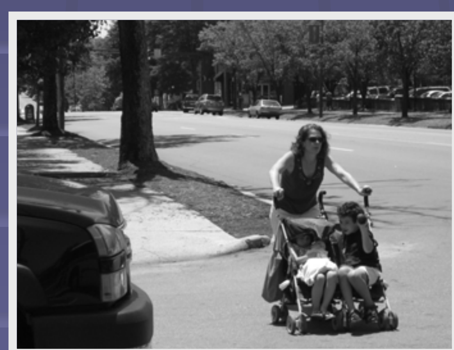
Identifying Locations for Pedestrian and Bicyclist Safety Improvements in Chapel Hill and Carrboro, North Carolina






Final Report to
North Carolina Department of Transportation,
Traffic Engineering and Safety Systems Branch
December 2008, Revised July 2009

Libby Thomas
Charles Hamlett
William Hunter
Dan Gelinne
Other contributors: Craig Raborn, Jane Stutts, Charlie Zegeer

University of North Carolina
Highway Safety Research Center

THE UNIVERSITY OF NORTH CAROLINA
HIGHWAY SAFETY RESEARCH CENTER

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Executive Summary

Study Objectives and Methods

The objective of the present study was to identify areas with potential hazards for pedestrians and bicyclists to aid in prioritizing safety improvements. Crash factor analysis and spatial analysis of crash data were supplemented with proactive methods to identify potentially unsafe locations that may not have experienced crashes yet. Five years of pedestrian and bicycle crash data were obtained for the study area, which included Chapel Hill and Carrboro, North Carolina. A survey was conducted with 400 respondents who regularly travel in the area in order to identify locations perceived to be unsafe for pedestrians and bicyclists. The crash locations and the perceived risk locations resulting from the survey were entered into a GIS format and spatially analyzed and compared. Other proactive methods including intersection safety index ratings, speed studies, and other public input by way of various Town processes were also used to identify areas of potential concern. Roadway safety audits, which provide qualitative expert review of conditions, were conducted for eight comprehensive areas to identify problems and potential countermeasures.

Risk Factors and Areas of Concern Identified

Young adults were highly represented in collisions as bicyclists and pedestrians and as drivers involved in the collisions. The typical peak hours claim the most collisions – 22% of pedestrian and 28% of bicycle collisions occurred during peak afternoon hours of 3 to 6 pm. Also, significant proportions occur under low-light conditions: 29% and 22% of pedestrian and bicycle collisions, respectively occurred during night-time, dawn or dusk conditions.

Above half (55%) of pedestrian roadway collisions occurred at midblock locations; 45% were at or related to an intersection. A similar percentage of midblock locations (53%) and intersection locations (47%) were perceived as being unsafe for pedestrians by survey respondents. In contrast to pedestrian collisions, 56% of the on-street bicycle collisions occurred at intersections with 44% at midblock locations. However, more ‘segment’ or midblock locations (74%) were identified by survey respondents as unsafe for bicyclists, with intersections being identified 26% of the time. Thus, there is a seeming misperception about locations thought to be unsafe compared with where bicycle collisions actually have occurred in a general way. This perception may influence riders choice of where to ride (sidewalks versus street) which may in turn contribute to intersection collisions.

Crash types were examined and the most common pedestrian types included pedestrians crossing the roadway at intersections or midblock being struck by vehicles that were not turning (24%). About 17% of pedestrians struck were crossing and hit by turning vehicles, with about 10% being pedestrian dashes and dart-outs. More than 20% of bicyclists were struck by turning motorists and another 20% were struck by motorists pulling out at stop signs and driveways without yielding. Wrong-way and sidewalk bicyclists may have contributed to some of these collisions.

Results of spatial analyses of crash locations showed that there were substantial differences in crash and perceived risk hot spots as identified through kernel density analyses. The high pedestrian crash density areas were predominantly on downtown and campus streets with a few additional hot spots identified around some prominent intersections. Bicycle crashes were also predominantly clustered on the two downtowns and campus streets, in particular in a transition area of a corridor linking Chapel Hill and Carrboro. Other significant bicycle crash clusters were on Martin Luther King Jr Blvd, and Fordham Blvd at and near Estes Dr.

In addition to downtown and campus areas that substantially overlapped with crash occurrence, most areas perceived as risky that had not had prior crashes (or at least not at the same locations) were on the heavily traveled corridors leading to downtowns and campus or cross-town corridors. Crashes had occurred at one or more other locations along most of these corridors, including at major intersections. One corridor was identified as a primary area of concern for bicyclists, and also of high concern for pedestrians, yet few prior crashes occurred on this corridor during the study period. These findings reflect those in other studies. Areas perceived as very unsafe could generate changes in behavior that reduce actual crash risk. These possibilities do not imply that such areas are of low concern for remediation since although crash incidence may be low, crash severity when collisions do occur is likely to be quite high, and the problems may act as barriers to travel.

Nearly half of 69 separate pedestrian and bicycle risk areas highlighted by the spatial analyses were included in one of eight detailed audits; most remaining areas were visited at least once. Speed studies were also conducted near a majority of the locations identified and revealed excess speeds at most locations. Each of the areas examined during audits and site visits, including those highlighted by perception data but not by prior crashes, was found to have conditions that could affect pedestrian or bicyclist safety. Thus, the accumulation of perception data lead to identification of areas with significant safety concerns that would not have been identified by examining prior crashes alone. Other proactive screening tools, including locations identified by the Towns through regular public input processes, locations associated with transit stops, the intersection safety ranking tool, speed studies, and the audits themselves (which may be proactively conducted for an entire corridor or for intersections) also revealed areas of concern. These other proactive methods may be used by agencies that cannot conduct extensive public surveys.

Countermeasure Recommendations

In conjunction with the audits, potential countermeasures were identified and highlighted. Widely recommended countermeasures include the following:

- ⇒ Provide pedestrian crosswalks and pedestrian walk/don’t walk signals on all legs at signalized intersections throughout the Towns that lack them.
- ⇒ Complete sidewalk sections to transit stops and to connect other important walking links. Add buffers from traffic whenever possible.

⇒ Enhance lighting at intersections, near transit crossing areas, near path crossings and other busy areas. Consider pedestrian level lighting, especially at busier night-time locations.

⇒ Medians or median islands with accessible crossings would improve midblock crossings on multi-lane roads.

⇒ Also consider the use of innovative signals and warnings including HAWK or rapid-flash beacons, both of which have had positive evaluations, to enhance uncontrolled crosswalks. (These devices are tentatively approved for inclusion in the next MUTCD.)

⇒ Americans with Disabilities Act-compliant curbs, ramps, and landings should be provided as well.

⇒ Provide for bicycle detection on side streets that require vehicle-activation to get a green light.

⇒ Bicycle facilities such as bike lanes would improve bicycle comfort and level of service along key arterials, and may help to reduce wrong-way and sidewalk riding – a risk factor for collisions at intersections. Wide outside lanes and shared lane markings are other potential improvements.

⇒ Also consider intersection markings, signal timing improvements, and other potential treatments for bicyclists at key arterial intersections.

⇒ Consider road diet/lane reduction measures especially on certain downtown streets, to reduce crossing distances, speeds, and provide additional space for other needs.

⇒ Reduce opportunities for crashes and conflicts with turning vehicles by:

- Providing protected left-turn phasing separated from pedestrian walk and through traffic phases at signalized intersections with dedicated left-turn lanes.
- Adding raised medians and other access management/driveway consolidation measures to reduce the number of conflict areas and sight distance issues.
- Adding sidewalk-level crossings to driveway junctions.
- Keep curb radii narrow whenever possible to keep turning speeds low.
- Consider the use of low-speed (preferably one-lane) roundabouts at appropriate locations.

⇒ Measures to reduce motorist speeds, including both engineering and enforcement should also be implemented.

Conclusions

The analyses and comparisons of areas of crash concentration with areas perceived to be unsafe highlighted a number of overlapping as well as separate areas of concern. It is likely that most communities would find similar results. One benefit of a survey to identify such areas may be that it highlights areas where people need to walk but may be avoiding to the extent possible. A disadvantage is that some populations, users, or neighborhoods may not be well-represented through any survey method. As a result, there could be serious safety problems in areas that did not come to our attention through the survey sample and analysis of crash and perception data. Therefore, continued use of proactive as well as reactive methods should be employed toward developing a safe pedestrian and bicycle network. Continued updating of crash data and reported problems, use of proactive tools such as speed studies, counts and surveys of walking/biking patterns, analysis of transit locations and access, analysis of gaps in facilities and connections, screening tools such as the Intersection Safety Index, and roadway safety audits should be used to identify safety problems. Attention to policies, manuals and procedures to institutionalize effective practices, as well as a focus on problem patterns, corridors and intersections is needed to address the deficiencies.

Behavioral countermeasures are also instrumental to help insure a roadway environment that is safe and accessible for pedestrians, bicyclists, and motorists. Such behavioral measures should include training of police officers to enforce speed limits and all traffic laws including those that pertain especially to bicycle and pedestrian safety such as yielding to pedestrians and bicyclists on sidewalks and at crosswalks, improved training of bus operators, working with transit agencies to assess location and operation of transit stops and accommodation for pedestrians and bicyclists, and reinforcement of safe walking and bicycling through educational programs targeting drivers as well as pedestrians and cyclists.

Introduction and Background of the Study

How does a community go about developing a pedestrian or bicycle safety action plan? “Crash, roadway, traffic, and other data are essential to identify pedestrian safety deficiencies and to select the appropriate improvements…” (Zegeer and Sandt, 2006). However, due to the relatively low frequency and somewhat random nature of collisions involving pedestrians and bicyclists, by the time a safety problem is recognized, fatal or serious injury crashes may have claimed or altered lives. Local residents may also push for improvements in locations perceived as unsafe from experience or where recent highly publicized collisions have occurred. Thus, a proactive approach to identifying unsafe locations may help to supplement the information available from reported crash databases. Other considerations such as utilizing other scheduled projects to make bicycle and pedestrian improvements may also be important in determining how to allocate resources to achieve long-term reductions in cashes and injuries.

A series of three fatal and two non-fatal collisions involving pedestrians and bicyclists within a week in the Chapel Hill, NC area in January of 2006 precipitated discussions between the Town and State traffic engineers on roadway safety improvements. These discussions ultimately led to this study. Such tragedies often create an urgency to “do something” about pedestrian and bicyclist safety at the crash locations. But, while the need to provide safe roads for all users is recognized, it is equally urgent that scarce resources be applied to the locations of greatest need, and that effective countermeasures are implemented.

In an attempt to be proactive and gain a fuller understanding of crash risk areas on a university campus (UNC-Chapel Hill), Schneider, Ryznar, and Khattak (2004) combined spatial crash analyses with spatial analyses of user perceptions of unsafe locations for pedestrian-motor vehicle crashes on the campus street network. The analyses revealed that the distributions of reported crashes and of perceived risk locations differed and that areas were identified from the risk perception data that were not identified from the crash data. The opposite was also true: some areas with high crash densities were not among those with high densities of perceived risk points.

According to Schneider et al., the crash prevention implications of the study were as follows:

High-High: Areas of high reported crashes and high perceived risk should be top priority areas for engineering, education, and enforcement countermeasures.

High-Low: Areas of high reported crashes and low perceived risk are apparently less safe as suggested by actual crashes, yet people do not perceive the location as particularly unsafe.[1] The area should be evaluated to assess physical and behavioral problems and develop engineering, enforcement and educational countermeasures.

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[1] There are several possible explanations for these findings. Users who were surveyed may not be aware of/walk in the area with high crashes, may not recognize problems if they do travel there, or the frequency of crashes could be related to high exposures and users’ perceptions of individual risk are basically accurate.

Low-High: Areas of low reported crashes and high perceived risks. These are areas that have not (yet) experienced a concentration of crashes, but users perceive them as unsafe. Further analysis should be carried out to determine if safety problems exist and what proactive measures may be implemented to prevent future crashes.

Low-Low: Areas of low reported crashes and low perceived risk. No ‘red flags’ are raised for these areas, but normal monitoring should be continued.

The objective of the present study was to perform similar spatial comparisons of both bicyclist- and pedestrian-motor vehicle collision locations with locations perceived to be unsafe for bicyclists or pedestrians, conduct additional investigations, and identify appropriate countermeasures for the problems identified. Analyses of crash and perception data, plus sites identified by local agencies through various processes, were used to identify locations with previous crash problems and/or perceived safety problems for further evaluation. Speed studies, site visits and other analyses including the use of Pedestrian and Bicycle Intersection Safety Index ratings (Carter et al, 2006) supplemented the spatial comparisons to prioritize locations for detailed on-site safety audits and identification of countermeasures.

The purpose of Road Safety Audits (RSA) is to qualitatively assess safety concerns associated with a particular roadway, area, or intersection, using an interdisciplinary team; evaluate the circumstances under which the concerns are most problematic; consider the users that are negatively impacted by these safety problems; and recommend treatments and solutions to be implemented (Road Safety Audits, n.d.). An RSA can be used to assess safety concerns that could arise due to development and construction of new roads, or to evaluate the safety of an existing roadway.

It is important to note that RSAs are not synonymous with traditional traffic safety reviews. There are several key differences between the two assessment methods. While a traffic safety review focuses primarily on the safety of motor vehicles, an RSA considers all road users, including bicyclists, pedestrians, and motor vehicles. Traditional RSAs are comprehensive with respect to road users, but RSAs can also be conducted with a particular user in mind. Pedestrian RSAs are specifically intended to evaluate a corridor or intersection with the safety needs of pedestrians in mind. Another key difference is the background of the team performing the review. In addition to traffic engineers, who are traditionally the only members of a traffic safety review team, an RSA team includes professionals from diverse fields. Planners, law enforcement officials, health experts, and others join engineers to conduct the audit, allowing a variety of viewpoints to contribute to the assessment. In general, an independent team should conduct or lead the audits. An RSA itself can serve as a proactive safety analysis method.

This study illustrates the use of spatial analyses to identify crash “hot spots” in addition to a number of tools and methods for proactively identifying areas with potential pedestrian and bicycle safety issues. Communities that wish to take a comprehensive approach to pedestrian and bicycle safety might benefit from using similar tools and methods. The study also demonstrates the use of Roadway Safety Audits to evaluate infrastructure and behavioral factors that may affect safety and identify potentially appropriate treatments. Finally, the study highlights some treatment prioritization considerations.

Serious safety issues for pedestrians and bicyclists were identified at most locations visited, leading the study team to believe that there are somewhat systemic problems in meeting the safety and accessibility needs of pedestrians and bicyclists in the study area. The survey of users helped to highlight safety concerns along many corridors and at intersections where prior collisions had not necessarily occurred. It is likely that most communities would find similar results. One benefit of the survey may be that it highlights areas that people need to walk. A disadvantage is that some populations, users, or neighborhoods may not be well-represented.

As a result, there could also be serious safety problems in areas that simply did not come to our attention through the survey sample and analysis of crash and perception data. Therefore, a methodological plan, including continued updating of crash data and reported problems, use of other proactive tools such as speed studies, counts and surveys of walking/biking patterns, analysis of transit access, use of screening tools such as the intersection screening tools, and roadway safety audits should be employed to develop a safe pedestrian and bicycle network. Attention to policies, manuals and procedures, as well as a focus on problem patterns, corridors and intersections is needed to address the deficiencies.

Behavioral countermeasures, including training of police officers to enforce traffic laws that pertain to bicycle and pedestrian safety, enforcement of speed limits, improved training of bus operators, working with transit agency to assess location and operation of transit stops and accommodation for other modes, and reinforcement of safe walking and bicycling through educational programs are also essential.

Overview of Study Methods

Study Area

The study area was comprised of two adjacent small towns, Chapel Hill (~50,000 residents) and Carrboro (~17,000 residents), in North Carolina (NC); (Figure 1). The largest influence on both communities is the University of North Carolina that occupies a significant part of the land use, and has approximately 28,000 students, many of whom live within the study area. The communities are set within the Triangle metro area of Raleigh and Durham, NC.

Fare-free bus service has been provided since January 2002; bicycle racks are on all buses. There is also regional bus service to and from major employment centers, including Research Triangle Park.

Bicycling and walking are common modes of transportation in the communities, as is transit use. People driving (71%) or driving alone (61.5%) to work in the Chapel Hill/Carrboro area is lower than the proportions of people driving (92%) or driving alone (78.5%) in the triangle region as a whole.

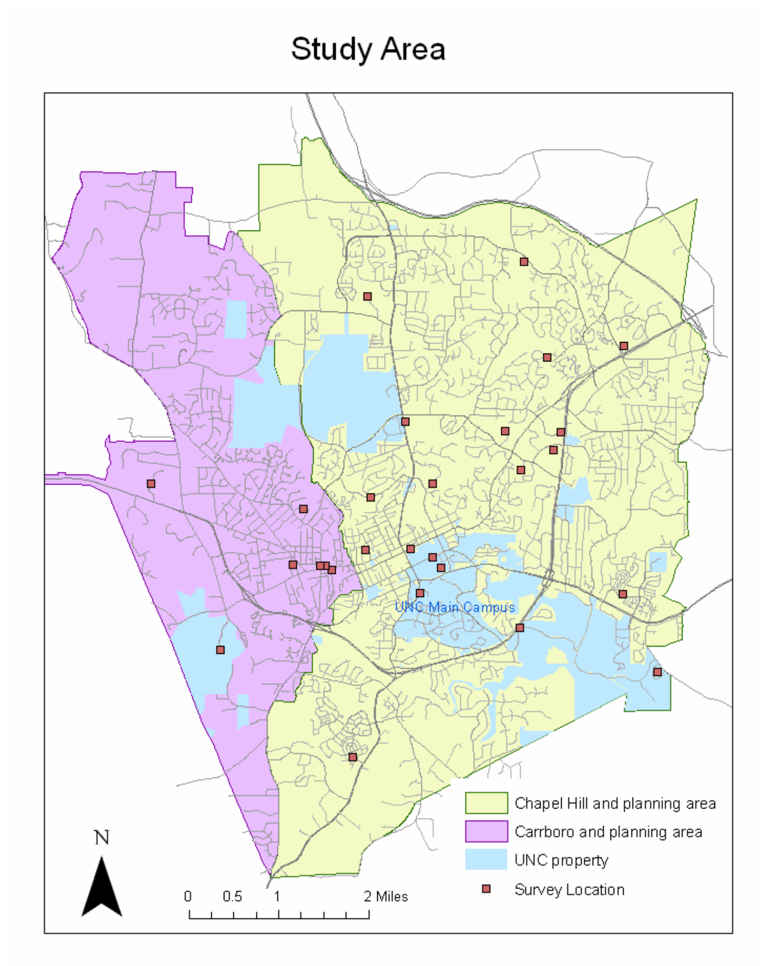

Figure 1. Map illustrating study area and survey locations. Survey was conducted in spring 2007.

Data

- Collision data – Police-reported pedestrian and bicycle collisions with motor vehicles from January, 2001 – December, 2005 were obtained from State crash files using NCDOT's Traffic Engineering Accident Analysis System (TEAAS). The project team added information by coding each crash type using PBCAT v. 2 software, and mapped each roadway collision location using ESRI® ArcMap™ 9.2 software. Roadway files for the study area derived from NCDOT centerlines files, and provided by the local (Town) agencies served as the reference layer.
- Perception data – Information on locations perceived to be unsafe for pedestrians or bicyclists was obtained from 400 intercept survey respondents. Each respondent could identify up to three locations that they perceived to be unsafe for pedestrians and three locations perceived to be unsafe for bicyclists. Additionally, respondents were asked whether they had experienced any near collisions as a pedestrian or bicyclist or with a pedestrian or bicyclist (as a motorist) and where these occurred. Respondents provided a general indication of where they resided and/or worked (within ½ mile), and limited demographic data were also noted from observation. A copy of the survey is included in Appendix A. Characteristics of survey respondents are also summarized in tables in Appendix A.
- Locations previously identified by the Towns for safety improvements. These data were obtained after the initial analyses of collision and perception data, and were also entered into spatial files for comparison with results from the crash and perception data analyses.
- Thirty-five spot speed studies were conducted near locations identified through the crash and perception data. Motor vehicle speeds are directly related to severity of crashes when they occur, particularly involving vulnerable road users, and higher speed affects the ability of motorists to avoid a crash.

Study Methods and Analyses

- Crash factors were analyzed for general trends in characteristics of people and environment. Crash types were examined for common area-wide crash characteristics and for specific locations to help target appropriate countermeasures.
- Crash, perception data, and locations identified by the Towns were compared spatially and used to identify locations for further assessment. The relative density of crashes and perception data were analyzed using kernel density analysis as a method to identify high priority locations (CrimeStat III, Levine, 2004). Results were displayed using ArcMap. Ripley's K-function test was used to determine whether crashes were clustered non-randomly. Analyses verified that pedestrian and bicycle crashes were non-randomly clustered across the street network. Then SANET (Okabe, Okunuki and Shiode, Spatial Analysis on a Network, version 3) was used to analyze crash clusters along the street network and compared to the results from the kernel density analyses.

- We highlighted and compared locations identified by analyses of crash data using both kernel density and network cluster analysis, kernel density analysis of perception data, and the locations that had been previously identified by the Towns as needing safety improvements.
- We performed other spatial analyses for intersections and of crash factors such as ages of those involved, relationship of child crashes to school locations and school travel times, time of day and light condition during collisions, and alcohol use indicators to gain a fuller understanding of crash problem locations and other factors.
- Pedestrian and Bicycle Intersection Safety Index Rankings (Pedestrian ISI and Bike ISI) were applied to a mix of intersections identified by crash data, by perception data, or by the Towns to compare results using this tool with intersection analyses of crash and perception data. The pedestrian and bicycle models were developed from expert safety ratings and behavioral data, and are intended to allow a proactive screening of intersection safety using readily available or obtainable intersection and street characteristics data (Carter et al., 2006).
- The study team conducted preliminary field visits to many of the locations having above the 20th percentile of either relative crash density or relative risk perception points, or that were identified by one of the Towns through public input or development of pedestrian or bicycle plans. Speed studies were also conducted at a majority of the locations identified. These visits and speed information helped to prioritize locations for in-depth audits.
- Subsequently, 8 detailed pedestrian/bicycle safety audits were conducted. The audit locations included a mix of locations with high crash and high perception densities, and those identified by either crash or perception data, or by one of the Towns. Each visit combined a mix of related locations (e.g. same area or corridor) that comprised several separate areas identified through one of the above methods. Six of the 8 detailed audits included staff engineers and planners from the State DOT and the jurisdiction where the sites were located. The FHWA's Pedestrian Road Safety Audit Guidelines and Prompt Lists provided a framework and guidance in conducting the audits (Nabors et al., 2007). (It should be noted that the final list of sites should not be interpreted as a definitive list of sites where improvements are needed most urgently but rather were a mix of locations which were selected for further investigation based on crash and perception densities and other characteristics.)
- Safety issues uncovered through the detailed audits were summarized for each audited area, and potential countermeasures were identified. Resources consulted to identify countermeasures include BIKESAFE (Hunter, Thomas, and Stutts, 2006; NCHRP Report 500, Volume 18: A Guide for Reducing Collisions Involving Bicycles (Raborn et al., 2008); PEDSAFE (Harkey and Zegeer, 2004); and the AASHTO Guide for the Development of Bicycle Facilities (American Association of State Highway and Transportation Officials, 1999).

Evaluation of Pedestrian Safety Problems

Pedestrian Crash and Perception Data Description

There were 157 pedestrian-motor vehicle collisions that occurred in the study area from January 2001 through December 2005. Over the five-year study period, approximately 18% of the pedestrian collisions occurred in Carrboro and its planning jurisdiction; 82% in Chapel Hill or its planning area, and the remainder, (<1%) in outlying areas on streets that were of interest to one of the jurisdictions (Table 1).

Accurate and precise mapping of crash locations is dependent on several steps in the process, from the indications on the police crash report (which are often estimated by officers arriving on scene after the crash occurred), to the precision with which collisions could be manually plotted in GIS. Some of the location descriptions in police crash reports seem to be rounded to the nearest 100 feet (lack of precision) or had contradictory information, so consideration of all the data, including descriptions and diagrams of the crash, or mentions of nearby businesses, were used to develop a best judgment of where the crash occurred.

Table 1. Pedestrian-Motor Vehicle Collisions in Study Area.

	City			
Crash Year	**Carrboro**	**Chapel Hill**	**Rural**	**Total**
2001	5 [1] 13.5% [2] 17.9% [3]	32 86.5% 25.0%	 .0% .0%	37 100.0% 23.6%
2002	7 28.0% 25.0%	18 72.0% 14.1%	 .0% .0%	25 100.0% 15.9%
2003	7 25.0% 25.0%	21 75.0% 16.4%	 .0% .0%	28 100.0% 17.8%
2004	2 5.7% 7.1%	32 91.4% 25.0%	1 2.9% 100.0%	35 100.0% 22.3%
2005	7 21.9% 25.0%	25 78.1% 19.5%	 .0% .0%	32 100.0% 20.4%
Total	28 17.8	128 81.5%	1 .6%	157 100.0%

[1] Count
[2] Percent within Crash Year
[3] Percent within City

In the complementary aspect of the study, nearly 400 survey respondents identified a total of 1,491 locations perceived to be unsafe for pedestrians or bicyclists, or where near-misses were reported to have been experienced by some of the respondents. Of these, 1,461 locations were described accurately enough to be located using the study area streets layer (845 pedestrian points; 616 bicycle points). With the assistance of maps, respondents identified locations as being at the intersection of two streets or as being located at some point between two intersections (not necessarily adjacent intersections) along a corridor. If the respondent could not identify a particular location, the point was indicated to represent a 'segment' in the data associated with that point. Many of the respondents did in fact identify segments or even entire corridors as opposed to specific locations. Thus, it should be borne in mind that much of the perception data represent segments or sometimes nearly entire corridors from the point of the view of the survey respondents, as opposed to reasonably precise locations such as where crash events occurred. Nevertheless, to analyze the spatial relationships using density or cluster analysis, it is necessary to treat the perception locations identified as 'points.' Twenty percent of points were located in Carrboro or planning jurisdiction, approximately 78% in Chapel Hill or planning jurisdiction, with 1.5% located in more rural locations (Table 2).

Table 2. Data Points for Perceived Unsafe Pedestrian Locations, 2007 Survey.

Locations Identified	Carrboro	Chapel Hill	Rural	Total
Pedestrian Perceived Risk Points	145 21.4% [1]	522 77.1%	10 1.5%	677 46.3%
Ped Near Miss Points	25 14.8%	140 83.3%	3 1.8%	168 11.5%
Total	170 20.1% [2]	662 78.3%	13 1.5%	845

[1] Column percent of row total
[2] Column percent of row total

Of the 157 reported pedestrian collisions, 31 occurred in parking lots or other non-roadway locations, with 126 pedestrian-motor vehicle crashes that occurred on public rights-of-way under consideration in this study (Table 3). All 126 on-street collisions were mapped using ArcMap® spatial software. The following crash factors analyses include all 157 collisions, while the spatial analyses following include only the 126 that occurred on the street network.

Above half (55%) of roadway collisions occurred at midblock locations with 45% at or related to an intersection (within 15 m) (Table 3). A similar percentage of midblock locations (53%) and intersection locations (47%) were identified as being unsafe for pedestrians by survey respondents (also Table 3). Two-thirds of "near miss" experiences (65%) were, however, reported to have occurred at intersections.

Table 3. Pedestrian Crash and Perception Data Locations.

Type	Intersection/ Intersection-related	Midblock/ Segment	Non-Roadway
157 Pedestrian Collisions	57 (45%)[1]	69 (55%)	31
677 Pedestrian Perceived Unsafe Points	321 (47%)	358 (53%)	n/a
168 Pedestrian "Near miss" Points	110 (65%)	58 (35%)	n/a

[1] Percent of roadway crashes only

Pedestrian Crash Factors

Pedestrian and driver characteristics

- Young adults ages 21 to 25 and those ages 16 to 20 were both highly represented as pedestrians in collisions compared to the averages for the state over the same time period. One-fifth of all the pedestrians involved in collisions were in the 21 to 25 year age group and together, these two groups of young adults represented 36% of pedestrians involved in collisions compared to a 21% state average over the time period (Figure 2). High crash involvement of the young adult population reflects the large population of university students walking in the community.
- Young adult drivers (20 to 29) were also highly involved in collisions with pedestrians, accounting for 35% of drivers involved (Table 4). Statewide, drivers in this age group accounted for 20% of collisions with pedestrians (data not shown).
- Adults aged 41 to 50 were next most often involved as pedestrians (17%), in a slightly higher proportion than the statewide average.
- Child pedestrians, ages 15 and under were involved in 8 collisions (5% of the total) during the study period. Children 15 and under made up a proportionally smaller representation in collisions in the community compared with statewide averages (18.5%) (Figure 2). Some additional analyses of child crashes were nevertheless undertaken to examine crash relationship to school locations and school travel times. While 5 of the 6 on-street collisions involving children occurred during typical after school hours, this time period is also the highest crash time for all ages and of course, for children who are in school during most daylight hours. There were no indications of particular problem locations in relationship to schools. The relatively low proportions of child collisions do not imply that the street network is safe for child pedestrians. District-wide, 40% of

students were transported to school by buses provided by the school district (2008 data; not including mini-buses) (2008 Opening of School Report, Chapel Hill Carrboro City Schools); unknown percentages are driven by parents or take public transit. It is probable that the low crash numbers are related to low exposure of walking to and from school. At least one elementary school and one high school had no walk zone during this time period. All children in the attendance zones were offered bus transportation because the roadways separating neighborhoods from the school were perceived as unsafe by school officials and parents.

- Male and female pedestrians were evenly represented with 78 females and 79 males involved in collisions. Statewide, males tend to account for 62% of pedestrians involved in collisions, so females have higher involvement in the study area than in the state on average.
- The reporting officer suspected or detected alcohol or drug use by the pedestrian in 10.2% of the total collisions and by the driver in 4.5% of the collisions. Both the driver and pedestrian were suspected in 2.5% of the collisions (data from Table 5). These percentages include cases in which impairment was clearly suspected and those in which use was suspected, but not necessarily impairment. In total, alcohol or drugs could have played a role in 12% of the collisions, but there are many cases of “unknown” recorded, especially for drivers, so an accurate assessment of the role of alcohol in collisions from these data is problematic.
- Ninety-four percent of the pedestrians involved were reported to receive injuries, including two fatalities and 8% reported disabling (Type A) injuries (Table 6).
- Only one of the fatalities occurred on the street network during the study period. The other occurred in a parking lot.
- Only 2 drivers (1%) were reported as receiving severe (disabling) injuries in these crashes, with 7% reported to receive evident injuries and another 8.9% possible injuries (data not shown).

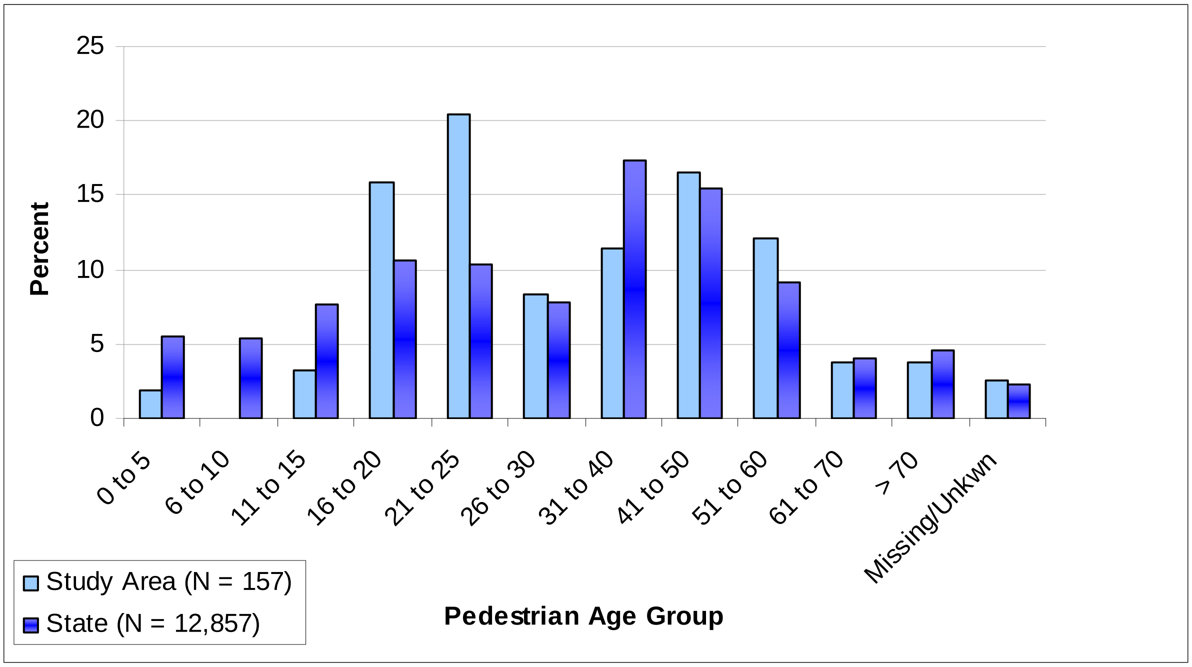

Figure 2. Ages of Pedestrians Involved in Collisions, 2001-2005.

Table 4. Ages of Drivers Involved in Collisions with Pedestrians in Study Area.

Driver Age	Frequency	Percent
16 to 19	12	7.6
20 to 29	60	38.2
30 to 39	16	10.2
40 to 49	21	13.4
50 to 59	23	14.6
60 to 69	9	5.7
> 70+	8	5.1
Unknown	8	5.1
Total	157	100.0

Table 5. Pedestrian and Driver Alcohol Use, 2001-2005.

Pedestrian Alcohol/Drug Use Suspected/ Detected	Driver Alcohol Use Suspected/Detected				
	Yes, Alc	Yes, Other Drugs	No	Unknown	Total
Yes, Alc	4		8	4	16
	25.0%	.0%	50.0%	25.0%	100.0%
	57.1%	.0%	7.2%	10.5%	10.2%
	2.5%	.0%	5.1%	2.5%	10.2%
No	3	1	97	29	130
	2.3%	.8%	74.6%	22.3%	100.0%
	42.9%	100.0%	87.4%	76.3%	82.8%
	1.9%	.6%	61.8%	18.5%	82.8%
Unknown			6	5	11
	.0%	.0%	54.5%	45.5%	100.0%
	.0%	.0%	5.4%	13.2%	7.0%
	.0%	.0%	3.8%	3.2%	7.0%
Total	7	1	111	38	157
	4.5%	.6%	70.7%	24.2%	100.0%
	100.0%	100.0%	100.0%	100.0%	100.0%
	4.5%	.6%	70.7%	24.2%	100.0%

Table 6. Severity of Injuries to Pedestrians, 2001-2005.

Injury Severity	Frequency	Percent
Fatal	2	1.3
A Type (disabling)	13	8.3
B Type (evident)	70	44.6
C Type (possible)	63	40.1
No injury	6	3.8
Unknown	3	1.9
Total	157	100.0

Pedestrian crash temporal factors

- The fall and winter months of October (13%), January (12%), December (11%), and September (11%) are the highest crash months for pedestrians in the study area (Figure 3).
- Wednesday has been the highest crash day of the week on average over the study period accounting for 20% of pedestrian collisions (Figure 4). Friday is the second highest crash day (17%); Sunday is the lowest (8%). Friday is typically the highest pedestrian crash day for the state on average.
- As in most areas, the peak crash hours are in the afternoon to early evening, 3 to 6 pm when after school and after work travel are at their peaks (Figure 5). This time period accounts for nearly 22% of collisions. Night (9 to midnight) and late night hours (midnight to 3 am) accounted for 21% of collisions.
- About two-thirds of pedestrian collisions occurred during daylight with one-third occurring under lower light conditions, particularly under conditions of darkness, on lighted roadways (29%), (see Figure 6). Examining the locations of pedestrian collisions showed that most night-time collisions occurred in downtown Chapel Hill and on some campus streets including South Rd and near the UNC hospitals. Severe and fatal injuries were over-represented for pedestrians struck at night compared to all collisions. Forty-four percent of the collisions under dark conditions occurred during months of October and November (data not shown).

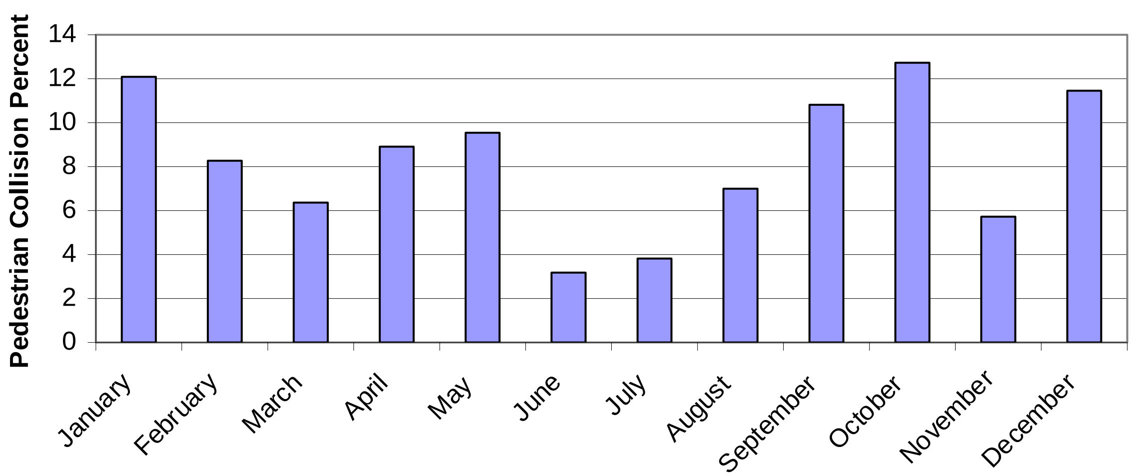

Figure 3. Average Percentage Pedestrian Collisions by Month, 2001-2005 (n = 157).

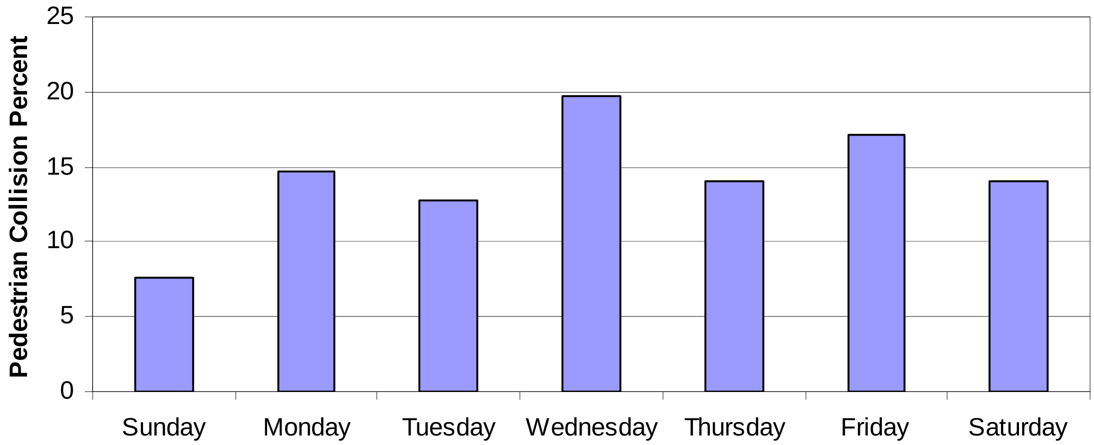

Figure 4. Average Pedestrian Collisions by Day of the Week, 2001-2005 (n = 157).

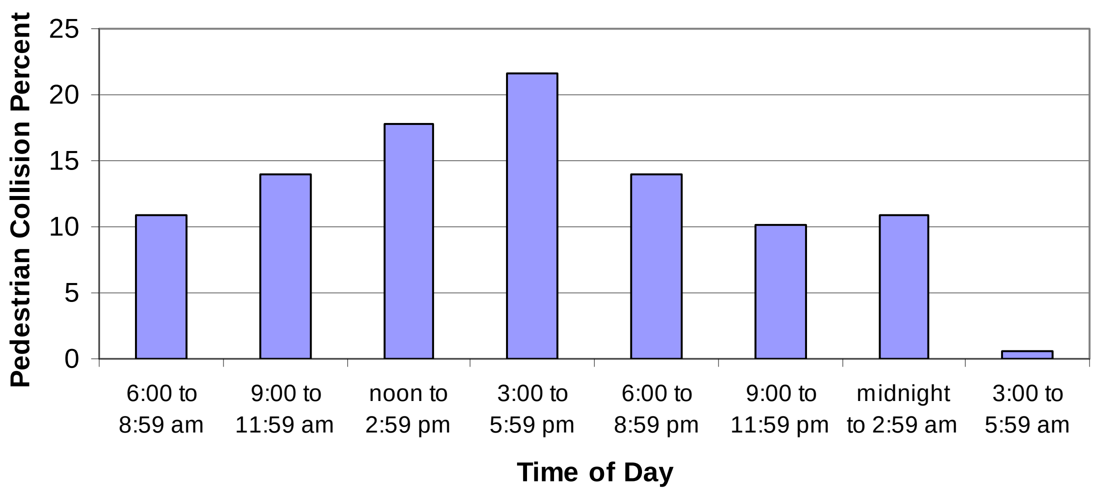

Figure 5 Average Pedestrian Collisions by Time of Day, 2001-2005 (n = 157).

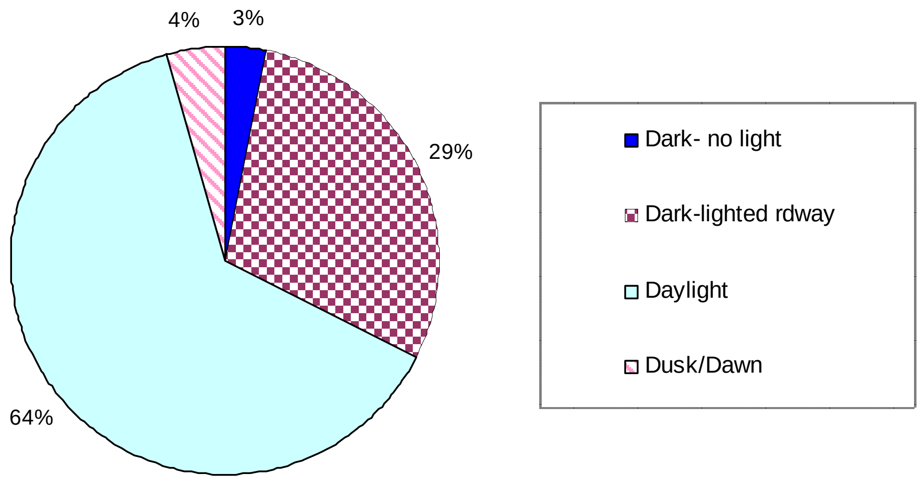

Figure 6. Average Pedestrian Collisions by Light Condition, 2001-2005 (n - 157).

Types of pedestrian crashes

Analyzing the types of crashes that have occurred can help target treatments in specific locations or situations where and when these collisions have occurred, or area-wide for similar locations/conditions. Nearly one-fourth of pedestrian collisions (23.6%) in the study area involved pedestrians crossing the roadway at intersections or midblock and being struck by vehicles that were not turning at the time (data from Table 7). More than half of these collisions occurred at midblock locations, with about 43% at or near intersections. The next largest groups of collisions were Unusual types, and collisions in which the pedestrian was Crossing the Roadway and was struck by a Turning Vehicle (16.6% each). Most of the Crossing Roadway, Vehicle Turning crashes occurred at or near intersections with about 1/5 occurring at non-intersection locations such as near driveways. The third largest group (of roadway collisions) involved pedestrians dashing or darting-out from behind other vehicles or objects into the roadway (9.6%). Most of these occurred at midblock locations. Walking along the Roadway collisions (with pedestrians being struck from the front or behind) accounted for 4.5%. Another 3.2% occurred when pedestrians were Crossing a Driveway or Alley entrance and were struck by motorists turning in or exiting. Another 3.2% were the Multiple Threat type of collisions, whereby a pedestrian enters the roadway in front of stopped or slowing traffic and is struck by a vehicle whose view of the pedestrian is obstructed by the stopped/slowed traffic. Most of these occurred at or related to an intersection. Bus-related accounted for another 3.2% with 4 of the 5 being commercial bus-related and 1 involving a school bus. Finally, 2 collisions (1.3%) involved pedestrians Working or Playing in the roadway. Most of the other collisions occurred off the road network such as on public and private parking lots; a number of off-roadway collisions involved backing vehicles, although 2 Backing Vehicle collisions occurred at non-intersection roadway locations. A few others occurred under other or unknown circumstances.

Table 7. Type and Location of Pedestrian-Motor Vehicle Collisions in Chapel Hill/Carrboro Study Area, 2001-2005.

Crash Location Crash Group	Intersection	Intersection-Related	Non-Intersection	Non-Roadway	Total
Backing Vehicle			2	11	13
	.0%	.0%	15.4%[1]	84.6%	100.0%
	.0%	.0%	2.9% [2]	35.5%	8.3% [3]
Bus-Related	2	2	1		5
	40.0%	40.0%	20.0%	.0%	100.0%
	4.8%	13.3%	1.4%	.0%	3.2%
Crossing Driveway or Alley			5		5
	.0%	.0%	100.0%	.0%	100.0%
	.0%	.0%	7.2%	.0%	3.2%
Crossing Roadway - Vehicle Not Turning	10	6	21		37
	27.0%	16.2%	56.8%	.0%	100.0%
	23.8%	40.0%	30.4%	.0%	23.6%
Crossing Roadway - Vehicle Turning	18	3	5		26
	69.2%	11.5%	19.2%	.0%	100.0%
	42.9%	20.0%	7.2%	.0%	16.6%
Dash / Dart-Out	4	1	10		15
	26.7%	6.7%	66.7%	.0%	100.0%
	9.5%	6.7%	14.5%	.0%	9.6%
Multiple Threat / Trapped	3	1	1		5
	60.0%	20.0%	20.0%	.0%	100.0%
	7.1%	6.7%	1.4%	.0%	3.2%
Off Roadway				11	11
	.0%	.0%	.0%	100.0%	100.0%
	.0%	.0%	.0%	35.5%	7.0%
Other / Unknown - Insufficient Details	1		3		4
	25.0%	.0%	75.0%	.0%	100.0%
	2.4%	.0%	4.3%	.0%	2.5%
Unique Midblock			1		1
	.0%	.0%	100.0%	.0%	100.0%
	.0%	.0%	1.4%	.0%	.6%
Unusual Circumstances	3	1	13	9	26
	11.5%	3.8%	50.0%	34.6%	100.0%
	7.1%	6.7%	18.8%	29.0%	16.6%
Walking Along Roadway		1	6		7
	.0%	14.3%	85.7%	.0%	100.0%
	.0%	6.7%	8.7%	.0%	4.5%
Working or Playing in Roadway	1		1		2
	50.0%	.0%	50.0%	.0%	100.0%
	2.4%	.0%	1.4%	.0%	1.3%
Total	42	15	69	31	157
	26.8%[3]	9.6%	43.9%	19.7%	100.0%

[1] Percent of Crash Group (row) total
[2] Percent of Crash Location (column) total
[3] Percent of Table Total

Spatial Comparisons of Pedestrian Crash and Perception Density Areas

Spatial cluster analysis and spatial density analyses were used to identify areas where crashes were concentrated.

Pedestrian high crash areas

Ripley's K-function analysis confirmed the non-random clustering of pedestrian collisions on a global level compared to the expected distribution of crashes if they were distributed more or less randomly over the street network. Overall, there were one each of 12- and 7-crash clusters, three clusters of 4, three clusters of 3, and 14, 2-crash clusters of pedestrian collisions (Figure 7 and Figure 8). (Figure 8 is an inset map highlighting the clusters in the downtown core areas and campus.)

Although points (crashes or perception) can be viewed on a map as illustrated in Appendix B, points may occur in the same or nearly the same location so that the actual distribution of points is difficult to observe in a dot map. Density analysis allows examination of the density of points over an area. A map illustrating the results of kernel density analysis of pedestrian crashes is displayed in Figure 9. Note that there are two different high density nodes in the downtown Chapel Hill area, one centered on Columbia and Franklin and one centered further west along Franklin St. These nodes correspond with the 12- and 7-crash clusters, respectively, that were identified in the network-based cluster analysis. In general effect, the results of the two types of analyses are very comparable in terms of locations identified. The cluster analysis defined problem areas somewhat more precisely in terms of the corridor and intersection areas involved, and a number of two-crash clusters were identified that were not in areas highlighted by the density analyses. (Since the density analysis searches in a radius in all directions from each crash point for nearest neighbors, the density nodes are sometimes between roadways.) However, one apparent cluster of two collisions at the same intersection (NC 54 W and W Main) was not identified although it was highlighted by the kernel density analysis. Since clusters as small as two crashes were allowed, the reason that this one was not identified is unclear.

We also analyzed kernel density of *near miss* locations. The results overlapped with those in the core areas of Towns and campus identified by the risk perception (and crash) data with fewer outlying areas identified. Since the analysis did not identify any new locations, the results are not discussed further. However, these data may be considered to capture reported 'conflicts' which are sometimes considered surrogates for actual collisions, and could be given more weight in analyses of problem locations.

Pedestrian Crash Statistical Clusters - 300 feet

Network-Based "Clumping" Analysis: 100 foot Intervals

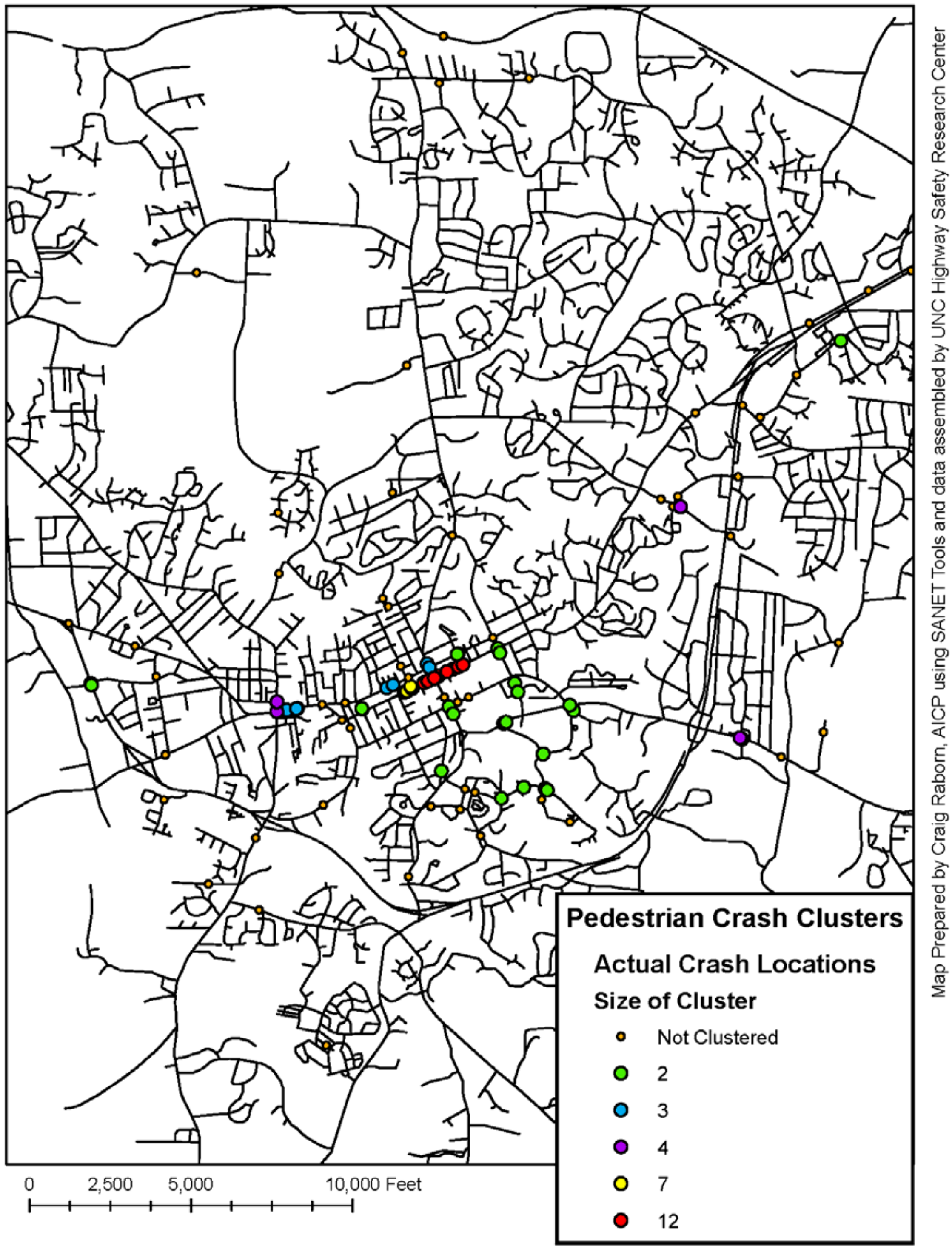

Figure 7. Map showing clusters of pedestrian collisions for the study area.

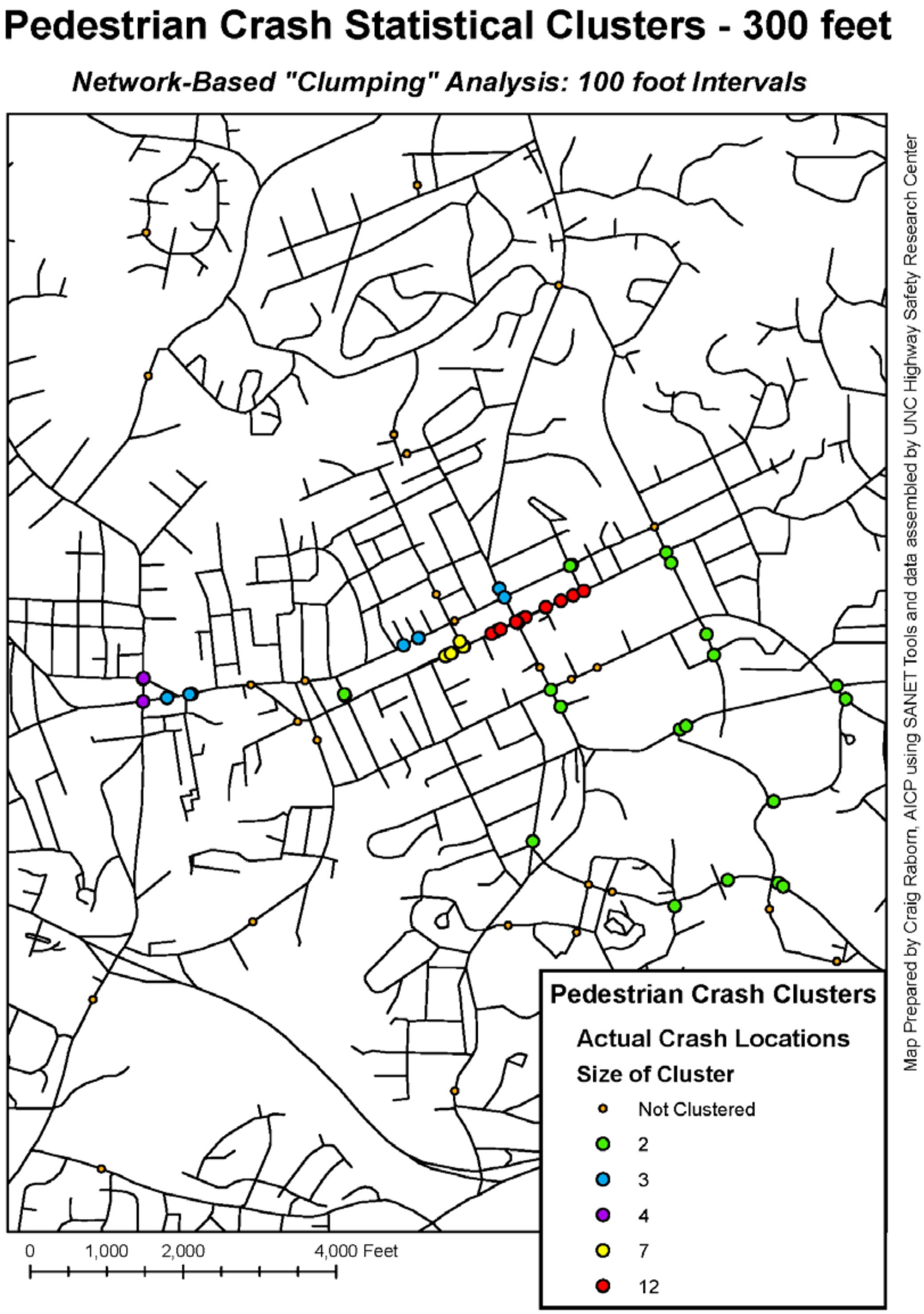

Figure 8. Map illustrating pedestrian crash clusters in the downtown and campus areas.

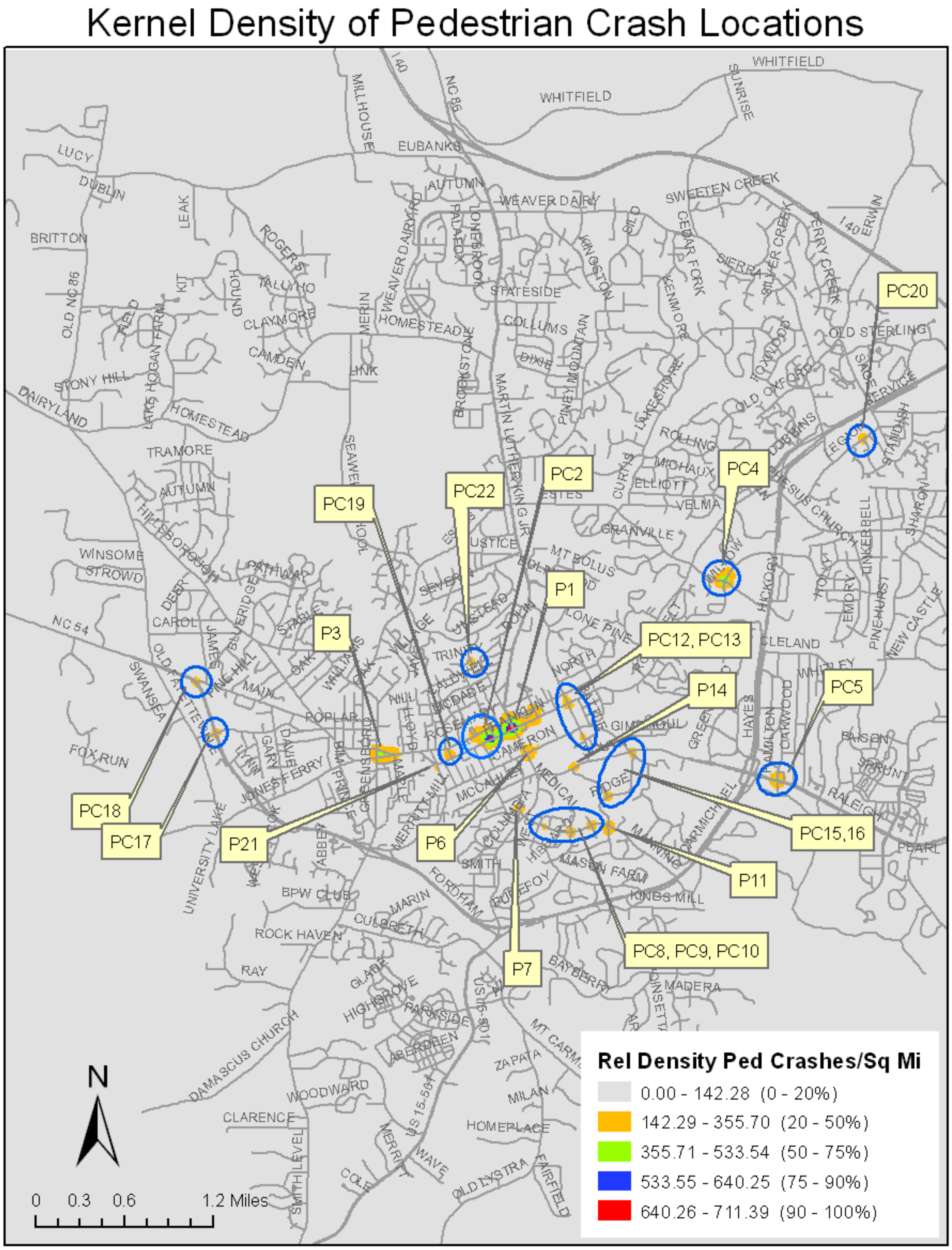

Figure 9. Map illustrating results of kernel density analysis of pedestrian collisions, 2001-2005.

Notes: Highest density = top 90th percentile (640 – 711 crashes/sq mi); Medium high 50th percentile; and Low = 0 to 20th percentile in relative density of collisions per sq mile. Areas above the 20th percentile that are circled were not identified by kernel density analysis of risk perception data (see figure 10).

The crash clusters, the related crash density and perception density rankings, whether the area overlaps with one identified by the Towns, and speed study results, are described in Table 8.

Table 8. Pedestrian Crash Clusters and Crash Density Areas and Corresponding Perception Density Rankings.

Crash Clusters – in decreasing order	Crash Density Area & Ranking	Perception Density Ranking	IDed by Town	Speed limit/ 85th% speed	Status
12-crash cluster - Downtown Chapel Hill, Franklin St. from Henderson St. on the east side to approximately the first entrance to Granville Towers/University Sq. drive on the west side; 2-crash cluster at Henderson & Rosemary; 3-crash cluster, Columbia and Rosemary and about 45 m N on Columbia	**P1** - High esp.around Columbia - just west of Columbia. Medium Low density east to Henderson	High to medium low	No	20 mph (no study in this section, but see next)	**Detailed audit**
7-crash cluster - Franklin St. from Church St intersection to the midblock area before Mallette St; 3-crash cluster - vicinity of Amity and Andrews on Rosemary St	**PC2** - High to Medium high	Low	Yes (midbl area)	20 34	**Detailed audit**
4-crash cluster - Downtown Carrboro at intersections of Main St and Weaver St with Greenboro; and 3 crash cluster – at and near Weaver Main and Roberson	**P3** - Medium	Medium high to Medium	Yes	20 32 (N Greensboro (near HT)	**Detailed audit**
4-crash cluster, 3 at intersection, and nearby Willow Dr. and Estes Dr. (Univ. Mall area) -	**PC4** - Medium	Low	No	35 42	**Detailed audit**
4-crash cluster - intersection NC 54/Raleigh Road and Hamilton Rd	**PC5 -** Medium	Low	No	35 49	**Detailed audit**
2-crash cluster – at Columbia and Cameron and other crashes on nearby Columbia and Cameron	**P6 -** Medium low	Medium Low	No	n/a	no further

Crash Clusters – in decreasing order	Crash Density Area & Ranking	Perception Density Ranking	IDed by Town	Speed limit/ 85th% speed	Status
Four 2-crash clusters – on Manning Dr at intersections including at Pittsboro/University; at Emergency/Hibbard; at Paul Hardin; and at or near Ridge/Skipper Bowles. Two other collisions at intersections or hospital driveways.	**P7, PC8, PC9, PC10, P11 -** Medium low density – five areas	Medium Low, particularly at Pittsboro/Columbia and at Ridge	No	25 32	**Detailed audit**
Two 2-crash clusters – on Hillsborough/Raleigh St, at Franklin, and @ south of Cameron; also 1 crash at Rosemary	**PC12, PC13 -** Medium low two separate areas	Low	No	n/a	no further
Three 2-crash clusters – South Rd & environs: 1along South Rd near Stadium; 1 at South, Raleigh & Country Club, and 1 at Stadium and Ridge	**P14, PC15, PC16 -** Medium low	Medium Low	No	n/a	no further
Two 2-crash clusters – on NC 54 W (Carrboro) at/near Poplar and at/near Main	**PC17, PC18 -** Medium low	Low	No	45 54	Brief audit
2-crash cluster – Roberson St	**PC19 -** Medium Low	Low			Brief visit
2-crash cluster – Legion Rd and Forsyth Dr	**PC20 -** Medium Low	Low			Brief visit
2 Non-clustered crashes - Brewers and Merritt Mill area	**P21 -** Medium low	Low	Yes	n/a	**Detailed audit**
2 Non-clustered crashes – Pritchard Ave and Longview area	**PC22 -** Medium Low	Low	No		Brief visit

Other pedestrian crashes not estimated to form part of a cluster, but of concern were six crashes on Fordham Blvd beginning near Estes Dr. intersection and northward, including at Willow Dr (also identified by the Town), and at Ephesus Church Rd/Eastgate. The Eastgate/Ephesus intersection with Fordham overlaps with Medium low perception of risk (see below). There were also several non-intersection crashes further north of these intersections along Fordham Blvd near, but not at, Erwin Rd junction (data are from before the Superstreet). Other isolated crashes on campus streets included two on Skipper Bowles, two on Mason Farm Rd. Other pedestrian crashes were more sporadically located on a variety of collector, local, arterial and even interstate roads. (See Appendix E for speed data summaries for all sites.)

Pedestrian perceived risk areas compared with crash areas

Comparing the crash results to the analyses of perception data, there were about 23 new areas (grouping some areas along corridors together) that were highlighted by the perception data that were not identified by either type of analysis of crash data. The new areas are described in Table 9. Seven areas overlapped significantly with those identified by crash density analysis (P1, P3, P6, P7, P11, P14, and P21). See Figure 10 for an illustration of all the perceived risk areas. All of the new areas highlighted by the risk perception data were along main corridors leading to the downtowns, including on Martin Luther King, Jr Blvd, S Columbia and Pittsboro Streets (one-way couplet), Franklin St; S Greensboro, and Main St; or on cross town(s) arteries such as Estes Dr Ext and Fordham Blvd. In addition to new areas highlighted, Chapel Hill and Carrboro downtown perceived risk areas, and an area along South Road, were somewhat more expansive than the crash density areas these overlapped.

A number of areas that were identified by the crash data (above the 20th percentile in relative density) were also not particularly perceived as unsafe, or at least not identified frequently enough by those surveyed to rise above the 20th percentile in rank. These areas were highlighted with blue outlines in the crash density map (Figure 9) and noted as “Low” in the Perception Density Ranking of crash areas in Table 8.

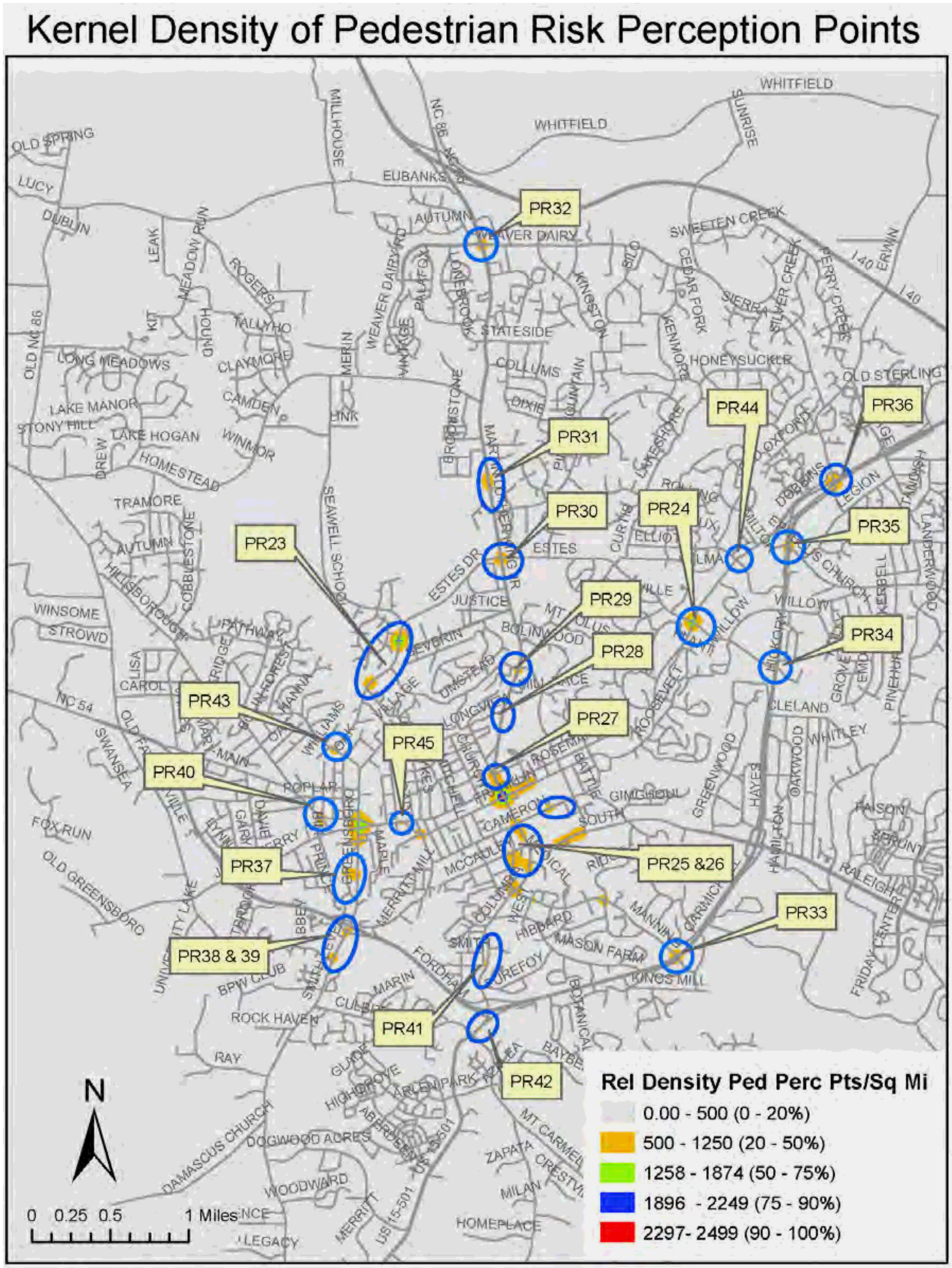

Figure 10. Map showing results of kernel density analysis of pedestrian perceived risk locations, 2007 survey.
Note: Areas circled in blue were not highlighted by kernel density analysis of collision data.

Table 9. New Areas Highlighted by Perception Data, but with Low Relative Crash Density.

Area description	Perception Ranking	Location ID'd by Town	Speed limit (mph)/ 85th percentile (mph)	Status
PR23 - Estes Dr Ext (segments – 2 areas)	Medium high, Medium	no	35 48	Brief visit
PR24 - Franklin St & Estes Dr	Medium	no	35 45 (near Davie Cir, Roosevelt)	**Detailed audit**
PR25 - S Columbia St south of Cameron Av; **PR26** S Columbia and Pittsboro Sts, S of McCauley, N of Manning)	Medium low	no	35 39 (So. Columbia)	Brief visit
Martin Luther King Jr. Blvd (MLK) **PR27** -@ Columbia/North St; **PR28** - @ Longview area; **PR29** @ Umstead / Hillsborough; **PR30** @ Estes	Medium low	(a prior study examined this corridor)	35 45 (SB), 47 (NB) (south of Hillsborough)	**Detailed audit**
PR31 – MLK Blvd near Timberhill Ct (Shadowood Apts.)	Medium low	Prior study	35 46	No further – treatment pending
PR32 - MLK Blvd & Weaver Dairy Rd	Medium low	Prior study	35 48 (afternoon & evening)	Brief visit
PR33 - Fordham Blvd & Manning Dr	Medium low	yes	45 52 SB, 55 NB	Improvements pending
PR34 - Fordham Blvd & Estes	Medium low	no	45 no study (but see PR33)	**Detailed audit**
PR35 - Fordham Blvd & Ephesus Ch Rd	Medium low	no	45 no study (but see PR33)	Brief visit
PR36 - Fordham Blvd and Erwin Rd	Medium low	yes	45 no study	Superstreet

Area description	Perception Ranking	Location ID'd by Town	Speed limit (mph)/ 85th percentile (mph)	Status
S Greensboro St **PR37** S Greensboro St and Old Pittsboro to NC 54 bypass (segments); **PR38** S Greensboro junctions with NC 54 bypass; **PR39** @ Public Works Dr	Medium low	no	35 44	**Brief audit**
PR40 - W Main & W Weaver (& Elm) Sts	Medium low	yes	n/a	**Detailed audit**
PR41 - S Columbia segment near Old Pittsboro	Medium low	no	35 39	Brief visit
PR42 - S Columbia near 15/501 interchanges	Medium low	no	35 See PR33	Brief visit
PR43 – Estes Dr Ext & N Greensboro St			35 48 (on Estes)	Brief visit
PR44 - Franklin St & Elliott Rd	Medium low	no	35 no study	No further
PR45 – Main St & Rosemary St	Medium low	no	20 no study	Brief visit

Ped ISI

The pedestrian intersection safety index ranking tool (Ped ISI, see Carter et al., 2006) was applied to a sample of 28 intersections with pedestrian collisions (8), or with perception points, or reported near-misses, but no collisions. The model was applied to each crossing of an intersection. Results showing the highest ranking (higher = greater perceived risk) value for any leg of each intersection are shown in Appendix C.

Examination of results shows that a number of the intersections with higher ISI rankings have had no crashes or only 1 crash (during the study period), and conversely a number of intersections with 2 collisions are rated fairly low on the ISI index. Three of the top (10+ with ties) intersections for ISI rating were among the highest-crash locations. It is worth noting that the highest ranked intersection of those evaluated using the Ped ISI, was the junction of Martin Luther King Jr Blvd with North Columbia and North Streets, a location at the edges of a medium low risk perception area, was not highlighted by crash data. (One woman surveyed, whom we know to walk extensively on a daily basis, emphasized this intersection as being very unsafe.) This junction is non-signalized and has a skewed, wide angle intersection – the latter risk factor for pedestrians that is not even captured by the high ISI rank. Another highly ranked intersection (3.9) was NC 54/Raleigh Rd and Hamilton Rd, which also ranked highly for collisions - tied for first with four - but was not identified above the 20th percentile of perception points as being unsafe. The other intersections along E NC 54 (Barbee Chapel E, Friday Center Dr) also have high index rankings. Although these latter intersections had no pedestrian collisions during the study period, they were identified by Chapel Hill as needing improvements.

In general, smaller, lower traffic volume intersections were more likely to have lower index rankings while larger, busier intersections were likely to have higher rankings. Thus, rankings at intersections along a number of key corridors tend to be very similar and supported paying further attention to these large intersections, some of which were identified by crash or perception data and some that were not. (If intersections lacked signal control, then they scored even higher. Higher 85th percentile speeds also increased the rankings.) However, the index does not apply to junctions such as interchange on/off ramp end points that often present difficult crossings situations. The rankings do not account for lack of marked crosswalks or the presence of pedestrian signals (if the intersection is signalized, the index apparently assumes that there is a pedestrian walk signal and a phase long enough to cross), skewness, poor visibility, lack of lighting (nighttime), unusual geometric configurations such as continuous right-flow turn lanes, or prevalence of several lanes of turning traffic. Thus, the index was primarily useful for highlighting intersections along multi-lane, high volume, higher speed corridors such as Fordham Blvd, Martin Luther King Jr Blvd, and NC 54, but lacked the sensitivity to discriminate other detailed factors that affect pedestrian safety, such as an absence of pedestrian signals, sufficient time to cross, skewed geometrics or other factors.

Since no intersection files could be located from state or local agencies prior to the study, data had to be gathered from multiple sources and street files, and supplemented with speed studies, on-site visits and examination of aerial and (recent) street views on Google® maps to ascertain lane configurations and signing/signalization. Thus, it was more time-consuming than anticipated to determine the index rankings. Since the tool is intended to be a first-run, proactive screening tool, the detailed information already available from the site visit, speed studies, and crash and perception data were considered more heavily in determining audit locations. However, if a site ranked highly on the index and was not identified by other methods, it would likely be useful to conduct further analysis of the intersection.

The tool would be more useful as a screening tool if a jurisdiction already has intersection files that contain all the necessary data items for each leg. Nevertheless, if a site ranked highly on the index and was not identified by other methods, or was not audited it would likely be useful to conduct further analysis of the intersection.

Evaluation of Bicycle Safety Problems

Bicycle Crash and Perception Data Description

There were a total of 102 reported bicycle-motor vehicle crashes within the study area over the five years. There were significant year-to-year fluctuations, but over the entire five years, 28% of the bicycle collisions occurred in Carrboro and planning jurisdiction while 69% occurred in Chapel Hill and planning areas; 3% were outside of these areas (Table 10).

Table 10. Bicycle-Motor Vehicle Collisions in Study Area.

Crash Year	City			Total
	Carrboro	Chapel Hill	Rural	
2001	10 [8]	16		26
	38.5% [9]	61.5%	.0%	100.0%
	34.5% [10]	22.9%	.0%	25.5%
2002	5	9		14
	35.7%	64.3%	.0%	100.0%
	17.2%	12.9%	.0%	13.7%
2003	4	11		15
	26.7%	73.3%	.0%	100.0%
	13.8%	15.7%	.0%	14.7%
2004	1	11	1	13
	7.7%	84.6%	7.7%	100.0%
	3.4%	15.7%	33.3%	12.7%
2005	9	23	2	34
	26.5%	67.6%	5.9%	100.0%
	31.0%	32.9%	66.7%	33.3%
Total	29	70	3	102
	28.4%	68.6%	2.9%	100.0%

[8] Count
[9] Percent of year total
[10] Percent of city total

Similar to the overall collision percentages, about 30% of locations *perceived to be unsafe* for bicyclists were located in Carrboro and planning areas and 64% in Chapel Hill and planning areas with about 7% of locations on more rural roads outside of these areas (Table 11). The locations of near-miss points reported differed more from crash percentages – 34% for Carrboro, and 60% for Chapel Hill (Table 11). About 6% of reported near misses occurred in rural areas.

Both the bicycle crash data and the risk perception data have the same considerations with regard to accuracy and precision of locations as described previously for the pedestrian data. The perceived risk locations for bicyclist, in particular, were often representative of segments or even entire corridors.

Table 11. Data Points for Perceived Unsafe Bicycle Locations, 2007 survey.

Locations Identified 2007 survey	City			Total
	Carrboro	Chapel Hill	Rural	
Bicycle Perceived Unsafe Points	132	307	31	470
	28.1% [11]	65.3%	6.6%	76.3%
Bicycle Near Miss Points	50	87	9	146
	34.2%	59.6%	6.2%	23.7%
Total	182	394	40	616
	29.5% [12]	64%	6.5%	

[11] Percent of row total
[12] Percent of Total

Of the 102 reported bicycle collisions, 4 occurred on non-roadway locations such as parking lots, resulting in 98 that occurred on public roads (Table 12). All except for one of the on-street bicycle collisions could be located on the study area streets layer. Fifty-six percent of the on-street collisions occurred at intersections with 44% at midblock locations (Table 12). Note that more 'segment' locations were identified by survey respondents as unsafe (74%) relative to bike collisions that occurred at midblock locations (44%). The locations identified as near-misses more closely align with crash experience.

Table 12. Bicycle and Perception Data Locations.

Type	Intersection or Intersection-related	Midblock or segment	Non-Roadway
102 bicycle collisions	55 (56%)	43 (44%)	4
470 bicycle perceived unsafe points	121 (26%)	350 (74%)	n/a
149 bike "near miss" points	76 (51%)	73 (49%)	n/a

Bicycle Crash Factors

The following analyses of crash factors include the full set of 102 collisions. Spatial analyses following incorporate the 97 collisions that could be mapped to the study area streets layer.

Bicyclist and driver characteristics

In the study area:

- Children, ages 15 and under had relatively low representation in bicycle collisions with motor vehicles (13%) compared with children of the same ages in the state as a whole over the same time period (30%, Figure 11). (Note that as proportional involvement of young adults increases, the proportion of children involved would decrease.) We also spatially examined collisions of children and of children during typical school travel times, but no obvious patterns or problem areas emerged in relation to school locations or otherwise.
- Young adult bicyclists ages 21 to 25 were involved in 22% of the collisions compared with 8% for this age group statewide (Figure 11). These and the previous results are likely associated with the large population of young adults in the university community and their related exposures as bicyclists.
- Young drivers, ages 20 to 29, as with pedestrian collisions, were again involved most often - in 35% of the collisions with bicyclists (see Table 13). Statewide, drivers 20 to 29 accounted for 22% of those involved in collisions with bicyclists (data not shown).
- Bicyclists were clearly suspected of alcohol use (although not necessarily impairment) in 5% of cases (Table 14). While there were no clear cases where officers indicated alcohol use by motorists, the large proportion of "unknowns" among both motorists (30%) and bicyclists (50%) again reduce the usefulness of these data.
- Bicyclists were reported injured in nearly 90% of the collisions, with no injuries reported in 4% and another 7% of unknown injury status (Table 15). There were no reported fatalities during this time period.
- Drivers were also reported to suffer injuries in 24% of the collisions (data not shown), but only 1 driver was reported to suffer a disabling injury.

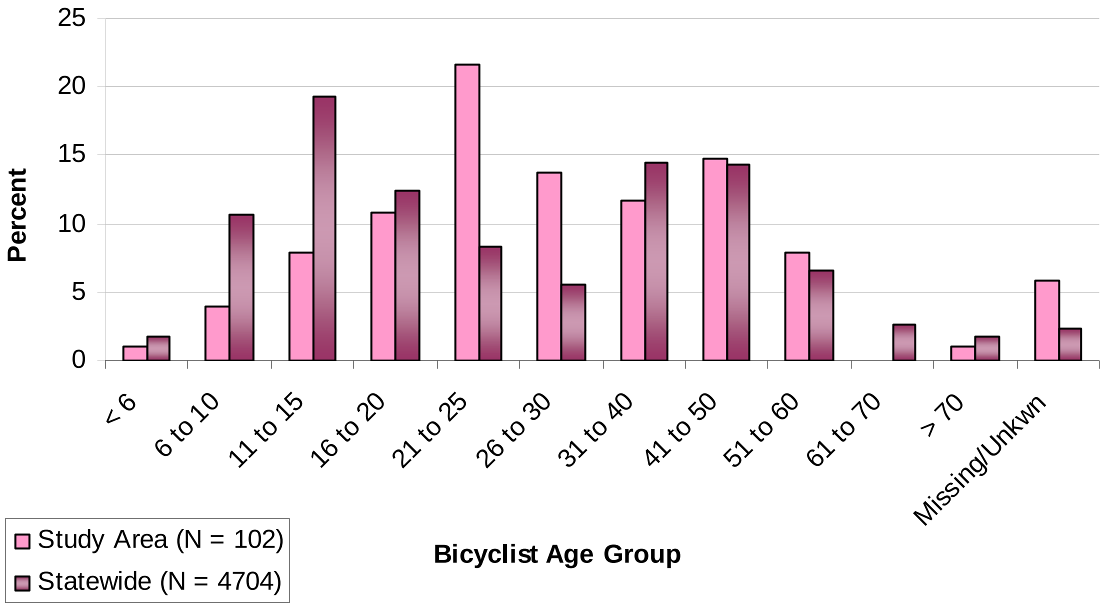

Figure 11. Ages of bicyclists involved in collisions with motor vehicles, 2001-2005.

Table 13. Ages of Drivers Involved in Collisions with Bicyclists.

Driver Age	Frequency	Percent
< 16 years	2	2.0
16 to 19	7	6.9
20 to 29	36	35.3
30 to 39	12	11.8
40 to 49	19	18.6
50 to 59	12	11.8
60 to 69	5	4.9
> 70+	2	2.0
Unknown	7	6.9
Total	102	100.0

Table 14. Suspected Alcohol Involvement by Bicyclists and Motorists in Collisions, 2001-2005.

Bicyclist Alcohol Use Suspected/ Detected	Driver Alcohol Use Suspected/Detected		
	No	Unknown	Total
Yes	3	2	5
	60.0%	40.0%	100.0%
	4.2%	6.5%	4.9%
	2.9%	2.0%	4.9%
No	34	12	46
	73.9%	26.1%	100.0%
	47.9%	38.7%	45.1%
	33.3%	11.8%	45.1%
Unknown	34	17	51
	66.7%	33.3%	100.0%
	47.9%	54.8%	50.0%
	33.3%	16.7%	50.0%
Total	71	31	102
	69.6%	30.4%	100.0%
	100.0%	100.0%	100.0%
	69.6%	30.4%	100.0%

Table 15. Bicyclist Injury Severity, 2001 - 2005

Bicyclist Injury	Frequency	Percent
A (disabling)	2	2.0
B (evident)	45	44.1
C (possible)	44	43.1
None	4	3.9
Unknown	7	6.9
Total	102	100.0

Bicycle crash temporal factors

There is more variability by month in when bicycle collisions occur than for pedestrian collisions, likely due to variations in amounts of riding between the cooler and warmer months. On average, the highest crash month for bicycle collisions has been October with nearly 19% of the reported collisions occurring during that month, followed by April with 11% (Figure 12). The trend toward fewer daylight hours, plus the shift from daylight savings time to eastern standard may result in more commuter bicyclists riding during low-light and dark hours in the early evening during fall months. In fact, 11 of the 15 collisions that occurred during dark conditions occurred during the months of October and November. Bicyclists should be encouraged to use lights and reflective gear during dawn and dusk as well as during nighttime hours.

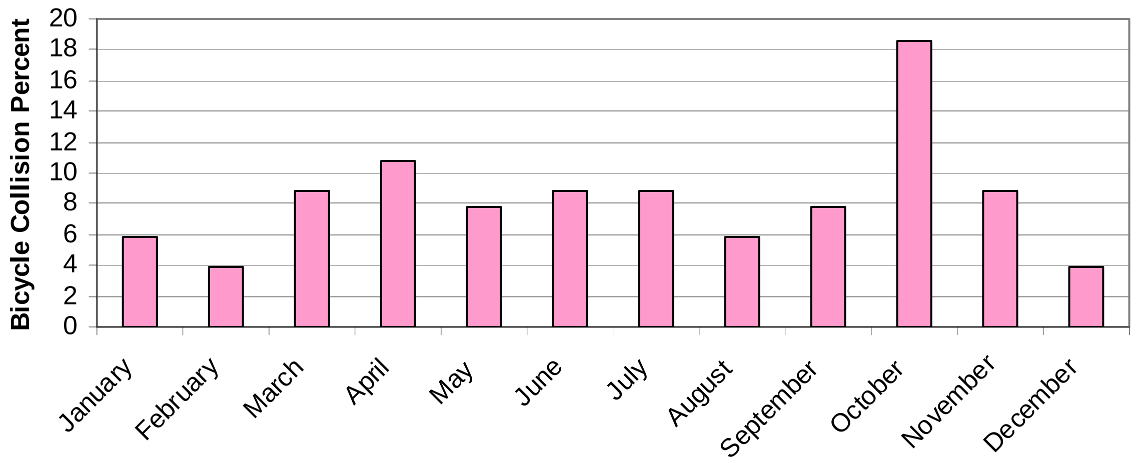

Figure 12. Bicycle-Motor Vehicle Collisions by Month, 2001-2005.

Regarding days of the week, more bicycle collisions occurred on Friday (20%), followed by Tuesday (18%) and Wednesday (17%), than on other days (Figure 13).

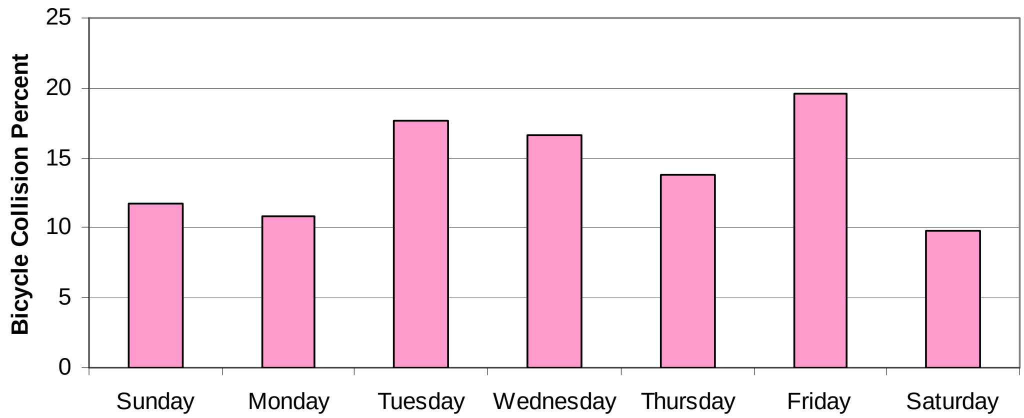

Figure 13. Crash Day-of-week of bicycle-motor vehicle collisions, 2001-2005.

The afternoon hours from 3 to 6 pm have been the highest crash period for bicycle as well as pedestrian collisions (Figure 14). Nearly 28% of bicycle-motor vehicle collisions occurred during the three-hour period from 3 to 6 pm. Nearly 10% occurred during nighttime hours from 9 pm to 6 am.

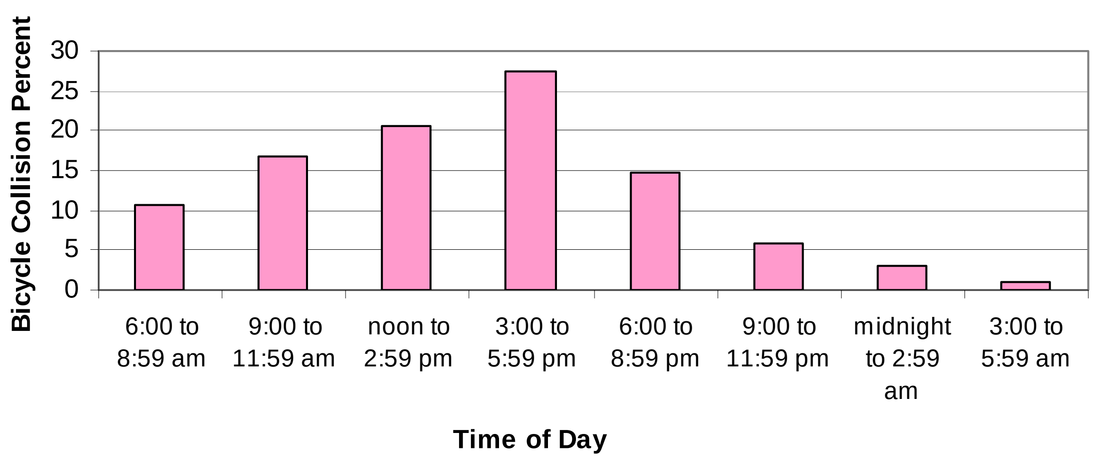

Figure 14. Time of day of bicycle-motor vehicle collisions, 2001-2005 (n = 102).

More than three-fourths of bicycle-motor vehicle collisions occurred during daylight hours (Figure 15). Twenty-two percent of collisions occurred, however, during low light hours with 15% at night on lighted roadways, 1% at night on unlighted roadways, and another 6% at dawn or dusk according to data derived from police crash reports. Crashes at night may be over-represented, though exposure data are lacking to verify this. Examination of the spatial distribution of crashes shows that a majority of nighttime collisions occurred in the downtown Chapel Hill area. In a number of police crash reports for night-time crashes, officers noted that the bicyclists did not have proper lighting. As mentioned previously, this behavior could be addressed programmatically on campus, and by the communities.

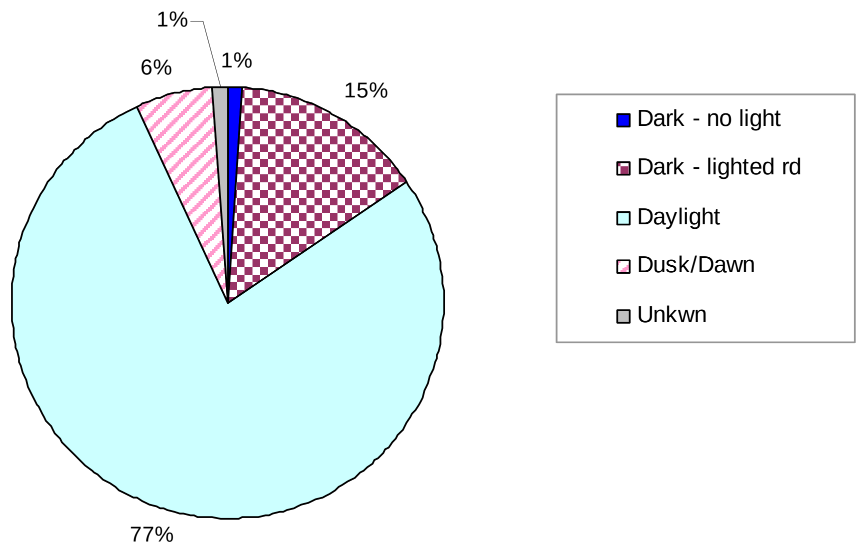

Figure 15. Light condition of bicycle-motor vehicle collisions, 2001-2005 (n = 102).

Bicycle crash types

The most frequent type of crash in the study area occurred when motorists turned or merged left in front of oncoming bicyclists (12.7%, Table 16). Almost equal portions of these took place at intersections and at other junctions such as driveways. Together, crashes involving left and right-turning motorists accounted for more than 1/5 of all collisions between bicyclists and motorists with Motorist Right Turn/Merge accounting for 7.8%. The second and third most frequent types were Motorists Failed to Yield at Stop signs (11%) and at Midblock driveways (10%). Other types that accounted for more than 5% of collisions included Bicyclist Left Turn/Merge (8.8%); Bicyclist Failed to Yield – Signalized intersection (7.8%); Bicyclist Failed to Yield – Sign-Controlled Intersection; Crossing Paths – Other Circumstances; and Motorist Overtaking Bicyclist (5.9%). Other crash types are also shown in Table 16). This information was examined in more detail during audits of particular locations, and informs system-wide countermeasure strategies. For example, efforts should be made to separate turning movements from through movements at intersections to the extent possible, and to prevent motorists turning left without yielding to bicyclists at non-signalized junctions.

Table 16. Crash Type group and Locations of Bicycle-Motor Vehicle Collisions, 2001-2005.

Crash Location / Crash Group	Intersection	Intersection-Related	Non-Intersection	Non-Roadway	Total
Backing Vehicle		1	2		3
	.0%	33.3%[1]	66.7%	.0%	100.0%
	.0%	25.0% [2]	4.7%	.0%	2.9%
Bicyclist Failed to Yield - Midblock			2		2
	.0%	.0%	100.0%	.0%	100.0%
	.0%	.0%	4.7%	.0%	2.0%
Bicyclist Failed to Yield - Sign-Controlled Intersection	6				6
	100.0%	.0%	.0%	.0%	100.0%
	11.8%	.0%	.0%	.0%	5.9%
Bicyclist Failed to Yield - Signalized Intersection	8				8
	100.0%	.0%	.0%	.0%	100.0%
	15.7%	.0%	.0%	.0%	7.8%
Bicyclist Left Turn / Merge	3	1	5		9
	33.3%	11.1%	55.6%	.0%	100.0%
	5.9%	25.0%	11.6%	.0%	8.8%
Bicyclist Overtaking Motorist		1	3		4
	.0%	25.0%	75.0%	.0%	100.0%
	.0%	25.0%	7.0%	.0%	3.9%
Bicyclist Right Turn / Merge			2		2
	.0%	.0%	100.0%	.0%	100.0%
	.0%	.0%	4.7%	.0%	2.0%
Crossing Paths - Other Circumstances	5		1		6
	83.3%	.0%	16.7%	.0%	100.0%
	9.8%	.0%	2.3%	.0%	5.9%
Head-On			1		1
	.0%	.0%	100.0%	.0%	100.0%
	.0%	.0%	2.3%	.0%	1.0%
Loss of Control / Turning Error	2		1		3
	66.7%	.0%	33.3%	.0%	100.0%
	3.9%	.0%	2.3%	.0%	2.9%

Crash Location / Crash Group	Intersection	Intersection-Related	Non-Intersection	Non-Roadway	Total
Motorist Failed to Yield - Midblock			10		10
	.0%	.0%	100.0%	.0%	100.0%
	.0%	.0%	23.3%	.0%	9.8%
Motorist Failed to Yield - Sign-Controlled Intersection	11				11
	100.0%	.0%	.0%	.0%	100.0%
	21.6%	.0%	.0%	.0%	10.8%
Motorist Failed to Yield - Signalized Intersection	3				3
	100.0%	.0%	.0%	.0%	100.0%
	5.9%	.0%	.0%	.0%	2.9%
Motorist Left Turn / Merge	7		6		13
	53.8%	.0%	46.2%	.0%	100.0%
	13.7%	.0%	14.0%	.0%	12.7%
Motorist Overtaking Bicyclist	1	1	4		6
	16.7%	16.7%	66.7%	.0%	100.0%
	2.0%	25.0%	9.3%	.0%	5.9%
Motorist Right Turn / Merge	4		4		8
	50.0%	.0%	50.0%	.0%	100.0%
	7.8%	.0%	9.3%	.0%	7.8%
Non-Roadway				4	4
	.0%	.0%	.0%	100.0%	100.0%
	.0%	.0%	.0%	100.0%	3.9%
Other / Unusual Circumstances			1		1
	.0%	.0%	100.0%	.0%	100.0%
	.0%	.0%	2.3%	.0%	1.0%
Parallel Paths - Other Circumstances	1		1		2
	50.0%	.0%	50.0%	.0%	100.0%
	2.0%	.0%	2.3%	.0%	2.0%
Total	51	4	43	4	102
	50.0%	3.9%	42.2%	3.9%	100.0%
	100.0%	100.0%	100.0%	100.0%	100.0%

[1] Percent of Crash Group (row) total
[2] Percent of Crash Location (column) total

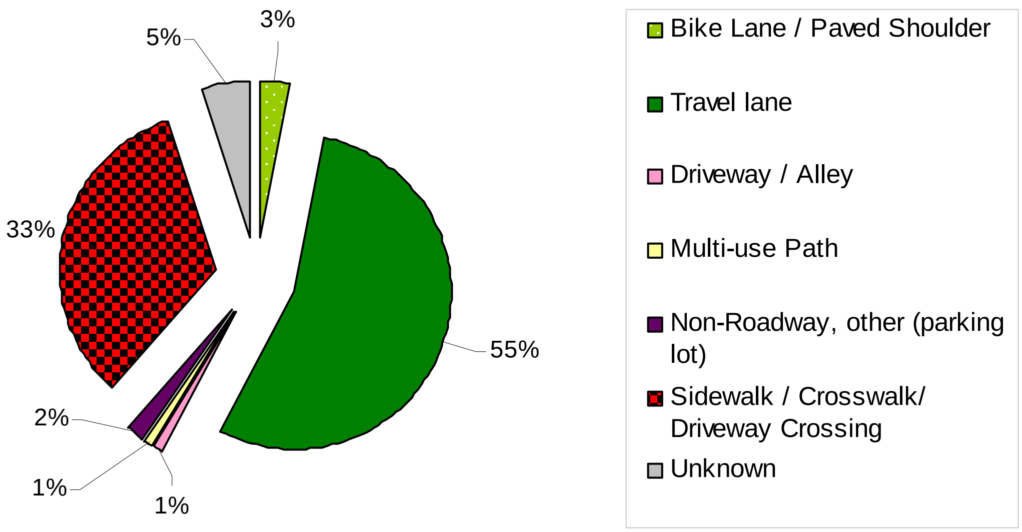

Figure 16. Bicyclist position at time of crash.

One-third of bicyclists involved in collisions were riding on sidewalks (Figure 16), and at least 22% were riding in the wrong direction, facing traffic (Figure 17) just before their collisions occurred.

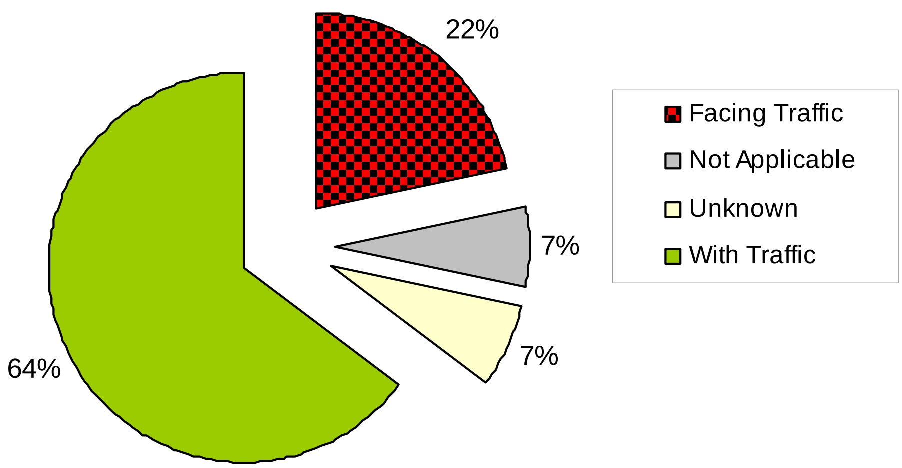

Figure 17. Bicyclist travel direction at time of crash.

Spatial Comparisons of Bicycle Crash and Perception Density Areas

Bicycle high crash areas

Ripley's K-function analysis confirmed the non-random clustering of bicycle collisions. There were a total of 13 clusters of bicycle collisions identified by the analysis: one each of 12 crashes, 10 crashes, 6 crashes, 5 crashes, 4 crashes, and 3 crashes; and seven 2-crash clusters. Bicycle crash clusters are illustrated in Figure 18 and Figure 19 and described in Table 17. The largest cluster spanned a corridor from Chapel Hill's W Franklin St to Carrboro's E Main to Weaver St (in red in Figure 18). The second highest cluster included part of W Rosemary, Columbia St, and W Franklin from Columbia St to Kenan St. The third largest cluster was along Carrboro's N Greensboro St from the intersection with Weaver St to Shelton St. Other larger clusters (>2 crashes) were primarily along Martin Luther King Jr. Blvd (three different clusters of 3, 4, and 5 crashes). All of the bicycle crash clusters were also highlighted by the density analysis of bicycle collisions (Figure 20).

Bicycle perceived risk areas compared with crash areas

Apart from core downtown Chapel Hill and Carrboro locations, bicycle perception areas (> 20th percentile in relative density) differed from higher density crash areas (> 20th percentile in relative density) (Figure 21). Nine areas were newly identified from the perception density analysis (Table 18), while only two areas overlapped substantially with crash areas (B2 and B3). More attention was focused on segments than on intersections and the highest concentrations of perception points were along a sections of one of the main corridors that had no collisions during the five year study period, Estes Dr Ext. This corridor section west of MLK Blvd received a paved shoulder for most of the length subsequent to the survey. Other perception locations tended to be along main arteries and collectors, particularly in the outlying areas, although the locations highlighted were different from those highlighted by crashes.

The downtown areas perceived to be unsafe for bicyclists overlapped with high crash locations in the downtown areas, although the shapes of the areas were different, and perception ranking was lower than the crash ranking. Surprisingly, none of the campus streets were clearly highlighted by the perception data except areas of S Columbia St that pass through campus. The area of downtown where most bicycle collisions occurred (part of W Franklin, Chapel Hill to E Main in Carrboro) was not identified as particularly risky (above the 20th percentile) by the perception density analysis.

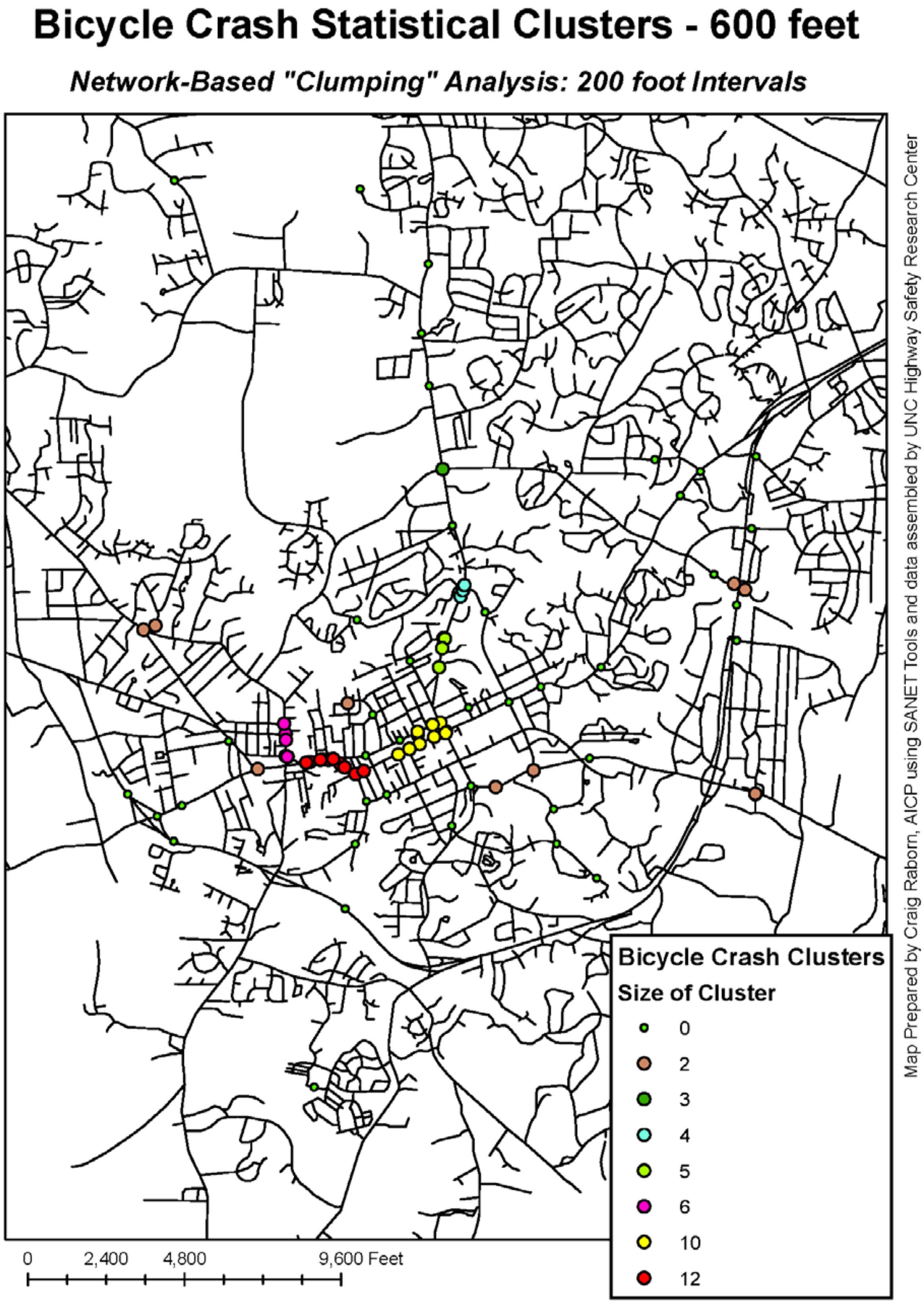

Figure 18. Bicycle crash clusters, 2001-2005 data.

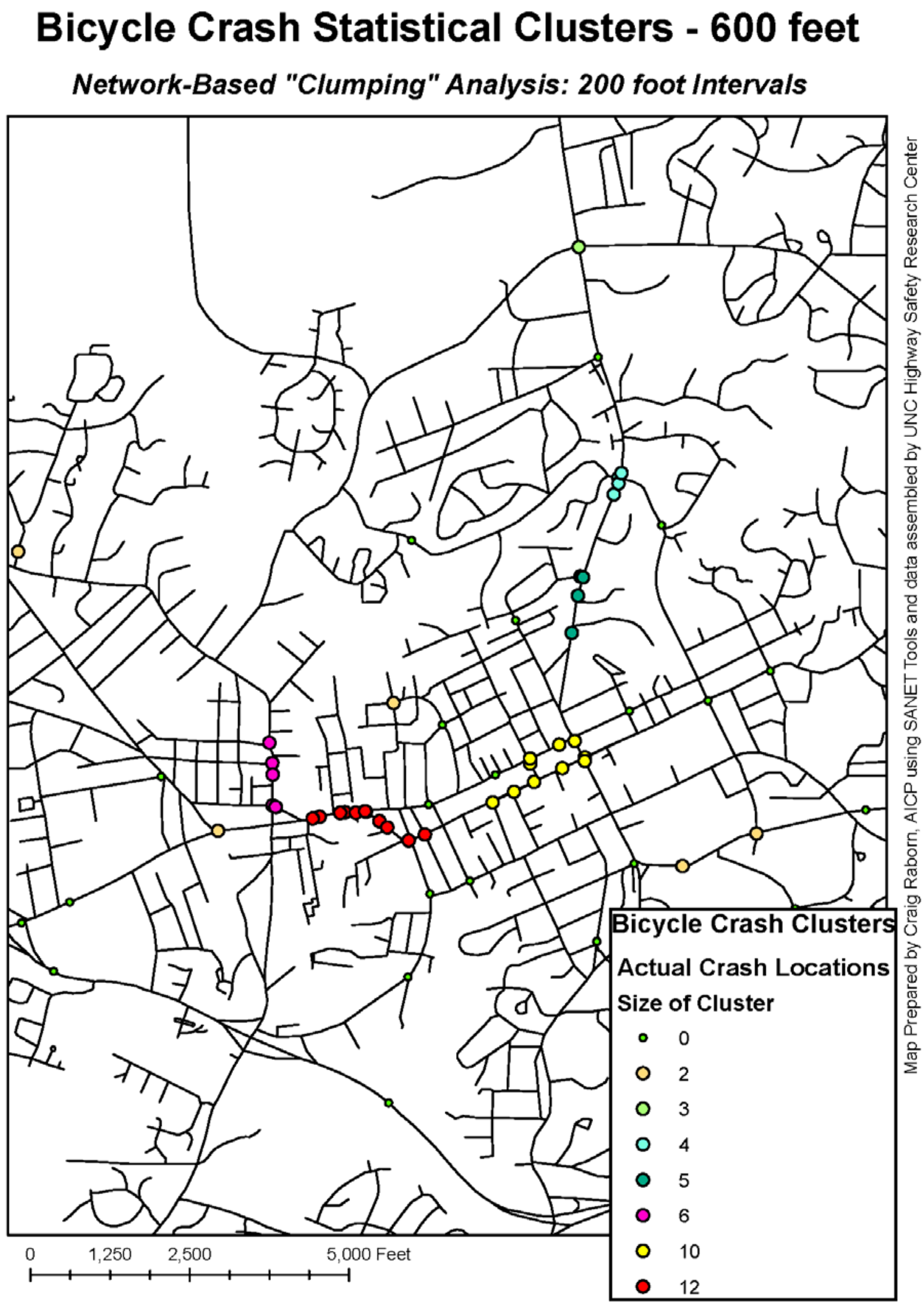

Figure 19. Bicycle crash clusters, 2001-2005 data – inset, downtown and campus.

Kernel Density of Bicycle Crash Locations

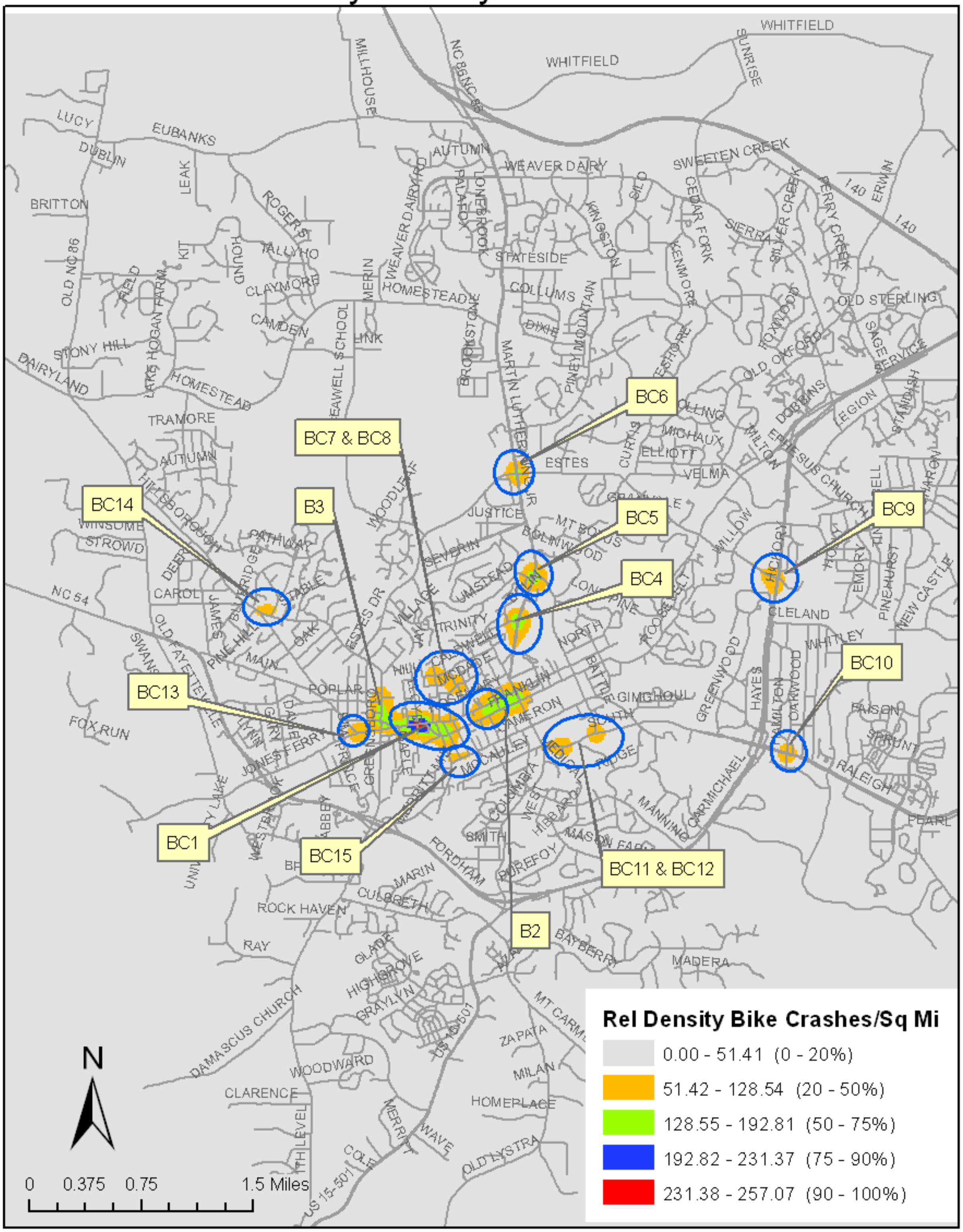

Figure 20. Map showing results of kernel density analyses of bicycle crashes, 2001-2005.

Notes: Circled areas were not highlighted by analyses of risk perception points. The highest density (90th percentile) of bicycle crashes occurred along an E Main St segment in Carrboro.

Table 17. Bicycle Crash Clusters and Density Areas and Corresponding Perception Density Ranking.

Crash Clusters – in decreasing order	Crash Density Area Ranking	Perception Density Ranking	Identified by Town	Speed limit/ 85th% speed	Status
12-crash cluster occurring along W Franklin to E Main in Carrboro from about Graham St in Chapel Hill continuing along E Main to Weaver St in Carrboro	**BC1** High to Medium	Low	Intersection of Franklin, Main, Merritt Mill, Brewers	20 34; 20 28	**Detailed audit**
10-crash cluster W Rosemary, Columbia and W Franklin to about Kenan St in Chapel Hill.	**B2** Medium	Medium low to low	No	see above; and 25 34 Rosemary	**Detailed audit**
6-crash cluster from near and at intersection of Weaver St and Greensboro St, turning north on Greensboro St to intersection with Shelton St in Carrboro.	**B3** Medium	Medium low	Yes	20 32	**Detailed audit**
5-crash cluster MLK Blvd. from north of Stephens St to Longview St	**BC4** Medium	Low	No (prior study)	35 47	**Detailed audit**
4-crash cluster on MLK Blvd. near intersection with Hillsborough St/Umstead Dr	**BC5** Medium	Low	No (prior study)	35 45	**Detailed audit**
3-crash cluster - MLK and Estes Dr intersection; Also 4 other non-clustered bicycle collisions at various locations along MLK Blvd.	**BC6** Medium	Medium (more on Estes, E of MLK)	No (prior study	35 46	Brief visit
2-crash cluster - Sykes and Gomains (both local streets) - Chapel Hill	**BC7** Medium low	Low	No	no study	Brief visit
2-crashes at intersection of McDade & Roberson with Mitchell, two local streets and a collector, same general neighborhood as BC7, above.	**BC8** Medium low	Low	No	no study	Brief visit

Crash Clusters – in decreasing order	**Crash Density Area Ranking**	**Perception Density Ranking**	**Identified by Town**	**Speed limit/ 85th% speed**	**Status**
2-crash cluster at Fordham Blvd. and Estes Dr intersection (with two others on Estes midblock and one nearby on Fordham)	**BC9** Medium low	Low	No	SB NB 45 45 55 52 (near Old Mason Farm)	**Detailed audit**
2-crash cluster at Raleigh Rd/NC 54 E at/near Hamilton	**BC10** Medium low	Low	No	35 49	**Detailed audit**
2-crash cluster on South Rd at Bell Tower (parking lot drive); 2 crash cluster, South Rd at Raleigh St; also involving South Rd, 1 crash at Columbia and 1 east of Country Club	**BC11, BC 12** Medium low	Low	No	No speed study	No further
2-crash cluster - Main St and Jones Ferry Rd	**BC13** Medium low	Low	No		Brief visit
2-crash cluster - Hillsborough and N Greensboro	**BC14** Medium Low	Low	No		Brief visit
Non-clustered crashes at Cameron at Roberson and at Merritt Mill	**BC15**	Low	Yes	No speed study	Brief visit

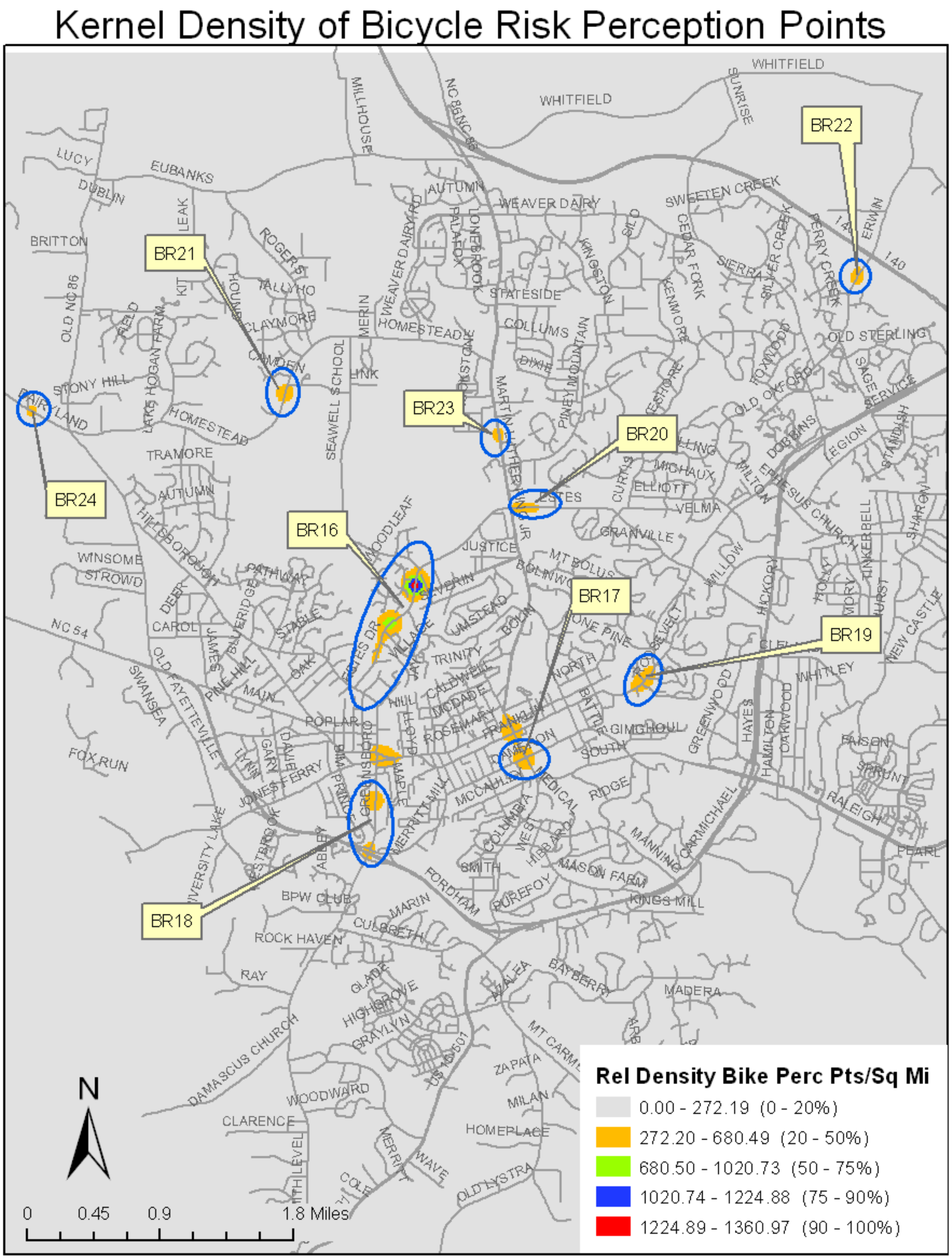

Figure 21. Map showing results of kernel density analysis of bicycle risk perception data, 2007 survey.

Note: Circled areas were not areas of higher relative crash density.

Table 18. New Areas Highlighted by Perception Data but with Low Relative Bicycle Crash Density.

Area description	Perception Ranking	Identified by Town	Speed limit (mph)/85th percentile (mph)	Status
BR16 - Estes Dr Ext	High	Estes and Greensboro intersection	35 48	Brief visit (improvements made since survey); may still need attention for crossings, accessing Estes from junctions
BR17 - South Columbia St centered on Cameron	Medium Low	No (although signal timing changes are planned)	35 39	Brief visit
BR18 - South Greensboro St segments so of downtown and near bypass junctions	Medium Low	Yes	35 44	Brief visit
BR19 - Franklin St near Roosevelt, Davie Circle	Medium Low	nearby (Franklin near Elizabeth)	35 45	Brief visit
BR20 - Estes Dr east of MLK Jr Blvd	Medium Low (overlaps with crashes at intersection)	No	no study on this section of Estes	**Detailed audit**
BR21 - Homestead Rd near High School Road	Medium Low	No	35 46	Brief visit
BR22 - Erwin Rd near Chipoak	Medium Low	Erwin and Weaver Dairy intersection	35 56	No further
BR23 - Martin Luther King Jr Blvd near Timber Ct	Medium Low	No (previous study)	35 46	Brief visit
BR24 - Dairyland Rd near Old NC 86	Medium Low	No	45 52	Brief visit

BIKE ISI

We applied the bicycle index calculator to 29 intersections, the top 9 intersections ranked by number of crashes, 13 by perception points, and 7 more with reported near-misses not identified by either of the previous two methods. There are 3 different equations that are applied to each approach leg: one each for through movement, right turns, and left turns. The models and definitions are shown in Appendix D.

As with the pedestrian index, the intersections with the higher index rankings are not necessarily those where the most crashes have been observed, although the intersection with the highest number of bicycle crashes during the study period, Martin Luther King Jr Blvd and Estes Dr with 3, did have a relatively high index of 3.8 (5^{th} highest). Of the top 10 intersections for collisions, only 1 is in the top 10 for ISI rating. The ratings again tend to be higher for intersections of multi-lane arterials with higher traffic volumes and speeds, which are not necessarily the intersections with the greatest numbers of bicyclists. As seen in the model, the index also captures elements of potential conflicts such as number of lanes to merge across to make right and left turns, as well as potential conflicts for through bicyclists with right-turning vehicles. Presence of traffic signals, and presence of bike lanes are also important predictors of perceived safety of an intersection by the expert raters.

Not captured by the index are elements such as bicycle detection for smaller streets with activation, signal timing, unusual geometrics (skewness, interchange, etc.) or other conditions (sight distance problems) that might affect bicycle safety at an intersection. Again, the tool is intended to be a broad brush, proactive indicator of intersections that might warrant further investigation, but would not capture all intersections that might need a detailed audit. The general results support conducting further assessment of larger intersections involving higher volume, higher speed streets, and particularly those with more lanes to merge across for left or right turns, or those with conflicting right turning movements affecting through bicyclists.

Locations Identified by the Towns

There were fifteen locations identified by Chapel Hill, and 16 different areas identified by Carrboro as needing safety improvements, as described in Table 19 and illustrated in the map (Figure 22). In Chapel Hill, a number of locations had been identified through earlier studies and evaluation of transit corridors (and including public input). The Carrboro locations were derived from public input/complaints and work by the Town's Transportation Advisory Board. Most of the locations identified by Carrboro were also identified through analyses of crash and perceived risk data. There was less direct overlap of specific locations identified by Chapel Hill with locations identified by analyses of crash and perceived risk data. However, the intersection locations identified by Chapel Hill tended to have high Ped and Bicycle ISI rankings, and were along corridors where intersection crashes or other perceived risk areas were identified.

Table 19. Locations Identified by the Towns for Pedestrian and Bicycle Safety Improvements.

Location Description	Ped/bike	Identified by other methods	Town	Status
T1 - W Franklin St at near McDonalds	Ped?	Yes – pedestrian crashes	CH	**Detailed audit**
T2 - NC 54 and E Barbee Chapel Rd	Both	Not specific intersection	CH	**Detailed audit**
T3 - NC 54 and Burning Tree Dr, Finley Golf Course Rd	Both	Not specific intersection	CH	**Detailed audit**
T4 - NC 54 and Meadowmont Ln, Friday Center Dr	Both	Not specific intersection	CH	**Detailed audit**
T5 - Fordham Blvd and Old Mason Farm Rd	Both	Not specific intersection	CH	Improvements slated
T6 - Fordham Blvd and Manning Dr	Both	Yes, perception	CH	Improvements under way
T7 - Fordham Blvd and Willow Dr	Both	No - 1 ped crash and 1 bicycle crash	CH	No further
T8 - Homestead Rd and Weaver Dairy Rd Ext	Both	No	CH	Brief visit – skewed intersection; frequently used by rec bicyclists, narrow lanes, curves

Location Description	Ped/bike	Identified by other methods	Town	Status
T9 - US 15-501 S and Bennett Rd	Both	No - 3 perceived risk points (and a subsequent fatal crash)	CH	Brief visit - No pedestrian signals to cross 15/501 and insufficient time for peds to cross. No sidewalk leading to E side bus stop.
T10 - US 15-501 S and Market St	Both	No	CH	Brief visit No crosswalk or ped signal to cross Market or 15/501. The stop bar on Market is beyond the existing curb ramp. Lighting.
T11 - Erwin Rd and Weaver Dairy Rd	Both	No	CH	No further
T12 - E Franklin St and Couch St	Both	No (E Franklin & Estes – perception area)	CH	No further
T13 - E Franklin St and Elizabeth St	Both	Franklin closer to Roosevelt highlighted by bike perceived risk	CH	No further
T14 - Fordham Blvd and Erwin Rd	Both	Yes, ped perceived risk	CH	Improvements made recently – should be evaluated for ped and bike safety and access.
T15 - NC 54 Bypass E of Greensboro St	Both	There were points along this segment; because of their scattered nature, no particular area was highlighted	CH	Brief visit "Midblock" transit stops with no crossing amenities; high speed traffic; no sidewalks; improved nighttime lighting may be needed

Location Description	Ped/bike	Identified by other methods	Town	Status
T16 - N Greensboro St and Short, Shelton and Poplar Sts (Harris Teeter vicinity)	Both	Edges of perceived risk area, esp for bike (with next 2)	Carr	**Detailed audit**
T17 - S Greensboro St and Carr St	Both	Yes, perception	Carr	**Detailed audit**
T18 - N Greensboro St and Century Center	Both	Yes, perception	Carr	**Detailed audit**
T19 - Greensboro St and Main St	Both	Yes, ped and bike crash and perception	Carr Priority rank 4 for bikes	**Detailed audit**
T20 - N Greensboro and W Weaver St (esp heading west)	Both	Yes, ped and bicycle crash and perception	Carr Priority rank 2 for bikes	**Detailed audit**
T21 - W Main St and Poplar Av	Both	No	Carr	No further
T22 - E Main St, W Franklin St, Merritt Mill Rd, and Brewers Ln	Both	Yes, ped and bicycle crash and perception	Carr	**Detailed audit**
T23 - E Main St, Weaver St, Roberson St and Carr Mill entrance	Both	Yes, high crashes and mod. perception, ped and bike	Carr Priority rank 3 for bikes	**Detailed audit**
T24 - N Greensboro St and Estes Dr Ext. (heading north and crossing Greensboro)	Both	Yes, pedestrian perception	Carr Priority rank 1 for bikes	Brief visit
T25 - Jones Ferry Rd and Davie Rd High activity area	Both	No, although both one bike and one ped crash on JF near Davie and a # of bike perc. points along JF	Carr	Brief visit
T26 - Jones Ferry Rd and Old Fayetteville Rd	Both	No	Carr	No further
T27 - NC 54 and W Main St & shopping center intersection	Bike	Yes, ped crash (but not bike)	Carr Priority 5 - bikes	Brief site visit

Location Description	Ped/bike	Identified by other methods	Town	Status
T28 - NC 54 and Jones Ferry Rd interchanges	Bike	No, there have been 4 bicycle collisions in the area: 1 at each merge ramp on NC54, 1 at intersection of ramp with Jones Ferry, and 1 nearby on Jones Ferry, but due to the distance between these areas, a density area was not highlighted	Carr Priority 6 - bikes	Brief site visit
T29 - NC 54 and S Greensboro St interchanges	Bike	Yes, ped and bike perception	Carr Priority 8 - bikes	Brief site visit
T30 - W Main St and Weaver St skewed intersection with extra leg of Elm St;	Bike	Yes, ped perception (but not bike)	Carr Priority 9 - bikes	Detailed audit
T31 - Cameron Av and Merritt Mill Rd and multi-use path crossing offset from intersection	Bike	Yes, bike crash	Carr Priority 10 - bikes	Brief site visit

Locatons Identified by Towns for Further Assessment

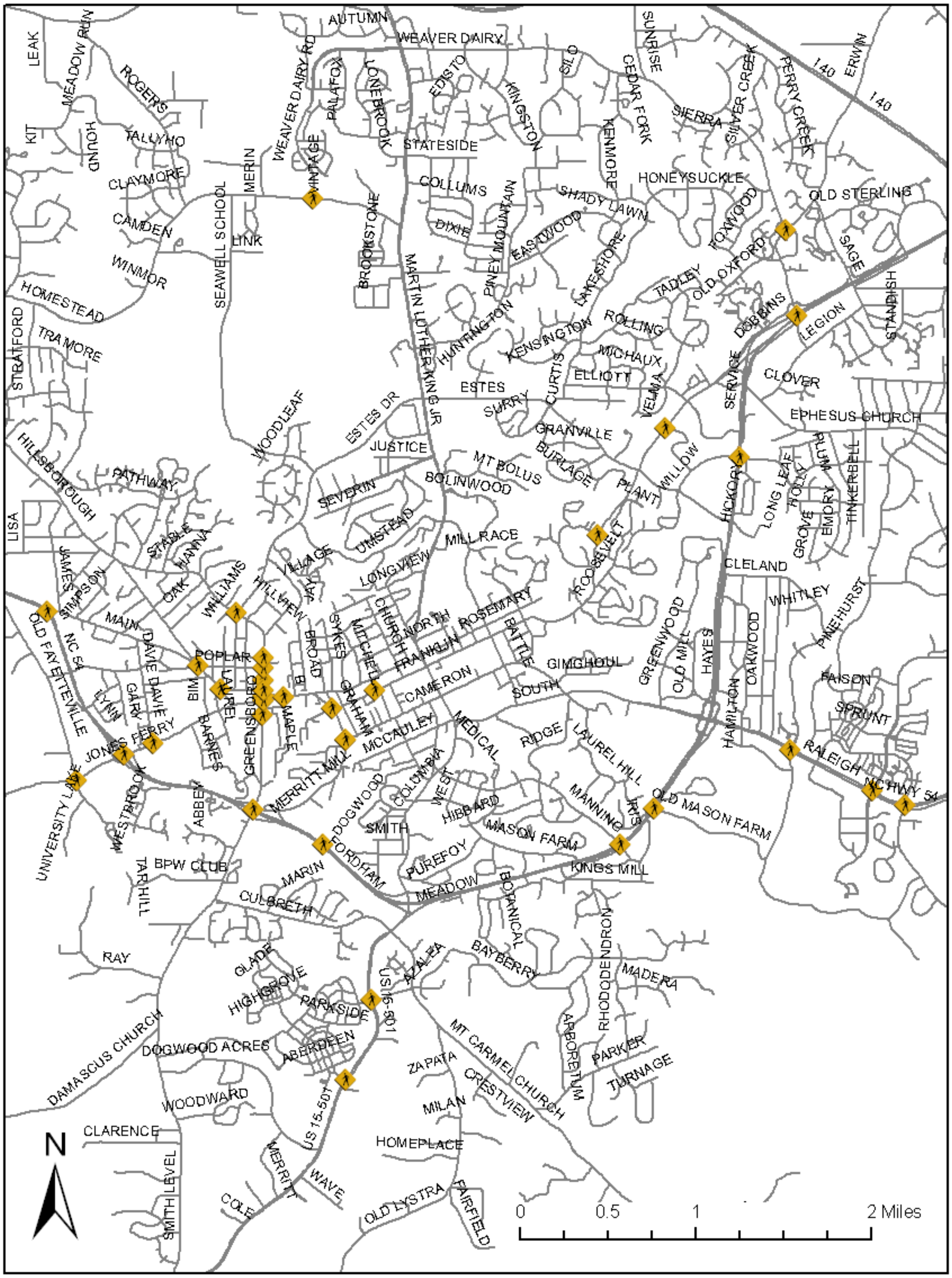

Figure 22. Locations identified by the Towns of Carrboro and Chapel Hill for further assessment or safety improvements.

Prioritizing Locations for Further Assessment

Given the large number of areas identified through analyses of crashes, of perception data, and locations identified by the towns, prioritizing locations for further assessment was extremely challenging. Areas with high density of pedestrian or bicycle crashes were clearly candidates for detailed audits. Areas with high density of perception points were also candidates. The highest densities of crash and perception points for both modes were in the downtown areas of the two towns, with the exception of Estes Dr Ext which was also an area of high density of perceived risk.

There were many other areas of medium to medium low density of crashes or perception points outside of the downtown areas that, although not in the highest categories, were deemed important to evaluate further. Areas with multiple crashes were deemed particularly indicative of problems since the crash rate at these locations (fewer walkers or bicyclists, yet significant crashes) implies a higher risk per individual. Corridors with multiple, separate areas of medium to medium low density of collisions or perception areas were considered important to assess since conditions all along the corridor may merit attention. In addition, intersections along these corridors tended to have high Ped and Bike ISI ratings and higher speeds than in the downtown areas. Due to the importance of motor vehicle speed to severity of crashes and injuries, we consider speed of the involved corridors as another important factor in prioritizing treatment (Zegeer and Sandt, 2006).

The study team subsequently paid brief visits to many of the locations to examine roadway conditions and potential safety issues at a variety of sites. (Information on the Town-identified locations was obtained late in the study, so there was less time to incorporate all of these locations into brief visits.) This information on conditions at many locations provided a framework for understanding the network and needed improvements.

In addition, the study team undertook further spatial analyses of various crash factors such as light condition, ages and alcohol use by those involved to look for patterns of involvement by area. We reviewed rankings of the crash clusters/densities and perception densities, intersection crash rankings and intersection safety index results (see Appendices C and D), notes from the site visits, speed survey results, and selected locations for detailed safety audits.

The list of locations where detailed audits were conducted is shown in Table 20. A decision was made to examine cohesive areas or corridor segments (including intersections) that incorporated several separate crash or perception areas. The reasons for doing so include the following:

1) the numbers of crashes were relatively small in most of the separate areas identified;
2) chance plays a role in the precise location where crashes occur;

3) nearby areas (intersections or corridors) or areas with characteristics similar to those where crashes have already occurred might expect future crashes;
4) the perceived risk locations identified by survey respondents, particularly along segments, were imprecise and often involved an entire corridor that has a similar profile.

Finally, the spatial analysis parameters used have some effect on how finely risk (crash or perception) areas are divided.

Although there was sometimes complete non-overlap of perception and crash data, there were usually areas nearby or along the same corridor that were identified. Thus, by combining locations into area audits, these location mismatches could be incorporated into one audit session of, for example, a significant corridor section. Thus, in several cases we were able to audit a 'higher' crash/low perception area, and a nearby 'higher' perception/low crash area. Additionally, we made an effort to examine conditions for the mode that may not have been highlighted for that area. For example, the area of W Franklin St and E Main St was a high crash and a low-perceived risk area for bicyclists, and generally low (or medium low) for both crash and perception density with respect to pedestrians. One of the intersections in this area was also highlighted by Carrboro. Several other locations identified by one of the Towns were also included in detailed audits.

Detailed road audits were not performed for all higher crash or higher perceived risk areas nor all locations identified by one of the Towns. Estes Dr Ext., which was not a high-crash area, but was strongly perceived as a risky corridor, underwent improvements after the survey period. A paved shoulder was added for most of its length that provides some space for bicyclists and pedestrians, although the improvements end prior to the intersection with N Greensboro St. This gap leaves the western end and the junction with N Greensboro and the Shelton Bike Path with potential problems for pedestrians and bicyclists. A follow-up assessment should be performed to determine how pedestrian and bicyclist needs can be met throughout the corridor. The assessment should also consider the need for intersection or midblock crossing treatments since this corridor was one of great concern for both pedestrians and cyclists as identified by the survey. Another area that was undergoing significant changes during the study period, including construction and the addition of a bike lane on one segment and planned intersection signal phasing changes was S. Columbia St and Pittsboro St, and so a detailed audit was not conducted for this pair of parallel streets and their cross streets.

Brief site visits to most locations identified provided a frame of reference and also raised concerns for many other locations for which detailed audits were not conducted. In short, some of the many locations not described in the detailed audit results clearly merit further evaluation and consideration of improvements. Some of these are detailed in the ***Other Site Problems*** section.

Audit Locations

The locations that were included in one of the detailed audits are shown in Table 20, which describes the crash, perception, and Town-identified areas from the previous sections. As mentioned, audits were conducted for an entire area (downtowns), corridor section (e.g. MLK Blvd, Estes Dr), or group of intersections (e.g. Raleigh Rd) that shared similar characteristics.

With all of the information in hand, including descriptions of the collisions that occurred within each area being visited, detailed audits were conducted on eight separate occasions. Town and DOT staff participated in six of the detailed audits with the research team. HSRC staff alone conducted the remaining two.

Table 20. Audited Areas.

Descriptive name	Identified* areas included	Relative Crash Density	Relative Perception Density
I. Downtown East Chapel Hill	P1 (most) B2 (part)	High to Medium low Medium high	High to Medium low Medium low
II. Downtown West Chapel Hill	P1 (part) PC2 B2 (most) T1	High to Medium High to Medium High Medium to Medium low	High to Medium low Medium high to low Medium low to low
III. Transition zone - East Main from Weaver to W Franklin @ Graham	BC1 P21 PR45 T22	High to Medium high Medium low Low	Low Medium low Medium low
IV. Downtown Carrboro	P3 PR37 PR40 B3 T16, 17, 18, T19 T20, T22, T23, T30	Medium Low Low Medium	Medium high to Medium Medium low Medium low Medium low
V. Estes Dr, Franklin to Fordham	PC4 PR24 PR34 BC9	Medium Low Low Medium low	Low Medium Medium Low Low
VI. Manning Dr (Pittsboro/University to Ridge Rd) – around intersections particularly	P7 PC8, 9, 10 P11	Medium low Medium low Medium low	Medium low Low Medium low

Descriptive name	Identified* areas included	Relative Crash Density	Relative Perception Density
VII. Martin Luther King Blvd	PR27, 28, 29, 30	Low	Medium low
	BC4	Medium	Low
	BC5	Medium	Low
	BC6	Medium	Medium low (overlap)
VIII. Raleigh Rd / NC 54 E	PC5	Medium	Low
	BC10	Medium low	Low
	T2		
	T3		
	T4		

*P = location identified by both Pedestrian crash and perceived risk; PC = Pedestrian Crash (only); PR = Pedestrian Risk perception (only). B = Bike crash and perception analysis; BC = Bike Crash (only); and BR = Bike Perceived risk (Only); T are locations identified by the Towns.

We used the Pedestrian Road Safety Audit Guidelines and Prompt Lists (Nabors et al., 2007) recently released by FHWA which has guidelines for assessing conditions for street sections and for intersections. We adapted a similar framework for evaluating conditions for bicyclists. We note, however, that a uniform standard safety audit guide has not been developed/adopted for bicyclists. Other tools available to evaluate conditions for bicyclists include the Bicycle Compatibility Index (Harkey et al, 1998), and the somewhat more data-intensive Bicycle Level of Service models developed by Sprinkle Consulting (Landis, Vattikuti, and Brannick, 1997; and others). Arterial (Petritsch, et al. 2007) and intersection models (Landis et al., 2003) have also been developed more recently by the Sprinkle group.

Audit Results and Countermeasure Recommendations

The next eight numbered sections describe the general conditions of the audited areas including general functions of the street and area land uses, the safety issues identified during the audits, followed by countermeasure recommendations. The audit results are separated into discussions of Intersections and segments (Street Sections).

Potential countermeasures were identified using pedestrian and bicycle countermeasure selection tools (PEDSAFE and BIKESAFE, respectively) developed for FHWA (Harkey and Zegeer, 2004; and Hunter, Thomas, and Stutts, 2006) , other resources including the AASHTO Guides, and MUTCD, and our own knowledge of the research literature, including recent research not incorporated into the guides.

Although the term 'recommendations' is used, the potential countermeasures identified are offered for further consideration and investigation by the responsible agencies. Other countermeasures may also be identified as appropriate to treat the locations and problems identified, and both locations and countermeasures should be investigated further before treatments are implemented.

I. Downtown East Chapel Hill

Columbia St to Henderson St – including Franklin and Rosemary Sts

This area includes Franklin St and Rosemary St from Henderson St to Columbia St inclusive of intersections, and incorporates most of the top-ranked cluster for pedestrian crashes and a high crash density node, and most of the highest density of perceived risk areas for pedestrians. The area includes a portion of the area of the second largest bicycle crash cluster, medium crash-density area, and medium to medium low bicycle perceived risk areas.

Franklin St in this section carries about 15,000 vehicles per day, is the primary central business district street with shops and restaurants. It also serves as a transit hub, provides space for delivery vehicles, and serves numerous pedestrians and bicyclists. Over 10,000 pedestrians and more than 400 bicyclists have been counted (12-hour daily counts) at the key intersection of Columbia and Franklin Streets. The segment of Franklin between Henderson and Columbia Streets is four lanes plus on-street parallel parking and/or bus and loading zones on either side. There are no special bicycle facilities, and the outside travel lane is of normal width.

Rosemary St also serves a variety of roadway users and purposes including trucks delivering goods to the shops on both Franklin and Rosemary Streets. Many of these trucks seem to park temporarily in the center two-way turn lane in the downtown block. Rosemary St has a mix of storefronts including bars, restaurants and other businesses such as banks, and office and residential space.

As the primary north-south route, Columbia St carries between 16,000 – 19,000 vehicles per day, and is four lanes, plus dedicated left turn lanes in the section between Rosemary and Franklin Sts. This section also has bus stops on both sides - at the NW corner of the intersection with Franklin, and midblock between Franklin and Rosemary on the eastern, northbound side - and left turn lanes at the intersection. There are also mid-block bus stops between Franklin and Cameron, and buses queued at the stops often obstruct visibility of the midblock crosswalk. Although signalized, pedestrians sometimes cross against the signal. There are several other transit stops and crosswalks on both Columbia and Pittsboro St. Although the perceived risk areas, particularly for bicycles, extends south along Columbia to essentially South Rd, Columbia St was not audited in detail; we recommend an audit of this corridor, along with the companion one-way, Pittsboro St. (Extensive construction was occurring and changes were made to S. Columbia St during the study period, including the addition of a dedicated bus lane and bike lane facility that begins at Manning Dr and abruptly ends near South Rd. The section of Columbia from South Rd and northward remains a shared lane situation. The speed limit is 25 mph on Columbia St, compared to 20 mph on Franklin St.

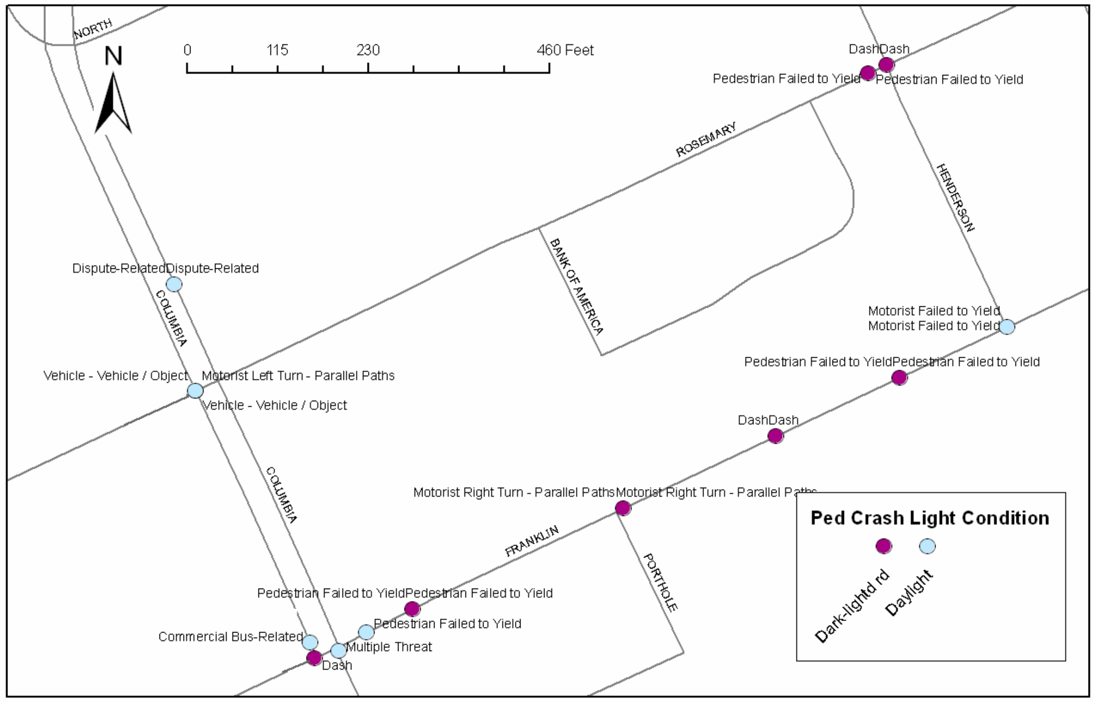

Figure 23. Downtown East Chapel Hill audit area and pedestrian crashes.

Ten of the 14 pedestrian collisions in this audited area occurred at night (Figure 23) even though Franklin St seems to be well-populated with street lights. However, pedestrian level sidewalk lighting could enhance the security and traffic safety of downtown by allowing motorists to notice pedestrians still on the sidewalks and enliven the nighttime pedestrian environment. About half of the collisions occurred at intersections and half at midblock locations.

Intersections & Midblock Crossings

Columbia & Rosemary

There are pedestrian crosswalks and push-button activated pedestrian signals for all legs of this intersection. The collisions at/near this intersection included a couple of unusual types: one on Columbia north of the intersection area that involved a dispute between driver and pedestrian, and another unusual collision (Vehicle into vehicle/object – before the pedestrian was struck). Also, one left turning motorist failed to yield to a parallel path pedestrian. The motorist was westbound on Rosemary. Signs have already been added warning turning motorists to yield to pedestrians. There may, however, be some sight distance issues related to the grade on the westbound approach of Rosemary that affect motorists' ability to focus on pedestrians when making unprotected left turns.

Other issues include:

- Stop bars and crosswalk markings are worn and need maintenance.
- Frequently there are pedestrians crossing Rosemary beyond the crosswalk area. The tight turns from SB Columbia onto WB Rosemary probably slow speeds enough that motorists generally have time to react to these pedestrians.
- There seems to be less overhead lighting here than at Franklin St, and it may not be directed over the crosswalks as well as it could be.
- The push-button activation on the SW corner (to cross Rosemary) did not seem to be working properly when we visited.
- Heavy utility lines in front of the north facing traffic signals seem to obscure the traffic lights and warning signs for motorists to some extent (Figure 24).

Figure 24.Utility lines obscure regulatory signs and traffic signals; pavement markings are worn and paved over at Columbia and Franklin St.

Recommendations:

- ⇒ Evaluate lighting at the intersection. Consider providing enhanced lighting over all crosswalk areas.
- ⇒ Maintain pavement markings in good condition.
- ⇒ Elevate/relocate the utility lines that are blocking visibility of the traffic signals.
- ⇒ As further described below in the "area-wide" problems section – consider removing push button pedestrian signals and adding a recall pedestrian phase to all cycles.
- ⇒ Consider separate pedestrian and protected left turn phases. (The sight distance on Rosemary seems to affect motorists' attention for pedestrians.)
- ⇒ Provide police reinforcement of good crossing behaviors.

Henderson & Rosemary

Around 2,000 pedestrians and nearly 200 bicyclists were observed at the intersection of Rosemary and Henderson in a 2005 count (LSA Assocs., 2007). There are no pedestrian signals at this intersection, and there appears to be inadequate time for pedestrians to cross Rosemary when traffic on Henderson trips the signal (Figure 25). The signal priority is currently extensively in the favor of Rosemary St. When the signal is tripped, Henderson St and corresponding pedestrians crossing Rosemary St have an estimated six seconds of green light to cross. Two collisions occurred late night at or close to this intersection involving pedestrians 'dashing' across, or 'failing to yield.' Given the lack of a pedestrian signal or sufficient green time to safely cross Rosemary St, these crashes are not surprising. Motorists on Rosemary may also come to expect a green light and may not be expecting to stop, although clearly pedestrians are a frequent presence here. We observed pedestrians crossing Rosemary at every cycle while we were present (during lower-volume, summer time). One bicycle crash at the intersection involved a motorist heading E on Rosemary turning left across the path of a westbound bicyclist.

Figure 25. Pedestrian signals are lacking; utility pole narrows useable space and may obstruct visibility; curb is nearly level with the street, with no detectable ramp for pedestrians with disabilities at the corner of Rosemary and Henderson Sts.

Safety issues include the following:

- o Bicyclists on Henderson may have inadequate time for start-up and getting through the intersection to cross Rosemary when they get a green signal, and would need to wait for a motorist to arrive since they cannot activate the signal.
- o The incline on Rosemary may somewhat reduce visibility at this intersection.
- o Sidewalk width is minimal and utility poles and other objects obstruct the approach to the intersection along Rosemary (Figure 25). Pedestrians may walk in the street as a result and pedestrians using wheelchairs may not have access.
- o There is no real delineation between the sidewalk/curb and the street at the southwest corner of intersection, which could be very problematic for pedestrians with low vision. (There is a general lack of accessible sidewalks and curb ramps throughout Rosemary St.)
- o Adequate lighting is vitally important to individuals walking home or to other destinations from campus and downtown during late hours. Although there are street lights along Rosemary, both of the collisions at this intersection occurred at night.

Recommendations:

- ⇒ Pedestrian signals are recommended for all legs of this intersection. Consideration could be given to automatic recall for a pedestrian phase in every cycle, given the likely constant presence of pedestrians here day and night-time due to the proximity to student housing, campus, and downtown destinations.
- ⇒ A bicycle loop detector should also be installed on Henderson approaches for when motor vehicles are not present. Bicycle detection would be a positive step to prevent potential red-light violations by bicyclists who currently cannot activate the signal at this location. Nearly 200 bicyclists were observed in 12 hours at this location in 2005.
- ⇒ Evaluate pedestrian access to and from the intersection, including accessible curb ramps.
- ⇒ Evaluate night-time lighting levels. Consider improving visibility here through lighting walkways, and focused illumination at intersections to provide a safer route between commercial and residential areas.
- ⇒ Consider "Turning motorists Yield to Pedestrians and Bicyclists" signs which may remind motorists to check for these users before turning.

Franklin & Henderson

Visibility and intersection design present problems for the three-way intersection of Franklin St with Henderson St. Two of the three crosswalks cross Franklin St. The crosswalk on the west side of the intersection is set back so that it may seem like a midblock crosswalk (Figure 26). One collision at this intersection in 2005 involved a motorist traveling west on Franklin and running a red signal, failing to yield to a pedestrian in the east side crosswalk during daylight hours. Safety issues observed for this intersection include the following:

- A driver traveling west along Franklin St may have just enough time to pass under the light as it goes from yellow to red, but may be still traveling through the west side crosswalk area after pedestrians have the “walk” signal. The separation distance between the crosswalk and intersection would not be immediately apparent to a driver who has his or her attention focused on the traffic light.

Figure 26. West side crosswalk on Franklin (crosswalk in the background with fluorescent yellow pedestrian warning sign) at Henderson St is set back from the intersection.

- Vehicles turning right onto westbound Franklin St from Henderson St may also have a limited view of this set-back crosswalk before turning. When they are given a green light, the crosswalk is given the “walk” signal. Motorists may turn and begin to accelerate, assuming they are past the crosswalk area, and then meet up with the west side crosswalk and crossing pedestrians.
- The setback distance of the west side crosswalk may contribute to observed eastbound drivers on Franklin stopping directly within the crosswalk itself, impeding the flow of pedestrian traffic. Drivers may also not anticipate the crosswalk that far in advance of the intersection, yet would not expect a midblock crossing that close to the intersection.
- Apparently, in answer to the previous, both east and west side crosswalks are marked with high visibility warning signs at present, which could be a distraction to those proceeding straight through the intersection who need to pay attention to the traffic signal and pedestrians in the crosswalks.

- Operable pedestrian signals are available at all three crosswalks, and include countdown features. The signal for the path across Henderson St gave the pedestrian an estimated 15 seconds, while the corresponding traffic light remained green for 30 seconds. After 15 seconds, the “don’t walk” indication was activated. Arriving with a green light and a don’t walk indication may generate disrespect for the pedestrian signals.
- There are shorter pedestrian phases crossing the busier Franklin St; the timing seems sufficient, but may be frustrating to pedestrians just missing a walk indication.

***Recommendations*:**

⇒ Consider relocating the west side crosswalk to a typical intersection location. The current configuration is probably chiefly based on aesthetics and a connection with a main sidewalk leading into/from UNC campus on the south side of Franklin St.

⇒ Consider whether it is possible to extend the Walk time allowed to cross Henderson to use more of the available corresponding green signal time. Pedestrians arriving after the initial walk indication would have more time to cross, and those arriving with a Don’t walk indication, but a green traffic signal in their direction will be less likely to have to wait for another cycle to get the walk indication (and be more likely to respect the pedestrian signal).

Franklin & Columbia

Several collisions at or near the intersection involved pedestrians dashing or otherwise failing to yield. There was also a multiple threat collision, and a collision involving a pedestrian leaving a bench and walking into a bus as it was pulling away from the stop. Three of the four occurred in 2001 or 2002; the fourth was a pedestrian dash that occurred in 2005. The following issues that affect pedestrian safety were noted:

- Left turns have a protected phase, and the pedestrian and through motor vehicle phases follow the protected left. This could be problematic when pedestrians assume that, since thru-traffic has stopped, they can proceed through the intersection. The study team has observed pedestrians frequently stepping out and continuing crossing when the protected left turn phase begins, resulting in conflicts.
- Right-turning vehicles also frequently conflict with pedestrians at this intersection.
- Bus stop prior to the intersection on NB Columbia may obscure pedestrians from motorists.

Recommendations:

⇒ Consider providing separate protected left turn phases after (rather than before) the through phases (lagging left turn phasing); thus, pedestrians would be able to cross immediately after the opposing traffic stops when they are inclined to step off the curb. This change in timing could prevent the frequent pedestrian step-outs and continuing across (and often once a few move forward, the entire platoon of pedestrians does) during the protected left turn phase.

⇒ Stop bars could be set further back from the intersection to help improve sight lines and reduce the multiple threat situation, and wider, high visibility crosswalks marked (given the frequent volume of pedestrians). The stop bars could also be staggered further (left to right) to allow improved visibility from the right (turn) lanes.

⇒ Consider prohibiting right-turn-on-red at the intersection. Currently motorists must pull forward into the crossing area before they can check for oncoming traffic from the left to make a right turn on red. Additionally, it is difficult to see approaching traffic with buildings close to the street. There are almost always pedestrians present, and even if not crossing at the moment, they may arrive as the motorist pulls forward to make a right turn, resulting in frequent conflicts.

⇒ Another alternative is to install a separate pedestrian exclusive, all-corner walk phase ("Barnes dance" or "Scramble" timing). A pilot implementation is planned for this intersection, as well as for Columbia and Cameron. Research by an HSRC researcher Zegeer et al., for FHWA has found that this type of signal timing can reduce the risk of pedestrian crashes by about 50%. This type of phasing has been used successfully in other cities where pedestrian crossing volumes are high.

⇒ Consideration could be given to relocating the NW side bus stop to the far (SW) leg of the intersection since there are nearby stops in both directions on Franklin St for routes that are turning.

Midblock crossings – Rosemary

On Franklin St, there is a midblock crosswalk between Henderson and Columbia Sts with push-button pedestrian signals and audible signals. The countdowns give plenty of crossing time for high volumes of pedestrians. Due to the still relatively long distances (500 feet in one direction) between intersections and this crossing, some pedestrians are no doubt going to continue crossing at other midblock locations. The four lanes of traffic and parking lanes in this section provide a lot of roadway to cross.

There are no midblock crossings on the equivalent section of Rosemary St, which includes extensive parking facilities, bars, banks, restaurants, and other businesses. The center two-way turn lane is often used as a loading zone for delivery vehicles, adding to a confusing traffic pattern.

Recommendations (long term):

A fully accessible midblock crossing island could be considered for some area along this section of Rosemary St (between Columbia St and Henderson St). A midblock crossing could provide a refuge area for those who need it, particularly older and younger pedestrians, parents pushing strollers, and pedestrians with disabilities. Use of a HAWK signal activated by pedestrians would give pedestrians a protected crossing (similar to a regular traffic signal) but only stops traffic when pedestrians are present (Figure 27). The HAWK pedestrian hybrid signal is approved for the next version of the MUTCD.

Figure 27. A HAWK signal provides a pedestrian-activated, stop-controlled crossing at midblock locations or other locations that do not warrant a regular traffic signal. (Photo by M. Cynecki)

Note: (See proposed new additions to the MUTCD)

⇒ An alternative to the HAWK signal is the rapid flash ("stutter") beacon which has been found to increase yielding compliance, also slated for approval in the next MUTCD edition (Figure 28). The rapid flash beacon has achieved the highest yielding rates of any non-red signal indication, and costs considerably less than the HAWK (Van Houten and Malenfant, n.d.).

Figure 28. The rapid-flash beacon has also been evaluated for multi-lane crosswalks and has achieved a high rate of yielding over a sustained time period (Van Houten and Malenfant, n.d. Image from Van Houten and Malenfant).

⇒ Consider eliminating the two-way turn lane on this section of Rosemary (between Columbia and Henderson) and striping bike lanes throughout the corridor, removing parking as needed.

Downtown area-wide problems

Each of the crosswalk locations in this area differed in terms of activation and/or signal phasing. Currently many pedestrians ignore the push-buttons and go with the green traffic signal or whenever it seems prudent to walk. At night, this type of behavior likely carries greater risks (and may involve less caution).

Recommendation:

⇒ Consider use of an automatic recall pedestrian phase in each signal cycle throughout the downtown area where pedestrians are almost always present. If possible, provide pedestrian phases in the same order in the cycle from location to location which might increase pedestrian understanding of when they can walk, maximize allowable walk time, and increase respect and use of signals and crosswalks. The current mix of push-button, automated, and non-existent pedestrian signals likely contributes to confusion, impatience, potential disrespect for following the rules, and lack of use of push-button signals.

⇒ Also, pedestrian countdown signals should be present at all signalized locations.

Street Sections

E Franklin

There are adequate sidewalks and good street separation between pedestrians and traffic, including parked vehicles in the downtown section of Franklin St. There are also few driveways/alleys for motorists in this section of Franklin St that create conflicts for pedestrians walking along the sidewalks. One exception is Porthole Alley, with sight distance for exiting motorists completely blocked by buildings adjacent to the sidewalk. One pedestrian collision occurred here. However, it involved the motorist turning right out of the alley and striking a pedestrian who was crossing in the midblock crosswalk (not a pedestrian traveling along the sidewalk).

Although this was not one of the densest areas for bicycle crashes, there are issues for bicyclists traversing this block, including poor cycling behaviors. Both sides of Franklin St downtown have a “No Bikes on Sidewalk” sign posted, which is appropriate for a downtown zone with heavy pedestrian traffic on the sidewalks. Compliance with this restriction seemed good during the site visit. Several bikes on the road were, however, observed riding in the opposite direction of traffic, and weaving through vehicles waiting at red lights. Of the bicyclists riding with traffic, no bicyclists were observed “taking the lane” during our afternoon observation interval, as almost all restricted themselves to the far right of the right lane, riding directly within the “door zone.” Cyclists during commute times may be more apt to ride correctly in traffic and take the lane.

Downtown streets are posted at 20 mph, and due to the general mix of modes in the street, pedestrian traffic, and midblock pedestrian signals, speeds should be slow in the downtown block. Downtown streets should be low-speed and allow for easy sharing of the lane by bicyclists who should be able to ride at speeds close to other traffic. Making full use of the travel lane on low-speed, narrow or regular lane width streets allows bicyclists to avoid the door zone, deter unsafe passing when there is insufficient room for a motor vehicle to overtake within the same lane, and reduce the opportunity for vehicles to turn right across their path. Again, on streets with low-speeds, bicyclists should be able to ride at speeds similar to other traffic, so making full use of the lane should not obstruct other traffic. It is possible, however, that like further west on Franklin St, speeds are actually much higher making it challenging for bicyclists to comfortably mix with traffic.

According to The Chapel Hill 2005 Mobility Report Card (LSA Associates, p. 6), 24-hour traffic volume downtown E Franklin St is 55% of the capacity of the street. Although the full capacity may be needed at times (special events, etc.), this excess capacity on a daily basis may contribute to higher traffic speeds and generally less safe conditions for pedestrians and bicyclists. This situation provides an excellent opportunity for re-evaluating how the street is currently designed and space allocated. Downtown intersections are also uncongested from a vehicular point of view according to the same Mobility Report Card.

Recommendations:

A mix of educational/enforcement and engineering and design remedies could enhance and create a much safer pedestrian and bicycling environment downtown.

⇒ Porthole Alley - The sidewalk is level across the alley, so further measures may be needed to slow vehicles and encourage safe passage across the sidewalk area. Stop bars and perhaps a raised sidewalk crossing of the alley could slow vehicles before they cross sidewalk area. A textured or colored sidewalk could be useful. Warning signs ("Turning Motorists Yield to Pedestrians") could be used to notify motorists to look for pedestrians on the sidewalk and in the roadway (at the midblock crossing).

⇒ See suggestion in the following section regarding a road diet to create a slower Franklin St that could be more comfortably shared by both pedestrians and bicyclists – and move cyclists away from the "door zone" and other conflicts. Bulb-outs, special parking treatments, and other features could also be used to foster low-speed downtown streets appropriate for a central business district (See images in Figure 29, Figure 30). Creating a shifting alignment (chicane) through alternating parking, for example could slow speeds. Back-in or reverse angle parking ensures that motorists are facing out with a view of on-coming traffic when leaving parking, and could increase the number of parking spaces. Back-in angle parking also eliminates the "dooring" type of bicycle crash (Figure 31). See BIKESAFE for further description of these treatments (Hunter et al. 2006).

⇒ It might also be possible to treat Rosemary St as the primary bicycling route and provide improved amenities on that street, but since Franklin St is a primary destination, bicyclist improvements would still be warranted for Franklin St.

⇒ Bicyclists should be encouraged through signing, markings, and through enforcement and possibly other educational efforts to ride with the flow of traffic and "take the lane" on low-speed, narrow-lane streets, particularly with on-street parking (See Figure 32 for a new regulatory sign, R4-11, proposed for the next MUTCD edition that could be used.) Taking the lane would position bicyclists out of the door zone, and also help bicyclists to avoid conflicts with buses and trucks loading/unloading and cars entering and leaving parking, and to be less likely to be struck by right-turning vehicles. The proposed language from MUTCD is as follows" "The Bicycles May Use Full Lane (R4-11) sign (see Figure 9B-2) may be used on roadways where no bicycle lanes or adjacent shoulders usable by bicyclists are present and where travel lanes are too narrow for bicyclists and motor vehicles to operate side by side. The Bicycles May Use Full Lane sign may be used in locations where it is important to inform road users that bicyclists might occupy the travel lane." Section 9B.06 Bicycles May Use Full Lane Sign (R4-11), MUTCD, 2007, Text Showing Revisions version).

⇒ Police should enforce motor vehicle speeds, turning vehicle yielding at intersections, yielding at midblock crosswalks, looking before opening car doors into traffic, etc. Publicizing enforcement may help its effectiveness. Enforcement must be seen to be frequent, random, and with consequences to be effective. Police officers can also provide educational reinforcement and enforcement of safe and legal riding behaviors, but other educational measures could also be considered. (Information on enforcement of laws affecting bicyclists and links to training resources may also be found in BIKESAFE.)

Figure 29. Downtown Hendersonville, NC streets have bulb-out sidewalk extensions. (Photo by Austin Brown)

High- visibility crosswalks and two-lane streets with on-street parking help to create a low-speed urban environment.

Figure 30. Downtown Kirkland, WA, has narrow streets with landscaped medians, bulb-outs and on-street parking. (Photo by Dale McKeel)

Police periodically enforce motorist yielding to pedestrians at midblock crosswalks (motorcyclist near center of photo).

Figure 31. Reverse angle parking could increase amount of parking downtown and eliminate 'dooring' type crashes with bicyclists. Motorists are also positioned to better view oncoming traffic before pulling out of parking. (Photo from the PBIC Image Library)

Figure 32. Sign (R4-11) expected to be included in the next edition of MUTCD. (See Section 9B.06 Bicycles May Use Full Lane Sign (R4-11) in the 2007 Text showing revisions.)

E Rosemary sections

Rosemary St is three lanes, including a center, two-way, left turn lane in this section that as mentioned previously, frequently serves as a loading zone. Driveways/alleys are numerous along Rosemary St and create many conflict points. Many do not have level pedestrian crossings; some are barely passable. Other safety issues include the following:

- Sidewalks are barely adequate to inadequate in this section of Rosemary St and have many obstructions that reduce useable width. When sidewalks do exist, there is often no buffer from traffic lanes. There are also slopes across driveways and numerous areas that may not be accessible, or would force pedestrians to step into the street when meeting another pedestrian. Provision of adequate sidewalks may be a key to keeping sometimes impaired pedestrians out of the roadway as much as possible.
- Street-level lighting seems adequate, but given that this is a street that is extensively traversed at night, there may be opportunities for enhancing sidewalk level lighting. In addition to local destinations, many students travel from campus through the area to nearby housing.
- Trucks parked in the center two-way turn lane in this area obscure sight distance.

Recommendations:

⇒ Evaluate lighting for sufficient roadway illumination.

⇒ Improve sidewalks throughout Rosemary St.

⇒ Consider pedestrian level lighting along walkways.

⇒ Consider creating a bike route along Rosemary St with bike lanes and improved intersection treatments.

⇒ Developing alternative loading zones and policies for delivery trucks that presently park in the street and on sidewalks throughout downtown and campus should be a short and long-term goal.

⇒ Ensure landscaping ordinances, utilities etc., and maintenance provide a clear, unobstructed pedestrian zone adequate to projected use and good visibility at all junctions.

⇒ Provide sidewalk level driveway crossings that meet ADA requirements, and will help to ensure slow motor vehicle maneuvers.

⇒ Provide access management such as closing/consolidating driveways especially as redevelopment occurs.

II. Downtown West Chapel Hill

This area includes W Rosemary St (from Columbia), Columbia between Franklin and Rosemary and W Franklin St from Columbia to just west of Kenan St (see Figure 33). Speeds are significantly higher than the posted 20 mph, with 85th percentile speeds measured at 34 mph near Mallette St.

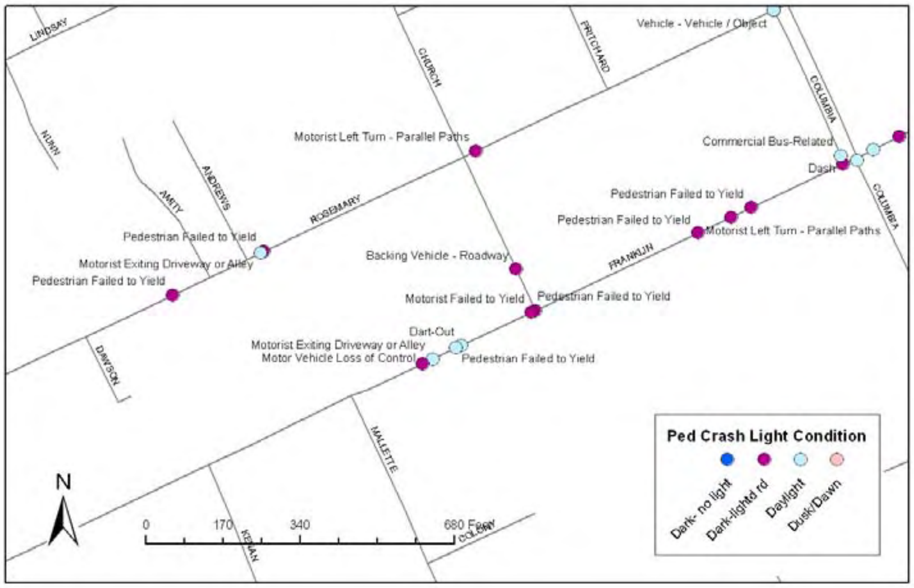

Figure 33. Downtown West Chapel Hill audit area and pedestrian crash locations. Midblock pedestrian crashes were prevalent in this area on both Franklin and Rosemary St. More than half of the pedestrian crashes also occurred at night.

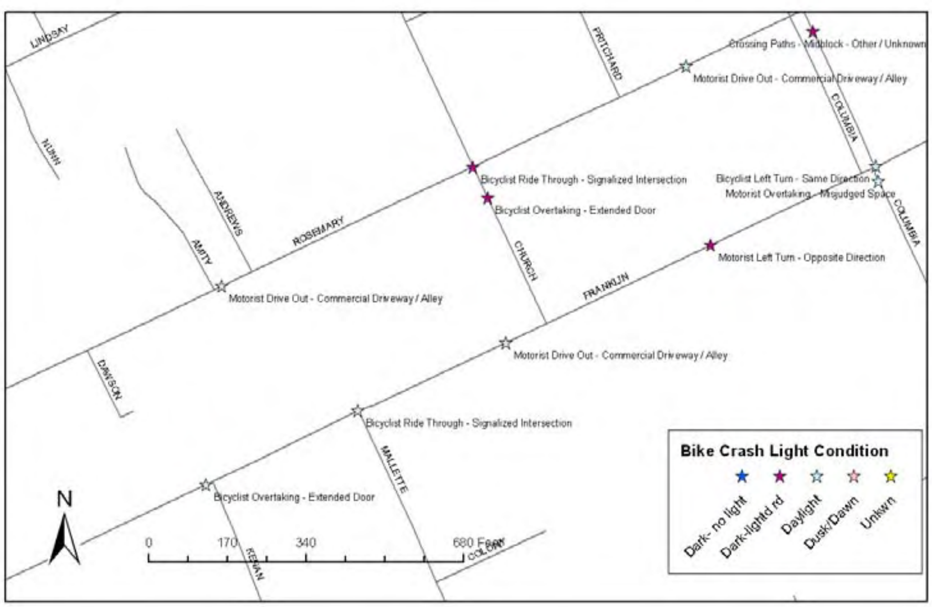

Figure 34. Downtown West Chapel Hill audit area and locations of bicyclist crashes. Four of 11 bicycle collisions also occurred at night and were a mix of types of collisions at intersections, driveways, and non-junction locations.

Intersections and Midblock Crossings

Franklin & Church

Two pedestrians were struck at this intersection over the study period. One elderly man was killed in 2002, and a young adult was struck in 2005. In both cases, the pedestrian was in the crosswalk or crosswalk area (no traffic control existed then according to the police crash reports), and the motorists failed to yield. This intersection is currently signalized and includes pedestrian countdown signals and crosswalks for all street legs. One leg is an entry into a commercial parking lot and is provided a sidewalk-level crossing, and includes stop bars prior to the sidewalk crossing area, although there are no pedestrian signals for this crossing.

Recommendations:

⇒ Lighting level could be re-evaluated for the intersection.

Franklin & Mallette

Mallette has a traffic signal and crosswalks, but there are no signals for pedestrians and no detection provided for bicycles. One leg of this intersection is actually a driveway into a shopping area parking lot. There is a ramp and a level crossing at this driveway. It would provide a more uniform environment if pedestrian countdown signals were provided here like those at Church St.

The current signal timing (on a regular cycle for Mallette) seems to allow sufficient green for pedestrians or bicyclists to cross Franklin; the yellow interval is, however, only 3 seconds which could result in pedestrians starting on a late green being trapped by a signal change.

Recommendations:

⇒ Provide pedestrian countdown signals like those at Church St and other downtown intersections.

⇒ Provide bicycle detection, or verify that signal timing allows sufficient clearance time for bicyclists entering the intersection on late green/early yellow (all directions).

Franklin & Kenan

Kenan is a T-intersection, with sign-control only for Kenan. There are no marked crosswalks, including across Kenan, although there are sidewalks on both sides of Franklin St and a sidewalk on the east side of Kenan. There are curb cuts on both sides of Kenan, but none on the west side of Franklin. Although these are legal, unmarked crosswalks across Franklin St and across Kenan, they may not be recognized as such by motorists, similar to Church St (above) before improvements were made. It is ¼ mile to the next marked crosswalk from Mallette to Roberson St toward the west, and 0.3 mile to the next signalized intersection. The long stretch of West Franklin with no crosswalks and four travel lanes makes this section appear more like a thoroughfare than a central business district street. The appearance of the road and lack of pedestrian crossings may contribute to 85^{th} percentile speeds that are 70% (at 34 mph) above the 20 mph limit.

Recommendations:

⇒ Adding marked crosswalks and signals at this location would provide another protected crossing opportunity for pedestrians. Kenan could remain STOP controlled for vehicles if traffic doesn't warrant a full signal, and a HAWK signal could be added for pedestrians and cycles.

⇒ A rapid flash beacon is another enhancement for marked pedestrian crosswalks on multi-lane streets that is reported to result in high motorist yielding.

⇒ Marked crosswalks should not be added across Franklin St unless some additional treatment (traffic or HAWK signal or rapid flash beacon) is also added.

⇒ If a signal is provided, also provide bicycle activation for Kenan.

⇒ Alternative crossing treatments might be effective if the number of lanes were reduced. Examples include bulb-outs, with perhaps a change in parking configuration, changes in pavement type or coloring (not MUTCD-approved) to highlight crossing areas, and others.

Midblock crossing

A midblock crossing is planned for west of Kenan near the public parking lot west of McDonalds.

Recommendations:

⇒ Given the distance between blocks and protected crossings on W Franklin St, enhancing the intersections and providing the midblock crossing would be desirable. Similar considerations would apply at a midblock crosswalk as at an uncontrolled intersection such as at Kenan.

⇒ A HAWK signal, rapid flash beacon, or other enhancements should be provided if crosswalks are marked on multi-lane streets with higher traffic volumes.

⇒ Ensure lighting is adequate.

Rosemary & Church

Pedestrian high visibility crosswalks and signals are present for all legs, though the priority given to Rosemary St traffic causes the crossing times to be markedly different. A pedestrian is given 36 seconds to cross the narrower Church St (32 for "walk" and a 4 second countdown). The 4-second countdown might be insufficient for some pedestrians who begin their crossing during the walk phase to complete that crossing. To cross the wider Rosemary St (2 lanes plus turn lanes), a pedestrian has 13 seconds (4 for "walk" plus a 9 second countdown). The pedestrian signals are only tripped when the button is pushed. Several pedestrians observed either ignored, or could not figure out which button to press for different crossing directions.) Bicycle loop detectors are provided for Church and were observed being used by bicyclists. Other safety issues include:

- Visibility could be an issue at the intersection of Rosemary St and Church St, where large electric boxes on utility poles are at eye-level and can obstruct a pedestrian's view of oncoming traffic or vice versa. There are also some low-hanging branches, but these (for now) seem to be out of the pedestrian and driver sight lines.
- On one corner, the sidewalk is unpaved and is level with the roadway. There is no curb between sidewalk/path and the road, so cars could easily encroach on the walkway, or pedestrians with low vision could enter the road inadvertently. Maintenance to keep the unpaved path up to ADA standards could be an issue.
- The intersection seems to have adequate sidewalk width near the intersection except for the northeast corner, where there is no real landing or sidewalk along Rosemary. The area along the curb is occupied by a rock wall that extends east along Rosemary St, effectively blocking pedestrian access.

Recommendations:

- ⇒ Complete curb and sidewalk with accessible curb ramps in line with crosswalks.
- ⇒ Consider location of utility poles and signal cabinets to ensure that they do not block sight distance between pedestrians and motorists at intersections.
- ⇒ Review placement of pedestrian push-buttons. Install supplemental signing which explains which buttons to push to cross each street.
- ⇒ It may also be a good idea to give the pedestrian signal whenever drivers have a green light, since a person arriving to the intersection after the green phase cannot activate the signal until the next phase. Many pedestrians would be disinclined to wait through an entire cycle when their direction of traffic had a green. Evaluate pedestrian volumes for consideration of this measure.
- ⇒ Maintain in-pavement bicycle loop detector markings.

Rosemary midblock crossings

Two other crosswalks exist within the study site and are located at midblock locations. These lead from a large parking area on the north side of Rosemary St to the southern side, where businesses are located. Each crosswalk has a “Ped Crossing” sign, but during a site visit 5 cars passed by pedestrians clearly waiting to cross before a motorist stopped to allow them to cross. The size of the parking lot and observations suggest that the area sees a great deal of crossings throughout the day. Motorist yielding rates seem to be low, but pedestrians were also observed crossing at their own discretion and away from the crosswalks. Thus, crosswalk improvements would likely need to have a significant effect on motorist yielding and perceived benefits to pedestrians to have a significant impact.

Recommendations:

⇒ Consider a HAWK signal. These push-button activated devices have been found to be effective at gaining motorist yielding compliance and will be included in the next MUTCD edition. If motorist yielding improves significantly, the devices could be effective enough to encourage greater pedestrian use of the crosswalks, particularly during higher traffic periods.

⇒ Consider rapid flash warning signs (triggered by pedestrian activation) which have also been approved for the next edition of MUTCD, illustrated previously.

⇒ Less preferred alternatives to the HAWK signal or Rapid Flash warning sign:

- Add in-street “Yield to Pedestrians” signs
- Add raised crosswalks

⇒ Consider enhanced lighting for nighttime crossings. See Gibbons et al. (2008) for more information on lighting design for midblock crosswalks.

⇒ With sidewalk continuity and crosswalk improvements, use of channelizing devices/pedestrian barricades could also direct pedestrians toward the crosswalks.

Street Sections

W Franklin sections

In contrast to the previous section, there is no midblock crossing for the section of Franklin St west of Columbia St; the next (west) intersection is 750 feet away. This section was observed to have substantial mid-block pedestrian crossings and is a high-density collision area (part of the 12-crash cluster), particularly around the transit stops (see Figure 33 and Figure 35). This section of Franklin St is 5-lanes with a continuous, two-way, center turn lane from Columbia to Mallette St. Although there is no parking for most of this section, the five lanes of traffic and substantial distance between signalized crossings create a challenging pedestrian crossing environment. There are also many driveways creating numerous conflict areas for bicyclists and pedestrians.

Three pedestrians were struck mid-block between Columbia and Church St. Since there is no signal or other traffic control or refuge, pedestrians dart or dash across the five lanes, using the center turning lane as a refuge. Traffic turning from Columbia onto Franklin may not be expecting pedestrians in the middle of the street just past the intersection and have little reaction time.

Figure 35. Pedestrians cross midblock to businesses and transit stops on opposite sides of Franklin St, west of Columbia St.

Note: Driveways and parked vehicles may block pedestrian throughway as seen here forcing pedestrians near or into the street.

Other problem conditions include:

- Numerous driveway ramps west of the bus stop (N side of Franklin) bring the sidewalk to street level and seem to invite pedestrians into and across the street, especially at these locations (Figure 35). The existence of bus stops on opposite sides of the road, as well as multiple parking and shopping locations, makes the area the most underserved pedestrian crossing location within the audit site.

- o The multiple driveways also create numerous conflict points, with motorists turning in and backing out, motorists parked across sidewalk, blocking pedestrian through way, etc. (north side of Franklin, particularly).
- o Observations at University Square (S side of Franklin) suggest that the volume of traffic entering and leaving this driveway (closest to Columbia) may warrant some changes. This driveway was observed to be affected by traffic queuing for the Columbia intersection, particularly when buses are in the queue. At some times, the sidewalk path was continuously blocked for several minutes by vehicles waiting to leave, and pedestrians were obstructed from continuing across the driveway (unless they entered the roadway). Additionally, motorists turning left from Franklin into this driveway may rush the turn to get across two traffic lanes and may fail to notice pedestrians traveling along the sidewalk. The driveway encourages this since it looks like a road rather than a driveway, is wider than many of the side streets, and lacks a level pedestrian crossing to slow motor vehicles entering. It even has a yellow line striped down the middle. One pedestrian was struck in this kind of maneuver at one of the University Square driveways (unclear which one). Pedestrians crossing midblock are also vulnerable to motorists turning into and out of driveways.
- o Four bicycle collisions occurred in this section along Franklin St (Figure 34). Collisions have occurred when motorists turned left in front of on-coming cyclists and drove out without yielding, both at driveways. In the drive-out, the bicyclist may have contributing by traveling wrong-way in the roadway. One bicyclist struck a door of a parked vehicle that was opened into his path (eastbound just west of Kenan St).

Recommendations:

- ⇒ Consider consolidating/eliminating driveways near the transit stop and reconstructing the curb. Consider adding landscape/streetscape barriers to crossing midblock (but these may be difficult to maintain).
- ⇒ Consider relocating the two transit stops on to the far sides of the Church St intersection where there are available crossings with pedestrian signals.
- ⇒ Add a level crossing to all driveways (continue pedestrian grade across driveways).
- ⇒ Consider narrowing the University Square driveways as well as providing sidewalk level crossings and other possible driveway improvements. (For example, the driveway nearer to Columbia could be an exit only, other driveways could be for ingress only.)
- ⇒ Consider re-striping/reallocating street space (reduce number of regular lanes and/or eliminate on-going turn lane), and adding striped bicycle lanes. This treatment would create a narrower profile of regular traffic lanes for pedestrians to cross and provide space for bicyclists to ride.

⇒ Consider adding signs to parking meters in areas with on-street parking to remind motorists to check behind for traffic before opening car doors facing the street and before parking or pulling back into the traffic stream.

⇒ Educate bicyclists to ride in the direction of traffic (on the street); avoid the door zone in parking areas; take the lane in narrow lane, low speed situations; use proper lighting and retro-reflective gear at night and dusk/dawn; and wear safety helmets and obey all traffic signs and signals.

Recommendations – long term:

Due to the long blocks, human nature and the locations of midblock transit stops and other destinations, there will continue to be people crossing midblock throughout W Franklin St. One of the few ways known to further reduce risk to pedestrians and to bicyclists is to reduce the number of lanes and expanse of pavement to cross (exposure). There is, according to the Mobility Report Card, excess motor vehicle capacity through downtown, and vehicle use has declined over the past two report periods (LSA Associates, Inc., 2007). The latest mobility study reported a 24-hour two-way volume of 18,900 vehicles just west of Raleigh Rd. (NCDOT shows an ADT of 15,000 for E Franklin, downtown, and 14,000 for W Franklin, downtown.) The trend toward decreasing traffic volume may continue with increasing transit and other multi-modal travel, particularly if other accommodation is provided. In any case, the roads should reflect a clear message to drivers that these are low-speed, downtown streets where pedestrians and bicycles have priority. With speeds sufficiently slowed, bicyclists should have no problem sharing a single travel lane with motorists. A friendlier pedestrian environment would also enhance downtown and possible revitalization efforts with more space for other activities (sidewalk dining, more attractive environment and easier to move around).

⇒ Change the continuous two-way turn lane configuration to left turn pockets (as needed) and provide a raised median or median refuge/crossing islands in between.

⇒ Consider other road diet measures such as reduction of number of lanes for all of downtown Franklin St to Carrboro. Space could be allocated for other needs such as on-street parking, expanded pedestrian areas, landscaping or possibly bike lanes.

⇒ Bulb-out curb extensions with any of the above measures could further increase pedestrian conspicuity and reduce crossing distance at intersection and midblock crossing locations, and slow turning speeds at intersections. As part of a road diet, more on-street parking could conceivably be added to parts of W Franklin St that now lack parking. Added on-street parking might compensate for closing driveways and reducing some off-street parking and claiming that space for pedestrians.

W Rosemary Street Sections

There are also significant numbers of bicyclists using Rosemary St. [Over 500 in a 12-hour count were observed at various locations west of Columbia St and more than 1800 at Rosemary and Church St in the latest (2005) count.] Bicyclists on Rosemary were observed to generally ride in the street with the flow of traffic. (As mentioned, sidewalk passage is not continuous along this stretch.) A number of bicyclists were observed to ride in the gutter area near the curb, although the approximate 18.5 feet lanes should be wide enough to allow bicyclists to take more space, and still allow safe passing by motorists. Concave drain grates are significantly below the pavement level; some also have slots parallel to the road direction. These drain grates would be hazardous to bikes riding too near the curb. Some of them are presently highlighted with a white stripe, while others are not. Again, collisions have involved motorists driving out at midblock locations to which bicyclists riding wrong-direction contributed, and a bicyclist failing to obey a red light at Church St opposing Rosemary. However, this collision occurred in 2001, prior to the installation of bike detection loops on Church St.

Issues for pedestrians were noted as follows:

- Availability, width, and quality of sidewalks through the study site are inconsistent and generally lacking continuity. Pedestrians were observed to have to walk in the street in some locations (see Figure 36 for an example). Pedestrians with disabilities would probably have to travel in the street for much of its length. Many of the curbs along the study site are deteriorating, and they are almost at the same level as the street. The result is a very low degree of separation between pedestrian and vehicle spaces.
- Lighting may not be adequate along this stretch of Rosemary St. Most of the lights are located along the south side of the road, and intersections may especially need enhanced lighting. Lights that do exist seem to be somewhat blocked by trees and branches – perhaps more strategic placement is needed to avoid this problem. Several of the collisions occurred at night.
- Poor sight distance at driveways can affect both pedestrians and bicyclists. Rosemary St (for a CBD area) has a large number of driveways entering the roadway from different businesses and parking lots. View from these driveways is often blocked by buildings, brick walls, and extensive vegetation set back at minimal distances (Figure 37). Several collisions in this area involved motorists exiting driveways.

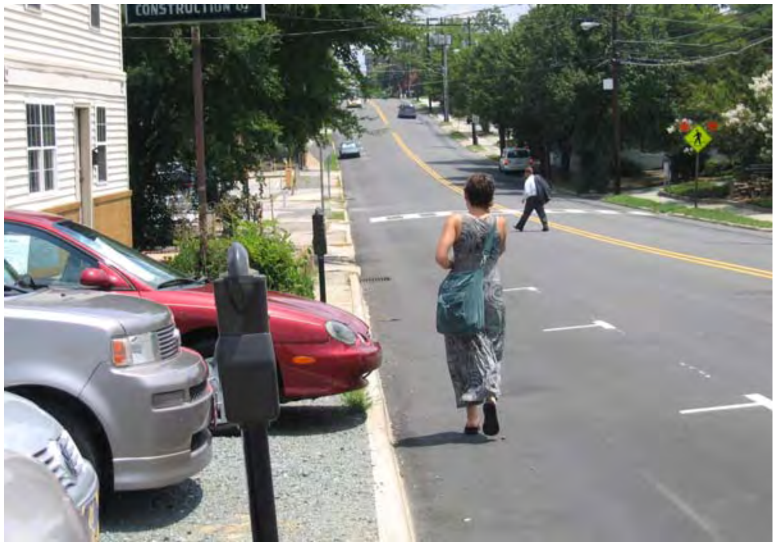

Figure 36. Pedestrians must enter the roadway to skirt parking meters and vehicles parked adjacent to Rosemary St. When the on-street spaces are occupied, pedestrians may have to walk in the middle of the traffic lane.

In the distance, another pedestrian crosses outside of the uncontrolled midblock crosswalk (with fluorescent yellow warning).

Figure 37. View of pedestrians, bicyclists, or oncoming motorists is blocked by shrubbery at this alley connecting with Rosemary St.

Recommendations:

- ⇒ Work with property owners in the short term to address sight distance issues at driveways, particularly with vegetation, but also hard objects such as walls.
- ⇒ Complete sidewalks on both sides of street; repair poor, irregular, surfaces of existing walkways. Ideally, provide wider sidewalks (6 feet or wider) separated by a buffer from traffic. Our understanding is that sidewalk improvements for Rosemary St are pending.
- ⇒ Provide sidewalk-level crossings across all driveways accessing Rosemary St.
- ⇒ Evaluate lighting and consider pedestrian-level lighting along walkways.
- ⇒ Create a bicycle-friendly street with a more uniform profile that may serve as a commuter route and alternate to Franklin St. Consider striping bike lanes along this street) to give bicyclists an obvious place to ride, and help motorists position relative to bicyclists. The intermittent parking would probably need to be removed to provide space, but relatively few parking spaces are available at present.
- ⇒ Remedy the hazardous drainage grates, or at least mark all of them.
- ⇒ Provide enforcement of traffic laws, and education of motorists about yielding to bicyclists and pedestrians at crosswalks, intersections and driveways.
- ⇒ Educate bicyclists about the importance of using lights at night, riding with the flow of traffic in the street, avoiding the gutter area, taking the lane in narrow-lane situations, and avoiding the door zone in areas with parking.
- ⇒ Manage access - consider consolidating/reducing number of driveways.
- ⇒ If there is not one, the Town could consider an ordinance requiring property owners to maintain clear sight lines around driveways, publicize the benefits, and enforce it as needed.

III. Transition Area - W Franklin @ Graham St to East Main @ Weaver St

This section, less than 0.4 mi, is the main corridor linking downtown Chapel Hill and the University of North Carolina, with Carrboro, and had the greatest density of bicycle collisions in the study area, although there was little indication that many survey respondents perceive the area as unsafe. Franklin St is four through lanes in this section; Main St is two lanes westbound and one lane eastbound from Franklin to Rosemary, then two lanes in each direction from Rosemary to Weaver St. There are four key intersections (not including Main, Weaver, & Roberson which will be discussed with the Downtown Carrboro audit). Two are skewed and one of these is also five-way and poorly defined for all users. In addition there are two other small side streets and numerous commercial driveways adding additional conflict points in this section. On-street parking ends east of Graham St, so there is one less source of potential conflict for bicyclists traveling along the street.

Seven of the bicycle collisions occurred at intersections with 5 at midblock or driveway locations. Three of the collisions occurred after dark, but roadways were considered lighted (Figure 38).

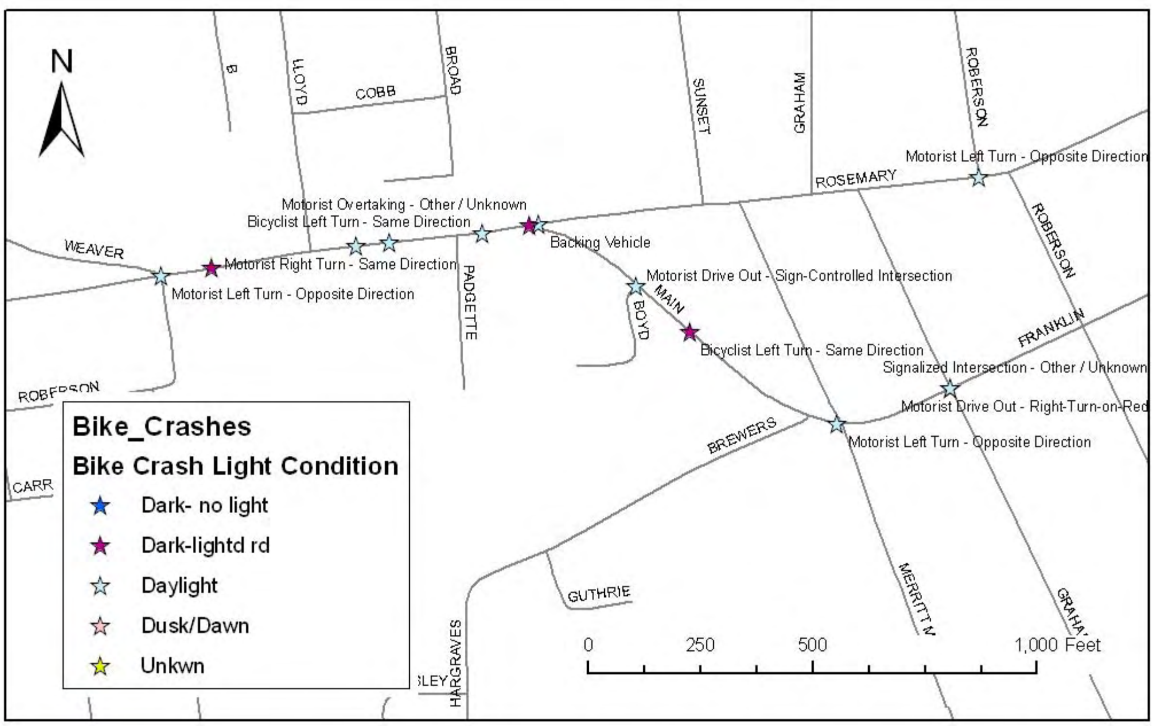

Figure 38. Chapel Hill- Carrboro transition area and bicycle crashes.

The crashes mostly involved motorist drive outs from driveways or stop-controlled intersections, and/or turning left and right across the path of through bicyclists without yielding to bikes. In most cases, the cyclist was riding on the sidewalk, but only two cases involved wrong-direction riding. Two overtaking motorists struck bicyclists traveling in a travel lane in the correct direction. Two bicyclists attempting to merge or turn left rode into the path of a motorist; one of these was a ride out from the sidewalk. Thus, the collisions suggest that this is a challenging roadway whether one is riding on the street in the direction of traffic, or opting for the sidewalk. One pedestrian collision occurred at Rosemary and Main during the study period. Several other pedestrian collisions occurred nearby on Roberson St, on Rosemary St near Graham, and on Brewers near the intersection, but no clear patterns emerged.

Intersections

While most of the reported collisions in this section involved bicyclists, conditions at intersections are unsafe for pedestrians and cyclists.

Franklin & Graham

This signalized intersection lacks amenities for pedestrians crossing Franklin St – with a wide 4 lanes plus turn lane. There is no crosswalk to cross Franklin on the west side of Graham St. There are no pedestrian signals for any legs. We did not evaluate signal timing to ensure that the green allows sufficient time for pedestrians to cross. New development in the area will likely increase the volume of pedestrians in the vicinity. The roadway is wide here, with 5-6 lanes (counting parking and/or turn lanes) to cross.

Recommendations:

Measures should be taken to enhance and call attention to pedestrian crossings. The area should reflect that this is a downtown, pedestrian-oriented environment.

⇒ Add pedestrian signals to all legs.

⇒ Add crosswalk to the west leg of Franklin St.

⇒ Consider adding bulb-out extensions from curb to reduce crossing distance and enhance pedestrian conspicuity. This could be done easily for the east leg of Franklin (where there is on-street parking).

⇒ Evaluate lighting, including street-level lighting.   Lighting presently seems to be focused primarily over Graham legs and may not sufficiently illuminate pedestrians crossing Franklin St.

Recommendations - long term:

⇒ Consider a road diet and pedestrian/bicycle-oriented countermeasures in context of the entire Franklin St downtown corridor as discussed previously.

Franklin, Main, Brewers & Merritt Mill

Over 700 pedestrians and 180 bicyclists were observed in a 12-hour count along the Main St section leading to this junction (LSA Associates, 2003). This 5-way, elongated intersection has a number of design and engineering issues relating to pedestrians and bicyclists (see images in Figure 39). Some of the issues include:

- There are no pedestrian crosswalks, signals or curb ramps crossing Franklin St or Main St.
- There are numerous visual obstructions (NE and SE corners of Franklin and Merritt Mill) and impediments to safe pedestrian travel (gaps in sidewalks, rough pathway, poor delineation between street and pedestrian route, particularly from Brewer around the entire corner and down Merritt Mill (SE).
- The southwest corner is marked by older business properties which have essentially open driveway access across most of the road frontage. Thus there is little delineation between the street and the expected pedestrian path, and pedestrians and bicyclists are exposed over a very wide expanse to vehicles that may be turning in and out of these businesses and cutting across corners, etc. (There are no sidewalks or curbs around the Merritt Mill to Brewer Ln corner).
- There are no pedestrian signals on any of the legs to help pedestrians know when it is their turn to cross. One example of the challenges: For pedestrians trying to cross Merritt Mill, Brewer traffic or Main St traffic may be released when traffic is stopped at Merritt Mill (and pedestrians might think it is safe to cross). Traffic on Brewer cannot see pedestrians who may be crossing at Merritt Mill until they come around the corner. Motorists on Main may not understand that they are also obligated to yield when turning right onto Merritt Mill as it may seem they are making a 'through' movement due to skewness of the intersection.
- Brewer forms a skewed angle with Main and a wide expanse to cross, and lacks crosswalk markings.
- Brewer connects to a neighborhood and also to the Libba Cotten bike path. Bicyclists trying to get to Brewer from southbound Merritt Mill face opposing left turning traffic from Northbound Merritt Mill. Although the right-turning bicyclist should have priority, with the two lanes, they may have difficulty moving left to make a quick left on Brewer and may find it very difficult to make this turn. One bicyclist trying to make this maneuver was struck by a motorist (originally northbound on Merritt Mill) going left on Main (failed to yield) at this junction. (Although the officer cited the bicyclist as having not yielded, observations of present conditions show that northbound and southbound traffic on Merritt Mill have green at the same time. Therefore, the left-turning motorist was obliged to yield to the right-turning bicyclist.) Motorists making the same maneuver would probably have similar difficulty. Bicyclists may also have trouble positioning to turn left onto Brewer as they approach from Franklin.
- The traffic signal here is apparently coordinated with others on W Main. Sufficient crossing and clearance time needs to be provided for both pedestrians and bicyclists.

Figure 39. The multi-leg intersection of Franklin, Main, Merritt Mill, and Brewer provides a large expanse of unmarked pavement for pedestrians, cyclists, and motorists to navigate. (Lower right image from Google Imagery © 2008 U.S. Geological Survey.)

Pedestrian signals and crosswalks are lacking, and objects and vegetation obstruct sight lines.

Recommendations:

Some improvements will be made in the area in conjunction with new development in the block of Merritt Mill, Rosemary and Graham. Hopefully, improvements to this five-way intersection will be implemented as well.

⇒ Help reduce skewed angles and crossing distance by construct curbs with narrow radii, ADA-compliant landings and curb ramps aligned with crosswalks, and add crosswalk markings (and pedestrian signals) at all corners for each of the legs. In addition to helping pedestrians navigate this complex area, narrowing the radii and crossing distance of some legs of this intersection (Brewer) should reduce exposure for bicyclists. For example, the skewed angle could be reduced with use of

⇒ Complete sidewalks along Merritt Mill, west side and around corner to Brewer Ln. Consider reducing driveway openings/consolidation to reasonable driveway access with level sidewalk crossings. Consider driveway locations relative to the intersection.

⇒ Provide pedestrian countdown signals and a pedestrian phase for each crossing coordinated with other traffic movements. A priority should be to reduce turning conflicts through protected turn phases or other measures since visibility is poor such. Other measures could be considered including leading pedestrian intervals, high visibility crosswalk markings and warning signs. If the signals remain in a coordinated cycle, the system may need to be re-timed to add a sufficient interval for pedestrian crossings and bicycle clearance. It is possible that a coordinated traffic signal system throughout the downtowns, timed for 20 mph flow, could improve conditions for all users.

⇒ Alternatively, consider adding pedestrian signals with pedestrian-activated push buttons and bicycle detection for the side streets. A traffic study could determine which mode induces least delay to both pedestrians and motor vehicle traffic. Address sight distance obstructions including a wall and vegetation at some legs of intersections. (For instance, southbound on Merritt Mill, vegetation and building close to the corner block view of westbound Franklin traffic, so right turns on red may not be advisable.) There is a wall on the south side of Franklin at Merritt Mill which blocks vision of pedestrians (or bicyclists) approaching Merritt Mill westbound on the sidewalk. Consider whether this wall might be removed.

⇒ Lane reductions/road diet on Franklin and Main could provide space for bulb-out extensions with curb ramps and landscaping space (as long as it is kept low or high so as not to obstruct sight lines).

⇒ As another long-term solution, consider the feasibility of a low-speed roundabout at this intersection which may provide better access to the various legs (including quick lefts), reduce the many conflict points of this 5-legged intersection, and provide an attractive gateway to and between Carrboro and Chapel Hill.

Main & Rosemary

This skewed intersection received crosswalk and signal improvements during the study period that should improve pedestrian accommodation. This may still be a challenging intersection for bicyclists, particularly for those traveling eastbound on Main who want to turn left onto Rosemary. The signal indication also seemed to sometimes have eastbound (Main) traffic stopped when there are no conflicting movements and no pedestrians crossing which may lead to driver frustration.

Recommendations:

⇒ If speeds can be slowed with engineering and enforcement measures and bicyclists encouraged to take the lane and ride with the flow of traffic, they should be better able to position for turns and navigate the intersection. A new sign to facilitate full lane use by bicyclists is slated for the next MUTCD edition. Bicyclists riding in the street with the flow of traffic would also be more visible to motorists. Sidewalk riding should be discouraged.

⇒ The intersection should be evaluated with respect to bicyclists in context with overall plans for Main, Rosemary and Franklin. For instance, if bike lanes are provided, consider a bike box at each intersection approach to allow bicyclists to come to the front of the line on a red traffic signal indication (see Figure 40).

⇒ We did not revisit this location at night, so nighttime lighting levels should be assessed. One collision at this intersection occurred at night.

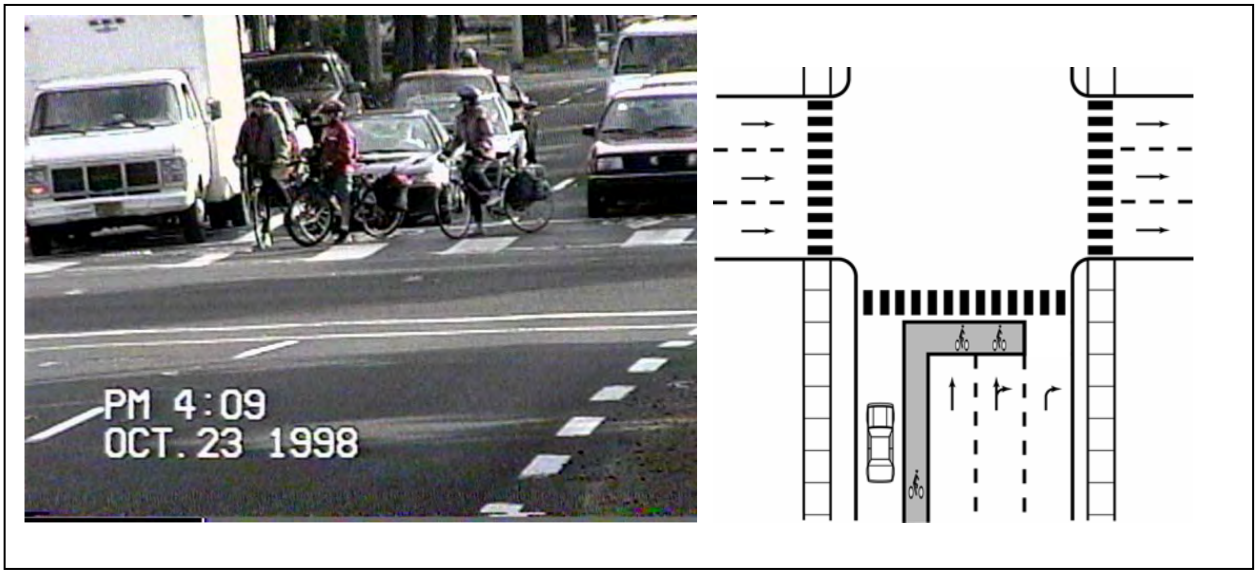

Figure 40. A bike box, used in conjunction with a bike lane, allows bicyclists to move to the front of a queue on a red signal to position for through or turning movement, and enhance cyclist conspicuity to motorists that may be turning.

Note: Some jurisdictions are using colored pavement to highlight bike boxes (not currently MUTCD-approved).

Street Sections

Franklin and Main Street Sections

Narrow lanes and low speeds (20 mph posted) should allow safe sharing of travel lanes by bicyclists with motor vehicle traffic. However, the number of lanes (4, with one 3-lane section from Rosemary to Franklin), may allow for higher speeds through this section. Speeds were much higher than 20 mph when measured on a 4-lane section of W Franklin St near Mallette and may be higher than 20 through this section as well. In addition, the changing profile from 4-lanes (Franklin), to 3 (Main between Merritt Mill and Rosemary), then back to 4 (Main) may add additional maneuvers and lane changing to the already complex environment that is intersected by numerous junctions. Based on both collisions and observations, many bicyclists apparently feel uncomfortable sharing the multiple, narrow lanes with motorized traffic, opting instead to ride on the frequently interrupted sidewalks (numerous driveway connections plus side streets). As mentioned previously, sidewalk and wrong-way riding puts bicyclists in unexpected locations at driveways and intersections. Sidewalks are also narrow (too narrow to be shared safely by pedestrians and bicyclists), have no buffer between pedestrians and traffic, and are of course intersected by the same driveways.

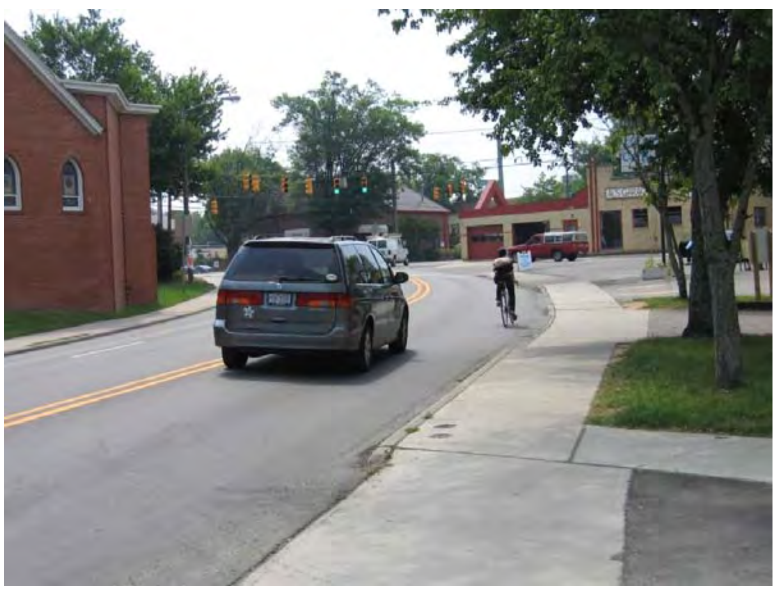

Figure 41. This bicyclist on E Main St is correctly riding on the street with traffic in the 3-lane section.

Notes: Bicyclists could 'take the lane' on low-speed, narrow lane streets when they can travel essentially at the speed of other traffic. Motorists should practice safe passing by waiting for a sufficient gap when they can allow at least 3 feet of lateral clearance and ensure a safe distance when merging back right.

When lanes are not wide enough to be shared by motor vehicles and bicyclists side by side, especially when bicyclists can ride close to the speed of other traffic, they should be encouraged to take full use of the lane. Bicyclists can better position for turns, be more visible at intersections, discourage motorists from making unsafe passing maneuvers, and avoid right-hook turning collisions if they make full use of the travel lane. It is, however, important that speeds be kept low. The current situation does not meet these conditions.

Recommendations:

⇒ Provide access management: Consider consolidating/reduce the number and width of driveways which create numerous conflict points along this section. This measure would go a long way toward enhancing the safety and comfort of bicyclists and pedestrians traversing this segment.

⇒ Ensure each driveway has a level crossing to slow motor vehicles when turning in and out of driveways.

⇒ Add signs such as the new R4-11 to encourage bicyclists to use the full travel lane. (See Figure 32.)

⇒ Consider prohibiting sidewalk riding; at least prohibit wrong-way riding on sidewalks and educate bicyclists to ride slowly and watch for turning vehicles at junctions if they are going to ride on sidewalks.

⇒ Provide police enforcement of speed limits, motorist yielding to bikes and pedestrians when turning, and other traffic regulations for both motorists and bicyclists.

⇒ Consider the use of shared lane markings ("Sharrow," see Figure 42). The "sharrow" might help to increase on-street and correct direction riding and promote safer sharing of the roadway by motorists and bicyclists. These are at present an experimental treatment and may be tried in various applications. They are, however, slated for inclusion in the next MUTCD. The recommended language (Section 1 9C.07 Shared Lane Marking, Notice of Proposed Amendments for the Manual on Uniform Traffic Control Devices, 2007) at present indicates that shared lane markings may be used to:

- "Assist bicyclists with lateral positioning in a shared lane with on-street parallel parking in order to reduce the chance of a bicyclist's impacting the open door of a parked vehicle,
- Assist bicyclists with lateral positioning in lanes that are too narrow for a motor vehicle and a bicycle to travel side by side within the same traffic lane,
- Alert road users of the lateral location bicyclists are likely to occupy within the traveled way,
- Encourage safe passing of bicyclists by motorists, and
- Reduce the incidence of wrong-way bicycling.
- Guidance: The Shared Lane Marking should not be placed on roadways that have a speed limit above 50 km/h or 35 mph."

⇒ There may still be limits to the numbers of bicyclists who will feel safe enough to share the roadway with traffic. Due to the physical constraints, there seem to be few other treatment options for the narrow-lane/sharing situation, other than a road diet and reallocating space for bike lanes, unless additional right-of-way beyond existing curbs is available or could be procured. Providing a space for bicyclists to ride on the street through this section could reduce congestion in the long-term and should help to move bicyclists off the sidewalk where crashes are frequent. (We should caution, however, that we do not have exposure data about the relative numbers of sidewalk and on-street riders on this street). Reducing number of lanes for this relatively short section may not make much difference in overall flow or congestion, especially since part of the section is already only 3 lanes at present. Reducing the number of lanes to one in each direction, plus pocket left turn lanes may help to slow speeds to the posted 20 mph, and reduce pedestrian and bicyclist exposure in this downtown environment. Temporary devices are sometimes used to experiment and evaluate potential treatments.

Figure 42. Sharrow (shared lane) pavement marking, as currently being evaluated on Martin Luther King Jr Blvd in Chapel Hill.

Rosemary Street Sections

Rosemary Street on the west end/transition area has intermittent parking, left turn lanes that span entire blocks, and, transitions from one to two-lanes at Sunset for the block continuing to Main. There are also offset intersections (none signalized) with poor pedestrian access, and a large residential area and a municipal parking lot on the north side of Rosemary St opposite a number of businesses. Once again, there are driveways with poor sight distance, compounded by on-street parking. Night-time lighting also seems to be deficient in this area. The current large construction project has also resulted in sidewalks being closed and pedestrian detours that lead to extra street crossings.

Recommendations:

⇒ Evaluate and provide enhanced night-time lighting in the area. Consider sidewalk lighting.

⇒ Consider a HAWK (pedestrian-activated) signal in this area to assist pedestrians crossing from the neighborhood and parking lot to the south side. The HAWK could be at an intersection (such as Sunset) or a midblock location. It would preferentially be located where the most pedestrians typically cross.

⇒ Consider removal of some on-street parking that adds to blocking sight distance at some driveways.

⇒ Hopefully, sidewalks and accessibility will be improved throughout the area in conjunction with the on-going development.

IV. Downtown Carrboro

Downtown Carrboro is another center of pedestrian and bicycle activity with nearly 2000 pedestrians and nearly 300 bicyclists recorded in a 12-hour period on Greensboro St between Main and Weaver Sts in 2003 (LSA Associates, 2003). Downtown streets are low-speed (marked at 20 mph), mostly 2-lane with extensive use of left turn lanes, and intersections have generally tight turns with narrow radii as befits a central business district. The area of downtown Carrboro defined approximately by the triangle of Weaver St, Greensboro St, and Main St (see Figure 43), and going north on Greensboro to about Shelton St was an area of medium pedestrian crash density and medium high to medium low perception density. Most of the pedestrian collisions occurred at or near intersections; one occurred at a midblock crosswalk. Two pedestrian collisions occurred at night, and one near dawn. The area was also identified as one of concern for bicyclists - with a medium crash density and a medium low density of perceived unsafe bicycle locations. While in general, the area is well-served by sidewalks, signals, and crosswalks, a number of sidewalks and curb ramps are in poor condition, and the southern entry into town on Greensboro St lacks a suitable urban appearance and pedestrian and bicycle accommodation. Other issues include motorists reportedly not yielding to pedestrians in crosswalks, and speeding. In addition to being highlighted by both crashes and perception data, several of the intersections and crosswalks and the area of N Greensboro St were identified by the Town based primarily on citizen complaints. One intersection not shown in the figures below – W Main and W Weaver St – was also highlighted by the Town and was visited during the audits.

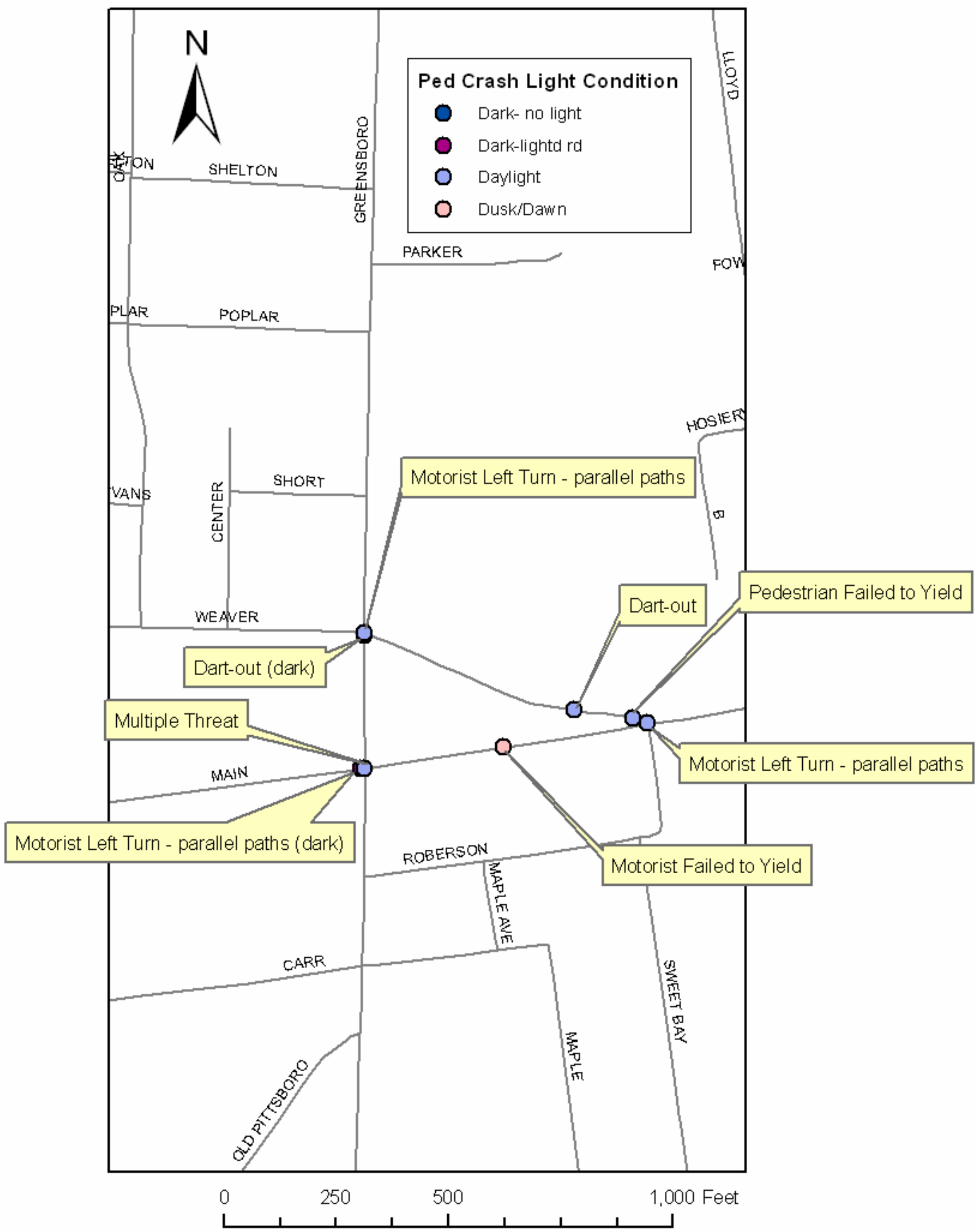

Figure 43. Downtown Carrboro audit area and pedestrian collisions.

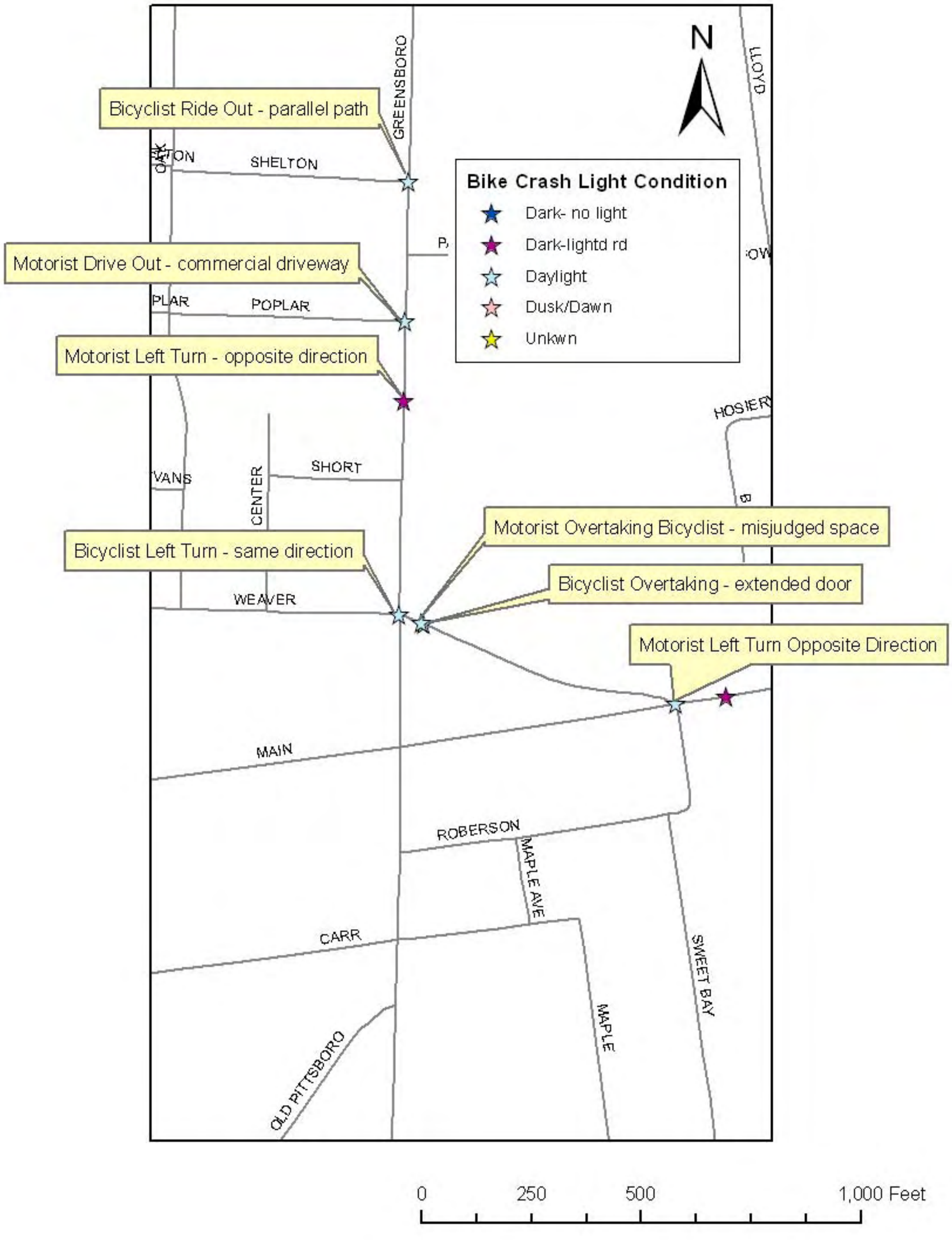

Figure 44. Downtown Carrboro audit area and bicycle collisions.

Intersections

Greensboro & Carr

This intersection was identified by the Town of Carrboro. There is a high visibility crosswalk and high visibility warning signs at this uncontrolled location on S Greensboro St (with stop control for Carr), but no traffic or pedestrian signals. The Town reports complaints that motorists do not yield to pedestrians trying to cross at this location. There are likely perception issues on the part of motorists since most of this section, from Main St (Old Pittsboro on the west side), south to beyond the NC 54 bypass, lacks sidewalks. Motorists approaching this crosswalk probably have the impression that they are in a semi-rural area (see Figure 45). A speed study on S Greensboro (south of Old Pittsboro) found that motorists (northbound and southbound) are traveling at 50^{th} percentile speeds of 39 mph and 85^{th} percentile speeds of 44 mph. Although the speed limit is reduced from 35 to 20 prior to reaching this junction, it is unlikely that motorists have much incentive to slow down before Carr St. Studies have found that motorists traveling at speeds above 20 mph are increasingly unlikely to slow or yield at uncontrolled crosswalks. There are no crosswalks across Carr, either side, and no crosswalk on the south side on Greensboro (Figure 46).

Figure 45. View of S Greensboro south of Carr St. Note the beaten path beyond where the sidewalk ends at Old Pittsboro.

Figure 46. View of Carr St crosswalk on S Greensboro.

Recommendations:

- ⇒ More forceful traffic control such as a HAWK signal could give pedestrians a protected crossing at this location – at least until other sidewalks, and bike lanes, and other roadway improvements are in place that convey to motorists they are in an 'urban' area. A HAWK (or a half signal) would be activated by pedestrian push button.
- ⇒ An alternative to the HAWK would be the rapid flashing beacon.
- ⇒ A low-cost improvement could include the center line "Yield to Pedestrians in Crosswalk" signs (as used on Main St).
- ⇒ Another alternative – consider a raised crosswalk/speed table using a 20 mph design speed and/or a raised crosswalk with bulb-out curb extensions and landings. Another vertical traffic calming device called speed cushions (prior to the crosswalk) could be used that larger wheel-based vehicles such as transit and emergency vehicles can span but passenger-sized vehicles cannot.
- ⇒ Ensure good visibility of speed limit signs and enforce speed limits.
- ⇒ Check that overhead lighting is sufficient. There is one streetlight, but this may be insufficient for night-time illumination.
- ⇒ Complete sidewalks along the corridor, and curbs and ADA-compliant ramps for all legs of the intersection. In addition to the problems at Carr St, there are beaten paths along S Greensboro St indicating the need for complete sidewalks along this corridor. There is at present no place for pedestrians to walk (not even a paved shoulder). This recommendation is mentioned here, because it affects motorists' perception of this key gateway to Carrboro, and because sidewalks are clearly needed (see S Greensboro Street sections).

Greensboro & Main and Greensboro & Weaver

There have been complaints of (turning) motorists not yielding to pedestrians in crosswalks at both of these intersections, and collisions of turning motorists with pedestrians bear out the complaints. The single luminaire (at Main) might be insufficient for Central Business District lighting of a main downtown intersection.

Recommendations:

⇒ Evaluate feasibility of protected left turns at both locations to reduce turning conflicts with pedestrians and bicyclists.

⇒ In addition - provide a leading pedestrian interval to allow pedestrians to establish presence in crosswalk before right-turning (or left-turning, if the protected left is not provided) motorists are released.

⇒ Evaluate/consider enhanced lighting at the intersections. Pedestrian level sidewalk lighting might also enhance motorists' perception of pedestrians approaching intersections.

⇒ Publicize and *enforce* laws regarding motorist yielding to pedestrians in crosswalks and when turning across sidewalks.

Main, Weaver, and Roberson Sts, with Carr Mill Mall driveway entrance

This skewed, four-way intersection functions like a five-way, with the Carr Mill Mall driveway entrance acting as the fifth approach. On the west side of the intersection, E Main and Weaver St form an acute angle junction. Pedestrians are served by high visibility crosswalks and pedestrian signals for all legs (except the Carr Mill driveway crossing). The intersection apparently presents problems for bicyclists and pedestrians conflicting with turning motorists. One bicyclist and one pedestrian have been struck by left-turning motorists during the study period. Numerous bicyclists use this junction, which provides access to and from the Libba Cotten path, to the heavily-used Mall shops and lawn and other destinations. According to Town representatives present at the audit, there are often vehicles in the queue of the Carr Mill driveway that are unable to get through the intersection on a signal change. Most traffic from Roberson and Carr Mill Mall driveway seems to be turning traffic. Bicyclists are frequently present as are pedestrians. Such delays may contribute to frustration and unsafe turning maneuvers into or across the path of bicyclists and pedestrians.

In addition to the marked crosswalk crossing Weaver and Main from the mall to Roberson St, there is another crosswalk further west, crossing only Weaver St. Pedestrians use this crosswalk to access businesses along the south side of Weaver St and north side of Main St on the inside of the triangle (Figure 47). There is no pedestrian signal associated with this crosswalk, and pedestrians using it may think that it is safe to cross when the traffic signal facing west (stopping eastbound traffic on Weaver St) is red; however westbound traffic on Main may have a green signal at this time unexpectedly conflicting directly with pedestrian movement.

Figure 47. Second crosswalk crossing to center of triangle bounded by Main and Weaver St has no pedestrian signal; pedestrians may not be able to recognize when it is safe to cross.

Recommendations:

⇒ Evaluate feasibility of protected left turns to reduce turning conflicts with pedestrians and bicyclists. The conflicts also slow clearance of motorists and pedestrians and bicyclists through the intersection and traffic sometimes backs up in the shopping center (unable to clear in one signal).

⇒ Alternatively to above, or in addition, consider increasing green time for the side streets (Carr Mill driveway and Roberson St) to give sufficient clearance time for queued motor vehicles, bicycles, and pedestrians.

⇒ Alternatively, consider adding "Turning Motorists Yield to Pedestrians and Bicyclists" signs and a leading pedestrian interval.

⇒ Add a pedestrian countdown signal to the west side crosswalk that crosses only Weaver St and link this signal to the phasing of the rest of the intersection.

⇒ Replace current pedestrian signals with countdown signals.

⇒ Add bicycle detection and bike boxes to Roberson and the Mall driveway. This marking would allow bicyclists to proceed to the front of the queue on red, increasing their conspicuity and allowing them to position for turns, as needed, and proceed through the intersection first.

W Main & W Weaver St

The Town of Carrboro identified this skewed, 5-leg intersection for further evaluation. This intersection is not shown on the maps above but an overhead view is shown in Figure 48. The audit team identified a number of safety issues including:

- There is a large "painted" triangle, presumably intended to serve as a pedestrian refuge area between the crossing of the continuous right-flow turn lane from Main, and the crossing for the rest of Main St or Weaver St. The painted markings provide little protection for pedestrians exposed to traffic while crossing the wide intersection (see Figure 49).
- There is a continuous flow, right-turn lane on westbound Main where sight-distance of the crosswalk is obscured due to crosswalk placement (in the middle of the turn) and to vegetation (see Figure 50).
- Vegetation on the southeast corner also obscures sight lines.
- Crosswalks are not aligned with the most direct pedestrian paths, particularly along the southeast corner of the intersection (see Figure 51).
- A number of pedestrians were observed to cross outside of the crosswalk areas, perhaps in part due to the conditions mentioned above, and also due to the skew and wide angle of the intersection (Figure 51).
- There are two push-buttons on the northeast side of the intersection – both activate the same crosswalk signal which serves pedestrians crossing the northwest leg of Main St. The redundant push-buttons in different positions relative to the crossing of interest could lead to pedestrian confusion.
- There are no pedestrian signals for crossing the most complicated southern leg of Main St, or to cross the eastern leg of Weaver St.
- Currently stop bars for motorists on westbound Weaver St are behind the junction with Elm St (5^{th} leg of the intersection) to prevent blocking access to Elm. Motorists on Weaver St who stop at the stop bars have little view of what is going on, or of pedestrians crossing at the "Main" intersection. Even so, motorists are allowed to make right turns on red. Many motorists simply do not comply with the stop bars.
- There are also several commercial driveways close to the intersection adding complexity to maneuvers and interactions, and additional conflict points.
- Some of the crosswalk markings were worn.
- There is no crosswalk for crossing Elm St which is stop-controlled for traffic on Elm and is not part of the signal phasing; there seems to be little traffic using this section of Elm.
- There are probably heavy right-turning movements from Weaver St (both directions), particularly on Farmer's Market weekends that may conflict with pedestrians.

Figure 48. Overhead view of W Main, W Weaver, and Elm St intersection (from Google Imagery, ©2008 U.S. Geological Survey).

Figure 49. Wide expanse of pavement with only 'paint' for refuge. Two legs of the intersection lack pedestrian walk signals.

Figure 50. Crosswalks across right-turn flow lanes should be prior to the curve of the turn. On NW-bound W Main at W Weaver, shrubbery also obscures the view of the crosswalk.

Figure 51. Pedestrians tend to take the shortest route between two points and should not be expected to cross extra legs of intersections in order to use crosswalks or pedestrian signals.

Recommendations:

The skewed intersection would benefit from simplification and narrowing of the pedestrian crossing distances, reducing the number of conflict areas, improving sight lines, and by adding pedestrian signals and crosswalks to all legs of the intersection. There are probably several potential ways to accomplish (some of) these objectives. Here are some potential treatments:

⇒ Pedestrian signals should be added for crossing both the south leg of Main, and the east leg of Weaver St.

⇒ Consider high visibility crosswalk markings.

⇒ Consider leading pedestrian intervals, and/or only protected left phases following the through and pedestrian walk phases.

⇒ Evaluate whether the right-turn lane from north/westbound Main St is needed. There may not be significant right-turn movements from this direction. If the turn lane is needed, consider modifying the continuous right-turn, flow lane design, including the location of the crosswalk, and adding a median refuge island. Pedestrian signals (and push buttons) should be added to the refuge island for crossing the main portions of the adjacent legs.

⇒ Ideally, the two-phase crossing of the free-flow turn lane and the rest of Main St may be eliminated. One possibility would be to add a bulb-out extension to the southeast (acute angle) corner where the turn lane and painted triangle are at present. An extension could include landscaped areas, a wide pedestrian landing and curb ramps, with or without some sort of right-turning accommodation (from Main). This would narrow the crossing distance and move pedestrians into a more visible position.

⇒ Landscape maintenance and other improvements should improve sight lines between pedestrians and motorists.

⇒ Consider use of diverters to close or allow only right-in movement to Elm St. Move the east side Weaver St Stop bars somewhat closer to Main St.

⇒ Consider driveway improvements including consolidation, narrowing, and providing a level pedestrian crossing that is clearly a pedestrian path across some of the driveways that lack such.

⇒ Consider restricting right-turn on red when pedestrians are present or on weekends or other times when pedestrians are most abundant.

⇒ Consider whether a roundabout might be feasible to improve safety and accessibility of this complex intersection.

Street Sections

Weaver St Sections

This section continues the link from E Main and W Franklin where a dozen bicycle collisions have occurred. Two additional bicycle collisions occurred in this segment, both involving overtaking maneuvers, one a motorist passing a bicyclist, the other a dooring crash (bicyclist hit an opening/opened door of a parked vehicle, eastbound). This section should function as a low speed, shared-lane situation under the present geometrics, but many bicyclists may feel uncomfortable taking the lane (thus the overtaking and dooring-type crashes). The pavement is also in rather poor condition through this section. Lighting could possibly be improved at the midblock crosswalk.

Recommendations:

⇒ Consider improvements to make Weaver St a bicycle/pedestrian priority street (bicycle boulevard) or a very low speed, narrow lane, shared street. The entire street or the section from Main to Greensboro could serve as a pedestrian/bicycle boulevard. (For example, bulb-outs and curb extensions at [possibly some] corners and midblock crosswalks could slow speeds, diverters could limit through traffic; pavement treatments, other design elements could be employed.)

E Main between Weaver and Greensboro

On this section, there is a midblock crosswalk with a center, "Yield to pedestrians in crosswalk" sign. However, in the westbound direction, a left turn lane is initiated before the crosswalk marking, setting up a multiple threat situation. Motorists entering the turn lane may not see pedestrians entering the crosswalk due to vehicles in the curb lane blocking their view.

⇒ It seems clear that the midblock crosswalk serves a well-used pedestrian route. Advance stop bars and signs ("Motorists Stop Here for pedestrian in crosswalk") for westbound traffic would increase the sight distance for motorists approaching in the left lane.

⇒ Evaluate whether it is possible to shorten the left turn lane approach so that there is only one lane to cross in each direction, eliminating the multiple threat possibility.

N Greensboro Street section

Entering Carrboro from the north, N Greensboro St, is two lanes plus bike lanes south to Poplar Ave. South of Parker St, the bicycle lanes end, and there are many commercial driveways and a continuous, two-way, left turn lane, adding a complex mix of conflict areas, just where some bicyclists probably take to the sidewalks. Several bicycle collisions with motor vehicles occurred in this area. Although no pedestrian collisions were reported over the study period, the Town has received complaints about the area for pedestrians. Speeds were not quite as high as on S Greensboro, but 85th percentile was measured at 32 mph – still in far excess of the 20 mph posted speed limit that is desirable for downtown mixing of motorized traffic, bikes, and pedestrians. With speeds this high, motorists may not be willing to yield at the uncontrolled crosswalks that have been added to this section, and bicyclists may have difficulty riding in the traffic stream.

Figure 52. Pedestrians and bicyclists may struggle with vehicles turning in and out of driveways, even where crosswalks are marked across N Greensboro St.

The mix of numerous driveways, several of them busy commercial driveways, and higher speeds of traffic entering town, and a lack of signalized crossings may make for difficulty in crossing N Greensboro as well as crossing at driveways as observed in Figure 52. Motorists turning in and out of these driveways may be looking for a gap in traffic and fail to notice pedestrians or bicyclists. Sidewalk conditions and accessibility are also poor in this area.

Recommendations:

Any reductions in the complexity of this thoroughfare and efforts to keep motor vehicle speeds low would help bicyclists and pedestrians navigate this section more safely. Again, bicyclists should ride with the flow, and mix with traffic in low-speed areas, but if they do not feel safe (and speeds are not truly low), they will likely continue to use sidewalks, often putting them in positions where they are not noticed by motorists.

⇒ Access management and driveway improvements should be sought. Parking areas with more than one driveway might be made one-directional so that bicyclists have to deal only with vehicles turning in or turning out, not both at once. This could also reduce the need for some left turn lanes and reduce other conflicts.

⇒ Pursue other driveway consolidation/narrowing as feasible.

⇒ Consider signalizing shopping center driveway(s) to accommodate access for all modes.

⇒ Consider the use of supplementary regulatory (HAWK signal) or warning beacons (rapid flash beacon) at crosswalks at non-signalized locations.

⇒ Provide level crossings across all driveways to keep motor vehicle turning speeds low and remind motorists of pedestrian right-of-way.

⇒ Provide crosswalks across side streets to remind motorists of the pedestrian right-of-way when turning. Ensure that stop bars are behind pedestrian crossing areas and that visibility is good at driveways.

⇒ Keep turning radii/curbs narrow.

⇒ Enforce speed limit.

⇒ Consider adding "Bicyclist May Use Full Lane" signs.

S Greensboro St Sections

S Greensboro St from just north of the NC 54 bypass looks more like a rural, narrow 2-lane road and lacks even paved shoulders to accommodate pedestrians or bicyclists. A beaten path alongside the road attests to the presence of pedestrians here. Since it is a key thoroughfare into Town, this is also an important corridor for bicyclists and was highlighted by the perception data. Since there is a steep uphill grade into Town, many bicyclists would feel uncomfortable taking the lane and the lane is clearly not wide enough for side-by-side overtaking or sharing.

Recommendations:

⇒ Sidewalks should be provided along this section. Residential areas adjoining the road have limited pedestrian access to downtown. Include crosswalk markings across side street junctions. Provide level crossings across all driveways.

⇒ Add bike lanes along S Greensboro St. With the grade on this section, inbound/northbound bicyclists are especially likely to appreciate a designated bike lane (of at least 5'). The preferred treatment to accommodate as many cyclists as possible would be to provide bike lanes in both directions.

⇒ An alternative, if space is limited, might be to provide shared lane markings in the downhill (southbound direction) and bike lanes in the uphill direction.

- ⇒ Regular street lighting should be provided with extra emphasis at junctions.
- ⇒ Consider whether other crossing opportunities are needed – possibly at the junctions of Old Pittsboro with S Greensboro.

V. Estes Drive from Franklin Street to 15/501-Fordham Blvd and Willow Dr. intersection

Estes Drive through this segment is a 5-lane cross-section handling 15,500 vehicles per day (2005) and connecting Fordham Blvd to Franklin St. Continuing on Estes, it ultimately connects to Martin Luther King Jr. Blvd, and N Greensboro St in Carrboro. The posted limit is 35 mph, but a speed study of 100 free-flowing vehicles found a 50^{th} percentile speed of 38 mph, and 85^{th} percentile speed of 43 mph. The segment is largely commercial, but with extensive adjacent multi-family residential areas. The commercial areas include University Mall at the east end, with extensive off-street parking surrounding the facility; and numerous businesses and offices, including the main post office on the western portion. Access to Community Center Park and Bolin Creek Trail is directly off Estes Dr. Across Fordham Blvd are several multi- and single-family residential communities, a shared use path parallel to Fordham Blvd that connects to other neighborhoods, and recreational league soccer fields. Thus, the area meets the conditions for high levels of walking and cycling with both generators and destinations within close proximity. The southeastern segment of the corridor (corner of 15/501 across from University Mall) is the only undeveloped parcel and has no sidewalk access or driveway connections.

Given the substantial pedestrian and bicycle traffic and number of generators in this area, and the number of collisions that have already occurred (see Figure 53), this would seem to be a priority area for improving safety and providing amenities for both bicyclists and pedestrians. The intersections of Franklin and Estes, and to a lesser extent Fordham and Estes, were also highlighted by perception data for pedestrians.

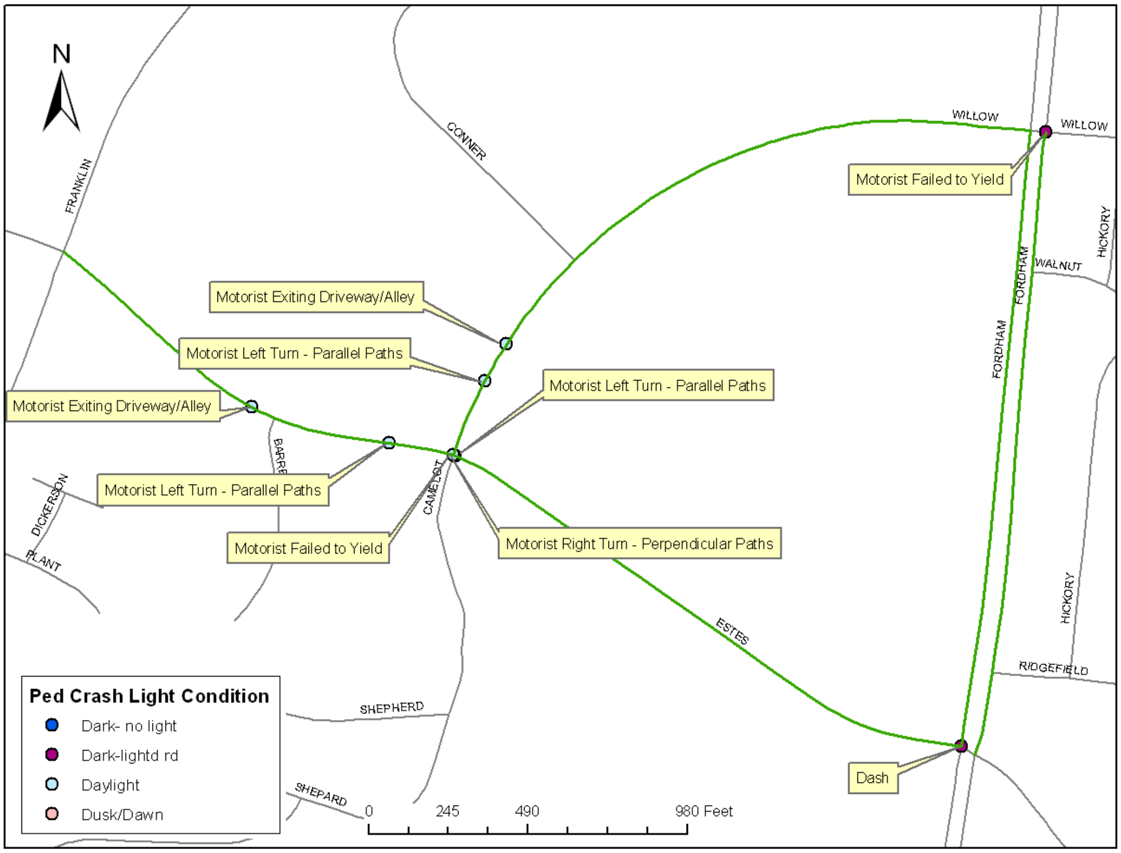

Figure 53. Estes Dr audit area and pedestrian crash locations.

Intersections

There are only three signalized intersections along this 0.6 mi segment, and these are the only locations where pedestrians have aid in crossing the five lane road. As mentioned above, a number of pedestrians were observed to cross midblock near the post office and Community Center Park. At street crossings, curb cuts and ramps were not provided for all legs of crossings; most of them do not meet ADA guidelines, and are not aligned with the pedestrian path. Most curb ramps did not have contrasting color or texture or sufficient landing space. Pedestrians were observed to cross on legs of intersections with no pedestrian signals or crosswalks. Heavy RTOR movements were also observed that may affect both pedestrians and bicyclists.

Estes & Franklin

There were no collisions at Franklin and Estes, but this intersection was highlighted as an area of concern for pedestrians based on the survey results. The intersection safety index rankings for both bicycle and pedestrian safety are also relatively high for this intersection. The pedestrian ISI is tied for third highest (3.4) and the bike ISI is tied for4th highest (3.9).

The audit revealed the following safety problems:

- The intersection lacks a crosswalk and pedestrian signal crossing the south leg of Franklin.
- There is a large shrub and a utility pole at the southeast corner that likely hinders sight lines between pedestrians and motorists approaching northbound on Franklin. There is also a shrub on the NE corner and a utility/signal box and pole on NW corner.
- There are 5 lanes to cross for all but the western leg of Estes Dr which is two through lanes plus a left turn lane. Turning movements may cause conflicts.
- The curb line on the southeast corner has a wide radius, probably due to the skew (southeast corner < right angle) of the intersection.
- Single corner curb cuts and non-ADA compliant ramps may place pedestrians into the traffic stream for some approaches (particularly the single southwest ramp), and may be extremely difficult for wheel-chair bound pedestrians to use.
- There are street lights on two corners, but they may not be in the ideal location for highlighting pedestrians crossing at the intersection.

Recommendations:

⇒ Add a pedestrian (countdown) signal and marked crosswalk and ADA-compatible curb ramp to the remaining leg (south side crossing Franklin) of the intersection.

⇒ There are protected left turns for all approaches; consider a lagging left, with pedestrian phase going with through traffic. Ensure sufficient crossing time for pedestrians (assumed crossing speed of 3.5 ft/sec.)

⇒ Evaluate clearance intervals for bicyclists for each approach leg and movement (through, left and right turns).

⇒ Set stop bars back further from the crosswalk area to improve sightlines.

⇒ Remove shrubbery that blocks sightlines at the corners.

⇒ Evaluate night-time lighting for potential improvements.

⇒ Since the northbound, right-turning lane on Franklin has two lanes on Estes to turn into, it appears possible to reduce the broad turning angle on the southeast corner through a curb realignment to slow turn speeds, improve visibility of pedestrians at or approaching the corner, and reduce the crossing distance somewhat.

⇒ Other means of addressing the skew and 'lining up the intersection' for Estes may be possible. Do traffic signals line-up with the intended lanes?

⇒ Add proper ADA-compliant landings and curb cuts at each side aligned with sidewalks.

⇒ Consider relocating utility/traffic control box to improve sight lines.

⇒ Evaluate whether lighting provides optimal illumination for pedestrian crossings.

⇒ Consider further assessment of the intersection operations with respect to bicycle safety. Can bicyclists position for left turns (especially during peak traffic), or should wider sidewalk landing areas be provided to accommodate bicyclists who wish to make 'pedestrian-style' left turns? Bicyclists traveling straight through the intersection may also be vulnerable to right-turning vehicles. Consider warning signs or other improvements.

Midblock between Willow & Franklin on Estes

There is currently no midblock crossing in this area but a number of pedestrians were observed to cross (dash) mid-block on Estes near Community Center Park and the post office Given the distance between signalized crossings and the number of destinations, pedestrians are likely to be often crossing midblock in this area. One midblock pedestrian crash occurred near the post office when a driver exiting and making a left turn struck a pedestrian crossing toward him in the travel lanes (see Figure 54). Given the large number of left and right turns into and out of driveways, pedestrians crossing Estes are vulnerable both to through vehicles and to vehicles making turning movements. There are street lights on both sides of Estes in this vicinity.

Bicyclists on Estes (westbound) must cross three lanes to position for a left turn at the non-signalized junction with Community Park. Especially at peak traffic, it may be difficult to make this maneuver.

Recommendations:

⇒ Consider a midblock traffic signal and pedestrian signals (if volumes warrant), along with high visibility crosswalks in the area near Community Center Park. Accessible curb ramps would be needed.

⇒ The TWLTL space could be also used for a median island with left turn pockets, and an accessible crossing traversing through it in the area near Community Center Drive and the Post office to provide a refuge and extra protection to pedestrians. If well-designed, a crossing island may help to slow vehicle speeds, and *may* encourage pedestrians to use the crossing rather than other midblock locations. "Detectable warnings are needed at cut-throughs to identify the pedestrian refuge area....Examples of good and bad designs for raised median crossings can be found in Chapter 8 of *Designing Sidewalks and Trails for Access: Part II of II: Best Practices Design Guide*." (PedSafe)

⇒ Alternatively, consider adding a HAWK signal or rapid flash beacon and midblock crosswalk which provides stop control during the pedestrian crossing, and may reduce motorist delay compared with regular traffic signals. A median refuge would further enhance this treatment.

⇒ Accessible curb ramps are needed for any midblock crossing.

⇒ Reducing the number or width of lanes (with space allocated to bike lanes) would also potentially help to reduce speeds and improve crossing conditions for pedestrians and promote bicycle travel.

⇒ One option to help bicyclists position for left turns at Community Center Park would be to add recessed stop bars or a bike box (along with bike lanes on Estes) at the intersection of Willow and Estes, on Estes. This innovative treatment would allow bicyclists to come to the front of the queue on red in order to position for the upcoming turn.

Figure 54. Estes Dr showing part of intersection with Willow Dr (and missing crosswalks) and views of driveways west and area where pedestrians often cross midblock.

Estes & Willow

A single marked crossing at Willow Dr is the only crossing between Franklin St (> 0.3 mi distant) and Fordham Blvd (> .25 mi distant). Three pedestrian crashes were reported at this intersection (2nd highest number for any intersection, Figure 53). All three of the crashes occurred during daylight conditions. One collision involved a hit-and-run motorist and a pedestrian using a wheel chair. All three of the collisions were a result of motorists failing to yield to pedestrians. Two crashes involved motorists turning east onto Estes from Willow and striking pedestrians in the crosswalk area. The third crash involved a motorist on Willow in the straight/right-turn lane striking a pedestrian coming from the motorist's right (eastbound). This collision involved a hit-and-run driver, so further details are sketchy.

The audit revealed the following other safety issues:

- The intersection lacks pedestrian crosswalks and pedestrian signals at two crossings – the north leg across Willow and west leg across Estes, both of which a number of people were observed to cross in the time we were present (about 45 minutes during one visit). (There are sidewalks on all sides, so there seems no explanation for the lack of crosswalks and pedestrian signals at these legs.)

- o Protected left turn is currently provided only for Estes eastbound.
- o Curb ramps are present, but not properly designed with ADA landings.
- o Pavement markings are worn/fading – and have poor visibility.
- o Stop bars on Estes are not staggered so motorists turning right on red may not be able to see pedestrians or bicyclists approaching from their left.
- o Vegetation at Camelot Village leg (southwest corner) of intersection may obscure vision.
- o There are currently street lights on two corners; visibility at night should be assessed.

Recommendations:

- ⇒ Given several crashes involving turning motorists failing to yield to pedestrians in crosswalks, consider adding protected left turn phases for Willow and Camelot following the pedestrian and through phase.
- ⇒ Alternatively, consider a leading pedestrian interval to allow pedestrians to establish presence in the crosswalk.
- ⇒ Regulatory signs, "Turning Traffic Yield to Pedestrians" could be added. At least one study has found that the percentage of turning motorists who yield has increased with the use of these signs (Karkee, Pulugurtha, Nambisan, 2006), but overuse could dilute their effectiveness.
- ⇒ Add pedestrian (countdown) signals and marked (high visibility) crosswalks on all legs of Willow and Estes intersection. Ensure good alignment of crosswalks and pedestrian access ramps, evaluate whether ADA access may be improved, ensure pedestrian push buttons are accessible and clearly indicate to which crosswalk they pertain. Consider an audible pedestrian signal and other issues for pedestrians with disabilities.
- ⇒ See above regarding adding bike boxes on Estes to allow bicyclists to position for turns at this intersection and at Community Park/Bolin Creek Trail. This treatment may help bicyclists traveling through the intersection be more conspicuous to left and right-turning vehicles.
- ⇒ Provide effective vegetation management in areas that affect the public right-of-way.

Estes & Fordham

Fordham Blvd is a four-lane divided highway with nearly 40,000 AADT in this area (annual average daily traffic, per most recent NCDOT AADT map). A total of 360 pedestrians and 71 bicyclists were tallied at this intersection in 12 hours during a 2005 count. An area including the intersection was identified with a medium low density of bicycle collisions, but was not highlighted by perception data. One bicycle collision and one pedestrian collision have occurred at the intersection proper; the pedestrian collision occurred at night. This intersection functions as a primary crossing for a neighborhood on the east side of Fordham, and for the shared use path also on the east side. The traffic volume and speed of traffic on Fordham alone create a challenging pedestrian crossing with a high severity index. In addition, the following safety issues were identified at this intersection:

- The audit team discussed the hazard posed by the two left turn lanes turning from Estes onto Fordham simultaneously with the current pedestrian phasing. This traffic often does not yield to pedestrians in the crosswalk.
- Pedestrians often don't bother pushing the pedestrian push-button when crossing Fordham, but given the lack of yielding by turning motorists, this is not surprising.
- An additional problem is a wide turning radius, lack of a curb and defined corner, and a right-turn only lane for southbound Fordham (which essentially functions as a continuous flow right turn lane) on the northwest side of the intersection (see Figure 55). This allows motorists to turn at high speed onto Estes on green. Motorists may also fail to slow or stop and look for pedestrian traffic before turning right on red. There is also a relic, extra sidewalk extension (at left side of photo in Figure 55) that doesn't align with the current crosswalk and may confuse motorists or pedestrians.
- There are no crosswalks or pedestrian signals for the south side (on Fordham) or for crossing either of the Estes approaches. There is, as mentioned, a shared-use path on the east side of Fordham. Although there are no sidewalks continuing south along Fordham, there is a bus stop on the south side of Estes (west of Fordham) so pedestrians are likely accessing this bus stop from the east side of Fordham.
- There is only one luminaire at this wide intersection, on the northwest corner.

Figure 55. A lack of a curb and wide turn radius may allow high-speed turns from southbound Fordham onto Estes.

Recommendations:

- ⇒ As discussed with the audit team, adding a protected left turn, following the pedestrian/through phase for Estes would give pedestrians help getting across this intersection and reduce the number of conflicts and collision potential.
- ⇒ Add a curb with a narrow turn radius, and add a proper ADA landing and ramps to the northwest corner (ideally all four corners) to separate the pedestrian zone from the travel lanes. Pedestrians with low vision could walk right into the highway with little to guide them.
- ⇒ Add signs warning turning motorists (Fordham, right-turn lane, especially) to yield to pedestrians. Alternatively, consider prohibiting right on red or prohibit right on red when pedestrians are present. (This could also be a quickly-implemented measure before adding the curb and narrowing the turn radius.)
- ⇒ Provide crosswalks and pedestrian signals to all legs of the intersection, and a sidewalk to help pedestrians safely access the bus stop on the southwest side of Estes. There would be less exposure for pedestrians if they did not have to cross the west leg of Estes, in addition to Fordham, to access the bus stop.
- ⇒ Consider high visibility crosswalks and advance stop bars.
- ⇒ Enhance lighting at this busy intersection.
- ⇒ Consider pedestrian and bicyclist educational and encouragement measures regarding proper crossing behaviors for the nearby neighborhoods once the new signal phasing is in place.
- ⇒ Evaluate wait time after push-button call, and consider reducing the pedestrian wait time for a crossing signal to improve pedestrian signal compliance.
- ⇒ Alternatively, consider automated pedestrian detection to trigger a pedestrian phase instead of push-button activation. Automated detection would have to be carefully designed to ensure pedestrians pass through the detection area.
- ⇒ Signal timing should accommodate a green and clearance interval (yellow and all red) sufficient for bicyclists just starting or arriving on green at the intersection to clear without being trapped by a change.
- ⇒ Add bicycle detection for Estes Dr Ext, and to the through lane (which has limited motor vehicle traffic to trip the signal) on eastbound Estes.
- ⇒ Note: overhead lighting is also needed on at the Fordham intersections with Willow Dr and with Cleland Dr.

Street Sections

Estes St Sections

Nearly 500 pedestrians and 96 bicyclists were observed at Estes and Community Center Dr in a 2005 daily (12 hour) count. The number of pedestrians seems to have increased considerably at Community Park since the original 2001 count when there were ~190 pedestrians in a 12 hour count. Sidewalks are provided on both sides of Estes along with a narrow grass buffer, although it is not continuous on the south side, ending near a bus stop east of Camelot Dr and cutting off a housing unit (Brookwood Apts.) and another transit stop closer to Fordham Blvd. A beaten path continues through this section. The older sidewalk sections also have some issues with uneven pavement, cracks, etc. that could present difficulties to senior pedestrians or pedestrians with disabilities. At driveway crossings, there are sometimes drop-offs/damaged pavement, and uneven slopes. Since the sidewalk slopes to the driveway level at most driveway crossings, particularly on the north (older) side, improperly designed curb ramps may also make travel difficult for pedestrians with disabilities. Steep lips at driveways also create challenging turns into these driveways for bicyclists. Both pedestrians and bicyclists were struck by motorists exiting driveways in this area. The bicyclist was riding facing traffic on the sidewalk. However, another bicyclist was struck by an overtaking motorist when riding properly in the direction of traffic in the travel lane (Figure 56). Both crashes occurred during daylight hours – the latter one during the morning traffic peak.

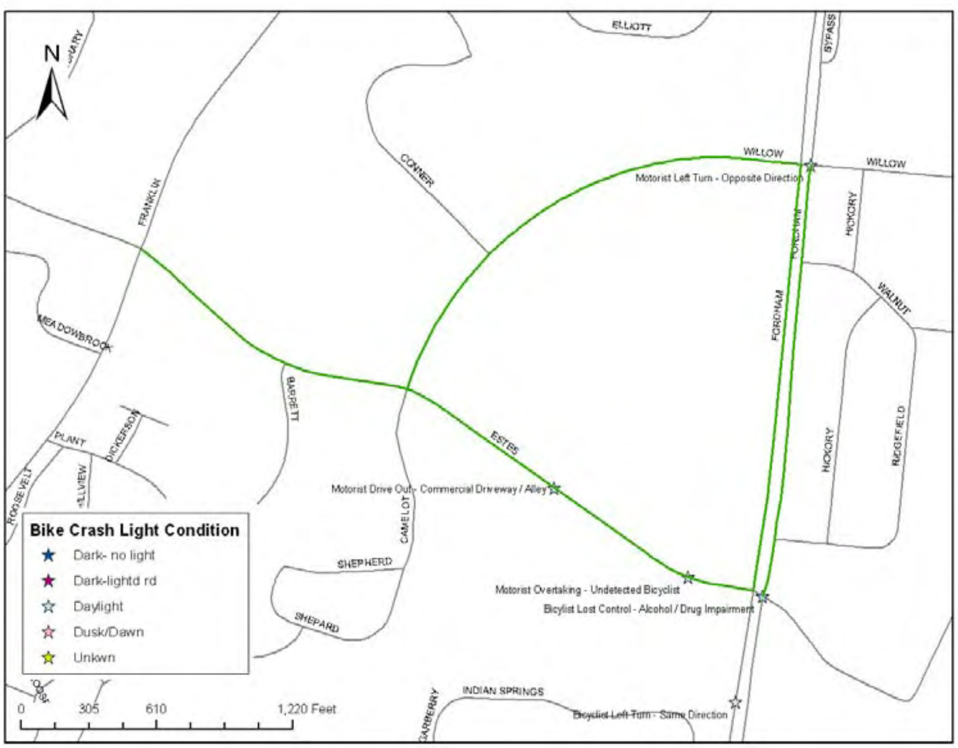

Figure 56. Estes audit area and bike crash locations.

Other key safety issues affecting pedestrian and bicyclist safety along this section of Estes Dr include:

- Given the large number of driveways, sometimes side-by-side, west of Willow Dr, the two-way left turn lane and multiple driveways result in numerous conflict areas, increasing the hazard for pedestrians, bicyclists, and motorists.
- There are also sight distance problems at a number of the driveways, with trees, signs, and other objects contributing to motorists pulling across the driveway crossing before they can view oncoming traffic, including pedestrians and cyclists. A notable example is the post office (exit) driveway (Figure 54, car at driveway in about center of photo).
- Given the relatively few driveways east of Willow Dr (three for the mall), the need for a continuous, two-way left turn lane could be reevaluated for that section. A two-way, center turn-lane does not provide refuge for crossing pedestrians and provides opportunities for numerous conflicts between turning motorists and pedestrians and cyclists.
- Other driveways are quite wide with wide turning radii, and since the driveways seem continuous with the street, may contribute to high speed turns and exits across the pedestrian path.
- Drain grates around Estes and Willow are flat but they may still cause some problems for bicyclists due to uneven pavement and drop-offs. Cracks are also emerging where the gutter pan was paved over.
- There is no dedicated space for cyclists on Estes. With the traffic volume of about 15,000 – 16,000, and speeds around 43 mph, many bicyclists may not to feel comfortable riding in a shared lane situation here, particularly during peak traffic hours.
- There is lighting along both sides of the entire segment, which appears to be generally adequate. The trees lining the street in some areas such as near the mall and post office create dark zones, however, so the location of lighting or need for pedestrian-level lighting should be evaluated, particularly near driveways and at intersections.

Recommendations:

⇒ Provide sidewalk crossings at-grade across driveways.

⇒ As an alternative to at-grade driveway crossings - stripe high visibility crosswalk markings across driveways.

⇒ Remove shrubbery, and relocate signs or other objects that obscure driveway sight distances, particularly at post office and nearby driveways on the north side of Estes.

⇒ Given the speed and volume of traffic, dedicated bicycle lanes would be the preferred facility for Estes. The current configuration according to roadway GIS files is 64’ of surface width, including a 16’ median (two-way, left turn lane). Consider whether this space could be reallocated through re-striping to provide bike lanes, and reduced width travel lanes. See alternative below, involving a raised median.

⇒ As a temporary measure, highlight drain grates with a white stripe as done on Martin Luther King Jr. Blvd and Raleigh Rd. Longer-term replace with a bicycle friendly (under the curb) design.

⇒ Consider alternatives to the TWLTL cross-section including using the space for bike lanes on each side and a narrow (at least 4 feet) median buffer or median islands with intermittent left-turn lanes. Such improvements as a raised median would be expected to provide safety improvements for all modes given the extensive conflict areas along this corridor section.

⇒ Consider other access management measures including reducing the number of driveways, or providing right-in, right-out only movements, and narrowing driveways to reduce the number and width of conflict areas.

Willow Drive sections

Willow Dr has a three lane profile with the third lane a two-way, left turn lane. Sidewalks have been completed on both sides of Willow Dr, a 0.4 mi connector between Fordham Blvd and Estes that also links dense housing, banks and medical offices, and University Mall, and neighborhoods on the east side of Fordham. The segment has no signalized intersections to assist pedestrians in crossing Willow Dr between Estes and Fordham. This street is also intersected by numerous side streets and driveways creating conflict areas for both pedestrians and cyclists (see Figure 57). Two pedestrians walking along or crossing Willow Drive were struck by motorists exiting driveways. Since the audit, a midblock crosswalk was installed.

- The center turn lane does not provide refuge for crossing pedestrians who are vulnerable to through and turning motorists at the numerous driveways ().
- Most of the driveway crossings along this road are very wide and at street level, rather than at sidewalk level, increasing pedestrian exposure and allowing for fast turns at these locations.

Figure 57. Pedestrian crossing midblock on Willow Drive while vehicle turns out of driveway.

Note: The two-way left turn lane and many driveways, mean pedestrians crossing midblock are exposed to turning and through traffic. Note: a midblock crosswalk has recently been installed further northeast of this location.

Recommendations:

⇒ Complete sidewalks at-grade across driveways (preferred) on Willow.

⇒ Alternatively to at-grade driveway crossings, stripe high visibility crosswalk markings across driveways.

⇒ Consider access management such as changing the two-way left turn design to two lanes with a raised median and intermittent turn lane pockets to reduce the numerous conflict areas; driveway consolidation or other measures could also help. A median island would also provide refuge for crossing pedestrians, and may help to slow motor vehicle speeds so bicyclists could more safely share the roadway. Some of the space (from center, two-way turn lane) might also be allocated for bike lanes, if sufficient space is available for the corridor as a whole.

VI. Manning Dr

Manning Drive serves UNC hospitals and other medical buildings, south campus dorms, and the Dean Smith Center (UNC basketball arena). This is a four-lane road plus turn lanes; ADT of about 17,000. The segment focused on, from University Drive to Ridge Rd and Skipper Bowles, is approximately 2/3 mi and there are 7 signalized intersections/driveways, plus assorted other driveways. The speed limit is posted at 25 mph in this section; average speed and 50th percentile were 27 mph; 85th percentile speed was 32 mph (near Ridge Rd). There are numerous parking decks, transit stops, and pedestrian overpasses that further complicate the environment and interactions of roadway users in this area. There is also likely to be extensive non-local traffic because of the hospitals and other medical facilities, and therefore, there may be a significant number of drivers and pedestrians who are unfamiliar with the area.

There have been 10 pedestrian collisions along the audited portion over the study period, all of them at or near intersections. A number of the collisions involved left turning motorists failing to yield to pedestrians in crosswalks (see Figure 58). Two bicyclist collisions also occurred at intersections.

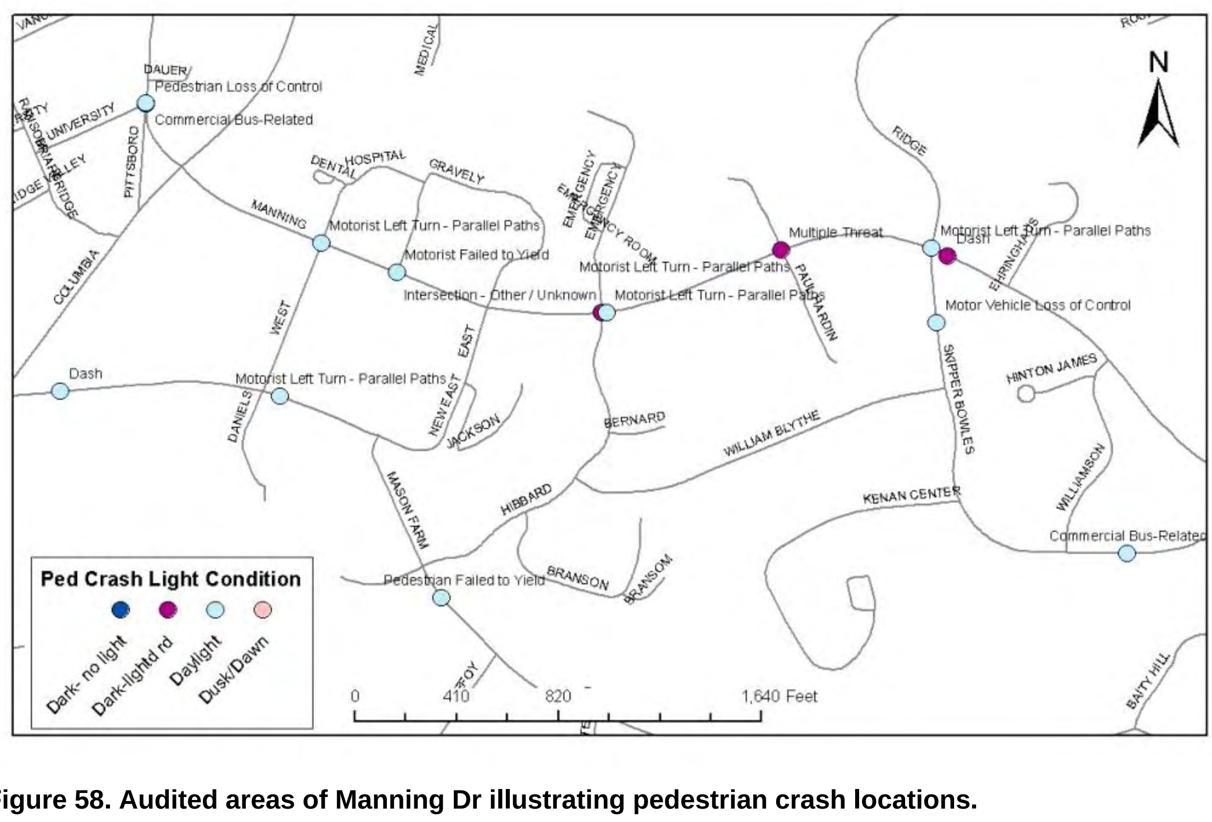

Figure 58. Audited areas of Manning Dr illustrating pedestrian crash locations.

Intersections

Manning, University & Pittsboro

This skewed intersection marks the split of the west end of Manning and the continued southbound lane of (one-way) Pittsboro before it joins two-way Columbia St. University is at a right angle to Pittsboro just north of the split. Numerous transit users disembark just north of University Dr and head east to Manning, crossing Pittsboro and Columbia in the process (see Figure 59 for an aerial view). Pittsboro is 2-lanes, one-way, southbound, and the section of Manning from Pittsboro/University to S. Columbia is 2-lanes one-way, eastbound. Pittsboro itself narrows to 1-lane before the merge with S Columbia (2-way south of Manning, 1-way, north of Manning). Two pedestrian collisions and one bicycle collision occurred in the vicinity of this intersection. One pedestrian collision was directly bus-related while the second involved a pedestrian who had just disembarked from a bus and stopped in the middle of crossing Pittsboro. The bicycle collision involved a motorist driving out from University Dr without yielding to the bicyclist (who was traveling wrong-direction on the sidewalk area according to information on the police crash report). There is a bike lane on Pittsboro that many bicyclists also use wrong-direction.

This area is in need of improvements to help pedestrians and bicyclists travel safely to and from transit stops and from nearby neighborhoods to campus destinations. Pedestrians crossing Pittsboro face traffic weaving and changing lanes to get around stopped buses and to position for heading south on Columbia or east on Manning prior to the splitter island. The west side lane can be used to continue south on Pittsboro to Columbia or to go east on Manning. Since both lanes have the option to continue east on Manning, pedestrians may falsely assume that vehicles in the west lane of Pittsboro are 'turning' east and step out to cross Pittsboro (see images in Figure 60). Additionally, while there is a curb cut on the east side (on the island) of Pittsboro, the sidewalk on the west side of Pittsboro ends at North St and there is no sidewalk or curb ramp to provide safe access for pedestrians with disabilities crossing at the splitter island or for pedestrians heading south on Pittsboro towards S Columbia (Figure 61).

A number of pedestrians also cross the merge area on the east side of the splitter island (vicinity of yield sign) for Pittsboro to S Columbia. Motorists approaching this Yield-controlled intersection are typically looking left for an opportunity to merge with S Columbia traffic and may not notice pedestrians, particularly those approaching from the right. Sight distance is also poor for motorists looking right.

Figure 59. Aerial view of intersection of S Columbia, Manning, & Pittsboro prior to new crosswalk installation on the south leg of Columbia.

Note: The angled 'median' separation between S Pittsboro (one-way, southbound) from the eastbound Manning Dr connector is also shown (from Google Imagery, ©2008 U.S. Geological Survey).

Figure 60. Many pedestrians cross the single, southbound lane of Pittsboro (left of splitter island in top left photo). (Photos by Charlie Zegeer)

Note: The current location of the bus stop (lower right) also contributes to visibility problems and weaving in advance of the crossing area.

Recommendations:

- ⇒ Consider a bulb-out extension of the landscaped island, *toward the west side of Pittsboro*, to narrow the lane of southbound Pittsboro (at start of the single-lane). A bulb-out would narrow the crossing distance, allow pedestrians to wait in a more conspicuous location where approaching motorists can see them, may help to make motorists intentions clear sooner, and should slow vehicles approaching the crossing area so they will be more inclined to notice and to yield to pedestrians. (A mountable curb could possibly be used, highlighted with yellow paint.)
- ⇒ Complete the sidewalk on the west side of Pittsboro and add ADA compliant curb ramp directly across from the east side ramp so pedestrians cross in the shortest distance.
- ⇒ We do not recommend adding crosswalk markings at the north side of the single-lane portion of Pittsboro. [Crosswalk markings could be considered for the merge area (with Yield control) of Pittsboro with S Columbia as pedestrians are observed to cross here to walk south on the east side of Columbia. Signs warning motorists to yield to pedestrians might also be considered.]
- ⇒ Consider adding directional signs to help motorists position before they reach the splitter island.
- ⇒ Evaluate whether Manning eastbound traffic could be restricted to the left lane in advance of the splitter island.
- ⇒ Evaluate relocating the transit stop (for southbound buses) from north of University Dr to further south, across from the splitter island. Relocating the transit stop to south of the crossing of Pittsboro could reduce the weaving maneuvers prior to the crosswalk area (which may increase motorists attention for pedestrians), and also reduce the possibility of crossing pedestrians being obscured by buses that currently stop in advance of the crossing area. Sidewalks would need to be completed.
- ⇒ Consider eliminating the Pittsboro southbound angled/yield approach that merges with southbound Columbia St. Skewed intersections such as this increase exposure for pedestrians and bicyclists, and motorists may not check, especially to their right on approach to Columbia. This “leg” could potentially serve as a transit stop area, with all other traffic flowing to the right-angle intersection at Manning and Columbia. As an alternative, consider realigning this approach with bulb-outs or other devices that could help to highlight pedestrians waiting to cross, and create a more right-angled junction.
- ⇒ Evaluate lighting – additional night-time lighting focused on the crossing area may be warranted.

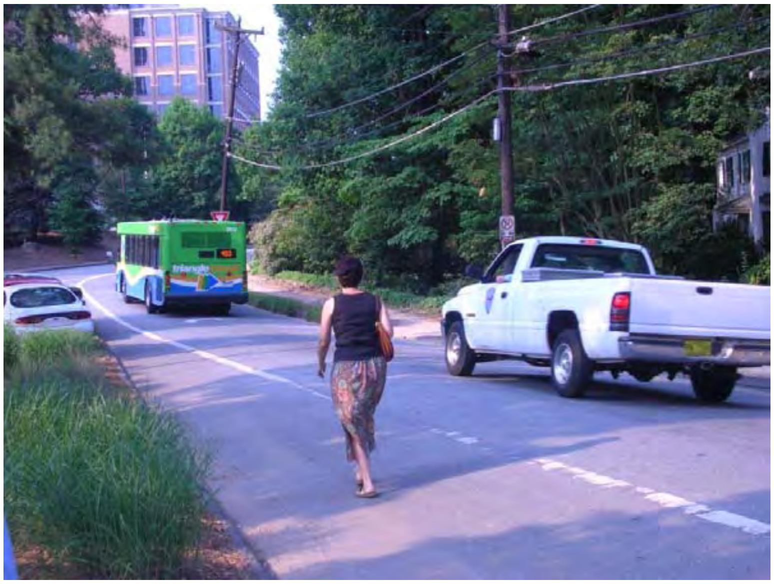

Figure 61. There is no sidewalk on the west side of Pittsboro across from the traffic island.

Notes: The bus stop north of University could possibly be relocated to south of the crossing area (behind white truck) to reduce weaving before the crosswalk area and multiple threat risk. The skewed Yield junction (beyond bus) also presents a hazardous crossing situation for pedestrians (Photo by Charlie Zegeer)

Columbia & Manning

This busy intersection of northbound, one-way Columbia with Manning Dr was also in need of pedestrian improvements. A recommended crosswalk and pedestrians signals for the south leg of Columbia have already been implemented. A shrub that was obscuring sight distance at the southeast corner has also been removed. A large sign has, however, since been erected in its place that may now be obscuring sight distance.

There is construction on the northeast side of this intersection and pedestrian detours encourage pedestrians to cross the street to the south and west sides (Figure 63). Requiring pedestrians to make extra crossings of roadways to avoid construction areas forces pedestrians to travel out of their way and increases their exposure to traffic through increased crossings. Not accommodating pedestrians near pre-existing sidewalks/pedestrian rights-of-way may also result in non-compliance and walking in the roadway.

There may also be a tendency toward conflicts with right-turning motorists, particularly on the two legs with exclusive right-turn lanes (see Figure 59).

Recommendations:

⇒ The stop bars on Columbia could be located further back from the (new) crosswalk on the south side of the intersection (as allowed by the MUTCD) to reduce the risk of multiple threat types of collisions.

⇒ Stop bars on northbound Columbia and westbound Manning should be adequately staggered so right-turning motorists may see pedestrians or traffic approaching from the left.

⇒ Consider, however, restricting right-on-red (or even eliminating the right-turn only lane), or at least warning turning motorists to yield to pedestrians.

Observation at many locations reveals that motorists often do not look to the right before making right-turn maneuvers.

⇒ Consider other signal phasing improvements such as separating pedestrian phase for crossing Columbia (when activated) and the left-turn phase for Manning.

⇒ Relocate signs and other objects where they will not obscure sight lines between motorists and pedestrian approaches to the intersection.

⇒ Ideally, a protected accessible, pedestrian walkway should be maintained without additional street crossings along construction zones if possible. The 2003 MUTCD states:

"Pedestrians should be provided with a reasonably safe, convenient, and accessible path that replicates as nearly as practical the most desirable characteristics of the existing sidewalk(s) or footpath(s). Where pedestrians who have visual disabilities encounter work sites that require them to cross the roadway to find an accessible route, instructions should be provided using an audible information device. Accessible pedestrian signals (see Section 4E.06) with accessible pedestrian detectors (see Section 4E.09) might be needed to enable pedestrians with visual disabilities to cross wide or heavily traveled roadways."

Figure 62. Closing sidewalks may result in extra roadway crossings and increased exposure for pedestrians. (Photo by Charlie Zegeer)

Note: Accessibility may also be an issue for work zone areas.

Ridge Rd & Skipper Bowles

There is significant conflict at this intersection with left and right-turning motorists. There are also large groups of students crossing here on the way to and from classes. Additionally, motorists approaching from the incline (northbound) section of Skipper Bowles may have a difficult time seeing pedestrians in the intersection, particularly those crossing from the far side of Manning as they approach on a green indication. There is also a right turn only lane on Ridge (southbound) that allows motorists to approach and make fairly fast right turns. West of Ridge Rd, an unused driveway access ramp may encourage pedestrians to cross midblock.

The intersection is also very wide, so pedestrians facing conflicts with turning motorists may have trouble completing their crossing.

This intersection would also have frequent volumes of non-local traffic for events at the Smith Center, so consideration could be given to improving way-finding and other measures to help reduce conflicts for night- and day-time events.

Recommendations:

⇒ This intersection would particularly benefit from all protected left turns with separate pedestrian phasing. Consider lagging lefts.

⇒ Alternatively, or in addition to the above, consider still providing a leading pedestrian interval to reduce conflicts with right-turning motor vehicles.

⇒ Provide enough time for the volume of pedestrians present to cross Manning. Only about 18 seconds were being allowed under the existing phasing. Different cycle lengths for different times of day could be considered.

⇒ Ensure that bicyclists are detected (side streets) and have sufficient time to clear the intersection.

⇒ Ensure adequate bicycle clearance intervals for main approaches (yellow plus all red).

⇒ Add high visibility crosswalk markings for all legs.

⇒ Consider large street name signs (and directional signs? Such as to 15/501) on the light/signal mast arms to help motorists leaving special events become oriented.

⇒ Ensure that lighting is sufficient.

Other intersections including West and East Dr., Emergency Dr, Hibbard, Paul Hardin, Craig Dorm

A number of the intersections along Manning Dr through the hospital area (and indeed on nearby streets) have had crashes resulting from turning motorists failing to yield to pedestrians in the crosswalks or otherwise failing to yield (traveling straight). There is a lot of visual clutter in the area and competition for motorists' attention, who may also be unfamiliar with the area (Figure 63). However, the failure of motorists to yield to pedestrians when turning is a repeated scenario throughout the study area (not likely due solely to "out-of-towners").

- Pedestrians were often observed ignoring the push buttons to call the pedestrian signal. Since priority is given for Manning traffic, there may be insufficient time to cross Manning if the call buttons are not used. However, since Manning has green a majority of the time, pedestrians are inclined to cross the side streets with the green indication.
- The push button on the east side of West Drive to cross West did not seem to be working at the time of the audit. Non-working signals could increase pedestrian non-compliance.
- High visibility crosswalk markings across Manning at Craig Dorm drive needed maintenance.

Figure 63. Motorists failing to yield when turning is a frequent cause of pedestrian collisions at intersections on Manning Dr.

Note: The presence of pedestrian overpasses and significant visual clutter may contribute to the difficulty in noticing pedestrians. In one of these collisions (at Ridge Rd), sunlight reportedly obscured the motorist's vision.

Recommendations:

- ⇒ With so much visual competition and activity in these areas, it is not clear whether adding more clutter such as signs warning turning motorists to yield is going to help or add another potential distraction. Consider protected left turn phasing separate from pedestrian phases (preferably as a lagging left-turn phasing).
- ⇒ Count pedestrians at these locations, and consider adding an automated call for pedestrians to cross Manning on each cycle.
- ⇒ A leading pedestrian interval is an alternative to protected left that would also allow pedestrians to establish position in the crosswalk prior to motorists beginning movement.
- ⇒ Repair push button at West. Check push buttons regularly to ensure they are working unless/until replaced with automatic call.
- ⇒ A pedestrian phase for pedestrians to cross the side streets could be part of every cycle given that Manning has extensive green priority, and should allow as much crossing time as possible while Manning has green, and countdown warnings.
- ⇒ Ensure bicyclist access through in-street loop detection and adequate clearance intervals at all signalized intersections in the area.

Street Sections

Although we did not focus primarily on sections since there is a complete sidewalk network for most of Manning, there are some issues with sidewalk quality, and also street conditions that would affect bicyclists.

The sidewalk on the western end abuts the roadway directly (no buffer between pedestrian zone and traffic lanes). The conditions of the walkways, curbs, and road surface through much of this section are very rough, apparently due in part to heavy use by buses stopping and starting near transit stops, and perhaps to construction traffic (Figure 64). Pavement is buckled, curbs are lifted, and sidewalks have serious irregularities. These conditions could contribute to pedestrians tripping or stumbling into the roadway. The rough condition of pavement would also be uncomfortable and potentially hazardous for bicyclists traveling along the roadway.

Signs and other objects seem occasionally to be blocking sight distance for some driveways. An example is the directional sign for UNC Health Care near the ITS driveway.

Bicyclists (helmeted, so likely to be safety-conscious) were observed riding wrong-way on the sidewalks along Manning. The multiple lanes (4 + turn lanes), volume of around 17,000 vehicles per day, traffic speed for some sections, and number of large vehicles may contribute to discomfort with riding on the street. However, the risk of being struck by turning vehicles at junctions is exacerbated by wrong-way and sidewalk riding.

Recommendations:

⇒ There may be a need for improved pavement structural support on Manning Dr, and indeed on most transit routes, particularly at bus stopping, loading and acceleration areas to reduce roadway pavement damage and damage to the adjacent walkways and curbs. (There is suggestive evidence that other areas in addition to bus stops, but where buses and other heavy vehicles slow and accelerate, are not able to withstand the stresses

⇒ A buffer between the sidewalks, with or without added barriers would enhance the safety of pedestrians walking along the roadway at the east end of Manning Dr. Barriers, such as on the western end of this section, may help to reduce unsafe midblock crossings.

⇒ Ensure that signs and other objects are not placed in areas that obstruct sight distance at driveways or side streets. University and construction policies need to be examined.

⇒ Bike lanes would increase the comfort level of bicyclists using Manning Dr. Since this road serves large populations of south campus residents and neighborhoods beyond south campus, a plan/route for bicyclists to safely share the road should be developed.

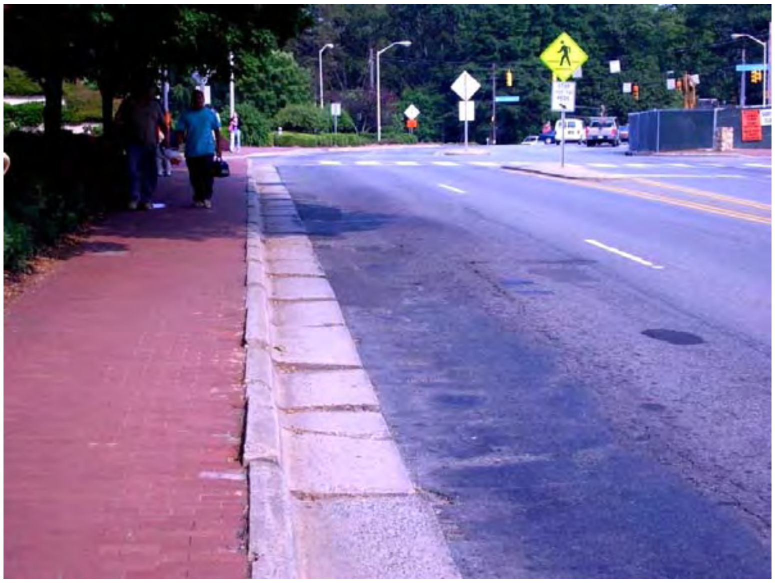

Figure 64. Sidewalk and curbs are extensively damaged in some areas along Manning Dr. Sidewalks on the west end are also immediately adjacent to traffic lanes. (Photo by Charlie Zegeer)

Figure 65. Right lane pavement in the area where bicyclists would ride is also very rough from heavy vehicle/transit use. Both pavement and sidewalks are in need of repair. (Photo by Charlie Zegeer)

VII. Martin Luther King Jr. Blvd (MLK)

This entire corridor was studied for the Town of Chapel Hill and reported on in August 2004 by the present research team (Thomas, Zegeer, & Hunter 2004). The approximately 1.4 mile section from North/Columbia St in the south to Estes Dr in the north focused on by the audit team in the present study, is 5 lanes including a center, two-way left turn lane, and has average traffic volumes of about 22,000 to 31,000 vehicles per day (see Figure 66). (DOT and Town representatives participated in the portion from North St to around Hillsborough and the Bolin Creek Greenway. Members of the HSRC research team completed the remainder from Hillsborough to Estes Dr.)

We will not go into as much detail here, except to elaborate on conditions for bicyclists and conditions for pedestrians at intersections. Few improvements have occurred since, however, so many of the problems and needs for improvements identified in that report remain. There are some pedestrian improvements under development involving a series of median crossing islands in the vicinity of midblock transit stops. The median island treatment should help pedestrians crossing this multi-lane (5-lanes) corridor at the midblock locations being treated. We are unaware of anything planned to help pedestrians or cyclists at intersections, many of which are very wide, with multiple through lanes and turn lanes, lack crosswalks and signals for all legs, and may have other challenges such as sight distance issues, conflicts with turning vehicles and lack of detection for bicyclists.

The median crossing islands may not offer much improvement in conditions for bicyclists unless they help to slow vehicle speeds significantly or restrict access at some of the many conflict areas. Although speed limits are posted at 35 mph, 50^{th} percentile speeds were around 41 to 42 mph, and 85^{th} percentile speeds were 45 to 47 mph during 2 late morning and 2 early afternoon speed studies at several locations (100 free-flowing cars each). Maximum speeds of 53, 55, 58, and 61 mph were measured.

There have been 16 collisions involving bicyclists along the corridor and two pedestrian collisions over the study period. (Thirteen of the bicycle collisions are shown in Figure 66.) A number of sections and intersections along the corridor were also perceived as unsafe by survey respondents. About half of the bicycle collisions occurred at intersections, and about half were at non-intersection locations such as driveways. (There were 8 pedestrian collisions and 27 bicycle collisions during the five-year period of 1998 to 2002 [Thomas et al., 2004].)

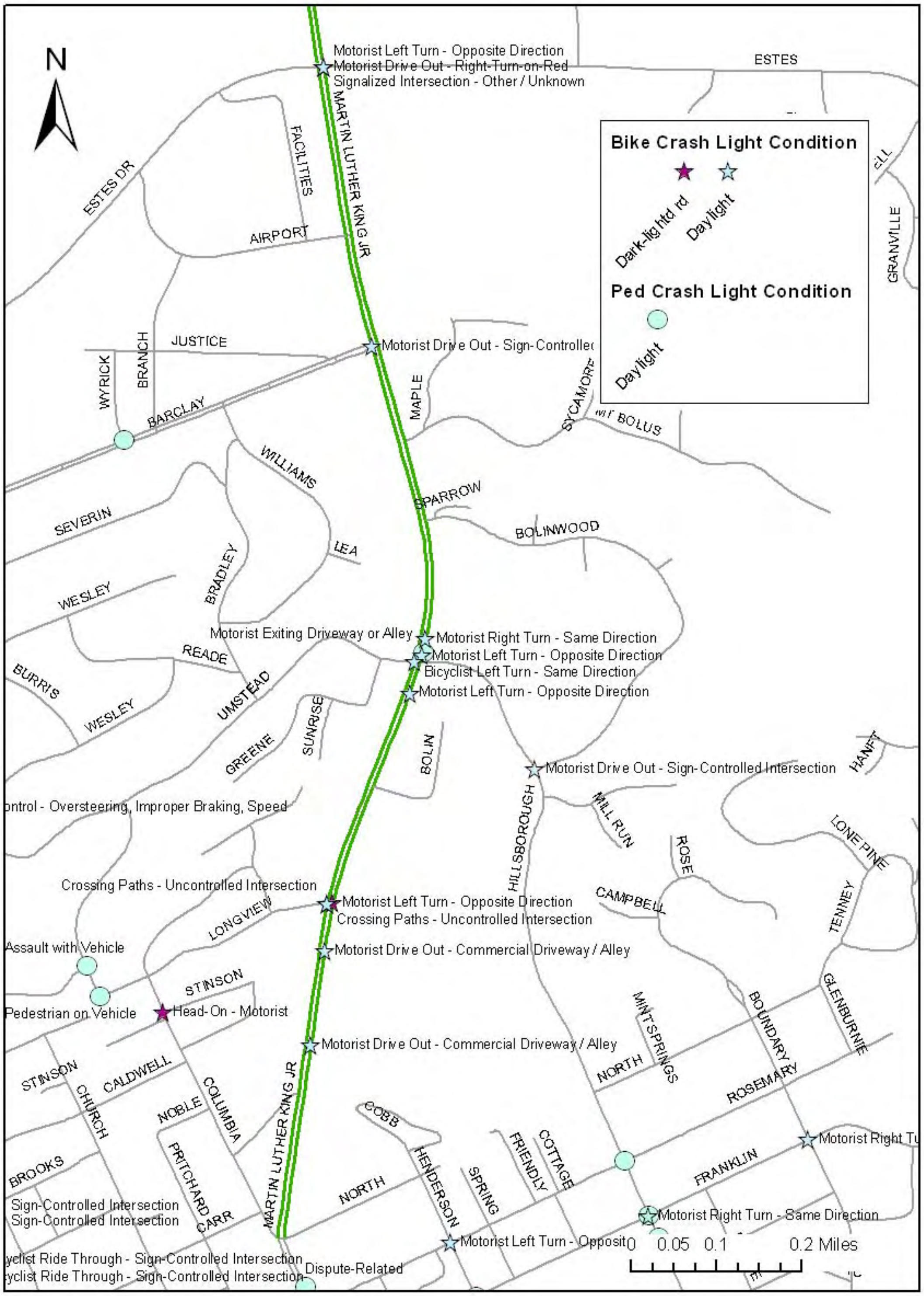

Figure 66. Audited areas of Martin Luther King Jr. Blvd showing locations of bicycle collisions.

Intersections - Unsignalized

All of the intersections discussed in this section lack signal control and provide challenging conditions for bicyclists or pedestrians to cross MLK and the side streets.

MLK, Columbia, & North St

The curved and highly skewed MLK, Columbia, and North St intersection creates a wide expanse for both bicyclists and pedestrians to cross Columbia St (west side of MLK). North St provides an alternative bike link to UNC campus, but it may be difficult in heavy traffic to merge to make a left turn, and at present, also a challenge to make a "pedestrian-style" turn since there is no good place to cross MLK as a pedestrian and no signal.

Recommendations:

⇒ Re-align intersection by re-aligning Columbia entry to MLK (with radius revision/bulb-out, etc.) Add crosswalk markings across Columbia and North Sts.

⇒ Consider whether traffic, collisions, and pedestrian and bicyclist needs may warrant a traffic signal or a HAWK signal for crossing MLK at this intersection.

MLK & Longview St

Longview St is also skewed enough to allow observed high, speed right turns from MLK onto Longview. There is also a multi-family residential driveway directly across from Longview. There have been 5 bicycle crashes in this area – three immediately at Longview and the driveway opposite and two others at nearby driveways. Two collisions at the driveway seem to have involved motorists driving directly across MLK from Longview to enter the driveway and bicyclists were struck in the process. Sight distance may also be obscured to the south of Longview by vegetation.

Recommendations:

⇒ Extend curb/bulb-out north on Longview to narrow turn radius. Add crosswalk markings across Longview.

⇒ Consider a signal at this location, if warranted.

⇒ Restrict left turns in this area, perhaps through strategic placement of the planned median crossing island, and/or a longer median divider. Bicycle access may be maintained through a longer median with the addition of a bicycle 'left turn lane' and cut in the median.

⇒ Consider enhancing lighting in this area. Darkness may have played a role in a few of the collisions.

⇒ Provide good vegetation management practices.

MLK & Bolinwood and MLK & Mt Bolus

Sight distance is limited at these two intersections; wrong-way bicycling could compound the problem for bicyclists.

Recommendations:

⇒ Add stop bars and stripe high visibility crosswalks across Bolinwood and Mt Bolus which may prompt motorists to stop prior to the crosswalk area and check for sidewalk traffic before pulling out.

⇒ Provide good vegetation management.

⇒ Consider whether other issues such as topography affect sight distance and whether other improvements are possible.

MLK & Barclay Rd

Barclay, which is two-lane with a center median, has a very wide crossing at MLK, resulting in considerable exposure for pedestrians and bicyclists at this crossing and allowing permissive, fast turns from MLK to Barclay. In addition there are no crosswalk markings across Barclay. The topography on the southwest corner may also limit sight distance on the Barclay approach somewhat, particularly if motorists are looking primary to the left before pulling out. A bicyclist was struck by a motorist driving out at Barclay; the bicyclist was also riding wrong-way on the sidewalk and so could have been obscured somewhat while approaching from the motorist's right.

Recommendations:

⇒ Extending the median island on Barclay in some form or another to the intersection would narrow exposure and tighten the turning radius to slow speeds.

⇒ Add stop bars. Striping a (high visibility) crosswalk across Barclay would also help to call attention to the pedestrian right-of-way across this street.

⇒ Consider whether sight distance might be improved.

Intersections - Signalized

MLK & Hillsborough/Umstead

This intersection and adjacent driveways saw four bicycle collisions and one pedestrian collision during the study period. (There were also several pedestrian collisions involving this intersection and driveways in the years preceding this study interval.)

- The mix of steep downgrades and high speeds, and several (wide) commercial driveways near the intersection create hazardous conditions for bicyclists and pedestrians both at the intersection and at the four nearby commercial driveways. The ones on the north side of Hillsborough have a particularly bad crash record. (Three bicyclists and one pedestrian have been struck by left-turning motorists and one bicyclist was struck by a right-turning motorist at these driveways from 1998 – 2005).
- In addition, the Bolin Creek greenway path ends at MLK north of the intersection and adjacent commercial property (at present), likely contributing to wrong-way riders on the sidewalk in this area (as observed in the prior study).
- While there is lighting on both sides throughout the corridor, illumination at night seems inadequate, particularly when fog or rain is also present. A recent pedestrian fatality was reported by Chapel Hill police involving a pedestrian crossing MLK at night and during rain. Several pedestrian collisions in the prior study also occurred under conditions of darkness.
- There are no pedestrian crosswalks and signals on the north side of MLK.
- The pedestrian signals for crossing the side streets are activated by push-button and are often disregarded as the signal is most often green for traffic on MLK, and pedestrians are reluctant to wait a cycle for a walk indication.
- A bus stop is situated on the east side, south of the intersection between two commercial driveways that adds to sight distance problems when buses are present, especially for southbound vehicles that may be turning left at the second driveway (from the intersection).

Recommendations:

⇒ Add marked crosswalks and pedestrian countdown signals to the north leg of MLK. High visibility crosswalks could be used on all legs.

⇒ Add “Turning Vehicles Yield to Pedestrians and Bicyclists” warning signs on all approaches. Signs could be added quickly before other intersection or driveway measures are implemented.

⇒ Allow only protected left turns at this location. This would protect bicyclists and pedestrians crossing Umstead and Hillsborough and MLK, but would not protect them crossing the driveways north and south of the intersection where left-turn crashes have already occurred.

- ⇒ An alternative would be to slow vehicles turning onto Hillsborough St and Umstead by placing a median divider at the intersection on these two approaches. However, this type of treatment might not be widely used in urban areas, especially on narrower two-lane streets such as Hillsborough and Umstead. (It could help to prevent high speed, cut-the-corner type turns that have been observed and that could also result in frontal collisions when vehicles turn into the wrong lane. We did not examine whether any collisions of this type between motorists had occurred.)
- ⇒ We recommend some type of driveway consolidation or access improvements in this area. Consider closing driveways closest to the intersection on MLK (north side and south side), OR possibly both MLK driveways on the northeast corner of MLK and Hillsborough. There is still entry access on Hillsborough St. MLK traffic from the north would be able to turn left onto Hillsborough and access the business from there.
- ⇒ Alternatively, provide a median divider at least 4 feet wide on the north and south approaches on MLK to restrict left turns into these driveways, *and* provide a refuge for pedestrians crossing MLK. Turning right in and right out from MLK would still be possible and access from the north would be possible from Hillsborough. This treatment should be designed to slow turns at the intersection as well.
- ⇒ Narrow the driveways near the intersection, and continue the sidewalk paving at sidewalk level across all the driveways north and south of the intersection to slow turning vehicles. (There is some transition from the roadway on the north side driveways, but the south side driveways are completely at street level.) This measure should be undertaken immediately while work toward further access and consolidation measures is underway. This measure, along with possible relocation of the transit stop, may be sufficient for the driveways on the south side of the intersection.
- ⇒ Evaluate lighting levels and consider improvements for the intersection and driveway areas, transit crossing area, and near the shared use path entry to MLK. Lighting resources are described in BIKESAFE (pp. 60-61, Hunter, et al. 2006). The Florida DOT recommends 16 as the baseline lux for bike facilities on arterial roads.
- ⇒ If one or more of the north side driveways is ultimately closed, consideration could be given to moving the transit stop to north of the intersection which may help encourage pedestrians to cross at the intersection and reduce midblock crossing and pedestrians obscured behind the bus.
- ⇒ Evaluate the wait time for pedestrians pushing the button to cross MLK and the side streets. Pedestrians may become frustrated at night when traffic seems low, and thus the tendency to cross against the signal which seems to have occurred in night-time collisions.
- ⇒ Consider adding a pedestrian recall to every signal cycle, removing the push buttons.

MLK & Estes Dr

This intersection represents a change in the roadway profile. Going north, on the east side of MLK, there is a wide walkway/shared use path and on the west side, a paved shoulder facility from the north that merges with the regular through/right-turn lane prior to the intersection. The experimental, shared-use pavement markings were not placed north of this intersection since a paved shoulder facility is separated by a lane line, and the wide outside lane on the east side ends near Piney Mountain Rd just north of Estes. (The wide path/walkway is not complete for the section north to Homestead Rd where both side bike lanes begin.)

Thus, bicyclists are somewhat encouraged to bicycle on the wide walkway on the east side in the area of Estes Dr, and many are heading wrong-direction on the walkway when they reach the intersection with Estes as opposed to using the paved shoulder on the opposite side. (Using the east side path also saves many the trouble of crossing MLK across five lanes of traffic.) Two of the three collisions at the intersection involved wrong-way, sidewalk riders at Estes; both were struck by motorists turning right from Estes westbound, one on a red signal; the other was more ambiguous.

The vegetation and topography on the northeast corner are also such that motorists probably cannot see sidewalk traffic approaching until they are very close to the intersection. Since bicyclists typically travel faster than pedestrians, they are likely to be most at risk for collisions at this corner.

The third collision involved a motorist southbound on MLK who turned left in front of a through cyclist traveling northbound with traffic. There is a mix of protected and unprotected left turns on all legs.

There is also a perception of risk for bicyclists approaching MLK from Estes Dr (west bound) and this may be due to the very gradual crossover/merge lane configuration creating a lengthy conflict area where right-turning motorists may cross bicyclists' path prior to the intersection.

For pedestrians, there is also a lack of continuity of pedestrian facilities in the area of this intersection. There are no crosswalks or pedestrian signals crossing MLK or the west leg of Estes Dr. As a result, midblock bus stops both north and south of the intersection on the west side of MLK are inaccessible by persons with disabilities or parents pushing strollers. Although there are no sidewalk facilities on the west side of MLK or on Estes Dr Ext (west side of intersection), there is a paved shoulder facility on Estes Dr Ext that may serve, temporarily, as a pedestrian facility. In addition, pedestrians need access to the bus stops on the west side and other potential destinations. The northern bus stop area is slated for a mid-block median island to assist in pedestrian crossings to the transit stop, but access should be provided along the west side as well. Finally, the stop bars on MLK at Estes are beyond the pedestrian curb ramp on the southeast corner so that pedestrians using the ramp may be placed into the traffic stream. The ramp is also not of accessible design and rough pavement further adds to the difficulties of using the ramp.

Recommendations:

- ⇒ Crosswalks and pedestrian signals should be added to both approaches of MLK and across the west leg of Estes Dr Ext.
- ⇒ The stop bars on MLK (NB) should be moved back behind the curb ramp, or else, the curb re-aligned with accessible curb ramps in each direction, in-line with the crossings. However, giving more space between stop bars and crosswalks could help improve visibility and reduce the chances of multiple-threat type collisions.
- ⇒ Consider only protected (not permissive) left turns for all approaches here.
- ⇒ Consider restricting right-on-red.
- ⇒ Alternatively, add "Turning Motorists Yield to Pedestrians and Bicyclists" signs (may have been added).
- ⇒ The signs are not likely to help much, if motorists cannot see pedestrians and bicyclists approaching. Therefore, there is a need to address the sight distance problems at this intersection.
- ⇒ Consider putting Stop or Yield signs for the path/walkway traffic, so bicyclists don't ride out suddenly (even if they have the green for their direction) into the path of right-turning motorists.
- ⇒ Also consider some signing such as route/directional signs that encourages bicyclists to cross over to travel in the correct direction (using the Sharrow-marked, shared lane) to continue southbound. There may be a need to provide ped/bike signals or improved intersection access to accomplish this.
- ⇒ Consider redesigning/elimination of the right turn lane, and/or highlighting of the merge area on Estes (east leg/westbound) through pavement markings and signs, or other treatments. Some communities have highlighted merge areas through special pavement markings and coloration, and special signs although some of these may not be MUTCD approved.

Other Signalized Intersections on MLK

- ⇒ All of the signalized intersections throughout the entire corridor that still lack pedestrian crosswalks and signals for all legs should be remedied.
- ⇒ Consider having only protected left turns to protect bicyclists and pedestrians from motorists failing to yield when turning. (Note that we did not investigate the signal operations of all the intersections along the corridor. Several may already be on such a scheme.)
- ⇒ Consider the need for enhanced lighting levels, particularly at intersections, transit stop areas, and busy commercial driveways.
- ⇒ Consider adding high visibility crosswalk markings at every side street along the entire N-S corridor, since many of the collisions along the corridor involve motorists turning into and out of side streets or driveways and striking bicyclists and pedestrians at these locations. Adding high visibility crosswalks might prompt motorists to look and yield before turning.

MLK Street Sections

Since planned pedestrian improvements are underway, this section focuses on conditions for bicyclists in particular. Although most of the collisions seem to have occurred at some type of junction - intersections or driveways - conditions on the roadway sections seem to be contributing to unsafe behaviors and collisions involving bicyclists. These sections, as mentioned, are 5-lane, with a center, two-way left turn lane, and are intersected by many driveways and side streets.

Half of the total collisions along the corridor involved cyclists on the sidewalk and motorists driving out at side streets or driveways. Six of 8 sidewalk riders were also riding facing traffic, putting them in an especially unexpected location where motorists turning in and out are especially unlikely to notice them. Problems noted in this and previous audits include the following:

- The number of lanes may make it more difficult for motorists to notice bicyclists, particularly for motorists making left turns. There were four collisions involving motorists turning left into the path of oncoming bicyclists – only 1 cyclist in these 4 cases was riding on the sidewalk.
- The continuous two-way left turn lane and numerous driveways and unsignalized side streets in this section mean that conflicts can occur essentially anywhere.
- Many bicyclists may not feel comfortable riding in traffic on MLK in the present conditions. The outside lanes are somewhat narrower (and variable) than the AASHTO-recommended width of 14 feet (when the gutter pan area is excluded), and with a significant presence of large vehicles (transit buses and trucks) in the traffic stream, as well as high speed traffic, as many as one-third of bicyclists opt to ride on the sidewalks.
- The sight distance problems at driveways and side streets also remain a significant issue and should be dealt with on a timely basis. Many are caused by poor vegetation management practices, locating of advertising/business signs, etc. within sight lines, but there are also more challenging conditions such as topography and structures.
- Utility poles, signal boxes, and other infrastructure may also add to problems at some locations.

Recommendations:

⇒ The experimental sharrow treatment presently implemented from North St/ Columbia St north to Estes Drive is intended to encourage bicyclists to ride in the direction of traffic on the roadway, outside of the gutter pan area and to encourage motorists to allow a safe passing space when overtaking. It is presently being evaluated and results will be reported to NCDOT and the Town of Chapel Hill.

⇒ The town should work with property owners to remove and prune shrubbery, relocate signs and other objects that are blocking sight distance from the corners of driveways and side streets. If there is not an enforceable ordinance in place to keep vegetation cleared from sight lines on private right-of-way at driveways and side streets, then one may be needed. These issues may be relevant to a number of other corridors as well. Other problems such as topography, walls, etc. may require longer-term remedies as discussed in the previous report, but should be dealt with as redevelopment and opportunities arise. Of course, areas of public right-of-way should be well-managed.

⇒ The Town has apparently acquired funds to raise and replace the drain grates along the corridor with a bicycle-friendly design which could enhance usable space for bicyclists.

⇒ Ideally, bicycle lanes of 5 feet or more would be the preferred facility for a roadway of this class, volume, speed, and number of lanes. The southern section of roadway would benefit from wide bike lanes (5 feet or more) to provide a designated space for bicyclists to ride on the roadway and a continuous facility with the northern sections of this corridor. Providing a dedicated facility for bicyclists on a road such as this with many conflict areas should reduce bicyclists' risk, as previous studies have shown that more bicyclists feel comfortable riding in dedicated bike lanes than in shared facilities. Traveling on the street and in the right direction, bicyclists would be more visible to motorists than many are at present. Bicycle lanes and the presence of more riders would likely also increase drivers' expectation of bicyclists on the roadway. The Town could consider reducing other lane widths, replacing the two-way left turn lane (which also causes problems for motorists, especially during peak times) with a narrower, raised median strip to reduce turning movements, otherwise reallocating space, or other design options. (We measured 63.5 feet total curb to curb width near 730 MLK Blvd. Subtracting a generous 4' for gutter areas on each side leaves approximately 59.5 feet for reallocation. With two 5 feet or more bike lanes, there would be ~49 feet remaining for allocation to travel lanes and a raised median or intermediate median islands.

VIII. NC 54E/Raleigh Road

This key arterial linking I 40 and west Durham and east Chapel Hill with downtown and campus is generally six through lanes, divided, with multiple turn lanes at intersections, and carries about 43,000 vehicles per day. The posted speed limit in this section is 35 mph, but speeds as high as 57 mph were observed. An average speed of 43 mph, and 85th percentile speeds of 48 - 49 mph were measured between Hamilton Rd and Burning Tree Dr. Speeds are likely to be higher in the eastern portions of the corridor. The corridor is flanked by older mixed use neighborhoods, other residential, office and commercial developments, and significant areas undergoing redevelopment to denser uses. The corridor is served by transit with a number of bus stops along the corridor, and a park and ride lot on Friday Center Dr. Shared use paths adjacent to the corridor and in Meadowmont Village also invite recreational activity.

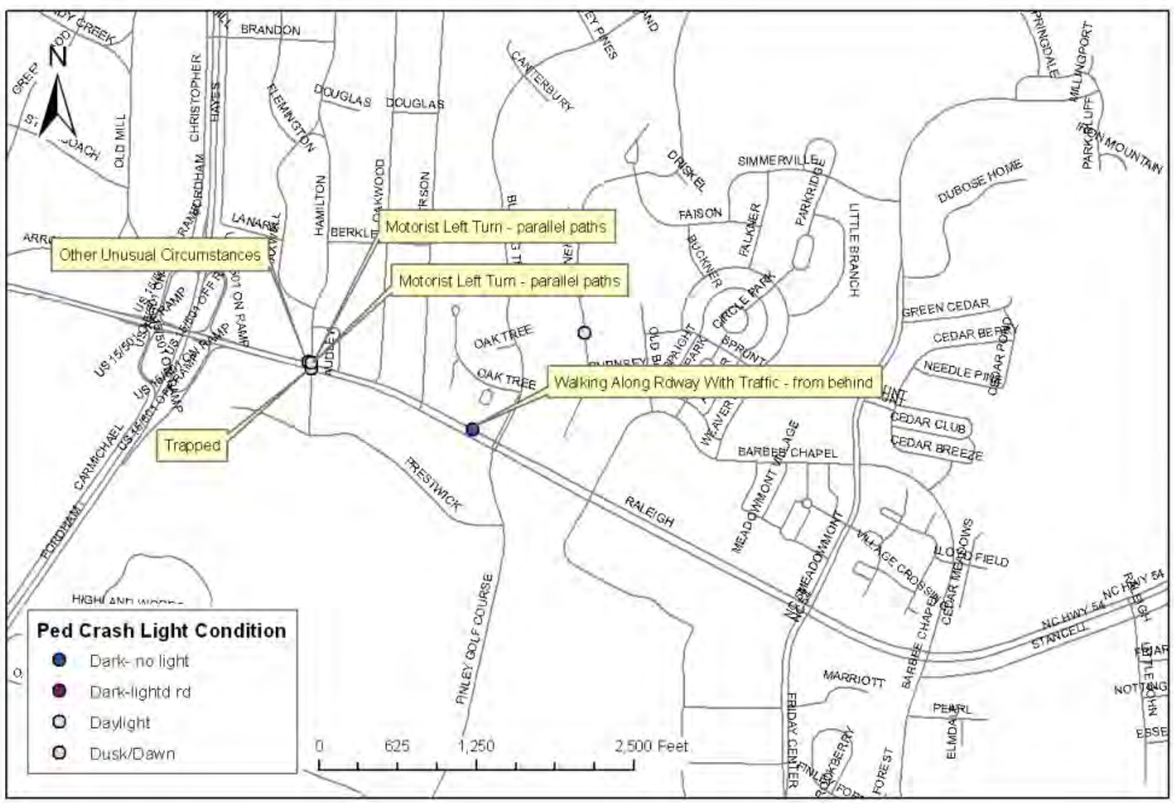

Figure 67. Raleigh Rd/NC 54 audit areas and pedestrian crash locations.

The area of interest is an approximate 1.2 mile segment from U.S. 15/501 to Barbee Chapel Rd (E). It was identified from a number of pedestrian and bicycle crashes, predominantly in the area of the intersection with Hamilton Rd (see Figure 67 to view the locations and types of pedestrian collisions). The Town of Chapel Hill also focused attention on three other intersections along the corridor including those at Barbee Chapel E, Meadowmont Lane/Friday Center Dr, and Burning Tree/Finley

Golf Course Rd. Subsequent site visits revealed serious safety deficiencies at these intersections.

There were no perception locations highlighted along the corridor from the survey data. Therefore, we focused our attention predominantly at the intersections along the corridor, although in our view, the corridor should receive a detailed audit throughout with respect to safe bicycle accommodation. As the main east/west access to UNC and downtown, this thoroughfare should provide access for all modes of travel. While there are adjacent sidepaths for parts of the corridor east of BurningTree/Finley Golf course, there is no continuity to campus. Additionally, these sidepaths may not be acceptable to commuter bicyclists due to the crossings with driveways and side streets. There is added risk at junctions with these side streets from traffic turning off of NC 54/Raleigh Road. (The AASHTO bicycle guide describes safety issues related to sidepaths. Some communities in Florida and NYC are including sidepaths and even on-road paths, but with innovative treatments to address the safety concerns.) At the western end of the corridor, the junctions with 15/501 on/off ramps and complex traffic patterns (including U-turn maneuvers at Hamilton), and busy commercial driveways between Glen Lennox/Hamilton Road and 15/501 should be part of a corridor-wide audit and plan to provide safe bicycle and pedestrian accommodation.

Intersections

Raleigh Rd & Hamilton

The intersection of NC 54/Raleigh Rd with Hamilton Road was the site of some improvements by NCDOT and the Town of Chapel Hill a few years ago, but some problems remain. The intersection tied with Columbia and Franklin St for the highest number of pedestrian collisions (4 collisions) at or near a single intersection. One bicycle crash also occurred at the intersection. Although substantial numbers of pedestrians (more than 600) and bicyclists (more than 300) were counted in 2005 (12 hour daily count), given the more than 10-fold fewer pedestrians at this location than downtown, the crash rate (based on apparent number of pedestrians) is higher here than downtown. The pedestrian crashes were notable for their being two involving motorists turning left onto Raleigh Rd from Hamilton and failing to yield to pedestrians in the crosswalks. And both a pedestrian and a young bicyclist were trapped in the intersection by signal changes and seriously injured when struck by cars approaching in outside lanes with no stopped cars. The curb lanes are combined through/right turn lanes, and may have no cars stopped at the signal at lower traffic periods, setting up a multiple threat situation with potentially high speed traffic. These lanes are also the lanes used by bicyclists. The speed differential may create a difficult sharing situation. The other pedestrian crash was an unusual type. A truck traveling on Raleigh Rd lost two tires, one of which struck a pedestrian waiting at a bus stop (seems to have been the north side bus stop west of Hamilton Rd rather than the one on the southeast side of the intersection).

A pullout bus stop on the southeast corner of the intersection generates substantial numbers of pedestrians as do the shopping center and residential neighborhoods on opposite sides of NC 54. The location of the bus stop is good, and should encourage pedestrians to walk to the intersection to cross. However, at least one bus was observed during the audit to 'park' in the stop area for a break, causing following buses to have nowhere to go to get out of the traffic stream, potentially blocking the intersection.

As mentioned, this intersection is complicated by the merge ramps to and from U.S. 15/501 west of the intersection along with a number of commercial driveways in the block in-between (Figure 68), so complicated traffic patterns exist here prior to and at the intersection. Substantial traffic coming from the Glen Lennox shopping center (south side) also enters NC 54 and makes a U-turn at the Hamilton intersection to head back west. The eastbound direction has a downgrade that may also contribute to high speeds at the intersection. All of these maneuvers may distract motorist's attention from the traffic signal and from pedestrians.

Figure 68. Eastbound Raleigh Rd looking toward 15/501 interchange areas and shopping center driveway (foreground) and merge areas.

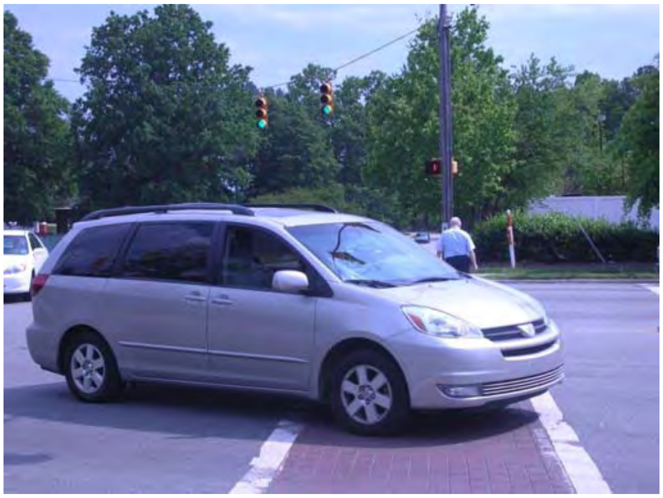

Figure 69. Turning vehicles threaten pedestrians at Raleigh Rd and Hamilton Rd.

Other safety issues include the following:

- There is no protected left turn phase on the Hamilton legs (substantial traffic leaving shopping center on the south side and the large residential neighborhood north side), so substantial numbers of turning motorists often conflict with crossing pedestrians (Figure 69).
- Multiple through lanes create a multiple threat situation for pedestrians and bicyclists trapped in the intersection by a signal change (see Figure 70). The existing countdown signals should help, but signal length should be evaluated to make sure sufficient time is being allowed.
- The planned addition of an exclusive right turn lane on NB Hamilton will likely increase conflicts with pedestrians crossing NC 54 (to from the bus stop on this corner).
- Some bicyclists would feel uncomfortable taking the outside through plus right turn lane (due to high speed and volume of traffic), yet if they do not they are still vulnerable to right-turning motorists. If they merge to the left of this lane, they will be to the left of traffic continuing through.
- Bicyclists are not detected on Hamilton approaches, and so may not receive enough time to get through the intersection.
- “One-way” and “Divided-median” signs in the median west of Hamilton were knocked down.
- Pavement markings are worn and the crosswalks are also losing their texture.
- There is a long wait for pedestrians waiting to cross NC 54 after activating the push-button which may reduce compliance with the pedestrian signal. Some, but by no means all, pedestrians ignored the signal and crosswalks and chose their own crossing opportunity. There was substantial compliance at this location, particularly among older pedestrians.

- Curb ramps and landings are not ADA compliant.

Figure 70. Advance stop bars and reallocation of lane uses could reduce the risk of multiple threat collisions and free up space for bicyclists and transit.

Recommendations:

⇒ Given several crashes involving motorists turning from Hamilton onto NC 54 who failed to yield to pedestrians in crosswalks, add protected left turn phasing following the through phase for motorists on Hamilton.

⇒ Consider adding a leading pedestrian interval, which would allow pedestrians to establish a presence in crosswalk before traffic begins turning. This may be especially important with the new right-turn lane on the south leg of Hamilton.

⇒ Regulatory signs, "Turning Traffic Yield to Pedestrians" could also be added.

⇒ Restripe crosswalk markings – consider wider crosswalk striping to enhance conspicuity of the crosswalks. Also, the crosswalks themselves need maintenance.

⇒ Given two multiple threat collisions at this location (one bicycle, one pedestrian), consider using advance stop bars (in addition to the existing countdown signals) which may enhance sight lines and reduce multiple threat risk if pedestrians are still in the intersection after a signal change. This may also allow bicyclists to move to the front of stopped traffic and enhance their conspicuity and provide some protection from turning vehicles.

- ⇒ Consider making the outside lanes on Raleigh Rd right-turn only and/or right-turn/bus/bike (instead of right-turn/through) so there will be less (only buses and bikes) through traffic in the outside lanes at signalized intersections. This would reduce the multiple threat risk at intersections and provide space for bicyclists. Bike pockets could be dashed to the left of these lanes at intersections so bicyclists would know where to position for through travel.
- ⇒ If the special lane improvements are adopted, signs or pavement markings could warn motorists to check for bikes before merging right for right turns.
- ⇒ Repair/re-erect signs that have been knocked down in the median.
- ⇒ Evaluate signal timing to ensure that pedestrians have sufficient time to cross. Upcoming recommendations are for signal timing to accommodate pedestrians assuming a walking speed of no greater than 3.5 feet/second, with consideration of lower speeds for areas with larger numbers of senior pedestrians.
- ⇒ Evaluate signal timing to ensure that bicyclists have sufficient time to clear the intersection – all approaches.
- ⇒ Provide bicycle detection on Hamilton and for left turn lanes from NC 54.
- ⇒ Evaluate lighting. Although all the crashes occurred during daylight hours, transit use and other destinations likely generates substantial after-dark pedestrian activity. (Currently there are lights on only two corners of the intersection which may not be sufficient for this wide intersection.)
- ⇒ Ensure good alignment of crosswalks and pedestrian access ramps, evaluate whether ADA access may be improved, ensure pedestrian push buttons are accessible and clearly indicate which crosswalk they pertain to. A standard for locating pedestrian push buttons would help to increase uniformity and comprehension across locations, including by users with disabilities. Consider audible pedestrian signals since users with low vision may need access to transit and to neighborhood shopping at this location. Some communities have found that audible signals also help those with cognitive impairments.
- ⇒ Improve pavement/underlying structure, particularly in outer lanes where bus and heavy traffic have buckled pavement in the bicyclist travel area.

Raleigh & Barbee Chapel E

In this area, signalized intersections are widely-spaced from a pedestrian perspective. Although this intersection is signalized, there is no pedestrian signal and inadequate time for pedestrians to cross with the green for Barbee Chapel, which would only be tripped if motor vehicles are present. Pedestrians presently must cross 8 lanes of NC 54 unassisted at a midblock location, or attempt to cross at the intersections when side traffic triggers the signal. (See Figure 71 for an aerial view.) Crossing time (green) was estimated at only about 12 seconds to cross the 8 lanes plus extra pavement and median.

Although there are no sidewalks on Barbee Chapel south side, there are beaten paths along the road demonstrating the presence of pedestrians. Pedestrians were observed dashing across four lanes in one direction, waiting in the median, and then dashing across the opposite-direction lanes at a non-intersection location – perhaps the best option at present, although given the high speed traffic, not an adequate one Figure 72).

Bicycle accommodation should be evaluated in this section, both for the roadway and for the path. There may be a need for highlighting of bicycle, right turn weave areas on the roadway. Additional warnings of the path crossing of this side street (and each of the other side streets) may be warranted to prevent motorists turning across without yielding to path traffic. Additionally, bicyclists would not want to stop to use the pedestrian push-button activation, and with Raleigh Rd having extensive priority, consideration should be given to a pedestrian/cycle/path phase to cross the side streets with each signal. This would likely increase compliance.

Figure 71. Raleigh Rd & Barbee Chapel E, aerial view (from Google Imagery, ®2008 U.S. Geological Survey).

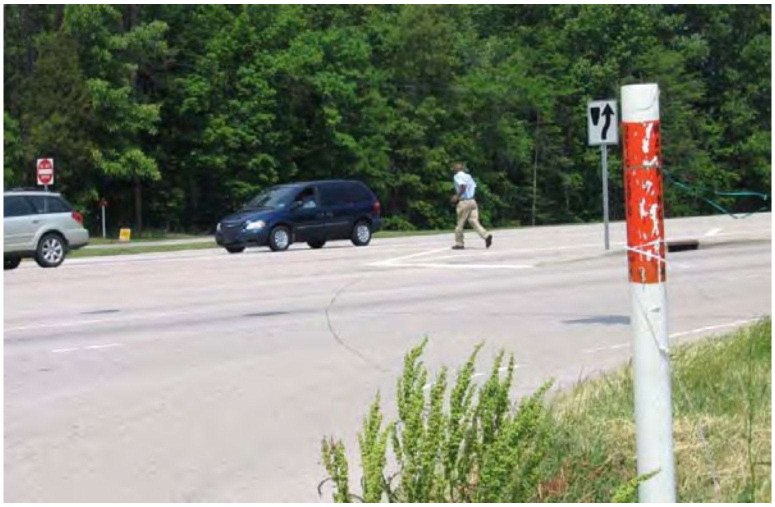

Figure 72. Pedestrian dash across Raleigh Rd near Barbee Chapel E.

There are no curbs on the south corners (Figure 73) and little delineation between the roadway and pedestrian path.

Figure 73. There is no curb and poor delineation between the road and pedestrian pathway at south side of Raleigh Rd and Barbee Chapel E.

Recommendations:

The need for crossing facilities at this and each of the signalized intersections along the corridor is paramount. Given the wide spacing between intersections, it is particularly important that some accommodation be provided pedestrians (other than the single pedestrian tunnel linking the shared-use path with the Meadowmont Village path).

⇒ Pedestrian signals (push-button activated) and crosswalk markings should be added to cross NC 54. Consider high visibility markings.

⇒ Bicycle loop detectors should be added simultaneously with pedestrian signals.

⇒ As an interim measure before pedestrian signals are installed, consider extending the green and clearance intervals for the side directions to give pedestrians time to cross Raleigh Rd.

⇒ Sidewalks, curbs and ramps at all corners should be improved and made ADA compliant (south side particularly) to define pedestrian space. Curb cuts and ramps should be aligned with the crosswalks.

⇒ Consider advance stop bars on Raleigh Rd to improve sight distance and help to reduce potential for crashes involving pedestrians who may be trapped by a signal change and still in the crosswalk (as at Hamilton Rd).

⇒ Consider protected left turn phasing for all approaches, with the pedestrian walk phase and through phase having priority. Turning vehicle conflicts are likely with this wide crossing if phases are not separated. Separate phasing would protect through bicyclists as well.

⇒ Providing protected left phases can reduce crashes, conflicts, and the amount of time needed for crossing, as pedestrians face fewer conflicts with turning vehicles. Other options are to provide a leading pedestrian interval to give pedestrians a head start in the crossing; this measure could help reduce conflicts with right-turning vehicles even if protected left turn phasing is used.

⇒ Adequate time should be provided to allow crossing in one phase for walking speeds of 3.5 feet/sec. Consider median improvements such as a refuge area and additional push-button activators for pedestrians who might not be able to cross both directions of travel lanes in a signal phase, even with a more generous walking time.

⇒ Given the potential for harm to pedestrians who do not complete the crossing in one phase, consideration could also be given to adding pedestrian detectors that will extend the signal if needed. This option might result in less delay to motorists than a pedestrian signal activated again in the next phase.

⇒ Provide adequate lighting at intersections.

⇒ Consider as short an interval as possible until signal change after push button activation to reduce frustration and violations of the walk signal.

⇒ Consider “No Turn on Red when Pedestrians Present” signs.

Raleigh Rd & Meadowmont Lane/Friday Center Drive

We made only a brief visit to this intersection, so a more detailed visit to determine whether there are more location-specific issues is needed, but the same amenities – marked crosswalks and pedestrian signals for all legs, adequate lighting, advance stop bars, and other precautions - are advised at this location as for Hamilton and Barbee Chapel E. Signal phasing and other options are recommended to protect crossing pedestrians and bicyclists from turning traffic. Accommodation for bicyclists (bicycle detection at side streets, advance stop bars on Raleigh Rd) and other measures may also be considered.

Raleigh Rd & Burning Tree /Finley Golf Course Rd

As at Barbee Chapel, there are no crosswalks or pedestrians signals across Raleigh Rd/ NC 54 OR across the side streets at this location. The multi-use path also comes to an abrupt end at Finley Golf Course Rd on the south side of NC 54, and there is no walkway or path continuing west of Finley Golf Course Rd (see images in Figure 75). Therefore, pedestrians and bicyclists using this path are essentially left with no way to cross Raleigh Rd and no way to continue on the south side. There are continuous sidewalks on the north side of Raleigh Rd.

There also seems to be significant cut-through traffic using Finley Golf Course Rd. There may be issues in the future with path traffic having difficulty crossing this side street at certain times of day if the cut through traffic continues to use this route and motorists do not yield or stop on red in advance of the crosswalk area (especially notable in right turn on red maneuvers). In addition, a right turn lane is presently being added to Finley Golf Course Rd. There may also be poor sight lines from Finley Golf Course Rd to the path traffic due to vegetation and road curvature. Sight lines should be corrected as per AASHTO Green Book recommendations for the speed of traffic. (Since the right-turn lane addition and removal of many trees, this problem may have been corrected.) There were no signs on Finley Golf Course Rd to warn of the path crossing (see Figure 74).

Figure 74. View of of Finley Golf Course Rd on approach to Raleigh Rd and adjacent path.

Figure 75. Images of the start/end of the NC 54 sidepath at Finley Golf Course Rd.

Note: There are no crosswalks or pedestrian signals in any direction for pedestrians and bicyclists to continue from or gain access to the end of the path.

Recommendations:

Accommodation is needed for pedestrians and cyclists who may be using the multi-use path, as well as those traveling along Raleigh Rd or the side streets.

- ⇒ Add cross walks and pedestrian signals to all legs of the intersection. Again, consider the separate phasing of left turns and pedestrian intervals.
- ⇒ Add bicycle detection to Finley Golf Course Rd and Burning Tree.
- ⇒ Consider the placement and visibility of crosswalks in light of the path ending.
- ⇒ Provide adequate lighting at the intersection.
- ⇒ Use advanced stop bars to improve sight distance and perhaps provide some protection from multiple threat crashes. This may also allow bicyclists to move to the front of stopped traffic in order to position for left turns.
- ⇒ Improve or add properly-designed accessible pedestrian landings and ramps in line with crosswalks.

⇒ Advance path warning signs could also be used for Finley Golf Course Rd and potentially for Raleigh Rd (turning traffic).

Raleigh Rd Street Sections

As mentioned previously, we did not focus attention on segments, but as with other multi-lane, and high speed, high volume corridors in the study area, there are few alternatives for bicyclists in this area to reach campus or downtown apart from this roadway. Although there are adjacent, multi-use paths for part of the corridor, there are numerous crossings that make the paths less desirable for bicycle travel, particularly for commuters. Two-way bicycle travel on adjacent paths also creates safety issues at intersections with side streets (AASHTO, 1999). In addition, the paths stop abruptly at Finley Golf Course Rd, and at present, there is not even a sidewalk continuing on the south side of NC 54. So, using the path is not really an option for cyclists continuing west beyond its end, such as commuter cyclists.

Along the street, there is significant rough pavement particularly in the vicinity of intersections and transit stops and where the gutter pan has been paved over that could adversely affect bicyclists (Figure 76). There are also hazardous drainage grates which seem to have been highlighted with a stripe.

One cyclist was struck at a driveway along the corridor (former Aurora site) when a motorist turned right across the path of a same direction bicyclist (right hook) who was traveling along the roadway. Bicyclists attempting to travel near the right edge of the outside lane are vulnerable at many locations to right-turning motorists. Bicyclists riding on walk ways or adjacent paths are, however, perhaps even more vulnerable to turning traffic and may be in an even less expected location at side street and driveway interactions.

Long term plans for this and all of the major corridors leading to downtowns and the University should address accommodation for bicyclists.

Figure 76. Rough pavement near the right side of the lane is hazardous for bicyclists (near Hamilton intersection).

Figure 77. Bicyclist choosing to ride on the sidewalk, which ends ahead, during a heavy traffic time.

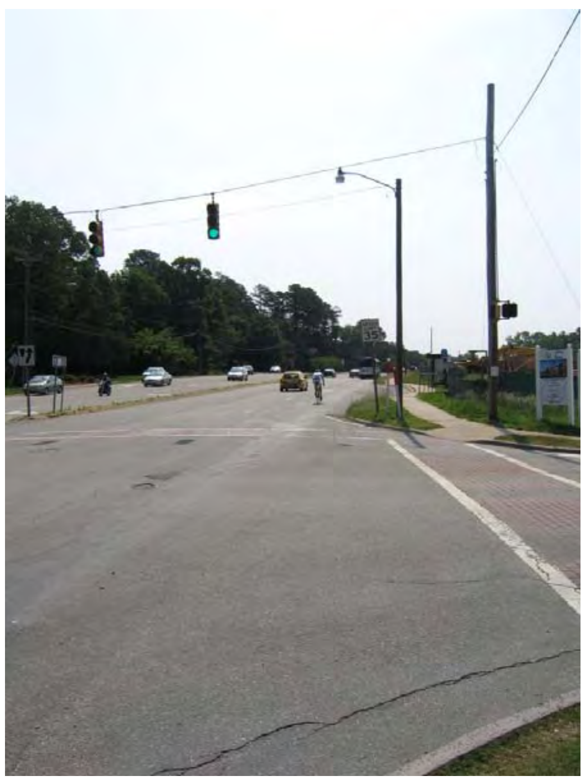

Figure 78. Another cyclist uses the street during a period of lighter traffic.

Recommendations:

⇒ Consider a road diet and using space for bicycle lanes. It would be preferable, as done on S Columbia St, to move bicyclists to the left of bus traffic and stopping areas, and right-turning traffic. However, merge areas would continue to be problematic. Signs and pavement markings could be used to highlight merge areas and provide warnings.

⇒ As discussed previously, a combined bike/bus, and limited right-turn only lane could potentially be a solution as done in Madison Wisconsin on a high-volume corridor, with bicyclists encouraged to take the lane through signing and other measures. (Madison has since provided separate bus/bike facilities on this corridor more similar to that described in the first bullet.) As discussed previously the ongoing through, right-turn lane with high speed traffic may provide a difficult sharing situation for many bicyclists and also contributes to hazards from turning vehicles for through bicyclists (as seen with a crash at Hamilton), as well as sidewalk and wrong-way riding.

⇒ Reevaluate the ramp and merge designs for 15/501 with Raleigh Rd and how bicyclists and pedestrians may be better accommodated.

⇒ Assess pavement and structural support for this transit corridor. Particularly pay attention to maintaining areas along the right side of the roadway where bicyclists ride.

⇒ In conjunction with a road diet, consider as a long-term solution, the addition of Intelligent Transportation Solutions (ITS) such as changeable traffic flow / traffic control – for when traffic volumes/ special events warrant different than regular, week-day traffic patterns (e.g. excessive traffic turning right for NB or SB 15/501). (This could conceivably be linked with HOV lanes and ITS solutions region-wide.)

Other Site Problems

Finally, a number of areas not described in the detailed audits were also visited, and significant safety issues were noted at a number of these locations as well. The brief field inspections of many additional locations revealed that they often shared similar safety issues to a number of those identified in the detailed audits or in the prior study of Martin Luther King Jr. Blvd. Some of the issues identified include a lack of pedestrian crosswalks and pedestrian signals at signalized intersections and junctions with on/off ramps (for some or all legs), lack of sidewalks leading to transit stops or discontinuity of sidewalks along important walking corridors, lack of safe crossing accommodation near midblock transit stops on high volume corridors, and lack of lighting in important pedestrian areas, including intersections and transit stops.

For example, the signalized intersection of US 15/501 (4 lanes plus turn lanes) and Bennett Road lacks pedestrian signals and crosswalks for any legs and, until recently, lacked overhead lighting. There is also a bus stop opposite a large residential neighborhood near this intersection that lacks sidewalk access. A night-time fatality also occurred at this intersection.

Other roads may have, over the years, been widened, intersections have grown more complex, transit stops have been added, and more pedestrians are walking in more locations; additional pedestrian and bicyclist accommodation is needed at many of these locations. Examples include:

- Similar conditions existed (signalized intersection with no pedestrian signals or crosswalks, no overhead lighting) at the time of the 2005 nighttime pedestrian fatality at US 15/501 and Manning Dr.
- Intersections with NC 54 W (Main St and Poplar) lack crosswalks and pedestrian signals for some legs. Pedestrians are unlikely, nor should they be encouraged, to cross extra legs of intersections (increasing their exposure) in order to use the legs with crosswalks and pedestrian walk signals.
- Several transit stops along NC 54 W also lack overhead lighting and sidewalks leading to transit stops. Some pedestrians were observed to walk in the roadway on a rainy day during a site visit.
- S Columbia St from Manning Dr and south through the bypass interchanges lacks a sidewalk or paved shoulder for pedestrians or bicyclists. Along this section, there are midblock transit stops (some located unexpectedly) on curves with no sidewalk or crossing access. There are also no signalized pedestrian crossings of the interchange ramps and sidewalk access on only one side of the bridge crossing NC 54.
- The long and winding section of E Franklin St between downtown and Estes Dr has overhead lighting provided on only one side of the road (switching back and forth) and also lacks signalized intersections or other accommodation where pedestrians may cross. Lighting is recommended for both sides of wider streets.
- The north sidewalk on Weaver Dairy Rd ends at Perkins Drive where there is no traffic signal or lighting, and there is limited sight distance. There are no crossing accommodations. A recent nighttime, fatal pedestrian collision occurred at this

location. These are just some additional locations visited, because these areas were also identified through crash or perception data, or were locations where fatalities have occurred since the study period. It is likely that other similar locations could be identified.

There is also a general lack of suitable accommodation for bicyclists along many of the busier, multi-lane corridors. There are few (no) bike lanes for dedicated space to ride on high volume, multi-lane, and high-speed corridors, with significant large vehicle/bus traffic, although these are often the only through streets available. Consequently, bicyclists often tend to ride on sidewalks (when available), sometimes wrong-way, which may increase propensity of becoming involved in collisions with motorists entering and exiting side streets and driveways as well as with pedestrians. E Franklin St for example, was identified as problematic by bicyclists. The outside lane widths seem insufficient to be shared by a motorist or bicyclist side-by-side and there are no bicycle lanes. Speeds (eastbound) were 41 mph (50th percentile), and 45 mph (85th percentile) which creates a difficult merge and turning situation, especially given the curves and perhaps limited sight distance.

Throughout the study area, 85th percentile speeds are significantly in excess of posted limits on nearly every segment evaluated. Motorized traffic volumes have decreased in some cases, so that capacity is above demand and speeding is probably even more likely,. All of these factors may help to explain the tendency for survey respondents to identify midblock sections as problematic for bicyclists more frequently than intersections, although more bicycle collisions occur at intersections. In addition, some of the road surfaces are in poor condition, particularly in the areas where bicyclists often ride.

Pertaining to intersections, bicyclists are also unable to activate a green light at many side street connections with arterial streets, possibly leading to signal violations and contributing to wrong-way riding on sidewalks or in the street. The Town of Chapel Hill's plans to add in-roadway bicycle detection at many signalized locations will help to address this problem. Side street junctions are sometimes skewed, have wide turning radii, and lack crosswalk markings, possibly contributing to fast right turns that are dangerous for bicyclists and pedestrians. Some examples were described in the section on Martin Luther King Jr Blvd. Another example is Roosevelt at Franklin St. Several problem roadways have continuous two-way, left turn lanes, which combined with numerous driveways resulting from past development, create numerous conflict areas where bicyclists and pedestrians are exposed to turning traffic.

Protected left turn phasing is often not provided at signalized intersections with dedicated turn lanes. A frequent collision type is unprotected left turning traffic failing to yield to parallel path crossing pedestrians or oncoming bicyclists. Consideration could be given to adopting a town-wide standard signal phasing scheme that provides for protected left-turn movements separated from the pedestrian walk and through traffic phases.

As the Towns have grown in population, and transit and multi-modal transport have become increasingly important, sidewalks and other amenities have not kept pace with growing demand. A key example is S Greensboro St from NC 54 to Carr St which appears to be a rural road, lacking even shoulders, and further south, Smith Level Rd, which is lacking sidewalks, has rough paved shoulders, and poor intersection and ramp crossing accommodations for pedestrians. The areas around the NC 54 access ramps are very wide with multiple lanes tapering to two lanes in each direction; signals are probably not timed for pedestrian and bicyclist accommodation, lacking pedestrian signal heads.

Finally, in downtown and campus areas, due to an apparent lack of suitable accommodation, and potentially policy and enforcement issues, delivery and construction vehicles often park in the bicyclist path, in center turn lanes, or on sidewalks apparently causing damage to curbs and sidewalks, and also blocking access and forcing pedestrians into the street.

Summary and Conclusions

Study Objectives and Methods

The objective of the present study was to identify areas with potential hazards for pedestrians and bicyclists to aid in prioritizing safety improvements. Crash factor analysis and spatial analyses of crash data were supplemented with proactive methods to identify potentially unsafe locations that may not have experienced crashes yet. Five years of pedestrian and bicycle crash data were obtained for the study area, which included Chapel Hill and Carrboro, NC. A survey was conducted with 400 respondents who regularly travel in the area order to identify locations perceived to be unsafe for pedestrians and bicyclists. The crash locations and the perceived risk locations were entered into a GIS format and spatially analyzed and compared to identify higher crash and higher perceived risk areas for further evaluation. Other proactive tools were also used to identify areas of potential concern. Roadway safety audits were conducted for eight areas to identify problems and potential countermeasures.

Safety Problems Identified

There were substantial differences in crash and perceived risk hot spots as identified through kernel density analyses. The pedestrian crash density areas were predominantly on downtown and campus streets including Franklin St, Rosemary St, Columbia St, Main St, Weaver St, Greensboro St, South Rd, Manning Dr, Raleigh St, with a few additional hot spots identified on Estes Dr near Willow Dr, at NC 54 E and Hamilton Rd, NC 54 W in Carrboro (at Main St and at Poplar), a location on Legion Rd, and at Pritchard Ave and Longview St in Chapel Hill. Bicycle crashes were also predominantly clustered on the two downtowns and campus streets, in particular in the transition area between Chapel Hill and Carrboro from W Franklin St to E Main St. Other significant bicycle crash clusters were on Martin Luther King Jr Blvd, and Fordham Blvd at and near Estes Dr.

In addition to downtown and campus areas that did substantially overlap with crash occurrence, most perceived risk areas identified tended to be on the heavily traveled corridors leading to downtowns and campus or cross-town corridors. One corridor, Estes Dr Ext (portion of Estes from MLK west), was identified as a primary area of concern for bicyclists, and also of high concern for pedestrians, yet prior crashes have not occurred on this corridor. These findings reflect those in a study by Cho, Rodriguez and Khattak (2009) as well as the earlier studies by Schneider et al. Areas perceived as very unsafe could generate changes in behavior that reduce actual crash risk. These behaviors could include avoiding walking and biking in the area altogether (if possible), and taking extra precautions when walking/biking in the area. These possibilities do not imply that such areas are of low concern for remediation since although crash incidence may be low, crash severity when collisions do occur is likely to be quite high.

Other corridors with areas of relatively high perceived risk included Martin Luther King Jr Blvd, Fordham Blvd/NC 54 sometimes referred to as the “bypass,” S Columbia St and Pittsboro St, E Franklin St, and S Greensboro St. While NC 54/Raleigh Rd east pf the bypass was not particularly perceived as risky, the Town of Chapel Hill had identified several intersections along this corridor as needing improvement. There were also a few additional locations identified particularly by the bicycle perceived risk data which included several locations on two-lane roads further away from town centers and campus.

As mentioned, apart from some downtown and campus areas, there was significant non-overlap between crash density areas and perceived risk areas. A total of about 69 areas (45 pedestrian and 24 bicycle locations) were identified for further safety assessment, although a number of the pedestrian and bicycle areas overlapped. Nearly half of the areas were included in a detailed audit and most other areas were visited at least once. Speed studies were also conducted near a majority of the locations identified (when feasible).

A decision was made to examine cohesive areas or corridor segments (including intersections) that incorporated several separate crash or perception areas into areas of concern. The reasons for doing so include the following: 1) the numbers of crashes were relatively small in most of the separate areas identified; 2) chance plays a role in the precise location where crashes occur; 3) nearby areas or areas with characteristics similar to those where crashes have already occurred might expect future crashes; 4) the perceived risk locations were somewhat imprecise and often involved entire corridors that shared a similar profile. Finally, the spatial analysis parameters used have some effect on how finely risk areas are divided.

About 45%, or a total of 31 bicycle and pedestrian locations identified by crash or perception data, were included in one of the eight detailed audits. Along with a number of areas for which there was significant overlap of crashes and perceived risk, four pedestrian areas that were highlighted by perceived risk only (not crashes) and one bicycle area highlighted by perceived risk, but not crashes (precisely) were incorporated into detailed audits. Three areas with significant pedestrian crashes but low perceived risk, and five areas with significant bicycle crashes but low perceived risk were also included in audits. Thirteen Town-identified locations were included, most of which overlapped with crash or perception-identified locations, although three did not.

Each of the areas, including those highlighted by perception data but not by prior crashes, was found to have conditions that could affect pedestrian or bicyclist safety (usually both). Thus, the accumulation of perception data did lead to identification of areas with significant safety concerns.

Countermeasure recommendations

Recommendations for potential countermeasures were identified for each of the eight areas where detailed audits were conducted. Some of these recommendations would also apply to other locations, including crash and risk perception areas that were not included in detailed audits but were visited. ***Each site and potential countermeasures should be carefully assessed by the responsible agencies prior to implementation.***

Widely recommended countermeasures include the following:

⇒ Provide pedestrian crosswalks and pedestrian walk/don't walk signals on all legs at signalized intersections throughout the Towns that lack them.

⇒ Complete sidewalk sections to transit stops and to connect other important walking links. Add buffers from traffic whenever possible.

⇒ Enhance lighting at intersections, near transit crossing areas, near path crossings and other busy areas. Consider pedestrian level lighting, especially at busier night-time locations.

⇒ Medians or median islands with accessible crossings would improve midblock crossings on multi-lane roads.

⇒ Also consider the use of HAWK or rapid-flash beacons to enhance uncontrolled midblock crosswalks.

⇒ Americans with Disabilities Act-compliant curbs, ramps, and landings should be provided as well.

⇒ Provide for bicycle detection on side streets that require vehicle-activation to get a green light.

⇒ Bicycle facilities such as bike lanes would improve bicycle comfort and level of service along key arterials, and may help to reduce wrong-way and sidewalk riding – a risk factor for collisions at intersections. Wide outside lanes and shared lane markings are other potential improvements for some locations.

⇒ Also consider intersection markings, signal timing improvements, and other potential treatments for bicyclists at key arterial intersections.

⇒ Consider road diet/lane reduction measures especially on certain downtown streets, to reduce crossing distances, speeds, and provide additional space for other needs.

⇒ Reduce opportunities for crashes and conflicts with turning vehicles by:

- Providing protected left-turn phasing separated from pedestrian walk and through traffic phases at signalized intersections with dedicated left-turn lanes.
- Adding raised medians and other access management/driveway consolidation measures to reduce the number of conflict areas and sight distance issues.
- Adding sidewalk-level crossings to driveway junctions.
- Keep curb radii narrow whenever possible to keep turning speeds low.
- Consider the use of low-speed (preferably one-lane) roundabouts at appropriate locations.

⇒ Measures to reduce motorist speeds, including both engineering and enforcement should also be implemented. Perhaps an area-wide anti-speeding campaign could be implemented.

Discussion of priorities for pedestrian and bicycle improvements

Since the downtown and campus areas, in general, account for a majority of pedestrian and bicycle collisions, efforts in these areas to improve safety for both groups should continue to be a priority – especially longer term. A number of issues were identified on downtown and campus streets including numerous lanes to cross on some streets, large spans between signalized crossings, sidewalks adjacent to traffic, numerous conflict areas (driveways and side streets) often with poor visibility, excessive downtown traffic capacity, and speeds that create uncomfortable conditions for pedestrians and bicyclists. Poor pavement conditions resulting from heavy vehicle traffic is also an issue for bicyclists. Transit stops (and sometimes queueing buses) on some streets are located where they block visibility of crosswalks at both intersection and midblock locations and may contribute to a multiple threat situation.

The many other crash and perception areas on the heavily traveled corridors warrant attention as well. Given the increasing amounts of walking, biking, and accessing of transit, presence of schools, parks, trails, shopping, and other businesses and destinations in all parts of the study area, it seems clear that the perception of risk along the busy, large arterials is warranted. The higher traffic speeds on these corridors outside the immediate downtown areas also means that the risk of severe injury in a crash is higher than on lower speed streets, although pedestrians and cyclists are vulnerable to severe injury in any crash. In addition, significant crashes have already occurred (during the study period) at several locations on such main corridors outside of the downtown and campus areas. Although the precise locations did not coincide specifically with density areas highlighted by perception data, we note that those data in fact lacked precision, and more often reflected area-wide concerns. At least six pedestrian fatalities have occurred in the study area since the end of the study period (2006 – present). Two of these involved commercial buses on campus/downtown corridors. Four of the pedestrian collisions occurred at night at locations away from core downtown or campus streets on busy, usually multi-lane, unlit arteries, often with no pedestrian crossing accommodation.

A primary challenge in prioritizing spot safety and longer term improvements among the many locations identified (and even those not identified) is that there is a significant element of chance to where the combination of human error and environmental conditions will lead to a crash or fatality. Thus, strategies to address pedestrian and bicyclist deficiencies need to incorporate developing a system-wide approach that considers crash and perception data, but addresses the randomness of collisions and the similarity of safety problems among many locations. Addressing deficiencies at all major intersections and along all the main corridors should be a priority as opportunities allow. Using information on the types of collisions frequently seen and other crash factors could also help in this process. Similarly, analysis of transit access, operations, and policies, and opportunities for educating users are important (Nabors et al., 2008).

Safety improvements among the many locations will no doubt have to be prioritized according to funding needs, opportunities to be incorporated with other projects, and other considerations (planning and design time, etc.). Other considerations could include providing geographic equity, and completing safe pedestrian and bicycle access for neighborhoods to transit, schools, parks, recreational paths, and nearby business centers (enhancing connectivity). Providing accessibility for persons with disabilities should also be addressed. Crash density and severity of course, as already outlined in this report, should also be factors. Prioritization may be either qualitative or quantitative. Some localities and states use numerical and weighted rating systems for different criteria to help rank projects (Natarajan and Demetsky, 2009).

Efforts to provide suitable accommodation *and* creating a connected network for bicyclists as well as pedestrians should be routine, since gaps in a network represent hazards as well as restricting freedom of movement. The Town's objective to provide bicycle detection at many signalized intersections is a step in the right direction. Providing space for bicyclists to ride on the arterials that often provide the only route to and from the downtowns and campus should also be a priority as bicyclists face increasing challenges in mingling with high speed, high volume, and large vehicle traffic. Operationally, evidence suggests that striping bicycle lanes offers advantages to both motorists and bicyclists.

Calming speeds on these arterials may go far toward improving safety for all users, and enforcement needs to play a role. It is clear that our road network must serve all users safely so that people have transportation choices and the opportunities for conflict and collisions are minimized. Any roadway improvement projects should include pedestrian and bicycle safety audits by independent and knowledgeable interdisciplinary teams during the planning stages to ensure that bicyclists and pedestrians will be fully and safely accommodated once the project is completed.

Conclusions

Serious safety issues for pedestrians and bicyclists were identified at most locations visited, leading the study team to believe that there are somewhat systemic problems in meeting the safety and accessibility needs of pedestrians and bicyclists in the study area. The survey of users helped to highlight safety concerns along many corridors and at intersections where prior collisions had not necessarily occurred. It is likely that most communities would find similar results. One benefit of the survey may be that it highlights areas that people need to walk. A disadvantage is that some populations, users, or neighborhoods may not be well-represented.

As a result, there could also be serious safety problems in areas that simply did not come to our attention through the survey sample and analysis of crash and perception data. Therefore, a methodological plan, including continued updating of crash data and reported problems, use of other proactive tools such as speed studies, counts and surveys of walking/biking patterns, analysis of transit access, use of screening tools such as the intersection screening tools, and roadway safety audits should be employed to develop a safe pedestrian and bicycle network. Attention to policies, manuals and procedures, as well as a focus on problem patterns, corridors and intersections is needed to address the deficiencies.

Behavioral countermeasures, including training of police officers to enforce traffic laws that pertain to bicycle and pedestrian safety, enforcement of speed limits, improved training of bus operators, working with transit agency to assess location and operation of transit stops and accommodation for other modes, and reinforcement of safe walking and bicycling through educational programs are also essential.

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Appendix A: Public Perception Survey and Survey Respondent Characteristics

Survey Date__________

Pedestrian and Bicyclist Roadway Safety Survey

[Introduce Self and the Study. Offer information card.]

Unique survey ID
Site ____Survey#_____
Surveyor Inits.__________

Request: Are you familiar with the roadways around Chapel Hill and Carrboro? Would you be willing to spend 10 minutes to help us identify roadway locations that may be unsafe for bicyclists and pedestrians?

Screen: Are you at least 18 years old?
[Surveyor note: Only ask if uncertain about age]

Questions:

1. If you don't mind, would you please answer a few questions about the general area where you live and work or go to school?

a) Do you **live** in:
☐ Chapel Hill ☐ Carrboro ☐ Orange County ☐ outside Orange County?
[*Only if respondent* ***doesn't live*** *in the study area:*
If travel into the area to work, please indicate the corridor (roadway) of entry:
____

If live within the study area (Chapel Hill or Carrboro), would you locate the square (1/2 mi grid imposed on the Chapel Hill/Carrboro study area) that encompasses where you live?
______ [*indicate square ID, e.g. A 16, or n/a if outside the Chapel Hill/Carrboro study area]*

b) Do you **work or go to school** in:
☐ Chapel Hill ☐ Carrboro ☐ Orange County ☐ outside Orange County?
[Only if respondent ***doesn't work*** *in study area:*
If travel out of the area to work, please indicate the corridor (roadway) of exit:
____

If you work or go to school within the study area, would you locate the square that encompasses where you work/go to school?
_______ [*indicate square ID or n/a, e.g. A12*]

c) ☐ Participant neither lives nor works/goes to school within study area/not on map.
d) ☐ Participant doesn't want to answer.

2. How many days per week (out of 7, on average) do you:
[*Don't indicate a range, ask respondent to pick the single best estimate of days per week.*]
_____ drive in the area?
_____ walk in the area? By walking, I mean that you travel a distance of a city block or more by foot, outside of your home or yard. This would be regardless of whether you are walking to get somewhere, such as to the store or a bus stop, or simply walking for recreation or exercise.
_____ bicycle in the area? Again, this would be traveling a block or more, regardless of the reason for bicycling.
_____ use transit in the area?
[continued – instructions – next page]

[*If respondent does not travel (by any mode) in the area at least one time per week, thank them for their time and discontinue the interview. If needed, may explain further that we are soliciting input from people who are currently familiar with roadways and travel scenarios in the study area.*]

3. What times of day do you usually travel in the area? [*name the times aloud, check all that apply*]

☐ morning ☐ mid-day ☐ afternoon to early evening (peak hours)
☐ nighttime

4. [*Describe/show large scale map as needed*] **Can you identify any (*up to 3*) locations (on roadway network) that you think are unsafe to pedestrians due to roadway or traffic risks (not personal security)?**

Pedestrian Locations:
a) ☐ [*check if located point on map; assign ID as SiteID____Survey#____ 4a*]

***Problem road:**____

Intersecting road:____

If not at intersection, between:________________________________
#[***distance from/between 2 cross-roads; if at intersection, write 0***]

When is this location unsafe? (all the time or at any particular times or days?)
☐ all or don't know
☐ certain/special times - specify: ___________________________

Is it unsafe to [*can check both if both apply*]:
☐ cross the roadway?
☐ walk along the roadway?

Can you tell me why you think this location is unsafe?

____

b) ☐ [*check if located point on map; assign ID as SiteID____Survey#___ 4b*]

***Problem road:**____

Intersecting road:____

If not at intersection, between:________________________________
[***distance from/between 2 cross-roads; if at intersection, write 0***]

When is this location unsafe? (all the time or at any particular times or days?)
☐ all or don't know
☐ certain/special times - specify: ___________________________

---

*Problem road is the road perceived to have greatest difficulty crossing, walking along, riding, etc. If a cross street is also a problem location, may need to describe a separate location.
\# Must be clear – indicate how far between two cross-streets, e.g. if anywhere midblock, can say midblock, between Hillsborough and Bolin Heights. If 100' from an intersection, indicate 100' North (example direction) of Hillsborough St.

Is it unsafe to [*can check both if both apply*]:
☐ cross the roadway?
☐ walk along the roadway?

Can you tell me why you think this location is unsafe?

____

c) ☐ [*check if located point on map; assign ID as SiteID___Survey#__4c*]

***Problem road:**____

Intersecting road:____

If not at intersection, between:____
[***distance from/between 2 cross-roads; if at intersection, write 0***]

When is this location unsafe? (all the time or at any particular times or days?)
☐ all or don't know
☐ certain/special times - specify: ______________________________

Is it unsafe to [*can check both if both apply*]:
☐ cross the roadway?
☐ walk along the roadway?

Can you tell me why you think this location is unsafe?

____

5. Can you identify some specific (*up to 3*) locations (on roadway network) that you think are unsafe to bicyclists due to roadway or traffic risks (not personal security)?

Bicyclist Locations:
a) ☐ [*check if located point on map; assign ID as SiteID___Survey#__5a*]

***Problem road:**____

Intersecting road:____

If not at intersection, between:____
[***distance from/between 2 cross-roads; if at intersection, write 0***]

When is this location unsafe? (all the time or at any particular times or days?)
☐ all or don't know
☐ certain/special times - specify: ______________________________

Can you tell me why you think this location is unsafe?

____

3

b) ☐ [*check if located point on map; assign ID as SiteID___Survey#__5b*]

***Problem road:**____

Intersecting road:____

If not at intersection, between:____

[***distance from/between 2 cross-roads; if at intersection, write 0***]

When is this location unsafe? (all the time or at any particular times or days?)
☐ all or don't know
☐ certain/special times - specify: ______________________________

Can you tell me why you think this location is unsafe?

____

c) ☐ [*check if located point on map; assign ID as SiteID___Survey#__5c*]

***Problem road:**____

Intersecting road:____

If not at intersection, between:____

[***distance from/between 2 cross-roads; if at intersection, write 0***]

When is this location unsafe? (all the time or at any particular times or days?)
☐ all or don't know
☐ certain/special times - specify: ______________________________

Can you tell me why you perceive this location to be unsafe?

____

6. [*If respondent drives*] **So, now I'm going to ask you a little different question, if you don't mind: Do you recall any locations where you think you have come close to hitting a bicyclist or pedestrian while driving in the area, or where one or both of you had to take action to avoid a probable collision? By take action, I mean that you had to slow or stop, swerve or change direction, honk horn, etc.**

a) ☐ near miss with someone walking ☐ [*checkSiteID__Survey#__ 6a, if new loc.*]

near-miss road:____

intersecting road:____

If not at intersection, between:____

[***distance from/between 2 cross-roads; if at intersection, write 0***]

If same as one of the already identified locations, indicate that id # here: __________.

b) ☐ near miss with someone riding a bicycle ☐ [*Site ID__Survey#__6b, if new loc.*]

near-miss road:____

intersecting road:____

4

If not at intersection, between:____

[***distance from/between 2 cross-roads; if at intersection, write 0***]

If same as one of the already identified locations, indicate that id # here: __________.

Can you describe what happened?

a) (walker) ____

b) (bicyclist) ____

7. Are there any locations in the area where you have come close to being struck by a motor vehicle?

a) ☐ while walking or ☐ *[Identify as Site*__Survey#__7a, if new]*

b) ☐ while bicycling ☐ *[Identify as Site*__Survey#__ 7b, if* **new]**

near-miss road:____

intersecting road:____

If not at intersection, between:____

[***distance from/between 2 cross-roads; if at intersection, write 0***]

If same as one of the already identified locations, indicate that id # here: __________

Can you describe what happened?

a) ____

b) ____

8. [Don't ask, but if the volunteer brings up non-roadway areas such as parking lots, multi-use paths, parks, school entrance roads/playgrounds, etc., *briefly describe location + problem here]*:

____

____

[*Indicate whether respondent is*]:

a) ☐ Male b) ☐ Female

[*Approximate age range of respondent (interviewer guesstimate)*]:

a) ☐ College age b) ☐ Mid-20's – mid-60's c) ☐ Older than 65

Thank you very much for your help!

5

Survey Respondents Characteristics

Sex

	Frequency	Percent
female	224	56.0
male	166	41.5
missing	10	2.5
Total	400	100.0

Age Range

missing	10	2.5
college-age	60	15.0
mid-20s to mid-60s	298	74.5
> 65	32	8.0
Total	400	100.0

Residence Jurisdiction

	Frequency	Percent
missing	6	1.5
Carrboro	96	24.0
Chapel Hill	244	61.0
Orange Co	21	5.3
Outside Orange Co	33	8.3
Total	400	100.0

Survey Respondents' Travel Characteristics

# Days/Week Walk	Frequency	Percent
0	31	7.8
0.5 - 1	15	3.8
2	21	5.3
3	29	7.3
4	31	7.8
5	54	13.5
6	19	4.8
7	191	47.8
missing	9	2.3
Total	400	100.0

# Days/Week Bike	Frequency	Percent
0	251	62.8
0.5 - 1	19	4.8
2 – 2.5	25	6.3
3 – 3.5	27	6.8
4	19	4.8
5	19	4.8
6	5	1.3
7	23	5.8
missing	12	3.0
Total	400	100.0

# Days/Week Use Transit	Frequency	Percent
0	236	59.0
0.5 - 1	44	11.0
2	17	4.3
3 – 3.5	13	3.3
4	23	5.8
5	46	11.5
6	2	.5
7	7	1.8
missing	12	3.0
Total	400	100.0

Survey Respondents' Travel Characteristics, cont.

 # Respondents Travel Morning

	Frequency	Percent
n	45	11.3
y	344	86.0
missing	11	2.8
Total	400	100.0

 # Respondents Travel Midday

	Frequency	Percent
n	213	53.3
y	176	44.0
missing	11	2.8
Total	400	100.0

 # Respondents Travel Afternoon/Eve.

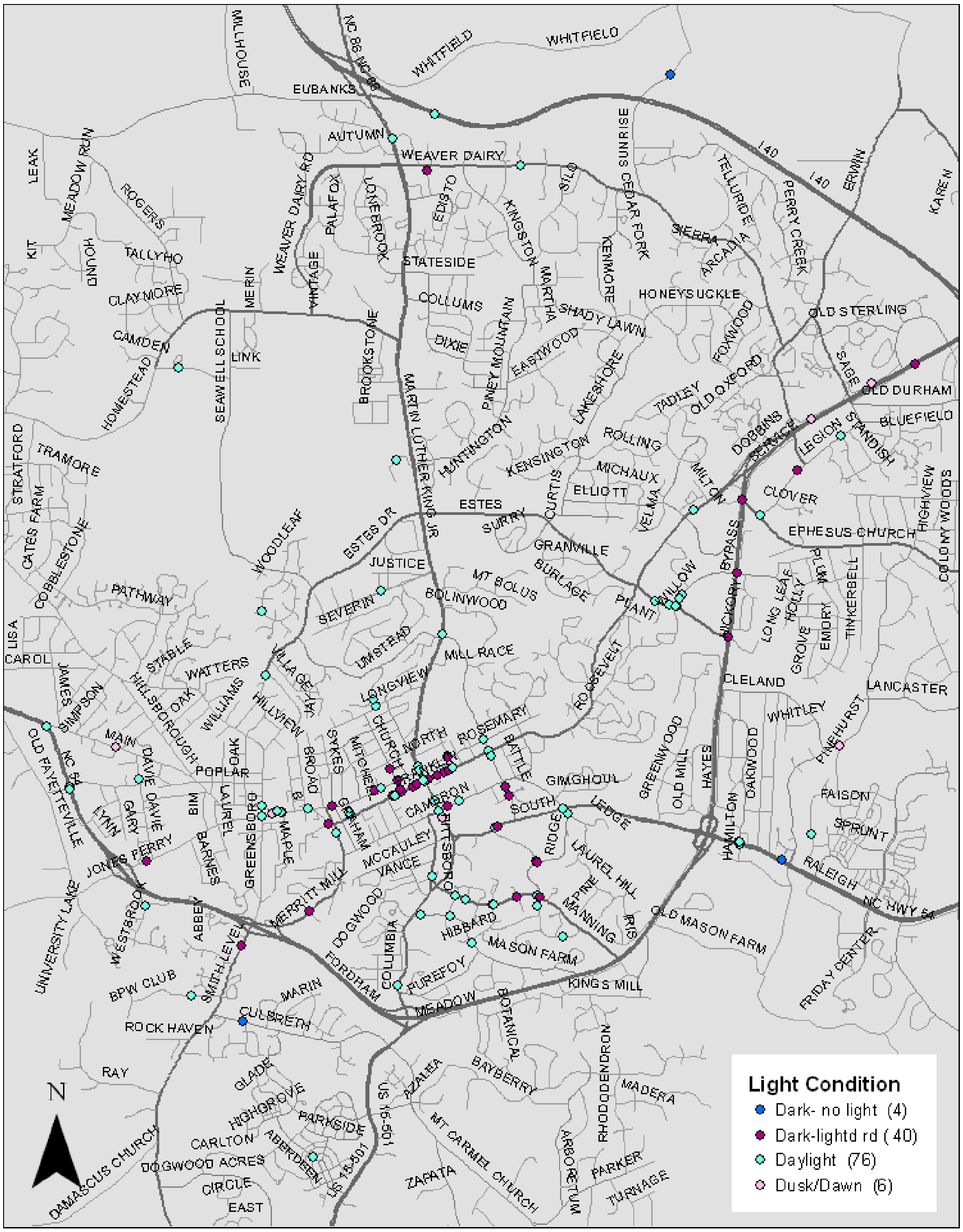
	Frequency	Percent
missing	11	2.8
n	42	10.5
y	347	86.8
Total	400	100.0

 # Respondents Travel at Nighttime

	Frequency	Percent
n	236	59.0
y	153	38.3
missing	11	2.8
Total	400	100.0

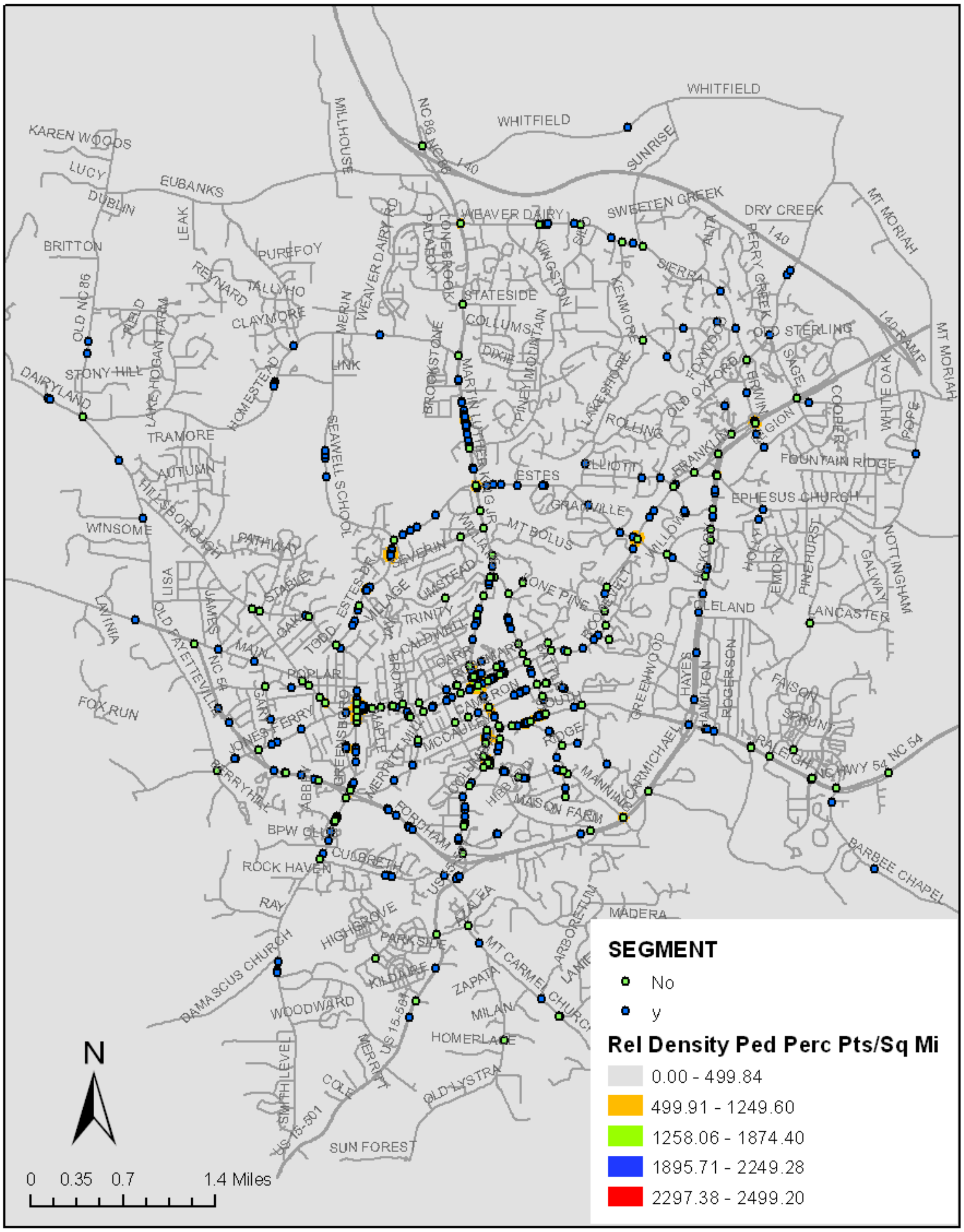
Appendix B: "Dot" Maps of Pedestrian and Bicycle Crash and Perception Locations

Pedestrian Collisions by Light Condition, 2001-2005



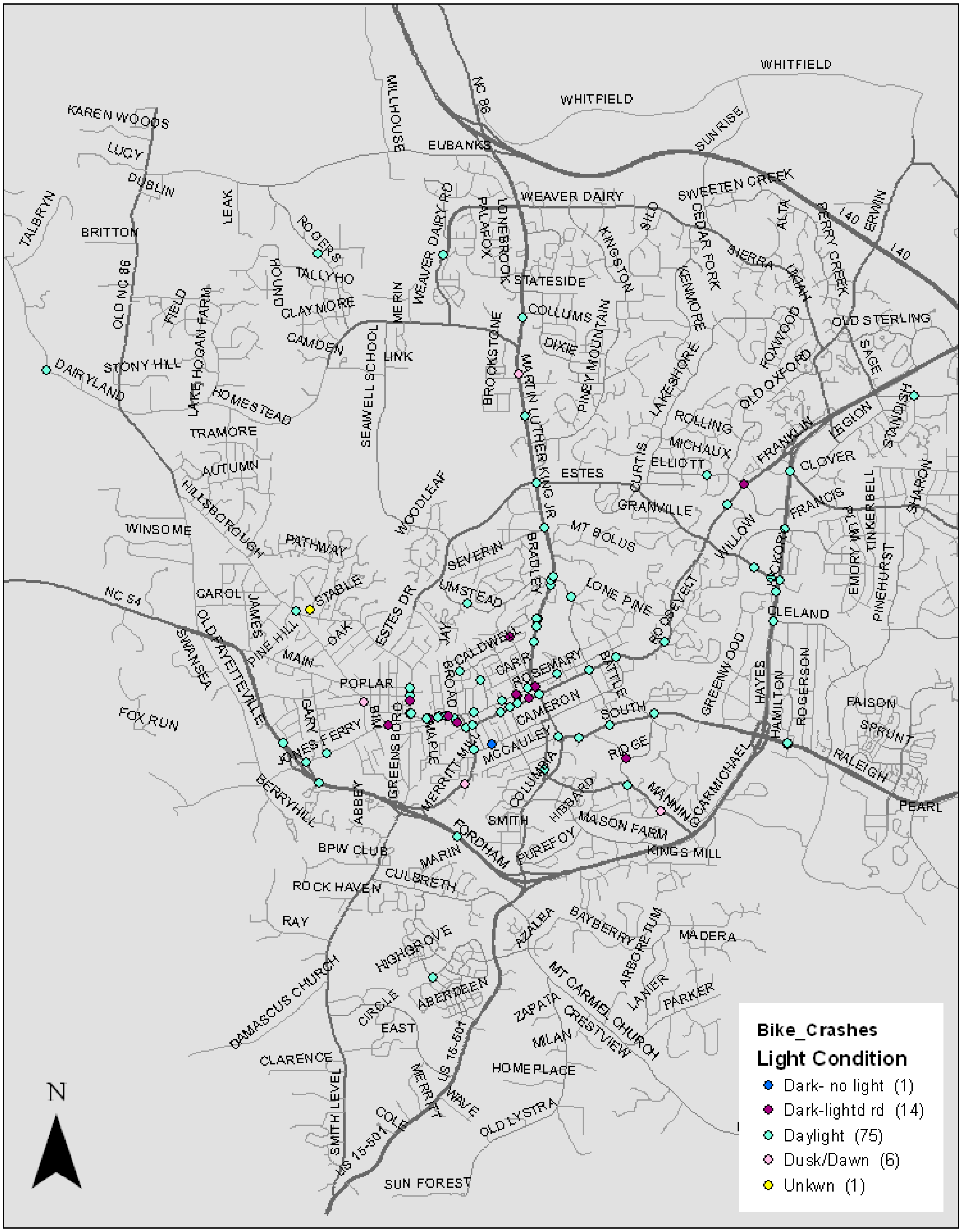
Dot map of pedestrian collisions illustrating the light condition at the time of the crash. Kernel density of pedestrian collisions is not shown on this map.

Pedestrian Risk Perception Points



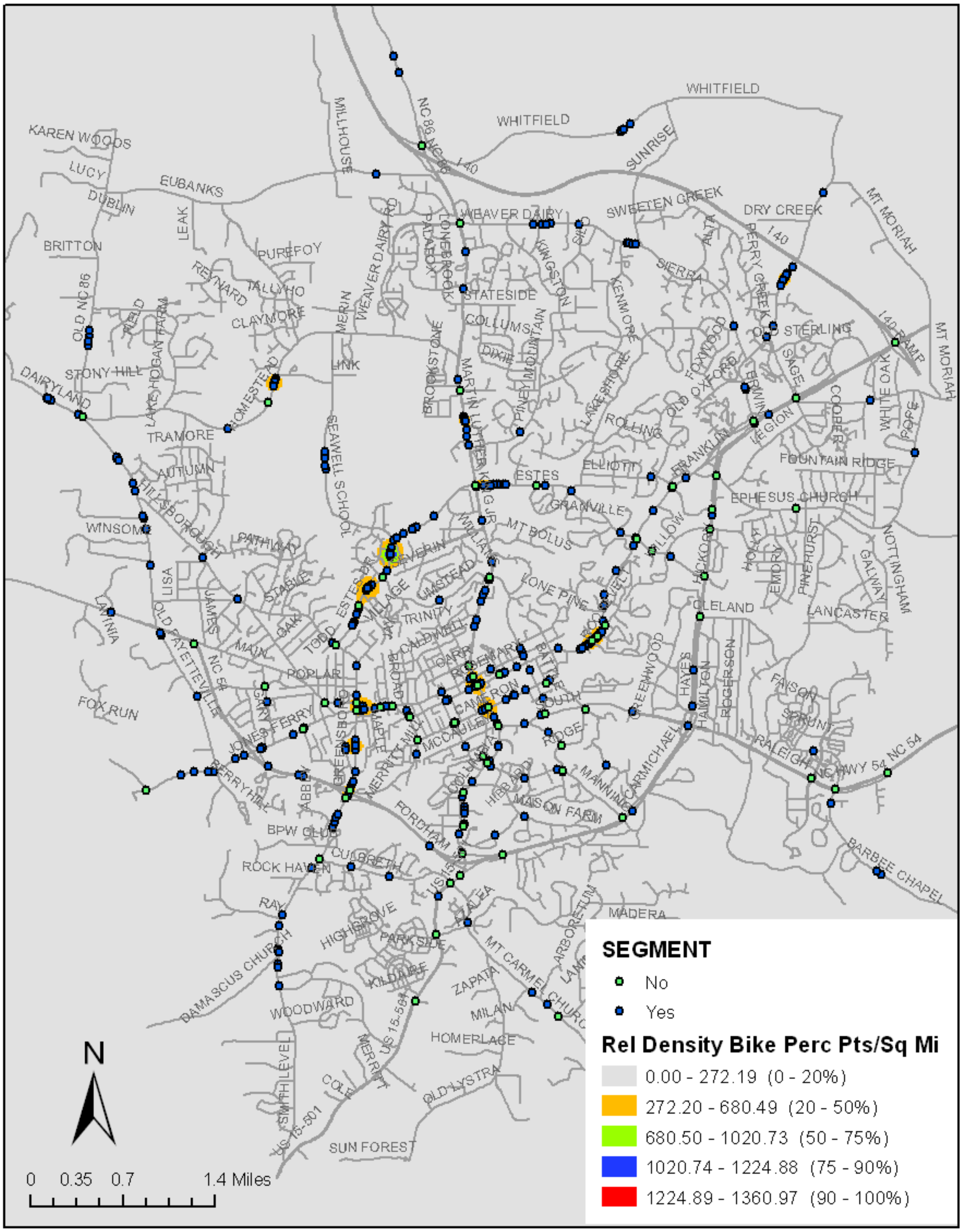
Dot map illustrating locations of pedestrian perceived risk points. Note the density results in comparison (partially visible behind dots). The blue points on the map represent locations the respondents indicated to involve a segment as opposed to a single location.

Bicycle Collisions by Light Condition, 2001-2005



Point locations of bicycle collisions with light condition at the time of the crash. (Kernel density of bicycle crashes is not shown on this map.)

Bicycle Risk Perception Points



Dot map illustrating locations of bicycle perceived risk points. Note the density results in comparison. The blue points on the map represent locations that survey respondents indicated to involve a segment as opposed to a single location.

Appendix C: Pedestrian Intersection Collisions and Intersection Safety Index Ratings

Intersections with Pedestrian Collisions within 100 feet of Intersection Center

Number of Pedestrian Crashes	Intersecting Street Names
4	E FRANKLIN ST & W FRANKLIN ST & N COLUMBIA ST & S COLUMBIA ST
4	RALEIGH RD & HAMILTON RD
3	S ESTES DR & WILLOW DR & CAMELOT DR
3	W ROSEMARY ST & AMITY ST & ANDREWS LN (Alleys)
2	E MAIN ST & E WEAVER ST & ROBERSON ST
2	E MAIN ST & W MAIN ST & N GREENSBORO ST & S GREENSBORO ST
2	E ROSEMARY ST & BANK OF AMERICA (Alley)
2	LEGION RD & FORSYTH DR
2	MANNING DR & HIBBARD DR & EMERGENCY DR
2	MANNING DR & PAUL HARDIN DR
2	MANNING DR & PITTSBORO ST & UNIVERSITY DR
2	MANNING DR & RIDGE RD & SKIPPER BOWLES DR
2	N GREENSBORO ST & E WEAVER ST & W WEAVER ST
2	NC 54 W POPLAR AVE
2	NC 54 & W MAIN ST
2	RIDGE RD & STADIUM DR
2	W FRANKLIN ST & CHURCH ST
2	W ROSEMARY ST & E ROSEMARY ST & N COLUMBIA ST & S COLUMBIA ST
1	BARCLAY RD & WYRICK ST
1	BROOKERGREEN DR & MARKET ST ALLEY
1	BURNING TREE DR & PINEHURST DR
1	CHURCH ST & SHORT ST
1	COUNTRY CLUB RD & RIDGE RD
1	CULBRETH RD & COBBLE RIDGE DR
1	E FRANKLIN ST & HENDERSON ST
1	E FRANKLIN ST & HILLSBOROUGH ST & RALEIGH ST
1	E MAIN ST & W FRANKLIN & BREWERS LN & MERRITT MILL RD
1	E ROSEMARY ST & HILLSBOROUGH ST
1	EPHESUS CHURCH RD & LEGION RD
1	ESTES DR EXT & ESTES PARK APT
1	FORDHAM BLVD & EASTGATE SHOPPING CENTER RD & EPHESUS CHURCH RD & SERVICE RD
1	FORDHAM BLVD & ESTES DR & S ESTES DR
1	FORDHAM BLVD & WILLOW DR
1	IRONWOODS DR & DARTMOUTH CT
1	MANNING DR & HOSPITAL DR & WEST DR
1	MARTIN LUTHER KING JR BLVD & HILLSBOROUGH ST & UMSTEAD DR
1	MARTIN LUTHER KING JR BLVD & PERKINS DR
1	MASON FARM RD & DANIELS DR & & WEST DR
1	MUNICIPAL DR & PUBLIC WORKS DR
1	PORTHOLE ALY & E FRANKLIN ST & E FRANKLIN ST

Number of Pedestrian Crashes	Intersecting Street Names
1	PRITCHARD AVE EXT & TRINITY CT
1	PRITCHARD AVE EXT & W LONGVIEW ST
1	RALEIGH RD & COUNTRY CLUB RD & SOUTH RD
1	RALEIGH ST & COBB DR
1	S COLUMBIA ST & W CAMERON AVE
1	S ESTES DR & COMMUNITY CENTER DR
1	S MERRITT MILL RD & PARK PL
1	STADIUM DR & SOUTH RD
1	W POPLAR AVE & DAVIE RD
1	W ROSEMARY ST & CHURCH ST
1	WEAVER DAIRY RD & WEATHERSTONE DR
1	WESTBROOK DR & BEECHWOOD DR
76	Total Intersection Collisions

Pedestrian Intersection Safety Index Model

Ped ISI = 2.372 – 1.867**SIGNAL** – 1.807**STOP** + 0.335**THRULNS** + 0.018**SPEED** + 0.006(**MAINADT*SIGNAL)** + 0.238**COMM**

where:

Ped ISI	*Safety index value (pedestrian)*	
SIGNAL	Signal controlled crossing	0 = no 1 = yes
STOP	Stop sign controlled crossing	0 = no 1 = yes
THRULNS	Number of through lanes on street being crossed (both directions)	1, 2, 3, …
SPEED	85^{th} percentile speed of street being crossed	Speed in mph
MAINADT	Main street traffic volume	ADT in thousands
COMM	Predominant land use on surrounding area is commercial development (i.e., retail, restaurants, etc)	0 = not predominantly commercial area 1 = predominantly commercial area

“Ped ISI and Bike ISI were developed at urban and suburban intersections with the following characteristics:

- Three-leg and four-leg intersections.
- Signalized, two-way stop, and four-way stop.
- Traffic volumes from 600 to 50,000 vehicles per day.
- One-way and two-way roads.
- One to four through lanes.
- Speed limits from 24.1 to 72.4 kilometers per hour (km/h) (15 to 45 miles per hour (mi/h)).

Ped ISI and Bike ISI are used most appropriately at intersections that meet the above ranges. Safety index values produced for intersections with characteristics outside these ranges should be used only with the understanding that the models were not developed using intersections of that type (Carter, et al., 2007).”

Pedestrian Intersection Safety Index Ratings, No. of Collisions, and No. of Perceived Risk Points for a Sample of Intersections with Crash or Perception Points

Ped_ISI Highest	No. Ped Collisions	No. Ped Perception Points	Intersecting Street Names
5.1	0	6	MARTIN LUTHER KING JR BLVD & NORTH ST & N COLUMBIA ST
3.9	4	1	RALEIGH RD & HAMILTON RD
3.9	2	3	MANNING DR & PITTSBORO ST & UNIVERSITY DR
3.4	1	4	MARTIN LUTHER KING JR BLVD & UMSTEAD DR & HILLSBOROUGH ST
3.4	0	14	E FRANKLIN ST & S ESTES DR & N ESTES DR
3.4	0	6	MARTIN LUTHER KING JR BLVD & N ESTES DR & ESTES DR EXT
3.4	0	7	MARTIN LUTHER KING JR BLVD & WEAVER DAIRY RD & WEAVER DAIRY RD EXT
3.3	3	1	S ESTES DR & WILLOW DR & CAMELOT DR
3.3	1	8	FORDHAM BLVD & EPHESUS CHURCH RD & EASTGATE SHOPPING CENTER & SERVICE RD
3.3	1	3	FORDHAM BLVD & WILLOW DR
3.3	1	4	S ESTES DR & FORDHAM BLVD
3.3	0	4	E FRANKLIN ST & ELLIOTT RD & N ELLIOTT RD
3.3	0	6	SMITH LEVEL RD & PUBLIC WORKS DR
3.1	4	20	E FRANKLIN ST & W FRANKLIN ST & N COLUMBIA ST
3.1	0	9	FORDHAM BLVD & MANNING DR
2.9	2	3	N COLUMBIA ST & E ROSEMARY ST & W ROSEMARY ST
2.9	2	0	NC 54 & W POPLAR AVE
2.8	2	0	MANNING DR & HIBBARD DR & EMERGENCY DR
2.8	2	0	MANNING DR & PAUL HARDIN DR
2.8	2	5	MANNING DR & RIDGE RD & SKIPPER BOWLES DR
2.8	2	1	W FRANKLIN ST & CHURCH ST
2.7	2	7	E MAIN ST & E WEAVER ST & ROBERSON ST
2.4	1	7	W CAMERON AVE & S COLUMBIA ST
2.1	2	7	N GREENSBORO ST & S GREENSBORO ST & E MAIN ST & W MAIN ST
2.1	0	0	N GREENSBORO ST & N GREENSBORO ST & SHELTON ST
2.0	2	0	LEGION RD & FORSYTH DR
2.0	0	2	RALEIGH ST & CAMERON AVE & COUNTRY CLUB RD

The intersections are ranked in order of highest ISI ranking for any pedestrian crossing of each respective intersection. The intersections highlighted in gray are the top 13 with respect to crashes (2 or more). As can be seen, a number of the intersections with higher ISI rankings have had no crashes or only 1 crash (during the study period). The intersection tied for the highest number of crashes (4) and with the highest number of perceived risk points (20, Franklin and Columbia) has a 5th highest index rating of 3.1, a rating significantly below the highest rating of 5.1 for Martin Luther King, Columbia, & North St intersection. The other intersection with 4 collisions (Raleigh Rd and Hamilton Rd) and 1 perceived risk point had the second highest index rating (3.9).

Appendix D: Bicycle Intersection Collisions and Intersection Safety Index Ratings

Bicycle Intersection Safety Index models

Through	Bike ISI = 1.13 + 0.019**MAINADT** + 0.815**MAINHISPD** + 0.650**TURNVEH** + 0.470(**RTLANES***BL**) + 0.023(**CROSSADT***NOBL**) + 0.428(**SIGNAL***NOBL**) + 0.200**PARKING**	
Right Turn	Bike ISI = 1.02 + 0.027**MAINADT** + 0.519**RTCROSS** + 0.151**CROSSLNS** + 0.200**PARKING**	
Left Turn	Bike ISI = 1.100 + 0.025**MAINADT** + 0.836**BL** + 0.485**SIGNAL** + 0.736(**MAINHISPD***BL**) + 0.380(**LTCROSS***NOBL**) + 0.200**PARKING**	
where:		
Bike ISI	*Safety index values (through, right, left)*	
BL	Bike lane presence	0 = NONE or WCL 1 = BL or BLX
CROSSADT	Cross street traffic volume	ADT in thousands
CROSSLNS	Number of through lanes on cross street	1, 2, …
LTCROSS	Number of traffic lanes for cyclists to cross to make a left turn	0, 1, 2, …
MAINADT	Main street traffic volume	ADT in thousands
MAINHISPD	Main street speed limit ≥ 35 mph	0 = no 1 = yes
NOBL	No bike lane present	0 = BL or BLX 1 = NONE or WCL
PARKING	On-street parking on main street approach	0 = no 1 = yes
RTCROSS	Number of traffic lanes for cyclists to cross to make a right turn	0, 1, 2, …
RTLANES	Number of right turn traffic lanes on main street approach	0, 1
SIGNAL	Traffic signal at intersection	0 = no 1 = yes
TURNVEH	Presence of turning vehicle traffic across the path of through cyclists	0 = no 1 = yes

"Ped ISI and Bike ISI were developed at urban and suburban intersections with the following characteristics:

- Three-leg and four-leg intersections.
- Signalized, two-way stop, and four-way stop.
- Traffic volumes from 600 to 50,000 vehicles per day.
- One-way and two-way roads.
- One to four through lanes.
- Speed limits from 24.1 to 72.4 kilometers per hour (km/h) (15 to 45 miles per hour (mi/h)).

Ped ISI and Bike ISI are used most appropriately at intersections that meet the above ranges. Safety index values produced for intersections with characteristics outside these ranges should be used only with the understanding that the models were not developed using intersections of that type" (Carter et al., 2007).

Intersections with Bicycle Collisions (determined to be an intersection crash in PBCAT and is within 100' buffer of the intersection center).

No. of Bike Crashes	Intersecting Street Names
3	MARTIN LUTHER KING JR BLVD & N ESTES DR & ESTES DR EXT
2	E FRANKLIN ST & W FRANKLIN ST & N COLUMBIA ST
2	MARTIN LUTHER KING JR BLVD & LONGVIEW ST
2	N ROBERSON ST & MCDADE ST & MITCHELL LN
2	RALEIGH ST & SOUTH RD
2	SOUTH RD & BELL TOWER DR
2	SYKES ST & GOMAINS AVE
2	W FRANKLIN ST & N GRAHAM ST & S GRAHAM ST
2	W ROSEMARY ST & E MAIN ST
1	DAIRYLAND RD & UNION GROVE CHURCH RD
1	E FRANKLIN ST & ELLIOTT RD & N ELLIOTT RD
1	E FRANKLIN ST & COUCH RD
1	E FRANKLIN ST & DAVIE CIR
1	E FRANKLIN ST & HILLSBOROUGH ST & RALEIGH ST
1	E FRANKLIN ST & N BOUNDARY ST & S BOUNDARY ST
1	E MAIN ST & BOYD ST
1	E MAIN ST & BREWERS LN
1	E MAIN ST & E WEAVER ST & ROBERSON ST
1	E ROSEMARY ST & HENDERSON ST
1	EDGEWATER CIR & BROOKEGREEN DR
1	FIDELITY ST & BIM ST
1	FORDHAM BLVD & CLELAND DR & CHRISTOPHER RD
1	FORDHAM BLVD & EASTGATE SHOPPING CENTER RD & EPHESUS CHURCH RD & SERVICE RD
1	FORDHAM BLVD & ESTES DR
1	FORDHAM BLVD & WILLOW DR
1	FULTON WAY & WEAVER DAIRY RD EXT
1	HILLSBOROUGH ST & BOLINWOOD DR
1	JONES FERRY RD & NC 54 OFF RAMP & NC 54 ON RAMP & JONES FERRY RD
1	MANNING DR & PITTSBORO ST & UNIVERSITY DR
1	MANNING DR & RIDGE RD & SKIPPER BOWLES DR
1	MANNING DR & SKIPPER BOWLES DR & MANNING DR
1	MARTIN LUTHER KING JR BLVD & BARCLAY RD
1	MARTIN LUTHER KING JR BLVD & HILLSBOROUGH ST & UMSTEAD DR
1	N ELLIOTT RD & MICHAUX RD
1	N GREENSBORO ST & E WEAVER ST & W WEAVER ST
1	N GREENSBORO ST & SHELTON ST
1	PUREFOY DR & ROGERS RD
1	RALEIGH RD & HAMILTON RD & S HAMILTON RD & RALEIGH RD & RALEIGH RD
1	S COLUMBIA ST & SOUTH RD & MCCAULEY ST
1	S MERRITT MILL RD & EDWARDS ST
1	W CAMERON AVE & S ROBERSON ST
1	W FRANKLIN ST & MALLETTE ST
1	W MAIN ST & JONES FERRY RD
1	W ROSEMARY ST & CHURCH ST
1	W ROSEMARY ST & N ROBERSON ST
55	Total Intersection Collisions

Bike_ISI Highest*	No. of Bike Collisions	No. Bike Perception Pts	Intersecting Street Names
4.4	0	3	FORDHAM BLVD & MANNING DR
4.3	0	3	FORDHAM BLVD & CHAPEL HILL BLVD & ERWIN RD
4.2	1	1	FORDHAM BLVD & ESTES DR
4.2	1	0	RALEIGH RD & HAMILTON RD & S HAMILTON RD
3.9	0	3	E FRANKLIN ST & S ESTES DR & N ESTES DR
3.9	1	1	FORDHAM BLVD & WILLOW DR
3.8	3	4	MARTIN LUTHER KING JR BLVD & N ESTES DR & ESTES DR EXT
3.7	1	1	E FRANKLIN ST & ELLIOTT RD & N ELLIOTT RD
3.7	1	2	MARTIN LUTHER KING JR BLVD & UMSTEAD DR & HILLSBOROUGH ST
3.4	0	4	HOMESTEAD RD & OLD NC 86 & DAIRYLAND RD & OLD NC 86
3.4	1	0	W MAIN ST & JONES FERRY RD
3.3	0	1	S COLUMBIA ST & SOUTH RD & MCCAULEY ST
3.3	2	5	W FRANKLIN ST & E FRANKLIN ST & N COLUMBIA ST & S COLUMBIA ST
3.3	2	0	W FRANKLIN ST & N GRAHAM ST & S GRAHAM ST
3.1	0	9	CAMERON AV & S COLUMBIA ST
3.1	0	2	MANNING DR & S COLUMBIA ST & S COLUMBIA ST & MANNING DR
3.1	0	3	SMITH LEVEL RD & PUBLIC WORKS DR
3.0	2	0	E LONGVIEW ST & MARTIN LUTHER KING JR BLVD
3.0	0	4	NORTH ST & N COLUMBIA ST & MARTIN LUTHER KING JR BLVD
2.8	0	1	E MAIN ST & LLOYD ST
2.8	0	3	E MAIN ST & W MAIN ST & N GREENSBORO ST & S GREENSBORO ST
2.8	0	0	HILLSBOROUGH RD & N GREENSBORO ST
2.7	1	5	MAIN ST WEAVER ST & ROBERSON ST
2.7	1	3	N GREENSBORO ST & E WEAVER ST & W WEAVER ST
2.7	2	1	W ROSEMARY ST & E MAIN ST
2.6	2	1	RALEIGH ST & SOUTH RD
2.6	0	4	S MERRITT MILL RD & W CAMERON AVE
2.2	0	1	N GREENSBORO ST & TODD ST
2.1	0	3	W CAMERON AVE & KENAN ST
1.9	2	0	MCDADE ST & MITCHELL LN & N ROBERSON ST
1.7	2	0	SYKES ST & GOMAINS AVE
n/a	1	0	BARCLAY, BARCLAY, MARTIN LUTHER KING JR, MARTIN LUTHER KING JR
n/a	1	0	BOUNDARY, BOUNDARY, FRANKLIN, FRANKLIN
n/a	1	1	BREWERS

*****The intersections are ranked in order of highest ISI ranking (which indicates greater priority for further assessment) of any approach leg. The intersections highlighted in gray are the eight intersections with the highest number, 2 or more, or bicycle collisions. As with the pedestrian index, the intersections with the higher index rankings are not necessarily those where the most crashes have been observed, although the single intersection with the highest number of crashes, Martin Luther King Jr Blvd and Estes Dr with 3, did have a relatively high index of 3.8 (5^{th} highest). Of the top 10 intersections for collisions, only 1 is in the top 10 for ISI rating. The ratings again tend to be higher for intersections of multi-lane arterials, and traffic volume and speed, presence of traffic signals, presence of bike lanes were important predictors of perceived safety of an intersection by the expert raters. As seen in the model, the index also captures elements of potential conflicts such as number of lanes to merge across to make right and left turns, as well as potential conflicts for through bicyclists with right-turning vehicles. Not captured are elements such as bicycle detection for smaller streets, signal timing, unusual geometrics, or other conditions (sight distance problems) that might affect bicycle safety at an intersection. The tool, is intended to be a broad brush, proactive indicator of intersections that might warrant further investigation, but would not capture all intersections that might need a detailed audit. The general results, again, support conducting further assessment of larger, intersections involving higher volume, higher speed streets, and particularly those with more lanes to merge across for left or right turns, or those with conflicting right turning movements for through bicyclists.

Appendix E: Speed Data Summaries for All Sites

Location	Survey Date	Survey Time	Posted SpeedLimit	Average	Minimum	Maximum	50th%	85th%	n*
S Columbia north of Merritt's Store, southbound	3/3/2008	10:03 AM	35	34.8	21	43	35	39	100
Dairyland and Old NC 86, eastbound and westbound	2/20/2008	1:51 PM	45	47.39	20	70	48	52	100
Erwin Rd north of Chip Oaks, southbound	2/27/2008	10:12 AM	35	49.61	36	66	49	56	100
Estes between Fordham & Willow	2/19/2008	2:00 PM	35	37.93	28	48	38	42	100
Estes ext. south of Seawell Sch Rd, sb/westbound	2/25/2008	10:32 AM	35	43.74	35	62	43	48	100
Fordham Blvd near Manning, northbound	2/15/2008	1:38 PM	45	51.02	41	61	51	55	100
Fordham Blvd near Manning, southbound	2/15/2008	2:05 PM	45	46.81	36	61	47	52	106
Fordham Blvd near Old Mason Farm, northbound	3/17/2008	7:00 PM	45	47.81	29	60	48	52	100
Fordham Blvd near Old Mason Farm, southbound	3/17/2008	6:31 PM	45	48.91	40	67	48	55	100
Franklin @ near Mallette, westbound	3/4/2008	10:43 AM	20	29.17	10	41	29	34	100
Franklin @ near Davie Circle, eastbound	2/29/2008	9:38 AM	35	41.36	34	53	41	45	100
Franklin @ near Estes, westbound	2/29/2008	10:11 AM	35	38.21	27	47	39	42	100
N Greensboro near Hillsborough St, northbound	3/3/2008	2:55 PM	35	34.93	26	49	35	38	100
N Greensboro near Harris Teeter, southbound	7/9/2008	2:06 PM	20	26.48	18	37	27	31	50
S Greensboro between Old Pittsboro & Merritt Mill	7/1/2008	3:05 PM	35	39.13	28	49	39	44	100
Homestead near High Sch Rd, westbound	2/21/2008	1:58 PM	35	42.15	25	53	42	46	100
Jones Ferry Rd w of Davie, westbound	6/26/2008	4:24 PM	35	35.95	25	50	36	39	100
Main between Rosemary and Weaver	7/7/2008	2:40 PM	20	24.49	14	36	24	28	100
Manning @ near Ridge, westbound	3/3/2008	10:56 AM	25	27	18	37	27	32	100
Martin Luther King Jr near Hillsborough, southbound	3/3/2008	2:07 PM	35	41.51	34	53	41	45	100
Martin Luther King Jr near Longview, northbound	3/4/2008	10:02 AM	35	41.41	21	61	41	47	100
Martin Luther King Jr betw. Homestead & Estes	2/4/1900	10:41 AM	35	41.43	21	58	42	46	103
Martin Luther King Jr near Weaver Dairy,northbound	2/29/2008	2:23 PM	35	43.5	34	55	43	58	105
Martin Luther King Jr near Weaver Dairy,northbound	3/17/2008	5:51 PM	35	43.32	34	55	43	48	100
Old NC 86 and Dairyland/Homestead (bidirectional)	2/21/2008	1:23 PM	45	46.24	33	57	46	50	100
NC 54 bypass @ Kingswood Apts., eastbound	3/4/2008	2:10 PM	45	51.35	40	63	51	55	100
NC 54 bypass near Poplar	6/30/2008	4:11 PM	45	48.8	38	61	49	54	100
NC 54/Raleigh Rd between Hamilton & Burning Tree, eastbound	2/19/2008	10:00 AM	35	43.28	34	57	43	49	100
NC 54/Raleigh Rd between Hamilton & Burning Tree, westbound	2/29/2008	11:15 AM	35	42.69	31	55	42	48	100
Rosemary between Mitchell and Amity, eastbound	6/25/2008	3:06 PM	25	30.52	21	42	30	34	100
Seawell Sch Rd, 0.5 mi south of High School Rd, southbound	2/21/2008	3:00 PM	35	42.17	31	54	42	47	100
Smith Level Rd, between Ray and Damascus Ch, southbound	2/19/2008	2:45 PM	35	45.73	34	52	45	50	100
Weaver Dariy near Weatherstone, eastbound	2/29/2008	2:58 PM	35	41.51	32	55	41	46	100
*free-flowing vehicles									

Appendix F: Considerations Regarding Study Methods

Analysis of crash data is an important first step in determining both problem locations, and types of problems that are occurring in a community. The results of this study certainly were used in both ways, and should continue to inform identification and development of engineering *and* behavioral countermeasures such as enforcement and education. Crashes in general, and pedestrian and bicycle collisions, in particular have, however, a large random component, so that targeting only crash “black spots” leaves other areas with similar deficiencies open to future crashes. Thus, an important component of this study was an attempt to proactively identify other locations with safety problems, using public perception to do so.

From the analyses of perceived risk locations identified by the survey respondents, we were able to identify many additional locations that have not experienced significant crashes yet. These locations, when visited were found to also have significant safety problems. There are a number of reasons that there may be significant non-overlap between areas of crashes and areas perceived to be unsafe, (including areas identified by Chapel Hill and Carrboro for improvements that have not experienced significant crashes yet). The primary areas of overlap are likely related to where the greatest numbers of pedestrians or bicycles travel (exposure in terms of numbers). Another explanation includes the fact that safety or expected crashes in areas of less exposure (walking or bicycling) will be even more ‘stochastic’ in nature. This does not mean these locations are ‘safe’ (exposure to hazardous conditions) but that the frequency of crashes is less predictable in these areas than in areas with large amounts of bicycling or walking. Or, there may have been crashes during time intervals outside of the study interval.

In some areas, the crash rates based on numbers of pedestrians or bicyclists are higher in areas with fewer pedestrians and cyclists than in areas of more walking and bicycling. Thus, relative risk per individual is higher in some areas with low crash numbers and crash density but high perception density. Areas perceived as very unsafe may also generate changes in behaviors that reduce risk exposure or the incidence of actual crashes. These changes could include avoiding the area altogether, or taking extra precautions when walking, cycling, and even driving in the area. These possibilities were also raised by Cho, Rodriguez, and Khattak (2009).

Such areas may also be locations where motorists may have a low expectation of pedestrians or cyclists, because of the appearance of the roadway environment, and because pedestrians and bicyclists are less common (Zegeer and Sandt, 2006). As a result, such locations may present a high risk of the “first” collision resulting in a fatality, as has been observed with several fatal crashes that have occurred since the study period.

Another issue pointed out by Schneider et al. (2004), is whether the general public can accurately identify unsafe locations. As yet, we do not have a definitive answer to this question. Although safety issues were identified at virtually every perception location visited, this may be as much a function of the safety issues throughout the study area as of ‘expertise’ to identify particularly unsafe locations on the part of the public. The many areas that have experienced significant crashes, and that had significant safety issues that were not identified as unsafe raises valid questions in this regard. It is likely that some respondents have better judgment than others about safety issues. It is also likely that the results are to some extent a function of whom was surveyed.

Another issue regarding using survey data to identify and prioritize locations results from the methodology. Each survey methodology has weaknesses. One advantage of the methodology adapted – a convenience sample through an intercept survey conducted at locations across the study area – is that a high percentage of people encountered responded, and we were also able to obtain a relatively large sample of around 400 respondents. A high response rate does not rule out bias, but it may limit the extent of self-selection bias that might occur through a mail, phone, or internet survey, even one that is meant to be a representative sample. A disadvantage of the intercept survey is that it was not a random sample of all area residents/travelers and consequently may also lack proportional representation of exposure to the areas' street network. However, there is little reason to think that a random sample would generate an equal level of response or more knowledgeable responses. In fact, the opposite might be true. Nevertheless, given that the data from the survey result from a combination of who was surveyed (and who responded), where they travel (exposure), and the locations where they have experienced problems themselves or that they perceive to be unsafe for bicyclists or pedestrians, some areas may not have received equal consideration. Although an attempt was made to provide geographic coverage of the study area, it was difficult to find suitable survey locations in some areas, and thus people who travel in those areas may not have been well-represented. The lack of suitable locations to survey may also suggest that there is little opportunity for walking or bicycling in these areas.

Thus, it should be kept in mind that this study does not purport to have assessed bicycle and pedestrian safety for the entire street network of the study area. There could be serious safety problems in other areas that simply did not come to our attention. For example, several particular areas that were identified by the Towns for improvements were not identified in the spatial analyses of perception or crash data. These locations also tended to be on high speed, high volume, multi-lane corridors spanned by residential and commercial areas on both sides, and served by transit, and where basic crossing amenities are not available at intersections and/or intersections are few and far between. Thus significant safety issues exist, but these locations were not identified by the survey respondents, nor have they experienced crashes yet.

In conducting safety audits, we also strongly recommend conducting several visits per audited area at different times of day and to allow observations under different traffic flows, light conditions, and other circumstances. (HSRC staff did revisit a most areas at night, and at several other times in addition to the visits conducted with DOT. It would be preferable to do this as a team.) In conducting the audits, it is also likely that we did not focus the same level of attention to both bicycle and pedestrian issues throughout each audit. In addition, multiple visits would allow the opportunity to look again for things that might have been overlooked, even with the guidance of a checklist. For example, signal phasing and timing considerations could be assessed with more detail.