	Green Hills-Midtown	16	2
Charlotte Ave between 19th Ave N and Dr DB Todd Jr Blvd	North Nashville	17	2
Church St between YMCA Way and 9th Ave N	Downtown	18	2
16th Ave N and Jo Johnston Ave	North Nashville	19	2
6th Ave N between Church St and Commerce St	Downtown	20	2
Charlotte Ave and 5th Ave N	Downtown	21	2
Eastland Ave between Gallatin Ave and N 12th St	East Nashville	22	2
Gallatin Ave between Granada Ave and Sharpe Ave	East Nashville	23	2
Robinson Rd near Martingale Dr	Donelson-Hermitage	24	2
51st Ave N between Indiana Ave and I-40	West Nashville	25	2

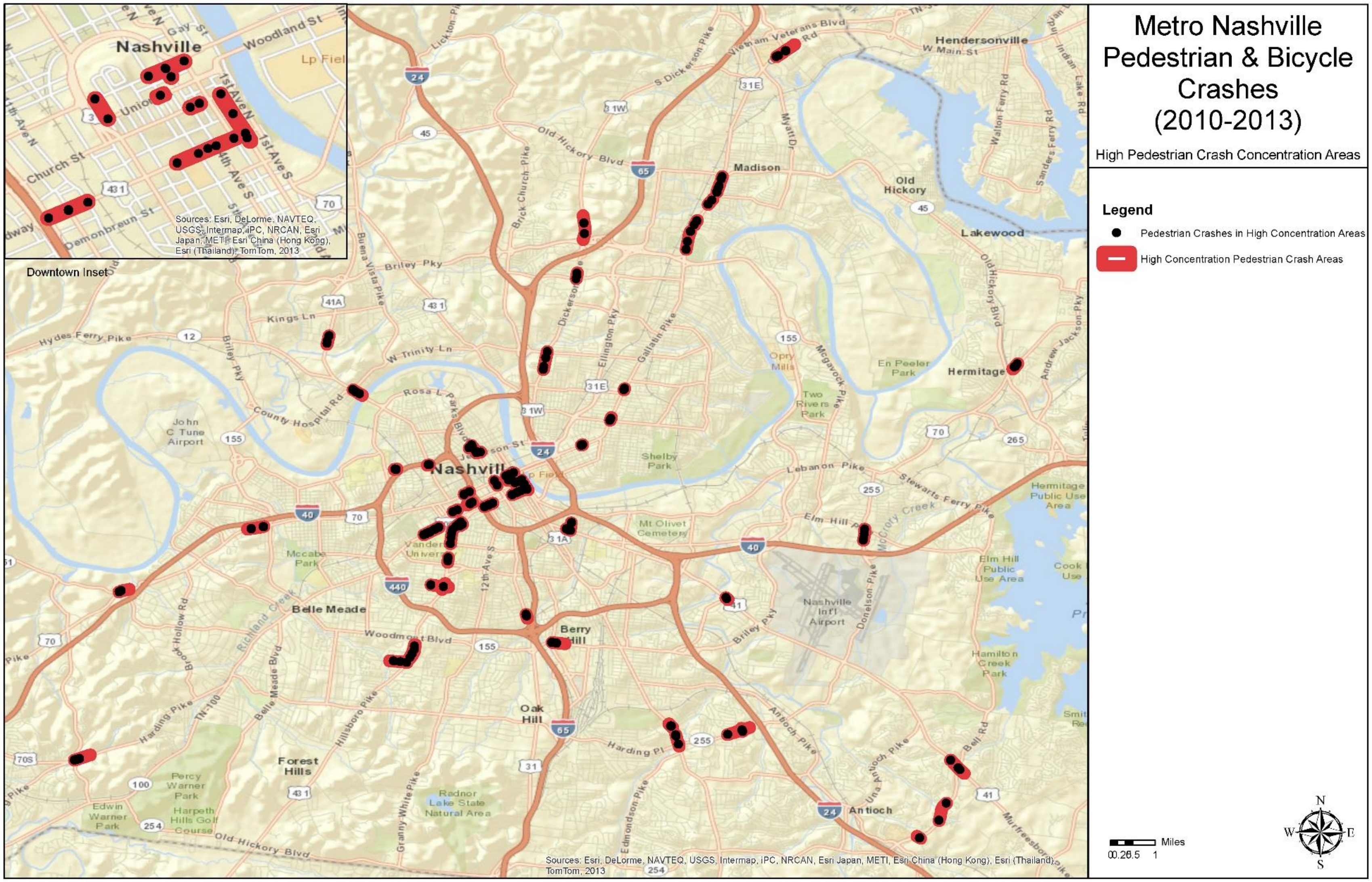

Figure 1 Pedestrian High Crash Locations

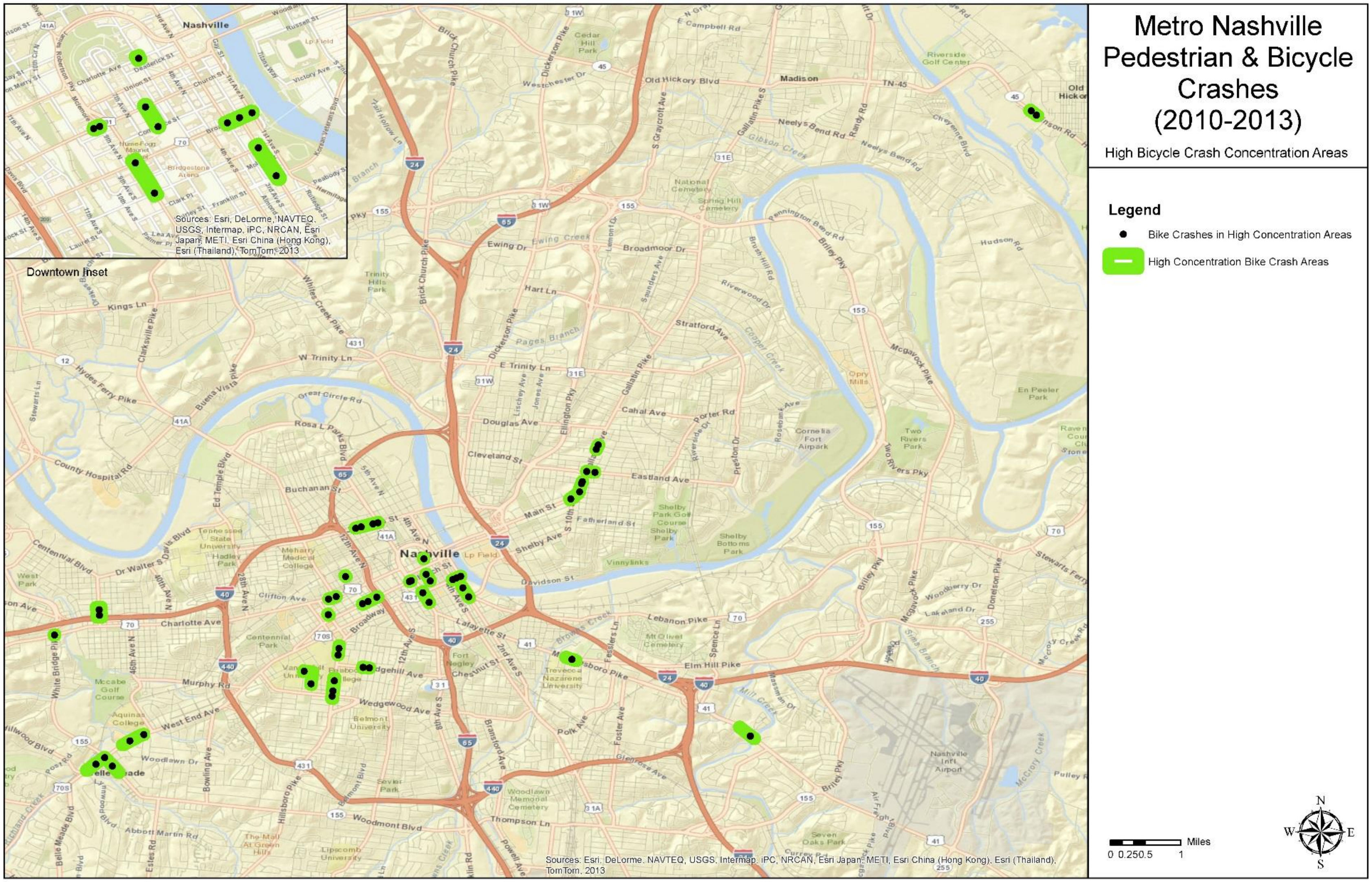

Figure 2 Bicycle High Crash Locations

3 Methodology for Assessing Hazardous Conditions

Before conducting field reviews of the top locations, crash map diagrams were created to depict the types of crashes that occurred at each of the high crash locations. To accurately map the crash types, individual crash reports were pulled from MNPD's database for all 75 high crash locations. Specific information from the crash reports was recorded in an Excel spreadsheet such as time and date of the crash, injury codes for the drivers and the pedestrian/bicyclist, if there was alcohol present, etc. Additionally, the narratives provided in the reports by police officers helped to pinpoint the specific locations of the crashes. This was beneficial as the geocoding procedure could not address crashes that occurred in parking lots or outside the roadways.

3.1 Field Review Procedures

After crash map diagrams were created, field reviews were conducted for each of the 75 high crash locations. This field review process constituted visiting each location and documenting various conditions at the intersections, on the roadways, and in the surrounding areas. Specifically, land uses, transit accessibility, geometric design elements, pedestrian and bicycle accommodations, signage, and signalization were recorded for each location on a field review sheet shown in Appendix A through a methodical process documented in a Procedures Manual in Appendix B. While in the field, potential safety issues were identified and documented along with possible mitigation solutions and/or strategies.

3.2 Methods for Selecting Top Crash Locations

After field reviews were conducted, each of the 75 locations was examined more thoroughly for cost-effective, easily-implementable, and innovative countermeasure solutions. The ideal solution in some locations would be relatively high in cost or would likely take longer to implement; however, an attempt was made to recommend an easily-implementable countermeasure from the toolbox for each high crash location. Based on the information collected from the crash reports as well as the field reviews, the 75 high crash locations were then categorized into the following two groups: locations that had a pattern of crashes and/or a possible countermeasure solution and locations where crashes seemed to be random and/or did not appear to have an easily-implementable solution.

From this point, a variety of solutions was considered in determining the top 17 locations for which countermeasure concept plans would be developed. This process ultimately resulted in the tables presented in Appendix C, which detail the proposed countermeasure(s) for each of the 75 locations and the justification for not selecting locations for the development of concept plans. Reasons for not selecting certain locations for the initial run of countermeasure implementation included the following:

- Recent improvements to intersection and/or segments have been made since time of crashes
- Capital investments underway and/or projects currently planned for location
- Uncertainty regarding the potential effectiveness of the countermeasure
- Apparent randomness of crash occurrence
- Location of crashes outside Metro Nashville Public Works' control (i.e. private property parking lots)
- Need for major investments, beyond the extent of this study

Through coordination with Metro Nashville Public Works, 14 locations were chosen based on the feasibility of implementing a variety of countermeasures within Metro Nashville. These 14 locations included seven to address pedestrian safety concerns and seven to address bicyclist safety concerns. Countermeasure concept plans for these locations.

4 Establishment of Countermeasures

One of the primary purposes of this project was to research a variety of countermeasures that could be implemented to address the safety concerns that come with pedestrian and bicyclist usage of roadways. Specifically, this study aimed to examine and identify countermeasures that were relatively low in cost, quickly implementable, and could have the highest transferability application to other locations within Metro Nashville based on the evaluated crashes. A variety of literature exists documenting case studies and research on pedestrian and bicycle safety countermeasures, conducted both internationally and domestically. Using this information, a list was compiled of proven cost-effective countermeasures. Each of these solutions is specifically designed to accomplish certain goals, whether that be reducing vehicular speeds, reducing conflicts, improving pedestrian visibility, among many others. As such, each countermeasure may only be applicable and/or appropriate in selected situations.

In order to establish a toolbox of countermeasures, each of the 75 'high crash locations' were examined individually for problems that pedestrians and/or bicyclists experience. These problems were classified into one of the following three categories: conflicts, exposure, and vehicular speeds. Additionally, each of these problems was examined at both a segment and intersection level. In developing the toolbox, countermeasures were classified in the following three groups based on the intended outcome of their implementation:

- reducing conflict between pedestrians and/or cyclists and vehicles,
- reducing the exposure of pedestrians and/or bicyclists, and
- alerting the motorist as to the presence of pedestrians and/or bicyclists in order to reduce their speeds.

Countermeasures were also classified by the following types: signalization improvements, signs and markings, and geometric/roadway improvements. From this point, the data-driven countermeasures were assigned to populate the matrices below, one for pedestrian countermeasures, shown in Table 3, and one for bicycle countermeasures, shown in Table 4. Appendix D provides additional information on each proposed countermeasure application contained in the toolbox.

In addition to the countermeasures listed in the toolbox, which were derived from the evaluation of crash locations as part of this study, Tables 5 and 6 includes a series of other countermeasures which may have application in the Metro Nashville area. These additional countermeasures range in effectiveness and seek to employ innovative applications that have shown proven success in promoting safe environments for non-motorized users in other communities. Information on these countermeasures as well as other innovative applications can be found in the following available resources:

- The Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE), FHWA. http://www.pedbikesafe.org/PEDSAFE
- The Bicycle Countermeasure Selection System (BIKESAFE), FHWA. http://www.pedbikesafe.org/BIKESAFE
- Urban Street Design Guide and Urban Bikeway Design Guide, NACTO. http://nacto.org
- Guide for the Development of Bicycle Facilities, 2012, 4th Edition, AASHTO.
- The Manual on Uniform Traffic Control Devices (MUTCD), FHWA. http://mutcd.fhwa.dot.gov

Table 3 Pedestrian Countermeasure Toolbox

Goal / Countermeasure	Reduce Conflict	Reduce Exposure	Reduce Vehicle Speed / Alerting Motorist
Signalization	• Automated Pedestrian Detection • Increase Pedestrian Crossing Time • Install Pedestrian Signals • Leading Pedestrian Interval • Left Turn Phasing • Pedestrian Scramble	• Pedestrian Hybrid Beacon (HAWK) • Leading Pedestrian Interval	• Pedestrian Hybrid Beacon (HAWK)
Geometric/Roadway	• Fencing, Gating, or Landscaping	• Fencing, Gating, or Landscaping • Pedestrian Refuge Island • Road Diet	• Raised Pedestrian Crosswalk • Street Lighting
Signs & Markings	• Advance Stop Lines • High-Visibility Crosswalk • Prohibit Right-Turn-On-Red	• Advance Stop Lines • Advance Yield Markings • High-Visibility Crosswalk • Rectangular Rapid Flash Beacon	• Advance Yield Markings • High-Visibility Crosswalk • Rectangular Rapid Flash Beacon • Advanced Warning Signs and Devices

Table 4 Bicycle Countermeasure Toolbox

Goal / Countermeasure	Reduce Conflict	Reduce Exposure	Reduce Vehicle Speed / Alerting Motorist
Signalization	• Bike-Activated Signal • Optimize Signal Timing	• Bike-Activated Signal • Optimize Signal Timing	
Geometric/Roadway	• Dedicated Bike Lanes • Parking Treatments • Wide Outside/Curb Lanes	• Dedicated Bike Lanes • Fencing, Gating, or Landscaping • Parking Treatments • Road Diet	• Road Diet • Street Lighting
Signs & Markings	• Bike Box • Bike Pockets for Right Turns • Colored pavement • Rerouting Bike Routes • Turning Restrictions	• Rerouting Bike Routes	• Advanced Warning Signs and Devices • Bike Box

Table 5 Additional Pedestrian Countermeasures for Consideration

Goal / Countermeasure	Reduce Conflict	Reduce Exposure	Reduce Vehicle Speed / Alerting Motorist
Signalization	• Automated Pedestrian Detection	• Automated Pedestrian Detection	
Geometric/Roadway	• Sidewalks • Bus Stop Relocation • Curb Extensions • Grade Separated Crossings • Medians and Crossing Islands • Shared Use Paths	• Sidewalks • Bus Stop Relocation • Curb Extensions • Grade Separated Crossings • Medians and Crossing Islands • Shared Use Paths	• In-Pavement Flashing Lights • Raised Crosswalks
Signs & Markings	• Back-In Angled Parking		

Table 6 Additional Bicycle Countermeasures for Consideration

Goal / Countermeasure	Reduce Conflict	Reduce Exposure	Reduce Vehicle Speed / Alerting Motorist
Signalization	• Bicycle Signals	• Bicycle Signals	
Geometric/Roadway	• Bicycle Boulevards • Bike Lanes • Buffered Bike Lanes • Bus Bike Lanes • Cycle Tracks • Grade Separated Crossings • Left Side Bike Lanes • Paved Shoulders • Shared Use Paths	• Bicycle Boulevards • Bike Lanes • Buffered Bike Lanes • Bus Bike Lanes • Cycle Tracks • Grade Separated Crossings • Left Side Bike Lanes • Paved Shoulders • Shared Use Paths	
Signs & Markings	• Back-In Angled Parking	• Bicycle Boulevards	• Combined Bike Lane/Turn Lane

5 Development of Crash Profiles

To further Metro Nashville Public Works' ability to carry this process forward, efforts were undertaken in order to develop crash profiles by looking at all 1,199 crashes in Davidson County including the 357 crashes found to be in 'high crash zones'. However, due to limitations of the original crash database, this process was not used to refine the top study locations as originally intended; instead, it was later used to determine the presence or absence of relationships between the number of crashes that occur within a geographical area and certain characteristics of that area. As such, it can be used going forward to examine potential causes of crashes within an area.

5.1 Countywide Crash Analysis

As previously mentioned, there were 1,199 pedestrian and bicycle crashes geocoded within Metropolitan Nashville and Davidson County, spanning 2010 to mid-2013. In order to examine the relationship between crash frequency and different socioeconomic and demographic variables, data from the American Community Survey (ACS) was obtained. This data is issued each year by the U.S. Census Bureau and contains estimates of different socioeconomic and demographic characteristics for the population within census geographies; for this analysis, census block groups were used. Census block groups are the smallest geographical unit for which sample data is released, meaning that data was obtained for a sample of households, and the Census Bureau later released their corresponding estimates of variables. Census block group populations typically range from 600 to 3,000 people. In Davidson County, there are 4,125 census block groups with an average population of 1,540 people.

Certain socioeconomic and demographic variables have been shown to have relationships with the propensity for crash occurrence. As such, these variables were pulled from the ACS dataset for each census block group in the study area. Table 7 below shows the variables that were thought to be potentially related to crash occurrence as well as their relevance for Metropolitan Nashville and Davidson County.

Table 7 Important Socioeconomic and Demographic Variables

Variable	Statistics for Metropolitan Nashville and Davidson County
Auto-Ownership	6.2% of Households have Zero Vehicles
Disability Status	28.8% of Households have a Member with a Disability
Race	21.6% of the Population is a Minority
Poverty Status	16.3% of Households are Below the Poverty Line
Population Over 65	13.5% of the Population is Over Age 65

Using the variables listed above, a statistical analysis was undertaken to examine the correlations between these variables and the number of crashes occurring within each census block group. In order to do this, GIS was used to sum the number of crashes that occurred in each census block group over the 3-year time period. From this point, a short program was written for a statistical package called R in order to produce a correlation coefficient, commonly referred to as r^2, for each of these variables to help explain their relationship to crash occurrence. Table 8 below shows the correlation coefficients associated with each of the aforementioned variables. These numbers may be interpreted as a percentage of variability in crash occurrence that is explained by the variable; the closer to one, the better, as a value of one would indicate that the variable completely explains the number of crashes that occur within a census block group. Additionally, the algebraic sign of these correlation coefficients is indicative of the type of linear relationship between the two variables.

Table 8 Results from Correlation Analysis

Variable	Correlation with Crash Occurrence
Percent of Households with Zero Vehicles	0.10003
Percent of Households with a Disabled Member	-0.0953
Percent of Population that is a Minority	0.092806
Percent of Households below the Poverty Line	0.043346
Percent of Population Over Age 65	-0.09953

The interpretations for these variables are as follows:

- Approximately 10.0% of the variability in the number of crashes in a census block group can be explained by the percent of households with zero vehicles. Additionally, a positive algebraic sign indicates that the number of crashes can be expected to increase with an increased percentage of homes with no vehicles.
- Approximately 9.5% of the variability in the number of crashes in a census block group can be explained by the percent of households with a disabled member. Additionally, a negative algebraic sign indicates that the number of crashes can be expected to decrease with an increased percentage of homes containing a member who is classified as disabled.
- Approximately 9.3% of the variability in the number of crashes in a census block group can be explained by the percent of population that is not white. Additionally, a positive algebraic sign indicates that the number of crashes can be expected to increase with an increased percentage of minority population.
- Approximately 4.3% of the variability in the number of crashes in a census block group can be explained by the percent of households below the poverty line. Additionally, a positive algebraic sign indicates that the number of crashes can be expected to increase with an increased percentage of households below the poverty line.
- Approximately 10.0% of the variability in the number of crashes in a census block group can be explained by the percent of the population above age 65. Additionally, a negative algebraic sign indicates that the number of crashes can be expected to decrease with an increased percentage of population above this threshold.

These correlations revealed the anticipated relationships between these variables and crash occurrence. Having no vehicles available within a household or no income to purchase a vehicle increases the likelihood of using non-motorized modes for travel and thereby increases the likelihood of a crash occurring simply due to increased exposure; therefore the positive relationship implied by the correlations for these variables is explainable. Similarly, people over the age of 65 and those with disabilities are less likely to walk or bike due to physical constraints; therefore, the negative relationship seen in the correlations for these variables is logical.

One thing to consider in any statistical analysis is the interaction between variables. In this study, for instance, the percent of households below the poverty line is likely to be related to the percent of households with zero automobiles due to the relationship between income and the ability to purchase vehicles. Obviously, without adequate income, vehicles cannot be purchased; therefore, one variable can affect or be dependent on the other. Interaction effects between variables such as these were not taken into consideration in this analysis as models were not developed due to the relatively weak relationships exposed by the correlation coefficients.

While the correlations between the examined variables and the number of crashes in a census block group were relatively weak, they still exhibited the expected relationships. As such, areas with high percentages of minority population, households with zero automobiles, and households below the poverty line can be anticipated to have slightly increased levels of crash occurrence. Similarly, areas with an aging population and high percentages of disabled population can be expected to have slightly decreased levels of crash occurrence.

5.2 Top Locations Crash Analysis

In order to focus field review efforts and attempt to eliminate some of the randomness associated with pedestrian and bicycle crashes, the total 1,199 crashes were narrowed down to 357 crashes based on concentrations within 75 'high crash zones' as previously described. For these locations, crash reports were collected from the Metro Nashville Police Department and included in the statistical analysis. Additionally, information collected from field reviews of these 75 locations was also included. Table 9 below lists the information collected from both sources; however, not every variable was examined in the statistical analysis.

Table 9 Crash Data Collected

Information Collected	
Crash Reports	Age
	Gender
	Date and Time of Crash
	Weather Conditions
	Lighting Conditions
	Whether it was a Hit & Run
	Location of Crashes (roadway, shoulder, sidewalk, crosswalk, etc.)
	Drug/Alcohol Presence
	Actions by Driver and Pedestrian/Bicycle
	Injury Codes
Field Reviews	Signalization
	Posted Speed Limits
	Cross Section Attributes (number of lanes, sidewalks, shoulders, etc.)
	Presence of On-Street Parking
	Annual Average Daily Traffic (AADT) from TDOT Count Stations
	Presence of Bus Stops
	Land Use (residential, commercial, industrial, medical/office, public use)
	Presence of Schools
	Presence of Bicycle/Pedestrian Accommodations

Before running any statistical analyses, the data collected from crash reports was inspected to see if any surface level relationships could be found. With regard to person characteristics, the gender and age were looked at for both the driver of the vehicle involved and the pedestrian or bicyclist. Because race is not documented for the pedestrian or bicyclist in crash reports, it is difficult to infer a relationship between it and crash occurrence; however, areas with higher minority populations have shown to have a relatively higher correlation with the crash occurrence as previously mentioned. Furthermore, the time, location, and presence of alcohol were examined for both pedestrian and bicycle crashes. For the time of crashes, 'day' was considered 6:00 AM to 6:00 PM and 'night' was considered 6:00 PM to 6:00 AM. For the involvement of alcohol in crashes, hit and run crashes were not included in the calculation as the sobriety of the driver was not known. Table 10 below shows the crash-specific variables examined from the crash report data.

Table 10 Crash Report Variables

Variable	Pedestrian Crashes	Bicycle Crashes
Male Drivers	57%	60%
Female Drivers	43%	40%
Male Pedestrian/Cyclist	60%	77%
Female Pedestrian/Cyclist	40%	23%
Crashes Involving Alcohol	11%	2%
Crashes Occurring in Day	39%	84%
Crashes Occurring in Night	61%	16%
Average Driver Age	45	43
Average Pedestrian/Cyclist Age	40	32
Hit & Run Crashes	29%	15%
Number of Fatalities	8	0
Crash Occurred at Intersections	52%	81%
Crash Occurred not at Intersections	48%	19%
Crashes in Parking Lots	19%	9%
Crashes near Bus Stops	97%	94%

A variety of observations can be made from the information presented in this table. Simply due to increased exposure, male cyclists are more likely to be involved in a crash than female cyclists. Additionally, it appears that cyclists are more likely to be hit during the day when riding, whereas pedestrians are more likely to get hit during the evening hours. Although there were no bicycle crash fatalities in Davidson County for the time period examined, the data for all 1,199 crashes supports observed trends nationally that show fatalities are more likely to occur in pedestrian crashes versus bicycle crashes. This table also shows that pedestrians are almost equally as likely to be hit at an intersection as they are outside of an intersection area; bicyclists on the other hand are primarily hit at intersections. The data also highlights areas of non-motorized safety that can be addressed through educational efforts. Specifically, the number of pedestrian accidents that are hit and run exemplifies the need to inform residents of legal obligations in any crash scenario, but particularly in pedestrian crash situations where injuries are much more common. Furthermore, the number of crashes that occurred in parking lots seemed relatively high for pedestrians, showing the need for a potential reevaluation of design standards for pedestrian crossings within private property.

Initially, it was anticipated that a profile would be developed to predict whether a crash would occur based on specific variables including crash-specific data from the crash reports as well as non-crash data obtained from field reviews. This would usually be accomplished using logistic regression procedures to model a binary response, in this case, whether a crash occurred or did not occur. However, in order to accurately model the occurrence or probability of a crash based on a set of random variables, there must also be data collected on locations where crashes have not occurred. Since this study did not collect data in instances where crashes did not occur, a binary logistic regression model could not be developed. Instead, variables from the field reviews were used to simply examine the relationships between these variables and the number of crashes in a high crash zone.

A short program was written for the statistical package R to determine the statistical significance of certain variables and their relationship to the number of crashes that occurred in the 75 'high crash zones'. For this process, pedestrian and bicycle crashes were examined independently as it was anticipated the variables could possibly have different impacts on the different modes. It is important to note that some of these variables are continuous and some are categorical. For instance, the AADT of the major roadway in the zone is modeled as a continuous variable because it can take on any integer value greater than zero; conversely, the presence of different land uses is modeled as categorical, where a value of 1 indicates that the use is present in the zone and a value of 0 indicates that it is not. For this reason, the continuous variables and their corresponding p-values are shown below in Table 11 while the categorical variables and their corresponding p-values are shown in Table 12.

To examine the statistical significance of each variable, the number of crashes in a high crash zone was modeled as a function of each variable separately. Using hypothesis testing outputs from Analysis of Variance (ANOVA) regression procedures, the variables shown in Tables 11 and 12 below were then examined to determine if there are linear relationships between the number of crashes in a zone and each of the variables. The values shown represent a 'p-value' that explains the statistical significance of each variable in predicting the number of crashes in a zone; the lower the p-value, the better the variable is at predicting crash occurrence.

Table 11 ANOVA for Continuous Variables

Roadway Variables	**Pedestrian Pr >|t|**	**Bicycle Pr >|t|**
AADT of Major Roadway	0.444	0.5487
Posted Speed of Major Roadway	0.114887	0.1228
Number of Lanes on Major Roadway	0.0513*	0.8954

Table 12 ANOVA for Categorical Variables

Land Use Variables	***Pedestrian Pr >/t/***	***Bicycle Pr >/t/***
Presence of On-Street Parking on Major Roadway	0.01419*	0.1525
Presence of Bus Stops in Zone	0.3109	0.1375
Presence of Residential Land Use in Zone	0.7111	0.1269
Presence of Commercial Land Use in Zone	0.545	0.4484
Presence of Industrial Land Use in Zone	NA	0.2743
Presence of Office/Medical Land Use in Zone	0.837	0.5192
Presence of Schools in Zone	0.1045	0.6927
Presence of Tourism/Entertainment Establishments in Zone	<0.0001*	0.02718*
Presence of Hotels/Motels in Zone	0.5737	0.1677
Presence of Liquor Establishments in Zone	0.9184	0.8295

*Statistically significant at the 0.10 level

From these p-values it can be inferred that for bicycle crashes, the presence of tourism and entertainment land uses is statistically significant in predicting the number of bicycle crashes in a high crash location. The presence of on-street parking, the number of lanes in a roadway cross section, and the presence of tourism and entertainment establishments are all statistically significant variables in predicating the number of pedestrian crashes that occur in a high crash location. While the number of variables that appeared showed to be significant are few, it is important to recall that this analysis did not incorporate any interaction effects between variables. This ultimately means that the effects of one variable could be captured by another.

Based on information obtained in the field reviews, it was expected that the presence of a liquor establishment (i.e. bar, liquor store, etc.) in a zone would have a significant effect on the number of pedestrian crashes that occurred. However, as shown above, the data did not reveal this relationship. As such, a more detailed analysis of pedestrian crashes involving liquor establishments was performed using binary logistic regression techniques. This model attempted to explain whether a pedestrian was under the influence of alcohol based on the presence or absence of liquor establishments nearby. For the purpose of this analysis, liquor establishments were considered to be bars, liquor stores, or convenience stores. It was ultimately found that a pedestrian was 3 times more likely to be under the influence when involved in an accident if there was a liquor establishment nearby than not.

5.3 Summary

Overall, there are many contributing factors in both pedestrian and bicycle crash occurrence. From the statistical analyses performed in this study, conclusions can be derived to determine the increased or decreased potential for pedestrian and bicycle safety issues in an area. For all of Metro Nashville, increased percentages of minority populations, households below the poverty line, and households with zero automobiles positively impact pedestrian crash occurrence.

Specifically, the analyses showed that the following variables show significant relationships to crash occurrence:

- Number of lanes on the roadway (pedestrian)
- Presence of on-street parking on the roadway (pedestrian)
- Presence of tourism and entertainment establishments within the area (pedestrian and bicycle)

Ultimately, this information can be carried forward in the implementation of countermeasures, design of new facilities, and maintenance of existing facilities.

6 Findings and Recommendations

This section provides a summary of key findings and recommendations from the study. These results serve as a foundation of understanding in terms of pedestrian and bicycle hazards and safety needs throughout Metro Nashville and the range of cost-effective countermeasures available to Metro Public Works for improving roadway safety for all transportation users. In addition to these key findings and summarized recommendations, Appendix C details specific recommendations for each crash location identified as part of this study.

6.1 Findings

- There are a number of factors beyond engineering solutions that need to be explored and/or addressed (i.e. education, awareness, enforcement, and planning) that could greatly improve safety conditions for non-motorized modes within Metro Nashville.
- Using GIS, Metro Nashville's crash data can be used for identifying and assisting in the initial analysis of non-motorized roadway safety locations.
- A detailed review of individual crash reports is necessary to fully understand crash locations and associated safety factors given how crash data is collected and stored within various database structures.
- Site visits are necessary to understand the context of crash locations and environmental features which may influence a crash.
- Proven, cost-effective pedestrian and bicycle safety countermeasures exist that can be used in response to improving safety conditions for non-motorized modes within Metro Nashville.
- Certain socioeconomic variables (i.e. income, vehicle ownership) and the built environment (i.e. number of lanes on the roadway, presence of on-street parking, and surrounding land uses) can and do influence non-motorized crash occurrences.

6.2 Recommendations

- Implement concept plan countermeasures and conduct after studies to determine countermeasure effectiveness
- Consider formalizing the pilot study process as a formal practice within Metro Public Works' efforts to improve safety conditions for non-motorized modes throughout Metro Nashville
- Work with other departments and organizations to explore opportunities to address non-engineering solutions for improving safety conditions for non-motorized modes within Metro Nashville. Examples include:
    - Work with the Metropolitan Transit Authority (MTA) to establish best practices in bus stop placement as a means of reducing pedestrian exposure risks in accessing transit services throughout Metro Nashville
    - Work with the Metropolitan Planning Department to establish best practices in urban form standards which support safe pedestrian and bicycling environments while considering vehicular sight distance needs
    - Work with the Metro's Bicycle and Pedestrian Advisory Committee (BPAC) and the Metro Nashville Police Department to establish public awareness and enforcement campaigns that target safety risks which were found as part of this study

- Work with Metro's Bicycle and Pedestrian Advisory Committee (BPAC) and the Metro Nashville Police Department on ways to ensure improved consistency in crash reporting of incidents involving non-motorized modes

Appendices

Appendix A: Field Review Sheets

Metro Nashville PUBLIC WORKS

METRO PEDESTRIAN & BICYCLE ROAD SAFETY PILOT PROJECT
FIELD REVIEW CHECKLIST

Intersection(s) Segment: ____

Planning Subarea: ______________________ Pedestrian/Bicyclist # Crashes:_________

Date & Time of Field Review: ____

Weather & Lighting Conditions: ____

Auditor(s): ____

Intersection Type: rural / urban all-way stop / side street stop / signals

Posted Speed: Major Approach________ Minor Approach________ State Route?: ______

Number of Travel Lanes: Major Street____________ Minor Street(s)_______________

AADT: Major Street_____________ Minor Street(s)_______________

Sketch of Location:

North

(Please attach photos of each intersection approach.)

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Check all that apply and provide details, as necessary:
Is the visibility of the intersection or any approaches limited by:

☐ Parked or queued traffic? ____________________	☐ Vegetation? ____________________
☐ Signs, utility poles, fences? ____________________	☐ Approach angle? ____________________
☐ Embankments? ____________________	☐ Vertical or horizontal curves? ____________________
☐ Buildings? ____________________	☐ Other sight obstructions? ____________________

Please answer as applies to Location:

Are signs in good condition (vandalized / reflectivity, etc…)? ☐ Yes o Reflective Strips Only? ____________ ☐ No	Is there too much signage (visual clutter or confusing messages)? ☐ Yes (please describe signs to remove) ____________________ ☐ No
Is pavement marking clearly visible (daylight and dark) and appropriate for the conditions? ☐ Yes ☐ No (please describe) ____________ o Restripe?____________ o New Install?____________	Are traffic control devices clearly visible in advance of the intersection (daylight & dark)? ☐ Yes ☐ No
Is there sufficient street lighting/pedestrian scale lighting: (Describe) ☐ Yes ☐ No	Describe the bus facilities (location, etc.):

Describe Pedestrian/Bicycle Facilities or Lack of facilities:

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Metro Nashville
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Describe Surrounding Land Uses & Pedestrian/Bicycle Patterns:

____

____

____

Are any of the below items within the project limits:

☐ Guardrail? Add Delineation Enhancement? ______________________	☐ Bike/Pedestrian Accommodations? ______________________
☐ Snowplowable Reflective Markers or Raised Pavement Markers? ______________________	☐ Fixed object obstructions within the clear zone or area of influence? ______________________
☐ Rumble Strips/Rumble Stripes? ______________________	☐ Railroad? Distance from Intersection? ______________________

Describe any other observed obstructions, concerns, or hazards:

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Describe considered recommendations:

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Appendix B: Procedures Manual

Table of Contents

Table of Figures

Pedestrian and Bicycle Safety Overview

In order to develop a safety program aimed at reducing crashes involving all non-motorized users, Nashville's Metropolitan Public Works (MPW) began a pilot initiative in 2013 to study pedestrian and bicycle safety throughout all of Davidson County. One of the main outcomes of this study was to develop a process that MPW could carry forward to address the crashes involving pedestrians and bicyclists using relatively cost-effective and quickly-implementable safety countermeasures.

The process developed is based upon research, guidance, and standards documented by the Federal Highway Administration, the Manual on Uniform Transportation Control Devices (MUTCD), the National Association of City Transportation Officials (NACTO) Urban Street Design Guide, as well as many other documented research efforts throughout the country and abroad.

This procedures manual has been developed to assist Metro Public Works in the successful completion of a site-specific safety audit process involving pedestrian or bicycle crashes. This effort will blend roadway safety insights, practical engineering judgment, and an understanding of MPW's desire for a consistent process approach. This procedures manual should not replace creative thinking towards sound safety solutions. This manual should be regarded as a guide toward a repeatable procedure and study deliverable.

The on-site safety auditing process may be considered as two (2) different phases as illustrated in Figure 1. This procedures manual discusses each of these phases in depth.

Site Selection (by MPW)

↓

Phase 1: Pre-Site Visit Preparation

1. Intersection identification and mapping
2. Obtain and format aerial images
3. Obtain crash data from MNPD
4. Develop intersection and/or segment crash diagrams
5. Prepare Field Review Sheets

Products: Field Review Sheets, Crash Diagram

↓

Phase 2: Site Visit

1. Field Observations
2. Photo Inventory
3. Preliminary Recommendations

Products: Completed field review sheets including preliminary recommendations, and photo inventory

Figure 1 Pedestrian and Bicycle Safety Process

Before Beginning – The Crash Data

At the onset of the study, MPW will select a site location to be examined using this process. Usually it will be at an intersection or a segment of roadway. MPW will select these locations based on historic crash frequency, reoccurring crashes trends, recent changes in roadway or intersection characteristics, or a combination of factors. This method provides MPW with ample opportunity to decrease the vulnerability of pedestrians and bicyclists in Metro Nashville.

Phase 1: Pre-Site Visit Preparation

The objective of the first phase of the process is to familiarize oneself with the geographic location of each safety evaluation site, the crash experience of each location, and to gather the materials needed to make a comprehensive site visit as efficiently as possible. The location could potentially contain a significant number of intersections, driveways, or conflict points. Thus, being well prepared will maximize the effectiveness of time spent in data collection. The Pre-Site Visit Preparation contains two main elements: site identification and crash data analysis.

The intersection or segment for study will be provided by Metro Nashville's Public Works. Staff will be required to identify and locate each intersection or segment based on the information provided. A map of the chosen intersections and segments should be created using the latest aerial photography or detailed roadmap available. Additionally, crash records for the study location should be obtained from Metro Nashville's Police Department for the designated time period. These crash reports should be read thoroughly to understand the apparent cause for the crash. Crashes could be caused by various contributing factors such as deficiencies in the transportation system, weather conditions, driver or non-motorist actions, influence or alcohol or drugs, etc.

Using the map created, crash diagrams should be developed so that when on the site visit, the location and alignment of each crash is readily known. The following symbols, shown in Figure 2, should be used to construct the crash diagrams. Additionally, it may be helpful to designate each arrow in the crash diagrams as either a pedestrian, bicyclist, or automobile. An example of the finished product is shown in Figure 3. This map will be used in conjunction with the field review sheets shown in Figure 4.

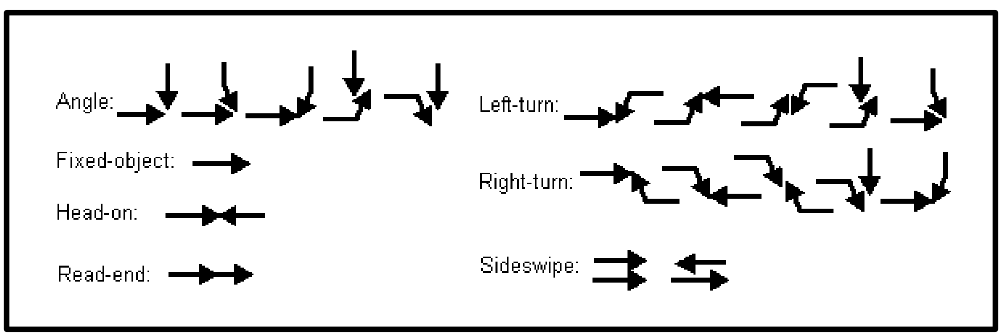

Figure 2 Crash Diagram Symbology

Figure 3 Completed Crash Diagram Map

Metro Nashville PUBLIC WORKS

METRO PEDESTRIAN & BICYCLE ROAD SAFETY PILOT PROJECT
FIELD REVIEW CHECKLIST

Intersection(s) Segment: ____

Planning Subarea: ______________________ Pedestrian/Bicyclist # Crashes: ________

Date & Time of Field Review: ____

Weather & Lighting Conditions: ____

Auditor(s): ____

Intersection Type: rural / urban all-way stop / side street stop / signals

Posted Speed: Major Approach________ Minor Approach________ State Route?: ______

Number of Travel Lanes: Major Street____________ Minor Street(s)_______________

AADT: Major Street_____________ Minor Street(s)_______________

Sketch of Location:

North

(Please attach photos of each intersection approach.)

Page **1** of **3**

Figure 4 Blank Field Review Sheet (1 of 3)

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Check all that apply and provide details, as necessary:
Is the visibility of the intersection or any approaches limited by:

☐ Parked or queued traffic? ____________	☐ Vegetation? ____________
☐ Signs, utility poles, fences? ____________	☐ Approach angle? ____________
☐ Embankments? ____________	☐ Vertical or horizontal curves? ____________
☐ Buildings? ____________	☐ Other sight obstructions? ____________

Please answer as applies to Location:

Are signs in good condition (vandalized / reflectivity, etc…)? ☐ Yes ○ Reflective Strips Only? ____________ ☐ No	Is there too much signage (visual clutter or confusing messages)? ☐ Yes (please describe signs to remove) ____________ ☐ No
Is pavement marking clearly visible (daylight and dark) and appropriate for the conditions? ☐ Yes ☐ No (please describe) ____________ ○ Restripe?____________ ○ New Install?____________	Are traffic control devices clearly visible in advance of the intersection (daylight & dark)? ☐ Yes ☐ No
Is there sufficient street lighting/pedestrian scale lighting: (Describe) ☐ Yes ☐ No	Describe the bus facilities (location, etc.):

Describe Pedestrian/Bicycle Facilities or Lack of facilities:

____
____
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____

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Figure 4 Blank Field Review Sheet (2 of 3)

Describe Surrounding Land Uses & Pedestrian/Bicycle Patterns:

Are any of the below items within the project limits:

☐ Guardrail? Add Delineation Enhancement?	☐ Bike/Pedestrian Accommodations?
☐ Snowplowable Reflective Markers or Raised Pavement Markers?	☐ Fixed object obstructions within the clear zone or area of influence?
☐ Rumble Strips/Rumble Stripes?	☐ Railroad? Distance from Intersection?

Describe any other observed obstructions, concerns, or hazards:

Describe considered recommendations:

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Figure 4 Blank Field Review Sheet (3 of 3)

Phase 2: Site Visit

The objective of Phase 2 is to document the existing intersection or segment and surrounding area's conditions and establish preliminary improvement recommendations for each study area. This requires observing the existing traffic conditions for both motorized and non-motorized users, documenting potential crash factors, noting locations of signs within the study limits, documenting other geometric attributes not apparent or different from existing data sources such as aerial photography, and creating a detailed photo inventory.

During the site visit, staff must accomplish the critical steps for problem determination, develop alternatives in keeping with the scope of the study, and develop a list of possible recommended improvements. The three major components of the Site Visit phase are (a) Site and Surrounding Area Analysis, (b) Photo Inventory, and (c) Recommendations.

Site and Surrounding Area Analysis

On the site visit, multiple safety-related aspects of the intersection or segment and surrounding area should be taken into account. Traffic characteristics, signing and striping, sight distances, roadway characteristics, lighting, pedestrian and bicycle facilities, presence of transit routes and stops, and adjacent intersections, driveways, or railroad crossings can all have an impact on safety. Some deficiencies of the intersection or segment will not fall under the scope of the study, but these and other conditions at each study location should be well documented on the Field Review Sheets to ensure a thorough site analysis to address further questions concerning the location.

The study limits of each intersection or segment are somewhat subjective. Therefore, the intersection and segment analyses should include as much area as needed in order to ensure that all factors potentially causing safety issues are documented.

For safety purposes, at least a two member team is required at all times to conduct site visits.

<u>Traffic Characteristics</u> – Observing traffic behaviors will give insight into possible safety deficiencies and conflict points within the site study area. Characteristics to look for include but are not limited to speed, turning conflicts, stop bar encroachment, vehicle classification mix, and drivers' ability to recognize the presence of non-motorized users at intersections or along segments. It may also be beneficial to both drive and walk through the study area segments as some safety aspects can only become apparent at operating speeds.

<u>Signing/Striping</u> – Any sign pertaining to pedestrian and bicycle usage should be documented in the site visit. Signing characteristics include quality, visibility, type, and placement distance to the centerline of the intersecting street. Also, the type and condition of the pavement marking within the limits of the intersection or segment shall be included in the site visit if applicable to non-motorized traffic (e.g., crosswalks, stop bars, etc.).

<u>Sight Distances</u> – Sight distances at intersections and/or driveways should be observed from all approaches. Sight distance along segments should be documented as well. Simple sight distance improvements such as removal/relocation of small obstructions within the right-of-way (ROW) are generally within the scope of the study. Earthwork, roadway realignment, or removal of obstructions not within the ROW should be documented, but will generally be outside the scope of the safety audit.

Roadway Characteristics – All dimensions and characteristics pertaining to the intersection or segment including type of intersection, number of lanes, lane widths, turn lane lengths, raised concrete islands, speed limits, and access points should be noted while on the site visit if not clearly identifiable on aerial photography. Traffic volumes on roadways will be difficult to approximate in the field and will likely need to be determined from outside sources such as count station volumes maintained by the Tennessee Department of Transportation.

Lighting – Lighting (illumination) conditions at the study area should be noted on the site visit.

Bicycle/Pedestrian Facilities – Bicycle and/or pedestrian facilities within the vicinity of the intersection or along a roadway segment should be noted. These include bike lanes, bike routes, sidewalks, handicap ramps, trails or greenways, and crosswalks. Additionally, the volumes of bicyclists and pedestrians should be documented as a means of gauging the usage of facilities and the need for improvements.

Special Conditions – School zones, playgrounds, congested areas, on street parking, or other conditions that might have special safety considerations should be noted and preliminary recommendations may be made to address the particular situation presented.

Adjacent Intersections – Any adjacent intersection (identified as a study area intersection or not) that presents additional potential safety issues to the study location should be inspected on the site visit, and, if engineering judgment deems necessary, included within the scope of the study.

Land Use – Land uses within the vicinity of the study area should be documented as different types of development often generate varying levels of pedestrian and bicycle activity. Any nearby areas with development occurring should also be noted as well as its anticipated impacts in the area.

Transit Facilities – Knowing that pedestrian and bicycle trips are often the first and last leg of transit trips, the presence of public transportation in the study area is important to document. Bus stop location, route numbers, amenities, and relative usage should all be recorded during the site visit.

Photo Inventory

A detailed photo inventory of the study intersections and segments play an integral part in the recommendations and review process later in the safety audit. All aspects discussed above should not only be documented but photographed as well. The photo inventory should include multiple photographs from every approach at intersections and from each direction along a roadway segment. Additionally, photos documenting specific hazards, seemingly common occurrences (e.g., midblock crossings), or any other potential problem should be included in this inventory of the study area.

Recommendations

Preliminary recommendations should be made while in the field to verify the validity of the improvements based on field observations. Typical improvements within the safety audit process will generally follow (with slight modifications) the guidance as set forth in MPW's Pedestrian and Bicycle Safety Pilot Project. Typical safety countermeasures will include cost-effective and easily-implementable solutions where appropriate. In all areas, careful engineering judgment should be used to try to address apparent safety problems while keeping the objective of low-cost, easy-to-implement countermeasures in mind.

The site visit is to provide officials with an in depth knowledge of the study area and provide a basis for recommendations to address the safety deficiencies present. After the site visit, the completed Field Review Sheet should contain enough information to give someone who has not been to the study intersection a detailed understanding of the study area location. A completed Field Review Sheet is provided as Figure 5.

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METRO PEDESTRIAN & BICYCLE ROAD SAFETY PILOT PROJECT
FIELD REVIEW CHECKLIST

Intersection(s) Segment: Nolensville Pike between Harding & Welshwood

Planning Subarea: Southeast Nashville (Pedestrian)/Bicyclist # Crashes: 10

Date & Time of Field Review: 10/18/13 9:00 a.m.

Weather & Lighting Conditions: clear, slightly foggy

Auditor(s): PJE / KMK

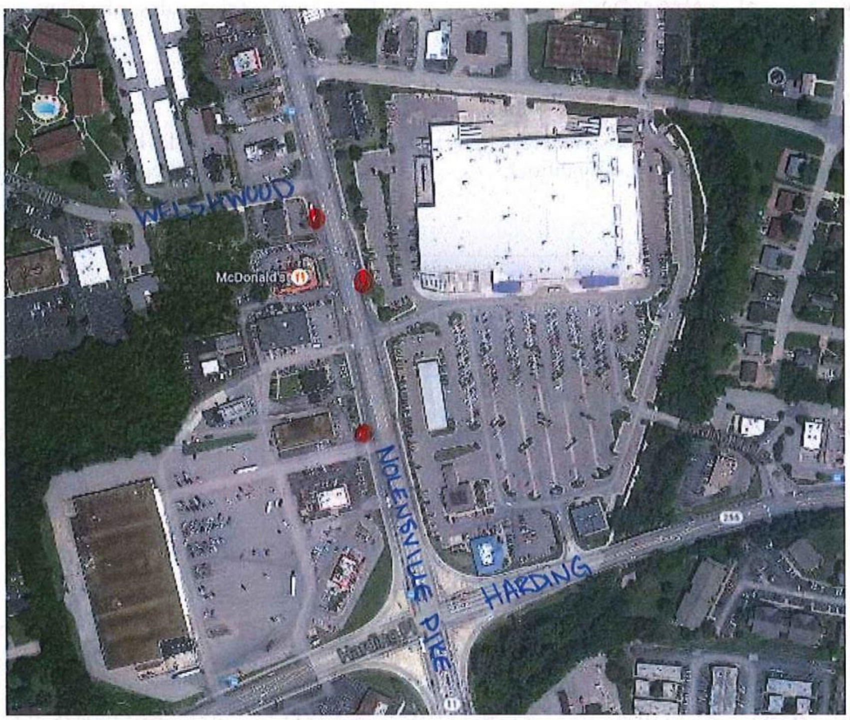
Intersection Type: rural / (urban) all-way stop / (side street stop) – Welshwood / (signals) – Harding

Posted Speed: Major Approach 40 Minor Approach 40 - Harding State Route?: 11

Number of Travel Lanes: Major Street 5 Minor Street(s) 4 - Harding, 2 - Welshwood

AADT: Major Street 44,757 (2012) Stn. 204 Minor Street(s) 29,419 (2012) Stn. 203 - Harding

Sketch of Location:



North

(Please attach photos of each intersection approach.)

● = bus stop

Page **1** of **3**

Figure 5 Completed Field Review Sheet (1 of 3)

Metro Nashville PUBLIC WORKS

Check all that apply and provide details, as necessary:
Is the visibility of the intersection or any approaches limited by:

☐ Parked or queued traffic? NA	☐ Vegetation? NA
☐ Signs, utility poles, fences? NA	☐ Approach angle? NA
☐ Embankments? NA	☐ Vertical or horizontal curves? NA
☐ Buildings? NA	☐ Other sight obstructions? NA

Please answer as applies to Location:

Are signs in good condition (vandalized / reflectivity, etc…)? ☒ Yes - at intersections o Reflective Strips Only? ☒ No - along segment, there are no ped-related signs	Is there too much signage (visual clutter or confusing messages)? ☐ Yes (please describe signs to remove) ☒ No
Is pavement marking clearly visible (daylight and dark) and appropriate for the conditions? ☒ Yes ☐ No (please describe) o Restripe? o New Install?	Are traffic control devices clearly visible in advance of the intersection (daylight & dark)? ☒ Yes ☐ No
Is there sufficient street lighting/pedestrian scale lighting: (Describe) ☒ Yes Pedestrian on site said some street lights are out. ☐ No	Describe the bus facilities (location, etc.): 3 stops in area - 1 on east side of N.P. 2 on west side of N.P. Routes #12 & #72

Describe Pedestrian/Bicycle Facilities or Lack of facilities:
wide shoulders along Nolensville Pike, intermittent sidewalks on SB Nolensville Pike, wide sidewalks along NB Nolensville Pike, no signs warning of pedestrian activity on segment or at intersections, crosswalks & ped signals at Harding intersection

Page 2 of 3

Figure 5 Completed Field Review Sheet (2 of 3)

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Describe Surrounding Land Uses & Pedestrian/Bicycle Patterns:
Wal-Mart, K-Mart, McDonald's, fast food, convenience/liquor/tobacco stores. Some cyclists, but lots of peds, high usage of bus stops, apartments west of Nolensville Pike

Are any of the below items within the project limits:

☒ Guardrail? Add Delineation Enhancement? along NB Nolensville Pike	☒ Bike/Pedestrian Accommodations? Ped at Harding intersection
☐ Snowplowable Reflective Markers or Raised Pavement Markers?	☐ Fixed object obstructions within the clear zone or area of influence?
☐ Rumble Strips/Rumble Stripes?	☐ Railroad? Distance from Intersection?

Describe any other observed obstructions, concerns, or hazards:
Bus stop mid-block on NB Nolensville Pike, Peds cross to get to Wal-Mart and don't use sidewalk south to enter Wal-Mart, very compacted dirt path behind gaurdrail → see photo inventory

Describe considered recommendations:
- Mid-block crossing to accommodate heavy bus traffic and heavy ped traffic from apartments to Wal-Mart
- Crosswalk w/ flashers? HAWK?
- Increased signage for yielding to pedestrians

Page 3 of 3

Figure 5 Completed Field Review Sheet (3 of 3)

Appendix C: Potential Countermeasures for Crash Locations

The following defines and explains the columns for the following tables, which include details on each crash location addressing both pedestrian and bicyclist safety:

- Zone – The zone is a number assigned to each high crash location. In most instances zone numbers are assigned in ascending order based on the number of crashes within that zone.
- Pedestrian/Bicycle Location – The pedestrian/bicycle location is a description of the boundary of the high crash zone. This can include a single intersection and/or a segment of roadway.
- Number of Crashes – The number of crashes is the total number of geocoded crashes within the pedestrian/bicycle zone.
- Description of Possible Solution – This column describes a potential cost-effective, innovative solution to address the observed safety issues within each zone.
- Classification of Countermeasures – These two columns classify the recommended countermeasure into the categories outlined in the countermeasure toolbox, shown in Section 4. The countermeasures are classified by the type of improvement (i.e. signs and markings, geometric/roadway, or signalization) as well as the goal of implementation (i.e. reduce conflict, reduce exposure, or alert motorist).
- Additional Evaluation Comments – In the event that a crash location was not identified for the development of concept plans for countermeasure implementation, a reason is provided as to why the location was not selected. Reasons include the following:
  - The zone includes an ongoing or proposed capital improvement project (CIP).
  - The safety issues identified require major investments beyond the scope of this study.
  - Improvements have been made at the location since the date of the crashes that potentially improve pedestrian and/or cyclist safety. Alternatively, the location may be part of a separate study that addresses safety of pedestrians and/or cyclists.
  - The effectiveness of the recommended countermeasure may be greater at other crash locations.
  - The majority of crashes in the zone occurred on private property (e.g., parking lots), where MPW has little influence in terms of countermeasure implementation.

Pedestrian Countermeasures

Zone	Pedestrian Location	Number of Crashes	Description of Possible Solution	Classification of Countermeasures		Additional Evaluation Comments
1	Broadway between 3rd Ave and 6th Ave	17	Advanced warning signs to indicate high pedestrian activity; "Look!" pavement markings	Signs and Markings	Reduce Conflict, Alert Motorist	
2	West End Ave between 25th Ave and Louise Ave	13	“Cross Only at Crosswalks” signs and wayfinding	Signs and Markings	Reduce Exposure	CIP (AMP)
3	Nolensville Pike between Harding Place and Welshwood Dr	10	Midblock crossing with pedestrian actuated signal, HAWK, or signalization of Wal-Mart access	Signs and Markings, Signalization	Reduce Conflict	
4	Donelson Pike between Elm Hill Pike and Shacklett Drive	9	Pedestrian refuge with median extensions on WB Royal Parkway	Geometric/Roadway	Reduce Exposure	
5	Broadway between George E. Davis Blvd and 11th Ave	9	Increase pedestrian crossing time; leading pedestrian interval	Signalization	Reduce Conflict	CIP (AMP)
6	Abbott Martin Pike between Hillsboro Rd and Hillsboro Cr	8	Crosswalk at Dillard's driveway with Rectangular Rapid Flashing Beacon (RRFB)	Signalization	Reduce Conflict, Alert Motorist	
7	21st Ave between Children's Way and Pierce Ave	8	New signal should address pedestrian/vehicle conflicts			CIP (Planned Signal Improvement)
8	2nd Ave N between Church Street and Broadway	8	Remove parking on 2nd Ave, expand pedestrian realm, increase lighting	Geometric/Roadway	Reduce Exposure	
9	Gallatin Pike between Shepherd Hills Dr and Liberty Ln	8	Extensive sidewalk, crosswalk, and signalization improvements	Geometric/Roadway	Reduce Exposure	Major investment needed
10	Murfreesboro Pike between Bell Road and Rural Hill Rd	7	Crosswalk relocation and increased signage on Rural Hill Rd.	Signs and Markings	Reduce Exposure, Alert Motorist	
11	Harding Place between Tampa Dr and Linbar Dr	7	Crosswalks and pedestrian signals at Linbar Dr.; sidewalk extension on Linbar Dr.	Signs and Markings, Geometric/Roadways	Reduce Exposure, Reduce Conflict	
12	21st Ave between 19th Ave South and Edgehill Ave	12	Increased signage to address pedestrian/cyclist conflicts; advanced warning signs for high pedestrian activity; include walk phase in signal timing	Signs and Markings, Signalization	Reduce Conflict, Alert Motorist	

Zone	Pedestrian Location	Number of Crashes	Description of Possible Solution	Classification of Countermeasures		Additional Evaluation Comments
13	Lafayette St between Charles Davis Blvd and Claiborne St	7	Barrier to minimize midblock crossings, improve intersection of Lafayette and Claiborne	Geometric/Roadway	Reduce Exposure	Recent improvements were made to intersections
14	Charlotte Ave between 3rd Ave N and 5th Ave N	7	New signal phase for pedestrian scramble with complementary signage	Signalization, Signs and Markings	Reduce Conflict, Alert Motorist	
15	Clarksville Pike between Buena Vista Pike and Cliff Dr	7	Leading pedestrian interval at Buena Vista; Turning Vehicles Yield To Pedestrians" sign to warn of pedestrians in crosswalk	Signalization, Signs and Markings	Reduce Conflict, Alert Motorist	Countermeasure effectiveness may be limited and/or greater at other locations
16	Gallatin Pike between Due West Ave and Berkley Dr	7	Add pedestrian accommodations at Due West, "Turning Vehicles Yield To Pedestrians" sign on Berkley EB approach	Signalization, Signs and Markings	Reduce Conflict	Improvements beyond countermeasures may be required (i.e. sidewalk, ADA improvements, etc.)
17	Thompson Lane between Bransford Ave and E Iris Dr	6	Provide sidewalk and crosswalk connections; convert striping to concrete island for pedestrian refuge	Geometric/Roadway	Reduce Conflict, Reduce Exposure	
18	Rosa L Parks Blvd between Jefferson St and Monroe St	6	Sign for "Cross Only at Crosswalks"	Signs and Markings	Reduce Exposure and Reduce Conflict	Countermeasure effectiveness may be limited and/or greater at other locations
19	Lebanon Pike near Tyler Dr	6	Retime signals to increase pedestrian crossing time, install pedestrian signals	Signalization	Reduce Conflict	Improvements beyond countermeasures may be required (i.e. sidewalk, ADA improvements, etc.)
20	Dickerson Pike between Trinity Ln and Gatewood Ave	6	Increase sidewalk infrastructure on southbound Dickerson Pike	Geometric/Roadway	Reduce Exposure	Major investment needed
21	Gallatin Pike between Harrington Ave and south of Maple St	6	High-visibility crosswalk and/or Pedestrian Hybrid Beacon (HAWK)	Signs and Markings, Signalization	Reduce Conflict	
22	21st Ave and Blair Blvd	5	Signage to reduce vehicular/pedestrian conflict; leading pedestrian interval	Signs and Markings, Signalization	Reduce Conflict, Reduce Exposure	
23	Charlotte Ave between Lellyett St and Oceola Ave	5	Increase sidewalk infrastructure on Charlotte	Signalization, Geometric/Roadway	Reduce Exposure	Major investment needed
24	Church St between 15th Ave N and 16th Ave N	5	Rectangular Rapid Flashing Beacon (RRFB)	Signalization	Reduce Conflict, Alert Motorist	
25	Gallatin Pike between Eastland Ave and Chickamauga Ave	5	Sign "Cross Only at Crosswalks"	Signs and Markings	Reduce Conflict	Countermeasure effectiveness may be limited and/or greater at other locations

Zone	Pedestrian Location	Number of Crashes	Description of Possible Solution	Classification of Countermeasures		Additional Evaluation Comments
26	Hillsboro Pike between Graybar Ln and Abbott Martin Rd	5	Sign "Cross Only at Crosswalks"	Signs and Markings	Reduce Conflict	Countermeasure effectiveness may be limited and/or greater at other locations
27	Bell Rd and Mount View Rd	4				Majority of crashes in parking lot
28	Bell Rd between Hickory Highlands Dr and Zelida Ave	4	Pull stop bar back on Zelida	Signs and Markings	Reduce Conflict	Countermeasure effectiveness may be limited and/or greater at other locations
29	US70 South and Old Hickory Blvd	4	Increased signage; leading pedestrian interval	Signs and Markings, Signalization	Reduce Conflict, Reduce Exposure	
30	Nolensville Pike and Paragon Mills Rd	4				Majority of crashes in parking lot
31	Franklin Pike between Gale Ln and Kirkwood Ave	4	Add pedestrian accommodations at Kirkwood/Franklin Rd intersection	Signalization	Reduce Conflict	New development to provide pedestrian signal accommodation
32	Murfreesboro Pike between Thompson Ln and Bowwood Ct	4	Add pedestrian accommodations at Thompson Lane, sidewalk improvements along Murfreesboro Pike	Signalization, Geometric/Roadway	Reduce Conflict, Reduce Exposure	MPW Top Intersections Project to include pedestrian accommodations
33	Charlotte Pike between River Rd and Davidson Rd	4	Add pedestrian accommodations at River/Charlotte intersection, sidewalk improvements on River	Signalization, Geometric/Roadway	Reduce Conflict, Reduce Exposure	Major investment needed
34	Division St between 19th Ave and Lyle Ave	4	Increase street lighting, provide crosswalks at intersections	Signs and Markings	Alert Motorist	Countermeasure effectiveness may be limited and/or greater at other locations
35	Church St between 18th Ave N and 19th Ave N	4	Signs "Turning Vehicles Yield to Pedestrians"	Signs and Markings	Alert Motorist	Countermeasure effectiveness may be limited and/or greater at other locations
36	Charlotte Ave between I-40/I-65 to 15th Ave N	4	Signs "Turning Vehicles Yield to Pedestrians"	Signs and Markings	Alert Motorist	Countermeasure effectiveness may be limited and/or greater at other locations
37	Church St between 4th Ave N and Printer's Alley	4	MUTCD sign W11-2 (pedestrian warning sign) to warn vehicles exiting parking garage/alley of presence of pedestrians	Signs and Markings	Alert Motorist	Countermeasure effectiveness may be limited and/or greater at other locations
38	Charlotte Ave and Rosa L Parks Ave	4	Add Stop sign at exit of state parking lot, pull stop bar back on WB Charlotte, Add "Turning Vehicles Yield To Pedestrians" sign	Signs and Markings	Reduce Conflict, Alert Motorist	Recent improvements to intersections

Zone	Pedestrian Location	Number of Crashes	Description of Possible Solution	Classification of Countermeasures		Additional Evaluation Comments
39	5th Ave N and Union St	4	Signage to indicate high pedestrian volumes, possible pedestrian scramble	Signs and Markings, Signalization	Alert Motorist, Reduce Conflict	Recent improvements to intersections and streets
40	Jefferson St between 26th Ave N and 28th Ave N	4	Sign "Cross Only at Crosswalks", MUTCD Sign W11-15 (combined bicycle/pedestrian warning sign) to warn of pedestrians and bicyclists, speed limit stencils	Signs and Markings	Reduce Conflict, Alert Motorist	Countermeasure effectiveness may be limited and/or greater at other locations
41	Jefferson St and Dr DB Todd Jr Blvd	4	MUTCD sign R1-5 or R1-5a "Yield to Pedestrians"	Signs and Markings	Alert Motorist	Countermeasure effectiveness may be limited and/or greater at other locations
42	Jefferson St between Rosa L Parks Blvd and 7th Ave N	4	Increase visibility of crosswalk at 7th accompanied with RRFB; consideration should be given to similar improvement at intersection of Jefferson and 6th Ave.	Signs and Markings	Reduce Conflict, Alert Motorist	Countermeasure effectiveness may be limited and/or greater at other locations
43	Main St between Neill Ave and S 9th St	4	Sign "Cross Only at Crosswalks", consider midblock crossing solution	Signs and Markings	Reduce Conflict	CIP (Amp)
44	Gallatin Ave between Straightway Ave and Strouse Ave	4	Crosswalk with Rectangular Rapid Flashing Beacon (RRFB)	Signs and Markings, Signalization	Reduce Conflict, Alert Motorist	
45	Clarksville Pike between Hamilton Rd and Fairview Dr	4	Add pedestrian accommodations along Clarksville Pike, Add pedestrian signals at Fairview	Signalization, Geometric/Roadway	Reduce Conflict, Reduce Exposure	Majority of crashes in parking lot, Major investments needed
46	Dickerson Pike between Broadmoor Dr and Oak Valley Dr	4	Add pedestrian signal heads at intersection of Ewing	Signalization	Reduce Conflict	Recent improvements to intersections and streets
47	Gallatin Pike between Lakewood Dr and Walton Ln	4	Sidewalk improvements along Gallatin	Geometric/Roadway	Reduce Exposure	Major investment needed
48	Dickerson Pike between Briley Pkwy and Old Due West Ave	4	Improve sidewalk connections from Wal-Mart and Skyline Medical Center	Geometric/Roadway	Reduce Exposure	Major investment needed
49	Gallatin Pike between Madison Blvd and Emmitt Ave	4	Sign "Turning Vehicles Yield to Pedestrians", Sidewalk improvements along Gallatin	Signs and Markings, Geometric/Roadways	Alert Motorist, Reduce Exposure	Major investment needed
50	Gallatin Pike between Old Hickory Blvd and Maple St	4	Sign "Cross Only at Crosswalks" at East Old Hickory Blvd.	Signs and Markings	Reduce Conflict	Countermeasure effectiveness may be limited and/or greater at other locations

Bicycle Countermeasures

Zone	Bicycle Location	Number of Crashes	Description of Possible Solution	Classification		Reason
1	Gallatin Ave between N 10th St and Calvin Ave	5	Restripe to provide wide outside lane with sharrows and accompanying signage	Signs and Markings	Reduce Conflict, Alert Motorists	
2	24th Ave between Highland Ave and Pierce Ave and Highland Ave between 24th Ave and 25th Ave S	4	Railing along 24th to force bicyclists to stay on sidewalks, MUTCD Sign W11-15 (combined bicycle/pedestrian warning sign) to warn of pedestrians and bicyclists	Geometric/Roadway, Signs and Markings	Reduce Exposure, Alert Motorists	Countermeasure effectiveness may be limited and/or greater at other locations
3	8th Ave S between Broadway and Demonbreun St	4				Recent improvements to segment
4	Broadway between 3rd Ave and 1st Ave	4				CIP (Proposed Improvements to Broadway)
5	Jefferson St between Warren St and Rosa L Parks Blvd	4	MUTCD Sign W11-15 (Combined Bicycle/Pedestrian Warning Sign) to warn of pedestrian and bike activity	Signs and Markings	Alert Motorist	Countermeasure effectiveness may be limited and/or greater at other locations
6	Harding Pike and White Bridge Road/Woodmont Blvd	3	Rerouting of bikes with signage	Signs and Markings	Reduce Exposure	
7	Edgehill Ave between 16th Ave and 17th Ave	3	Bike Boxes, MUTCD sign W11-2 (pedestrian warning sign) or pavement markings such as "Bike XING" in alley to warn vehicles of cyclists on Edgehill Ave	Signs and Markings	Reduce Conflict, Alert Motorists	
8	21st Ave between Scarritt Pl and Division St	3	Bike detection, increased signage (dismount bike signs)	Signs and Markings, Signalization	Reduce Conflict	
9	Church St between 16th Ave N and I-40/I-65	3	Add sharrows to pavement as Church is a signed bike route	Signs and Markings	Alert Motorist	Countermeasure effectiveness may be limited and/or greater at other locations
10	2nd Ave S between Demonbreun St and Peabody St	3				CIP (Planned Bike Lane Improvement)
11	21st Ave between Belcourt Ave and Dixie Pl	3	Dismount bike sign and/or pavement markings (i.e. "LOOK!" along 21st in crosswalk	Signs and Markings	Reduce Conflict	Countermeasure effectiveness may be limited and/or greater at other locations
12	Harding Pike between Woodlawn Dr and Cherokee Rd	2	Reduction in speed limit on Harding Pike	Signs and Markings	Alert Motorist	CIP (Amp)
13	Murfreesboro Pike near Millwood Dr	2	MUTCD Sign W11-15 (Combined Bicycle/Pedestrian Warning Sign) to warn of pedestrian and bike activity	Signs and Markings	Alert Motorist	Countermeasure effectiveness may be limited and/or greater at other locations

Zone	Bicycle Location	Number of Crashes	Description of Possible Solution	Classification		Reason
14	Murfreesboro Pike at Elm Hill Pike	2	Reduction in speed limit on Elm Hill Pike, MUTCD Sign W11-15 (Combined Bicycle/Pedestrian Warning Sign) to warn of pedestrian and bike activity	Signs and Markings	Alert Motorist	Countermeasure effectiveness may be limited and/or greater at other locations
15	Charlotte Pike and White Bridge Road	2	MUTCD Sign W11-15 (Combined Bicycle/Pedestrian Warning Sign) to warn of pedestrian and bike activity	Signs and Markings	Alert Motorist	Countermeasure effectiveness may be limited and/or greater at other locations
16	20th Ave N and State St	2	Increase signage to alert cyclists that 20th is a 1-way street, 'Wrong Way' signs	Signs and Markings	Reduce Conflict	Countermeasure effectiveness may be limited and/or greater at other locations
17	Charlotte Ave between 19th Ave N and Dr DB Todd Jr Blvd	2	Extend colorized bike lanes upstream of intersection, sharrows/signs on DB Todd	Signs and Markings	Alert Motorist	Countermeasure effectiveness may be limited and/or greater at other locations
18	Church St between YMCA Way and 9th Ave N	2	Road diet with colorized bike lanes from YMCA Way to 12th Ave	Signs and Markings, Geometric/Roadway	Reduce Exposure	
19	16th Ave N and Jo Johnston Ave	2	MUTCD sign W11-15 (Combined Bicycle/Pedestrian Warning Sign) to warn vehicles of bicycle and pedestrian activity generated by park nearby	Signs and Markings	Alert Motorist	
20	6th Ave N between Church St and Commerce St	2				CIP (Planned Shared Bike Route Improvement)
21	Charlotte Ave and 5th Ave N	2	Increased signage (dismount bikes); install bike rack to serve as a barrier to prevent cyclists from entering roadway from transit center exit	Signs and Markings, Geometric/Roadway	Reduce Conflict	
22	Eastland Ave between Gallatin Ave and N 12th St	2	MUTCD Sign W11-15 (Combined Bicycle/Pedestrian Warning Sign) to warn of pedestrian and bike activity after bike lane ends	Signs and Markings	Alert Motorist	Countermeasure effectiveness may be limited and/or greater at other locations
23	Gallatin Ave between Granada Ave and Sharpe Ave	2	Restripe to provide wide outside lane with sharrows and accompanying signage	Signs and Markings	Reduce Conflict, Alert Motorists	
24	Robinson Rd near Martingale Dr	2	MUTCD Sign W11-15 (Combined Bicycle/Pedestrian Warning Sign) to warn of pedestrian and bike activity	Signs and Markings	Alert Motorist	Countermeasure effectiveness may be limited and/or greater at other locations
25	51st Ave N between Indiana Ave and I-40	2	Road diet with added bike lane along 51st Ave.	Signs and Markings, Geometric/Roadway	Reduce Exposure	

Pedestrian Signalization Countermeasures

- **Leading Pedestrian Intervals** and other signal timing improvements can increase the visibility of pedestrians at intersections.

- **Pedestrian Signals** upgraded with countdown timers can alert pedestrians when conflicts with vehicles may impact their safety.

- **Pedestrian Scrambles**, or 'barn house dances' as they are sometimes called, provide an exclusive pedestrian phase at signalized intersections so that pedestrians can cross without conflicts.

- **Left Turn Phases** can decrease the conflict between pedestrians and left-turning vehicles

- **Pedestrian Hybrid Beacons** stop vehicular traffic with a familiar steady red signal to make pedestrian crossings safer in mid-block locations.

Pedestrian Geometric and Roadway Countermeasures

- **Pedestrian Refuge Islands** decrease the number of lanes pedestrians must cross at once.

- **Crosswalk Distances** at skewed intersections can be reduced to limit pedestrian exposure to vehicles.

- **Fencing, Gating, and Landscaping** can be used to direct pedestrian traffic to appropriate crossing locations and help prevent mid-block crossings.

- **Road Diets** are one way of decreasing pedestrian exposure to vehicles on roadways where traffic volumes are low and pedestrian facilities can be incorporated.

Pedestrian Sign and Marking Countermeasures

- **Rectangular Rapid Flash Beacons** increase awareness for pedestrians crossing in unusual locations.

- **Overhead Pedestrian Signs** increase awareness of crosswalk locations where visibility may be limited.

- **High-Visibility Crosswalks** increase vehicle awareness of crosswalk locations and regulations.

- **Right Turn on Red Restrictions** reduce pedestrian-vehicle conflicts at intersections.

- **Advanced Stop Bars and Yield Markings** show vehicles where they should yield or stop to allow pedestrians to cross safely.

Bicycle Signalization Countermeasures

- **Bike-Activated Signals** allow for cyclist detection at intersections and, therefore, can help prevent cyclists from entering intersections against signals.

- **Bike Signals** can accommodate bicycle-only phases for heavily trafficked cycling movements.

Bicycle Geometric and Roadway Countermeasures

- **Dedicated Bike Lanes** can decrease conflicts between vehicles and bicyclists by providing each mode with its own space.
- **Paved Shoulders or Wide Outside Lanes** can be used to give bicyclists space without providing a dedicated bike lane.
- **Parking Treatments** can be rearranged to provide an area for cyclists that's protected from vehicular traffic or increase the visibility of cyclists as is the case with back-in angled parking.
- **Fencing, Gating, and Landscaping** can be used to separate cyclists from vehicular traffic.
- **Road Diets** can be used to create a unique space for cyclists on low-volume streets using additional, unnecessary roadway width.

Bicycle Sign and Marking Countermeasures

- **Colorized Bike Lanes** can be used in areas of high conflict to alert motorists to the presence of bicyclists.
- **Signage** can be used as a way to inform motorists of the presence of bicyclists.
- **Sharrows** can be implemented to alert motorists of bicyclists that may be sharing their travel lanes.
- **Wrong Way Riding Signs** can be implemented to prevent bicyclists from traveling against vehicular traffic
- **Bike Lanes at Intersections** can be provided to prevent right-turn conflicts with bicyclists.
- **Bike Routes** can be rerouted to help cyclists avoid dangerous intersections
- **Bike Boxes** offer cyclists a means to jump ahead of traffic at intersections in preparation for weaving maneuvers.