North Carolina
Bicycle Crash Types
2012 - 2016

Prepared for

The North Carolina Department of Transportation
Division of Bicycle and Pedestrian Transportation

THE UNIVERSITY OF NORTH CAROLINA
HIGHWAY SAFETY RESEARCH CENTER

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Contents

Figures

Tables

Introduction and Purpose

During the five-year period of 2012-2016, 4,677 bicycle-motor vehicle crashes were reported to the North Carolina Division of Motor Vehicles. A total of 106 crashes led to a cyclist fatality with another 194 resulting in disabling injury for a cyclist.[1] See the companion *North Carolina Bicycle Crash Facts* report for a summary of bicyclist injuries and fatalities.

This report summarizes bicycle-motor vehicle crash information developed for 2012-2016 for the entire State. As noted in the North Carolina Bicycle Crash Facts summary report, there is likely an undercount of bicycle-motor vehicle crashes that occurred between 2012 and 2015 due to issues involving crash reporting in some jurisdictions that affected the identification of crashes involving bicyclists. For the data obtained, UNC Highway Safety Research Center staff reviewed diagrams and narratives and other details on copies of the crash report forms submitted to NCDOT, and used PBCAT software to code crash type, bicyclist position and direction, and crash location variables for each bicycle-motor vehicle crash. These data elements were combined with the crash data elements already available from the State's crash database. The results of analyzing the crash group data and other elements are summarized in the tables, figures, and text in the following sections.

This report provides information about typical safety issues across the state and suggests types of countermeasures that might be appropriate. Local agencies can use the information as a guide to analyze and understand their own specific crash issues and potential treatments. The information is for summary purposes only. Appropriate risk assessment, diagnosis and other procedures are necessary before implementing treatments at any location.

Background on Crash Typing

The information from the State crash report forms (DMV-349) and reported by public safety officials across the State is stored in electronic crash databases. Analysis of these data can provide information on *where* bicycle-motor vehicle crashes occur (e.g., city street, two-lane roadway, intersection location, etc.), *when* they occur (e.g., time of day, day of week, etc.), and *to whom* they occur (e.g., age of victim, gender, level of impairment).

However, the data contained in the crash database provides little information about the actual sequence of events leading to crashes between bicyclists and motor vehicles. The development of effective countermeasures to help prevent and reduce the severity of these crashes is limited by this lack of detail. To address this situation, the National Highway Traffic Safety Administration (NHTSA) developed a system of "typing" pedestrian and bicycle crashes. Each identified crash type is defined by a specific sequence of events, and each may have precipitating actions or behaviors, predisposing factors, and characteristic populations and/or locations that can be targeted for interventions. The original pedestrian crash typology was developed and applied during the early 1970's (Snyder and Knoblauch 1971; Knoblauch 1977; Knoblauch, Moore and Schmitz 1978). Cross and Fisher (1977) later developed a similar typology for bicycle crashes. A Federal Highway Administration (FHWA) study in the 1990s contributed to the evolution of the current PBCAT typologies with a somewhat greater focus on roadway location elements (Hunter et al., 1996). Following the FHWA study, Harkey, Mekemson, Chen, and Krull (2000) created the Pedestrian and Bicycle Crash Analysis Tool (PBCAT) that enabled both pedestrian and bicycle crash typing to be done by software. Harkey et al. updated this tool in 2006 in a

[1] These numbers reflect crashes that involved one or more fatalities or disabling injuries and does not capture if more than one bicyclist was struck and killed or injured.

project also sponsored by FHWA. The 2006 version of PBCAT has been used to type crashes from 2007 - 2016.

For more information on PBCAT and crash typing, including detailed descriptions and images of typical crash scenarios, see the PBCAT webpage. BIKESAFE: Bicycle Countermeasure Selection System, also sponsored by FHWA, is a companion tool that helps to identify potentially appropriate countermeasures for the types of crashes (and other problems identified by analyzing data from PBCAT and state crash files. The PBCAT crash groups provide a better match to BIKESAFE categories than the more specific crash types. Other FHWA tools that can assist with diagnosing problems are the North Carolina Pedestrian and Bicycle Road Safety Assessment Guide (Thomas et al. 2018) and the Bicycle Road Safety Audit Guidelines and Prompt Lists (Nabors et al. 2012). More resources are mentioned in the final section of this report, and in the crash facts summary report.

Crash Events and Description

This report examines crash groups instead of the more specific crash types, and the relationship of other variables to these groups. Some police reports are not detailed enough to arrive at a crash type (for example, being unclear as to a motorist's or cyclist's actions in an overtaking collision) leaving a coder to select "other/unknown." In previous years, it was discovered that due to numerous specific crash types, some with very low frequency, it can be challenging to identify trends and patterns that may provide the largest targets for treatment. Additionally, countermeasures can be developed based on the broader crash groups.

Crash Group

Table 1 shows a listing of 20 crash groups generated by the coding for each of the five years with their totals and percentages organized by prevalence. *Motorist Overtaking Bicyclist* is the most prevalent group over the study period with more than twice the frequency of the next group, *Motorist Left Turn or Merge* (turning across the path of a through bicyclist). Motorist overtaking crashes include situations where the motorist and cyclist were on a parallel path prior to the crash, or any turns to avoid a crash, with the motorist travelling at a faster speed than the cyclist.

The names of crash groups are reasonably self-explanatory, but more details as to the meaning of each crash group, and the more specific crash types associated with each group, are available on the PBCAT software web page, in the manual that accompanies in the software.

There is year-to-year variability in the frequencies and proportions of each crash group, especially those with smaller numbers. Much of this variation is likely explained by chance, but some variation is potentially attributable to changes in riding amounts, locations, and behaviors including effects of roadway treatments or education and enforcement measures. Numbers in some categories may vary somewhat due to different interpretations of information available in crash reports that is used to type the crashes. Additionally, note that the Other / Unknown – Insufficient details group was combined with Other / Unusual Circumstances group (from PBCAT) into *Other / Unknown* for this table.

Table 1 NC bicyclist crash group by year, 2012-2016 [2]

Crash group	2012	2013	2014	2015	2016	Total
Motorist Overtaking Bicyclist	204	183	158	208	193	946
	20.0[1]	20.4	18.6	21.9	20.2	20.2[2]
Motorist Left Turn / Merge	92	97	83	76	93	441
	9.0	10.8	9.8	8.0	9.7	9.4
Motorist Failed to Yield – Sign-Controlled Intersection	102	83	90	71	91	437
	10.0	9.3	10.6	7.5	9.5	9.4
Motorist Failed to Yield - Midblock	67	49	71	95	88	370
	6.6	5.5	8.4	10.0	9.2	7.9
Bicyclist Failed to Yield - Midblock	55	50	54	77	65	301
	5.4	5.6	6.4	8.1	6.8	6.4
Crossing Paths – Other Circumstances	80	47	23	65	60	275
	7.8	5.2	2.7	6.8	6.3	5.9
Bicyclist Failed to Yield – Sign-Controlled Intersection	73	50	48	43	39	253
	7.2	5.6	5.6	4.5	4.1	5.4
Bicyclist Failed to Yield – Signalized Intersection	48	53	43	57	50	251
	4.7	5.9	5.1	6.0	5.2	5.4
Motorist Right Turn / Merge	44	44	51	44	49	232
	4.3	4.9	6.0	4.6	5.1	5.0
Loss of Control / Turning Error	54	39	54	24	35	206
	5.3	4.3	6.4	2.5	3.7	4.4
Non-Roadway	31	46	38	35	47	197
	3.0	5.1	4.5	3.7	4.9	4.2
Motorist Failed to Yield – Signalized Intersection	33	33	31	42	29	168
	3.2	3.7	3.6	4.4	3.0	3.6
Bicyclist Left Turn / Merge	39	28	35	28	30	160
	3.8	3.1	4.1	2.9	3.1	3.4
Head-On	28	14	28	19	30	119
	2.7	1.6	3.3	2.0	3.1	2.5
Bicyclist Overtaking Motorist	21	22	23	21	16	103
	2.1	2.5	2.7	2.2	1.7	2.2
Parallel Paths – Other Circumstances	16	27	5	18	13	79
	1.6	3.0	0.6	1.9	1.4	1.7
Other / Unknown	11	11	6	11	12	51
	1.1	1.2	0.7	1.2	1.3	1.1
Bicyclist Right Turn / Merge	11	10	5	9	9	44
	1.1	1.1	0.6	0.9	0.9	0.9
Backing Vehicle	10	11	3	7	4	35
	1.0	1.2	0.4	0.7	0.4	0.7
Parking / Bus-Related	1	0	1	1	2	5
	0.1	0.0	0.1	0.1	0.2	0.1
Total	1,020	897	850	951	955	4,673[4]
	21.8[3]	19.2	18.2	20.4	20.4	

[2] The format for this and subsequent tables, unless otherwise noted:
[1] = Row percent of yearly (column) total
[2] = Row total percent of total
[3] = Column total percent of total
[4] = Total in each table is based on cases with no missing data for that variable

The remaining analyses focuses on those crashes that occurred on the roadway system (and excludes those where the crash location was indicated to be 'non-roadway' or was unknown (194 collisions). A much smaller proportion of bicycle collision than pedestrian collisions are reported from parking lots and other non-roadway areas. The remainder of this report focuses on crashes that occurred on or along roadways that are under the purview of state and local transportation system providers.

Crash Group and Severity

An average of 2.4 percent of all crashes resulted in fatal injuries and 4.2 percent in disabling (A-category on the KABCO scale) injuries (Table 2).

Motorist Overtaking Bicyclist is the group that is also most highly represented among crashes resulting in fatal or disabling injury by a substantial margin. Close to 40 percent of all crashes resulting in a fatal or disabling injury are in this group, more than 5 times as many as the next most prevalent groups. Other types of crashes that are over-represented for fatal and disabling injuries compared to all types include ***Bicyclist Failed to Yield at Sign-Controlled Intersection*** and ***Bicyclist Left Turn/Merge*** (and struck by a parallel path motorist). ***Bicyclist Failed to Yield Midblock*** and ***Loss of Control/Turning Errors*** were also somewhat over-represented for severe crashes. The 198 reported non-roadway (parking lot, driveway, and other non-roadway areas) crashes and crashes with an unknown location are excluded from the following analyses.

Table 2 Crash group and bicyclist injury severity (reported status of injury) - roadway crashes

Crash Group	Fatal Injury	Disabling Injury	Fatal + Disabling	% of Fatal and Disabling Injury [i]	Other/ Unknown Injury	Total	% of Col. Total [ii]
Motorist Overtaking Bicyclist	52	64	116	39.5%	832	948	21.2%
Motorist Left Turn / Merge	4	17	21	7.1%	420	441	9.8%
Motorist Failed to Yield – Sign-Controlled Intersection	3	6	9	3.1%	428	437	9.8%
Motorist Failed to Yield – Midblock	1	6	7	2.4%	363	370	8.3%
Bicyclist Failed to Yield – Midblock	6	15	21	7.1%	281	302	6.7%
Crossing Paths – Other Circumstances	4	6	10	3.4%	265	275	6.1%
Bicyclist Failed to Yield – Sign-Controlled Intersection	5	16	21	7.1%	232	253	5.6%
Bicyclist Failed to Yield – Signalized Intersection	3	12	15	5.1%	236	251	5.6%
Motorist Right Turn / Merge	0	6	6	2.0%	225	231	5.2%
Loss of Control / Turning Error	7	8	15	5.1%	192	207	4.6%
Motorist Failed to Yield – Signalized Intersection	1	0	1	0.3%	166	167	3.7%
Bicyclist Left Turn / Merge	7	13	20	6.8%	140	160	3.6%
Head-On	8	8	16	5.4%	104	120	2.7%
Bicyclist Overtaking Motorist	0	2	2	0.7%	101	103	2.3%
Parallel Paths – Other Circumstances	2	1	3	1.0%	76	79	1.8%
Bicyclist Right Turn / Merge	3	2	5	1.7%	39	44	1.0%
Backing Vehicle	0	0	0	0.0%	35	35	0.8%
Other / Unusual Circumstances	0	5	5	1.7%	25	30	0.7%
Other / Unknown – Insufficient Details	0	1	1	0.3%	20	21	0.5%
Parking / Bus-Related	0	0	0	0.0%	5	5	0.1%
Total	106	188	294	100%	4,185	4,479	100.0%
	2.4%	4.2%	6.6%		93.4%	100.0%	

[i] Percent of total fatal and disabling crashes, [ii] Percent of total crashes. The format in this tables differs from the previous.
Highlights indicate crash types that account for higher percentages of fatal / disabling crashes compared to their overall representation.

Roadway Location and Rural / Urban Setting

The injury severity trends of different types of crashes may be affected by a combination of factors including where these crashes typically occur, mediated by other specific circumstances. For example, while 64 percent of all roadway bicycle collisions involved a bicyclist who was riding in a regular traffic lane (as best can be determined from reviews of crash reports) just prior to the collision, 81 percent of crashes involving fatal or disabling injuries involved cyclists riding on these facility types (Table 3). The next most common location was crossing a driveway or alley connection. These tended to be associated with smaller proportions of severe (killed or disabling) injuries. Non-Roadway in this table indicates that the bicyclist was riding in a yard, or other off-roadway location, before riding into the road right-of-way and being struck. Similarly, Multi-Use Path implies that the cyclist approached the conflict area from a path facility.

Table 3 Bicyclist riding position just prior to crash and bicyclist injury status - roadway crashes

Bike Position prior to crash	Killed or Disabling Injury	Evident, Possible, No, or Unknown Injury	Total
Travel Lane	237	2,633	2,870
	80.6%	62.9%	64.1%
Sidewalk / Crosswalk / Driveway Crossing	10	848	858
	3.4%	20.3%	19.2%
Bike Lane / Paved Shoulder	21	280	301
	7.1%	6.7%	6.7%
Non-Roadway	4	107	111
	1.4%	2.6%	2.5%
Driveway / Alley	7	95	102
	2.4%	2.3%	2.3%
Multi-use Path	2	33	35
	0.7%	0.8%	0.8%
Other	2	29	31
	0.7%	0.7%	0.7%
Unknown	11	160	171
	3.7%	3.8%	3.8%
Total	294	4,185	4,479
	6.6%	93.4%	

Unlike what might be expected, when bicyclists were riding facing against the direction of adjacent traffic, they were less likely to be fatally or severely injured (Table 4). However, that is at least partly because bicyclists who were riding facing against the direction of adjacent traffic were most likely to be doing so (71% of the time) when on a sidewalk facility and least likely to be riding against traffic when riding in a regular traffic lane (17%) (Figure 1). As shown above, sidewalk riding was associated with much lower rates of fatal and disabling injuries. Riding on walkways may indicate discomfort with conditions on the roadway.

Table 4 Bicyclist riding direction relative to motorized traffic and injury status - roadway crashes

Bike Direction	Killed or Disabling Injury	Evident, Possible, No, or Unknown Injury	Total
Facing Traffic	42	1,111	1,153
	14.3%	26.5%	25.7%
Not Applicable	23	341	364
	7.8%	8.1%	8.1%
Unknown	9	138	147
	3.1%	3.3%	3.3%
With Traffic	220	2,595	2,815
	74.8%	62.0%	62.8%
Total	294	4,185	4,479
	6.6%	93.4%	

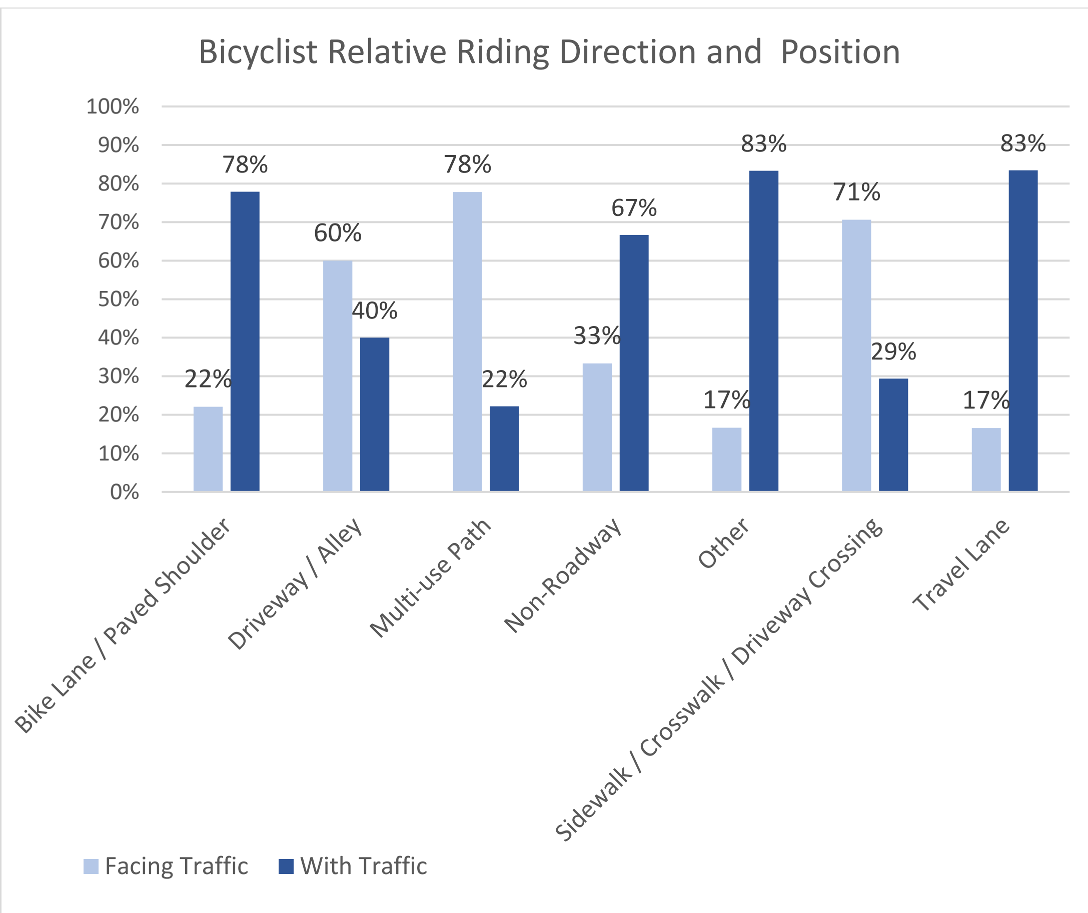

Figure 1 Bicyclist riding direction (when known and relevant) on different roadway facility types (n = 4,479).

A slight majority of roadway crashes occurred at an intersection (45%) or related or within 50 feet of an intersection (9%). Forty-seven percent occurred at a non-intersection location (Table 5).

Crashes that occurred at non-intersection locations were apt to be more severe (64% of killed and disabling compared to 47% of all severity of roadway crashes).

Table 5 Crash location and bicyclist injury status - roadway crashes only

Crash Location	Killed or Disabling Injury	Evident, Possible, No, or Unknown Injury	Total
Intersection	89	1,905	1,994
	30.3%	45.5%	44.5%
Intersection-Related	17	378	395
	5.8%	9.0%	8.8%
Non-Intersection	188	1,902	2,090
	63.9%	45.4%	46.7%
Total	294	4,185	4,479
	6.6%	93.4%	

As shown in Table 6, an average of 28 percent of all roadway crashes occurred in rural areas, but 53 percent of those involving bicyclists who were killed or injured occurred in rural areas. Seventy-two percent of all roadway crashes occurred in urban areas with 47 percent of killed and injured types in urban areas.

Table 6 Rural/Urban Setting and bicyclist injury status - roadway crashes only

Rural / Urban	Killed or Disabling Injury	Evident, Possible, No, or Unknown Injury	Total
Rural	157	1,103	1,260
	53.4%	26.4%	28.1%
Urban	137	3,082	3,219
	46.6%	73.6%	71.9%
Total	294	4,185	4,479
	6.6%	93.4%	

Rural / Urban Setting and Roadway Location

Besides being the most prevalent group of crashes overall, and also the type resulting in the most fatal and severe injuries across North Carolina, ***Motorist Overtaking Bicyclist*** is also the most prevalent crash group in both rural and urban areas (Table 7; percentages are not shown in this table to limit the table size for display purposes). These crashes largely occur at non-intersection (or midblock) locations in both rural and urban areas, although they also occur at or near intersections. Other prevalent combinations of crash type and location type are highlighted for the top six most frequent groups. Using the spatially-coded data, available from NCDOT to identify other prevalent factors, these crash groups, and others, depending on locally-specific crash types, may offer potential targets for a more systemic approach to

Table 7 Bicycle crash groups by rural/urban and roadway location (non-roadway crashes omitted)

Crash Group	Rural Inter-section	Intersec-tion-Related	Non-Intersec-tion	Rural Total	Urban Intersec-tion	Intersec-tion-Related	Non-Intersec-tion	Urban Total
Motorist Overtaking Bicyclist	18	25	483	526	43	89	290	422
Motorist Left Turn / Merge	59	4	28	91	270	19	61	350
Motorist Failed to Yield - Sign-Controlled Intersection	64	6	0	70	350	17	0	367
Motorist Failed to Yield - Midblock	0	0	46	46	0	0	324	324
Bicyclist Failed to Yield - Midblock	0	0	88	88	0	0	214	214
Crossing Paths - Other Circumstances	33	9	2	44	180	39	12	231
Bicyclist Failed to Yield - Sign-Controlled Intersection	52	4	0	56	184	13	0	197
Bicyclist Failed to Yield - Signalized Intersection	23	1	0	24	209	18	0	227
Motorist Right Turn / Merge	19	1	18	38	123	5	66	194
Loss of Control / Turning Error	23	11	31	65	74	28	40	142
Motorist Failed to Yield - Signalized Intersection	9	1	0	10	155	3	0	158
Bicyclist Left Turn / Merge	19	8	47	74	26	13	47	86
Head-On	4	3	42	49	12	13	45	70
Bicyclist Overtaking Motorist	2	0	16	18	15	15	55	85
Parallel Paths - Other Circumstances	2	2	13	17	11	17	34	62
Bicyclist Right Turn / Merge	2	4	16	22	2	6	14	22
Backing Vehicle	0	0	8	8	2	6	19	27
Other / Unusual Circumstances	2	1	9	12	5	5	8	18
Other / Unknown - Insufficient Details	1	1	0	2	1	6	11	18
Parking / Bus-Related	0	0	0	0	0	2	3	5
Totals	332	81	847	1,260	1,662	314	1,243	3,219

The most frequent combinations (above 100 crashes) are highlighted in yellow treatment.

More information is provided in the Additional Resources section at the end of this document. In addition, to address intersection crash types, a current NCHRP project is developing guidance for identification and treatment of intersections for bicycle and pedestrian safety. Watch for *Guidance to Improve Pedestrian and Bicyclist Safety at Intersections*.

Interactions of Crash Group with Initial Position and Direction of Bicyclist

Appendix A provides a table of crash groups by the initial position of the bicyclist. For the most prevalent crash group, ***Motorist Overtaking Bicyclist***, bicyclists were deemed to be riding in a shared travel lane 89 percent of the time, with only nine percent on a paved shoulder or bike lane. A sidewalk, crosswalk, or driveway crossing was the initial position in 64 percent of ***Motorist Failed to Yield – Midblock*** crashes***. Motorist Failed to Yield*** at ***Signalized*** and ***Sign-controlled*** intersections also involved significant proportions of sidewalk bicyclists. In 32 percent of ***Bicyclist Failed to Yield – Midblock*** crashes, a bicyclist rode out from a driveway, alley, or multi-use path (note that two position categories were combined for the table in Appendix A).

Bicyclist Direction of Travel

Table 8 isolates bicycle-motor vehicle crashes where the cyclist was riding either with (the preferred direction) or facing traffic. Collisions where the cyclist's direction of travel was not applicable (for instance, exiting a driveway) or unknown are not included in this analysis. In the cases where direction was known or applicable, close to 71 percent of cyclists traveled with traffic. However, there are crash groups which are over-represented in crashes where the cyclist was travelling facing traffic. The most notable groups are highlighted in Table 8, and include types in which the motorist drove into the path of the bicyclist at sign-controlled or signalized intersections, and at midblock locations. Nearly 71 percent of head-on collisions involved the cyclists riding wrong-way. Large majorities of Motorist Failed to Yield types (at both intersections and midblock) also tended to involve a bicyclist riding facing traffic.

Table 8 Crash groups by bicyclist direction of travel

Crash group	Facing Traffic	With Traffic	Total
Motorist Overtaking Bicyclist	7	937	944
	0.6	33.3	23.8
Motorist Failed to Yield – Sign-Controlled Intersection	241	191	432
	20.9	6.8	10.9
Motorist Left Turn / Merge	37	389	426
	3.2	13.8	10.7
Motorist Failed to Yield - Midblock	289	73	360
	25.0	2.6	9.1
Bicyclist Failed to Yield – Signalized Intersection	101	130	231
	8.8	4.6	5.8
Motorist Right Turn / Merge	27	203	230
	2.3	7.2	5.8
Bicyclist Failed to Yield – Sign-Controlled Intersection	39	184	223
	3.4	6.5	5.6
Crossing Paths – Other Circumstances	102	106	208
	8.8	3.8	5.2
Loss of Control / Turning Error	43	148	191
	3.7	5.3	4.8
Motorist Failed to Yield – Signalized Intersection	123	41	164
	10.7	1.5	4.1
Bicyclist Left Turn / Merge	5	155	160
	0.4	5.5	4.0
Loss of Control / Turning Error	43	148	191
	3.7	5.3	4.8
Head-On	79	33	112
	6.8	1.2	2.8
Bicyclist Overtaking Motorist	3	99	102
	0.3	3.5	2.6
Parallel Paths – Other Circumstances	10	55	65
	0.9	2.0	1.6
Bicyclist Right Turn / Merge	28	12	40
	2.4	0.4	1.0
Backing Vehicle	6	26	32
	0.5	0.9	0.8
Other / Unknown	4	24	28
	0.3	0.9	0.7
Bicyclist Failed to Yield - Midblock	10	0	10
	0.9	0.0	0.3
Parking / Bus-Related	0	5	5
	0.0	0.2	0.1
Total	1,154	2,811	3,965
	29.1	70.9	

As discussed previously, the most prevalent bicycle-motor vehicle crash group over the five-year period was a motorist overtaking a cyclist riding on a parallel path who was in the vast majority of cases travelling in a shared travel lane in the same direction as other traffic per traffic rules. This crash group accounted for 948 collisions, or more than one-fifth of all reported crashes and 40 percent of bicycle crashes that led to fatal or disabling type injuries. This was also the most frequent group of crashes in both urban and rural areas of the state. Therefore, the next sections of this report analyzes this group of crashes further.

Motorist Overtaking Bicyclist Crashes

Figure 2 illustrates three ways this collision can occur. These include A) the motorist failed to detect the bicyclist in time to avoid or safely pass (nighttime, curves, other traffic could obscure the motorist's view); B) the motorist misjudged the space needed to safely pass; and C) the bicyclist made a sudden swerve into the path of the overtaking motor vehicle. Often the specific scenario cannot be determined from information on the crash report. In 58 percent of the cases, none of these specific type scenarios could be determined from the information available on the crash report form, in part ***because 256 of overtaking crashes involved hit and run drivers***.

Potential countermeasures for these crashes include providing for sufficient sight distance for the speed of traffic, separated space to ride such as wide shoulders or bike lanes (or even separated facilities), and keeping shoulders or lanes clear of debris, overhanging branches, and well-maintained. These crash types can be severe, particularly when motorist speeds are high. If separate space (paved shoulders, lanes, or paths) or adequate sight distance cannot be provided, then it is important to consider whether speed limits should be lower so that overtaking motorists have sufficient sight distance and time to react to any slower vehicles ahead, including bikes or pedestrians walking along the roadway as well as other motorized traffic. Intermittent passing lanes could also be considered in some situations. Both motorist education and enforcement of safe passing rules; and bicyclist education about safe riding practices and using appropriate lights and being conspicuous at night could also be considered.

A)

B)

C)

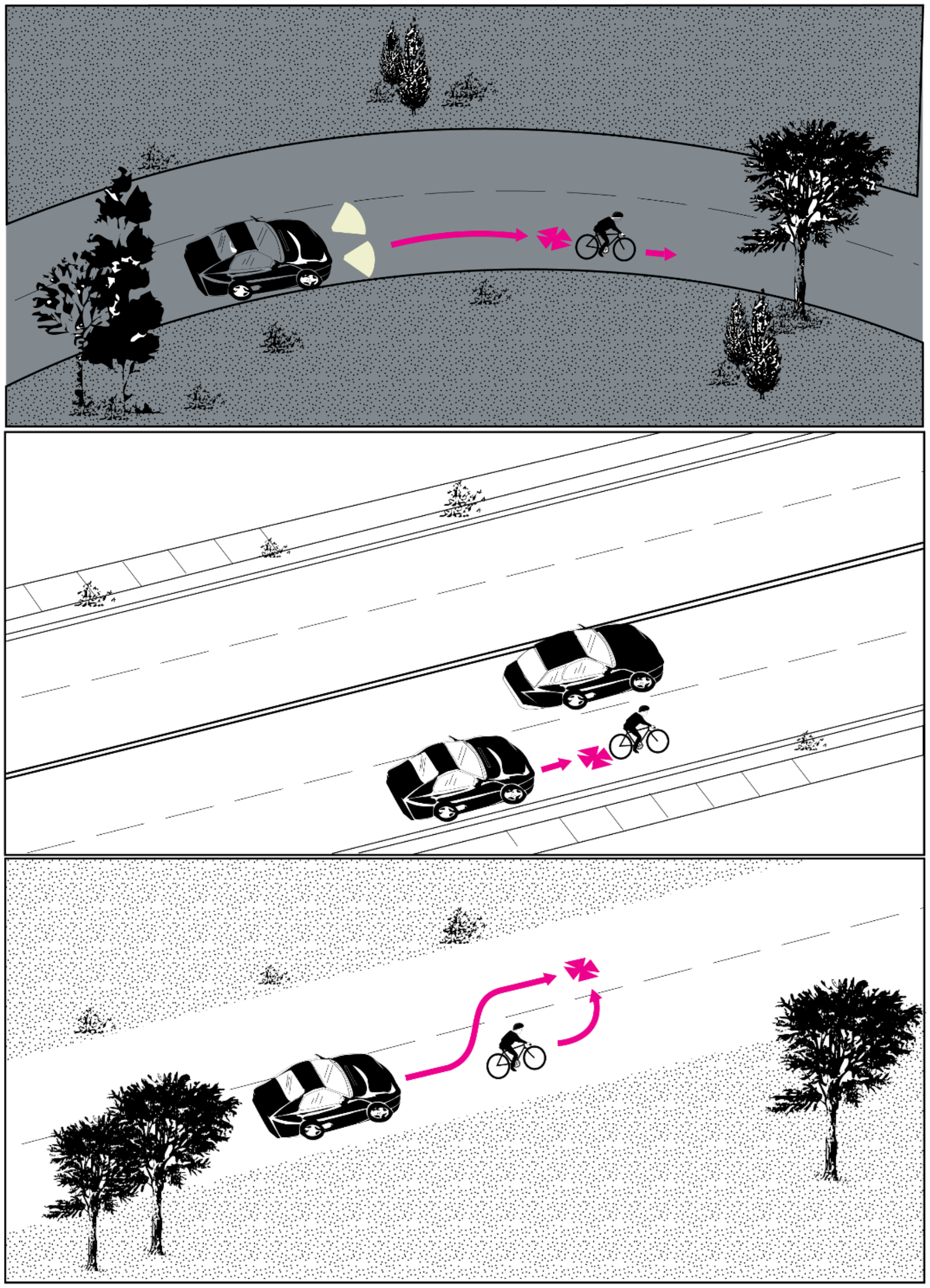

Figure 2 Three examples of how *Motorist Overtaking Bicyclist* crashes may occur

Over 50 percent of ***Motorist Overtaking Bicyclist*** crashes took place in a rural area and not at or near an intersection (Figure 3). An urban, non-intersection setting accounted for an additional 31 percent of this crash group. Overall, 55 percent occurred in rural locations, with 45 percent in urban settings.

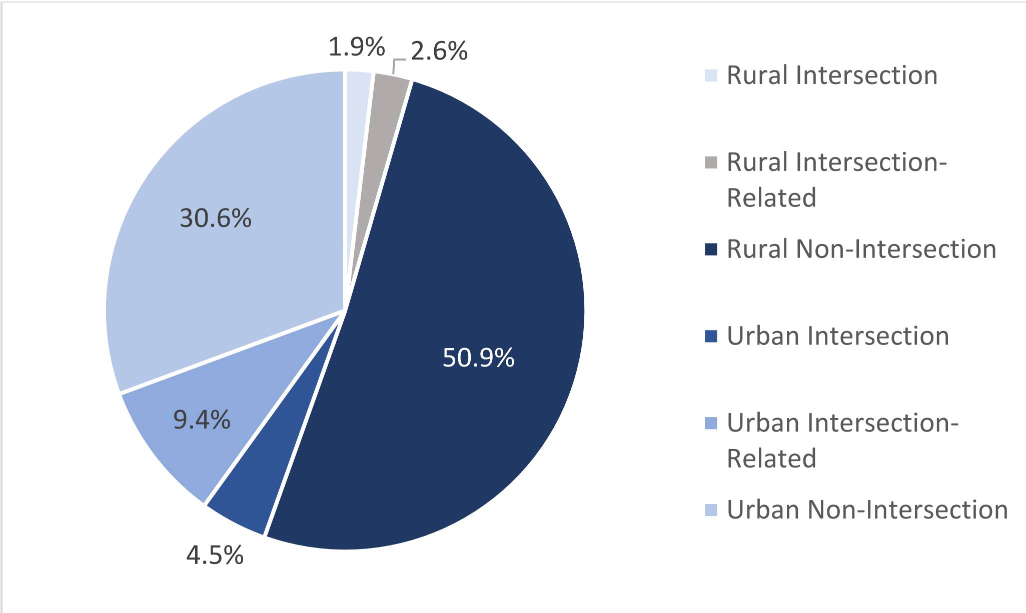

Figure 3 *Motorist Overtaking Bicyclist* crashes by rural or urban setting and roadway location (n = 948)

Not surprisingly considering the locations of many of these crashes, there was no traffic control present in over 60 percent of this crash group (Figure 4). A double yellow line, no passing zone control was present in another 32 percent of the time, with 96 percent of crashes that occurred with this control being on two-lane roads (data not shown). Only around 6 percent occurred at a location with either a stop and go signal or a stop sign.

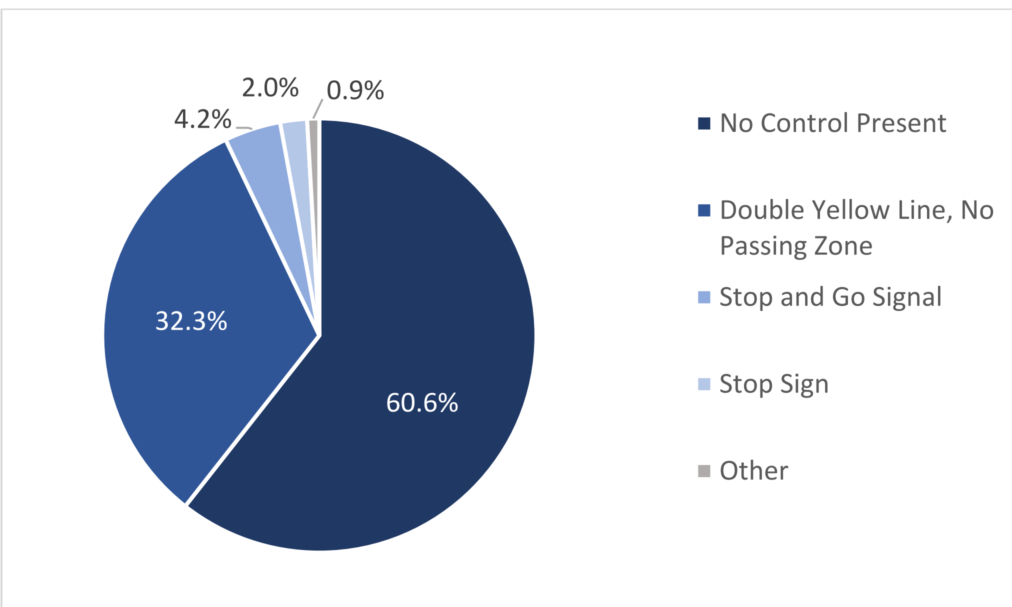

Figure 4 Traffic control for *Motorist Overtaking Bicyclist* crashes (n=948)

The most prevalent roadway configuration for ***Motorist Overtaking Bicyclist*** crashes was two-way, not divided, 80 percent of the group (Figure 5).

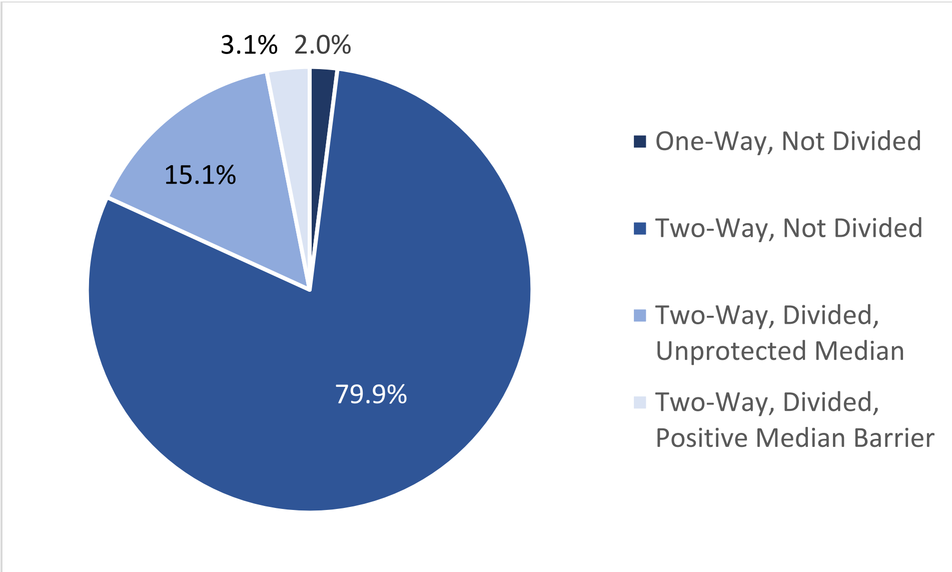

Figure 5 Roadway configuration where crash occurred (n=948)

Over 55 percent of motorist overtaking crashes occurred during daylight hours (Figure 6). However, these crashes are over-represented among dark, unlighted roadways (25 percent of this group compared with 9 percent of all bicycle crashes). Roads with no supplemental lighting are especially prevalent in rural areas, which contributes to the severity of these crashes.

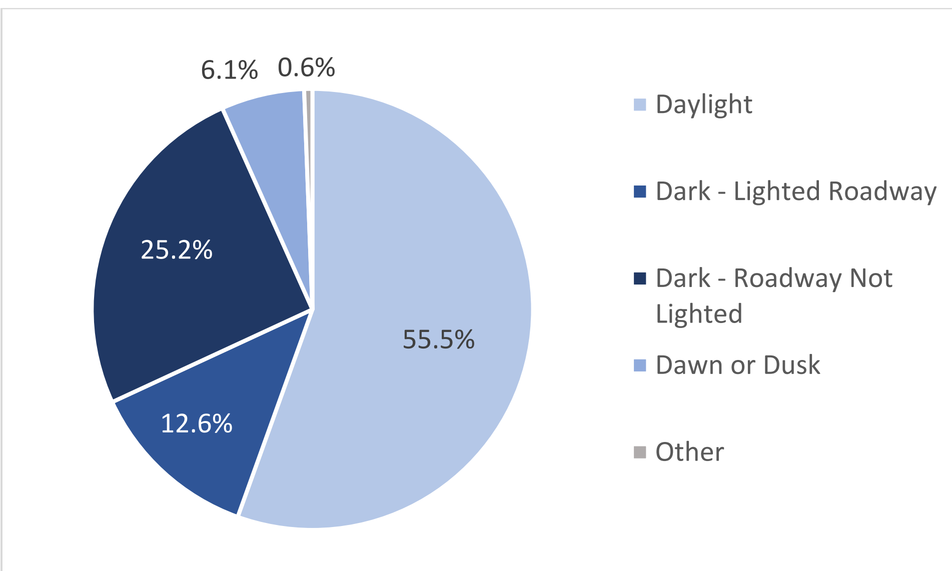

Figure 6 Light conditions for *Motorist Overtaking Bicyclist* crashes (n=948)

Two-thirds of motorist overtaking crashes take place on roadways with a speed limit of over 40 mph (Figure 7). This also is a likely contributing factor in the over-representation of fatal and disabling injuries among these collisions.

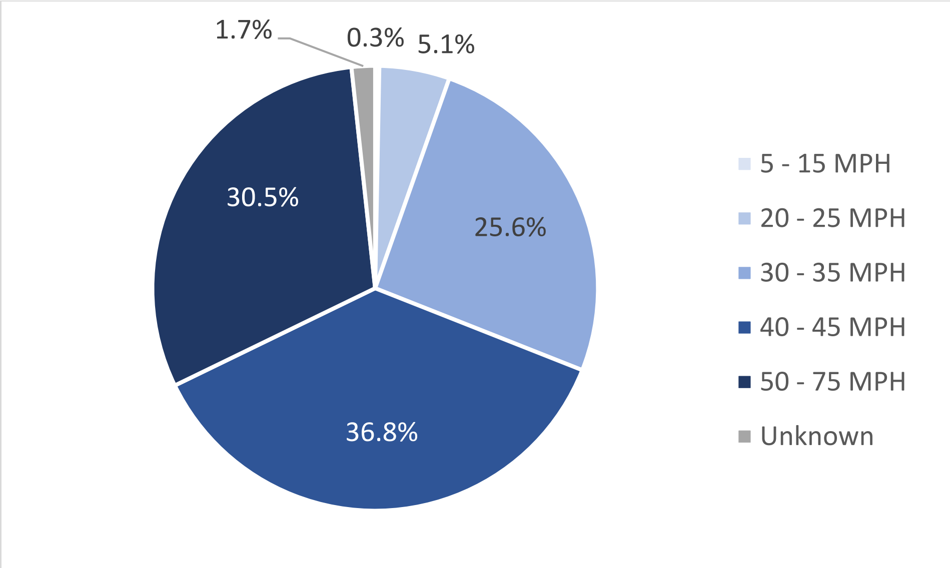

Figure 7 Speed limit for *Motorist Overtaking Bicyclist* crashes (n=948)

Alcohol and Drug Use

Alcohol and/or drug use was detected in around 4 percent of drivers and 9 percent of cyclists involved in motorist overtaking crashes where this variable was reported (Figure 8 and Figure 9). This indication does not confirm impairment or that alcohol and/or drugs were a factor in the crash. By comparison, alcohol and/or drug use was detected in 2 percent of all drivers and 5 percent of all cyclists overall. Impairments may exacerbate other risky conditions.

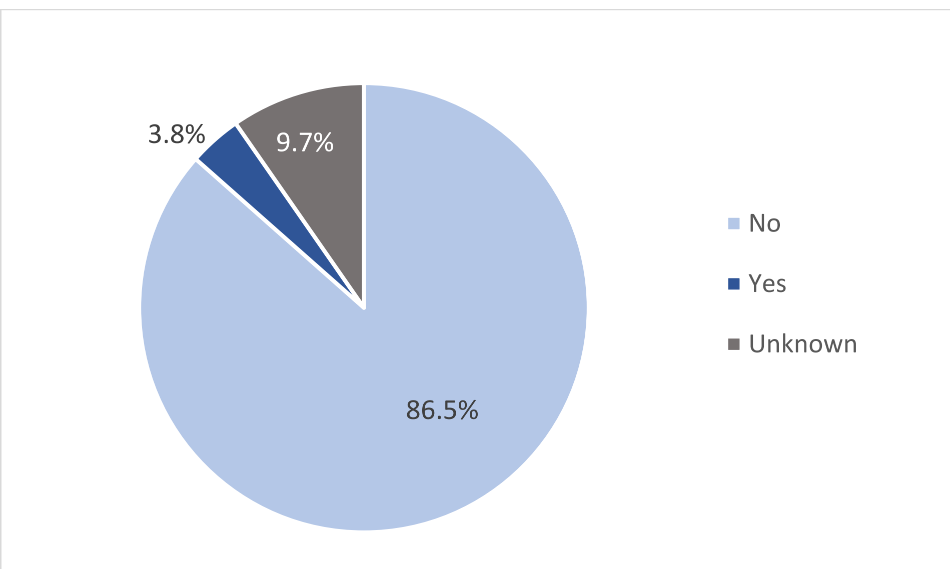

Figure 8 Driver intoxicant use in *Motorist Overtaking Bicyclist* crashes (n=786)

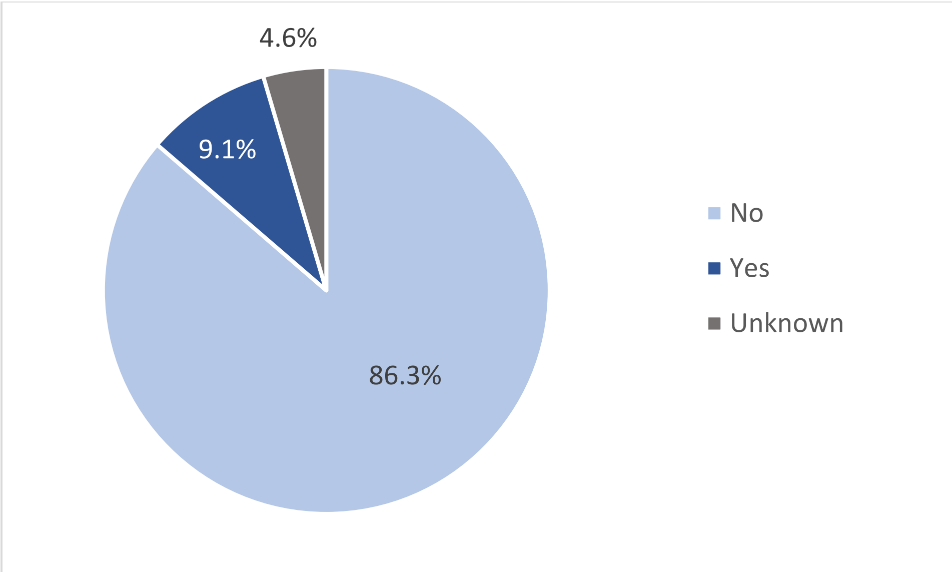

Figure 9 Bicyclist intoxicant use in *Motorist Overtaking Bicyclist* crashes (n=943)

When considering lighting conditions for motorist overtaking crashes where bicyclist alcohol and/or drug use was suspected, it is found that the majority of these crashes occurred on dark, unlighted roadways, but the numbers totaled less than 100 (Figure 10).

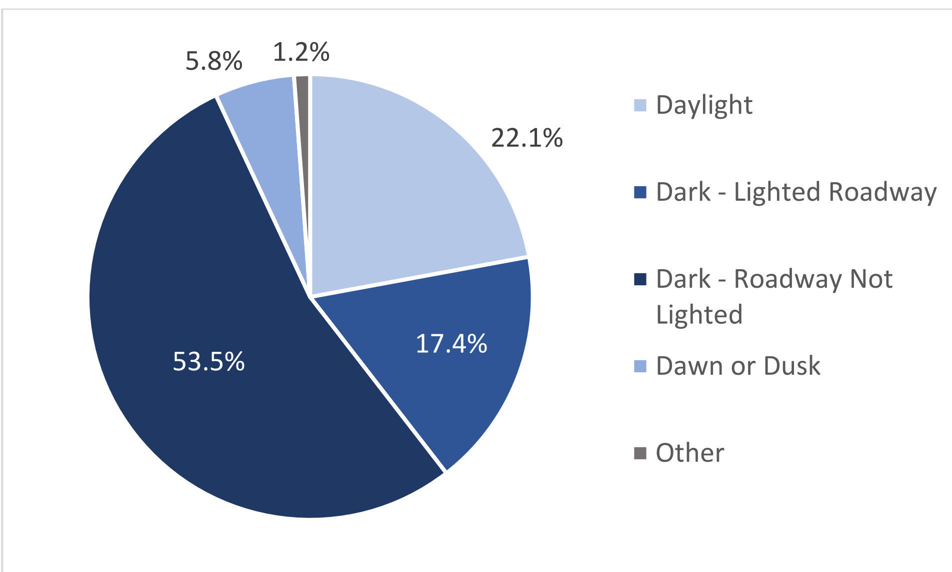

Figure 10 Light conditions in *Motorist Overtaking Bicyclist* crashes with suspected intoxicant use (n=86)

To take a closer look at some of these combinations of factors most associated with bicyclist being struck by overtaking motor vehicles, we developed a crash tree that looks at the combinations of the most prevalent factors and were associated with higher rates of severe injuries (Figure 11). The combination of bicyclists riding on two-way, undivided, two-lane roads, cycling in a travel lane, and speed limits of 40 mph and higher accounted for 44 percent (415/948) of the total crashes of this type, and 58 percent (67/116) of those killed and injured (K + A in diagram) in this type of crash. This suggests that locations with this combination of factors may be priorities for facility improvements. Further examination revealed that 146 (35 percent) of the all-severity crashes and 35 (or nearly half) of this group where the cyclist was killed or received disabling injuries, involved dark, unlighted roadways. Other information about where cyclists ride, and the specific locations of some of these crashes may be examined to look for potential ways to provide better facilities.

We also looked at the representation of ***Motorist Overtaking Bicyclist*** crash type in counties across the state by frequency and by population-based rates. These maps are presented in Appendix B and show that a few counties are over-represented for this type based on population. These results can be compared with similar maps showing where all bicycle crashes are concentrated (and also included in Appendix B). These differences may reflect the types of roads and riding conditions in those counties as well as exposure (or amounts of riding, and other behaviors) by bicyclists and motorists. Further, more in-depth studies would be needed to identify the specific risk factors that are associated with increased risk of this type (or other types) of crashes.

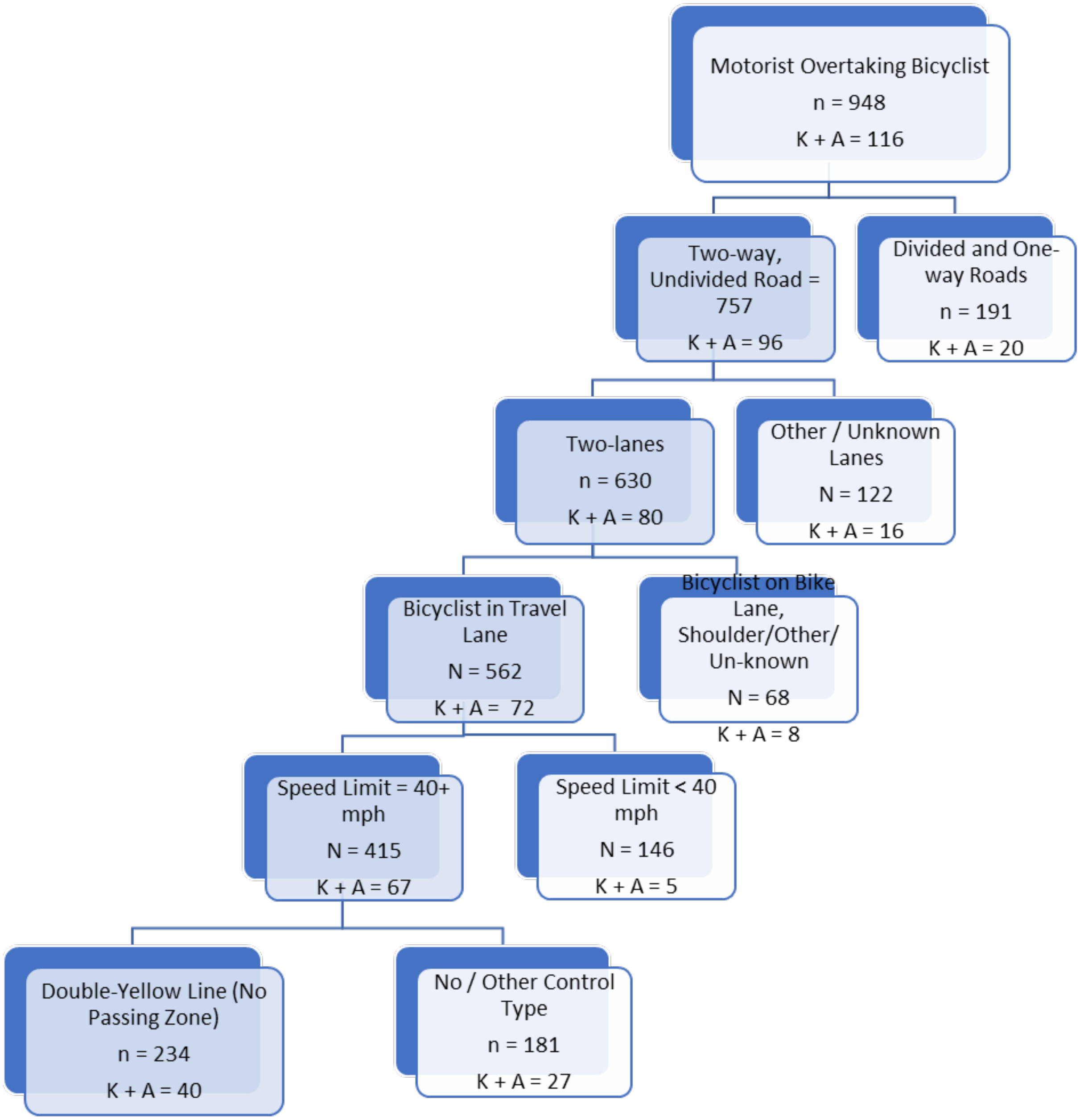

Figure 11 Diagram of interacting roadway and bicyclist riding position variables with crash frequencies and frequencies of killed (K) and disabling injury (A)

Additional Resources

For complete crash group and type definitions, see the PBCAT Manual, Images and Tech Support Information. More information on crash types and engineering countermeasures is available from BIKESAFE, developed for the U.S. Department of Transportation, Federal Highway Administration.

In order to develop countermeasures for particular locations, crash and other data specific to those locations should be examined. Identification of the specific problems and treatments should include site visits and problem diagnoses, such as through interdisciplinary roadway safety audits, before any treatments are selected or implemented. See the North Carolina Pedestrian and Bicycle Road Safety Assessment Guide (Thomas et al. 2018), Bicycle Road Safety Audit Guidelines and Prompt Lists (Nabors et al., 2012) and other sources such as NCHRP reports for more information.

For designing facilities, see the North Carolina Department of Transportation's Complete Streets webpage, the *Guide for the Development of Bicycle Facilities* available from AASHTO, and the NACTO Urban Bikeway Design Guide, among others.

To improve interactions of road users, see Watch for Me - NC webpage and NHTSA's *Countermeasures That Work*, which is updated frequently with information on effective behavior change programs.

For assistance with safety planning and assessment see *How to Develop a Pedestrian and Bicycle Safety Action Plan* (Gelinne et al., 2017).

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Appendix A – Where Bicyclists were Riding Before Crash

Table 9 Crash group by initial position of bicyclist

Crash Type	Travel Lane	Bike Lane / Paved Shoulder	Sidewalk/ Crosswalk/ Driveway Crossing	Driveway /Alley or Multi-use Path	Non-Roadway area	Other or Unknown	Total
Motorist Overtaking Bicyclist	841	84	3	0	0	20	948
	88.7% [i]	8.9%	0.3%	0.0%	0.0%	2.1%	21.2% [ii]
Motorist Left Turn / Merge	323	37	60	7	4	10	441
	73.2%	8.4%	13.6%	1.6%	0.9%	2.3%	9.8%
Motorist Failed to Yield - Sign-Controlled Intersection	253	29	138	6	1	10	437
	57.9%	6.6%	31.6%	1.4%	0.2%	2.3%	9.8%
Motorist Failed to Yield - Midblock	95	27	236	7	0	5	370
	25.7%	7.3%	63.8%	1.9%	0.0%	1.4%	8.3%
Bicyclist Failed to Yield - Midblock	50	5	13	96	82	56	302
	16.6%	1.7%	4.3%	31.8%	27.2%	18.5%	6.7%
Crossing Paths - Other Circumstances	154	8	70	7	10	26	275
	56.0%	2.9%	25.5%	2.5%	3.6%	9.5%	6.1%
Bicyclist Failed to Yield - Sign-Controlled Intersection	233	1	11	2	2	4	253
	92.1%	0.4%	4.3%	0.8%	0.8%	1.6%	5.6%
Bicyclist Failed to Yield - Signalized Intersection	142	1	87	3	3	15	251
	56.6%	0.4%	34.7%	1.2%	1.2%	6.0%	5.6%
Motorist Right Turn / Merge	107	50	63	3	1	7	231
	46.3%	21.6%	27.3%	1.3%	0.4%	3.0%	5.2%
Loss of Control / Turning Error	139	25	27	3	4	9	207
	67.1%	12.1%	13.0%	1.4%	1.9%	4.3%	4.6%
Motorist Failed to Yield - Signalized Intersection	59	3	92	2	2	9	167
	35.3%	1.8%	55.1%	1.2%	1.2%	5.4%	3.7%
Bicyclist Left Turn / Merge	136	10	7	0	0	7	160
	85.0%	6.3%	4.4%	0.0%	0.0%	4.4%	3.6%
Head-On	112	4	3	0	0	1	120
	93.3%	3.3%	2.5%	0.0%	0.0%	0.8%	2.7%
Bicyclist Overtaking Motorist	96	5	1	0	0	1	103
	93.2%	4.9%	1.0%	0.0%	0.0%	1.0%	2.3%
Parallel Paths - Other Circumstances	33	5	33	1	1	6	79
	41.8%	6.3%	41.8%	1.3%	1.3%	7.6%	1.8%
Bicyclist Right Turn / Merge	36	4	1	0	0	3	44
	81.8%	9.1%	2.3%	0.0%	0.0%	6.8%	1.0%
Backing Vehicle	28	0	6	0	0	1	35
	80.0%	0.0%	17.1%	0.0%	0.0%	2.9%	0.8%
Parking / Bus-Related	3	2	0	0	0	0	5
	60.0%	40.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Other and Unknown Circumstances	31	0	6	0	1	13	51
	60.8%	0.0%	11.8%	0.0%	2.0%	25.5%	1.1%
Total	2871	300	857	137	111	203	4479
	64.1%	6.7%	19.2%	3.1%	2.5%	4.6%	100.0%

[i] = col. % of row total; [ii] = row total % of total

Appendix B – Maps of Bicycle-Motor Vehicle Crashes

These North Carolina maps visualize the total number of bicycle-motor vehicle by county and the standard deviation of the average annual rate per 10,000 residents for all crashes (Figure 12 and Figure 13). The total number of ***Motorist Overtaking Bicyclist*** crashes and their average annual rate per 10,000 residents are also visualized (Figure 14 and Figure 15).

More populous, urbanized counties have the highest total number of all crashes (Table 10).[3] This is generally true when considering motorist overtaking crashes as well, with one exception being Robeson County, which is more rural (Table 11). Robeson County also has the highest proportion of motorist overtaking crashes of any in the Top 10 with 38 percent of all crashes being this category.

When analyzing the average annual rate per 10,000 residents, counties in the coastal plain region of the State are over-represented. Table 12 shows the four counties which have a rate of greater than 1.5 standard deviations from the median for total crashes, they are all in this region. When considering *Motorist Overtaking Bicyclist* crashes, ten counties have standard deviations greater than 1.5, all but one (Scotland) are in the coastal plain (Table 13).

Table 10 Top 10 NC counties for all bicycle crashes

County	Total Bicycle Crashes
Wake	654
Mecklenburg	495
New Hanover	340
Guilford	333
Durham	238
Pitt	163
Cumberland	153
Buncombe	134
Forsyth	110
Orange	101

Among the top 10 counties for frequency of motorist overtaking crashes, some have high proportions of this type compared to others in the list Table 11.

[3] There may have been some anomalies in reporting of data for at least one urban jurisdiction. In 2016, additional efforts were undertaken to identify all possible bicycle-motor vehicle crashes to help overcome these reporting differences but reported crash data are always subject to accuracy and completeness issues.

Table 11 Top 10 NC counties for *Motorist Overtaking Bicyclist* crashes

County	Total Motorist Overtaking Crashes	Proportion of Total Crashes in County
Wake	90	13.8%
Mecklenburg	55	11.1%
Guilford	48	14.4%
New Hanover	43	12.6%
Durham	40	16.8%
Robeson	34	38.2%
Buncombe	33	24.6%
Cumberland	32	20.9%
Pitt	28	17.2%
Forsyth	24	21.8%

Table 12 Counties with standard deviation > 1.5 for all crashes

County	Average Annual Rate per 10,000 Residents	Standard Deviation
Dare	4.95	> 2.5
New Hanover	3.13	> 2.5
Pitt	1.87	1.5 – 2.5
Carteret	1.87	1.5 – 2.5

Table 13 Counties with standard deviation > 1.5 for *Motorist Overtaking Bicyclist* crashes

County	Average Annual MOT Rate per 10,000 Residents	Standard Deviation
Hyde	1.05	> 1.5
Pamlico	0.61	> 1.5
Scotland	0.55	> 1.5
Robeson	0.51	> 1.5
Gates	0.51	> 1.5
Pasquotank	0.50	> 1.5
Hertford	0.49	> 1.5
Washington	0.47	> 1.5
Greene	0.47	> 1.5
Carteret	0.46	> 1.5

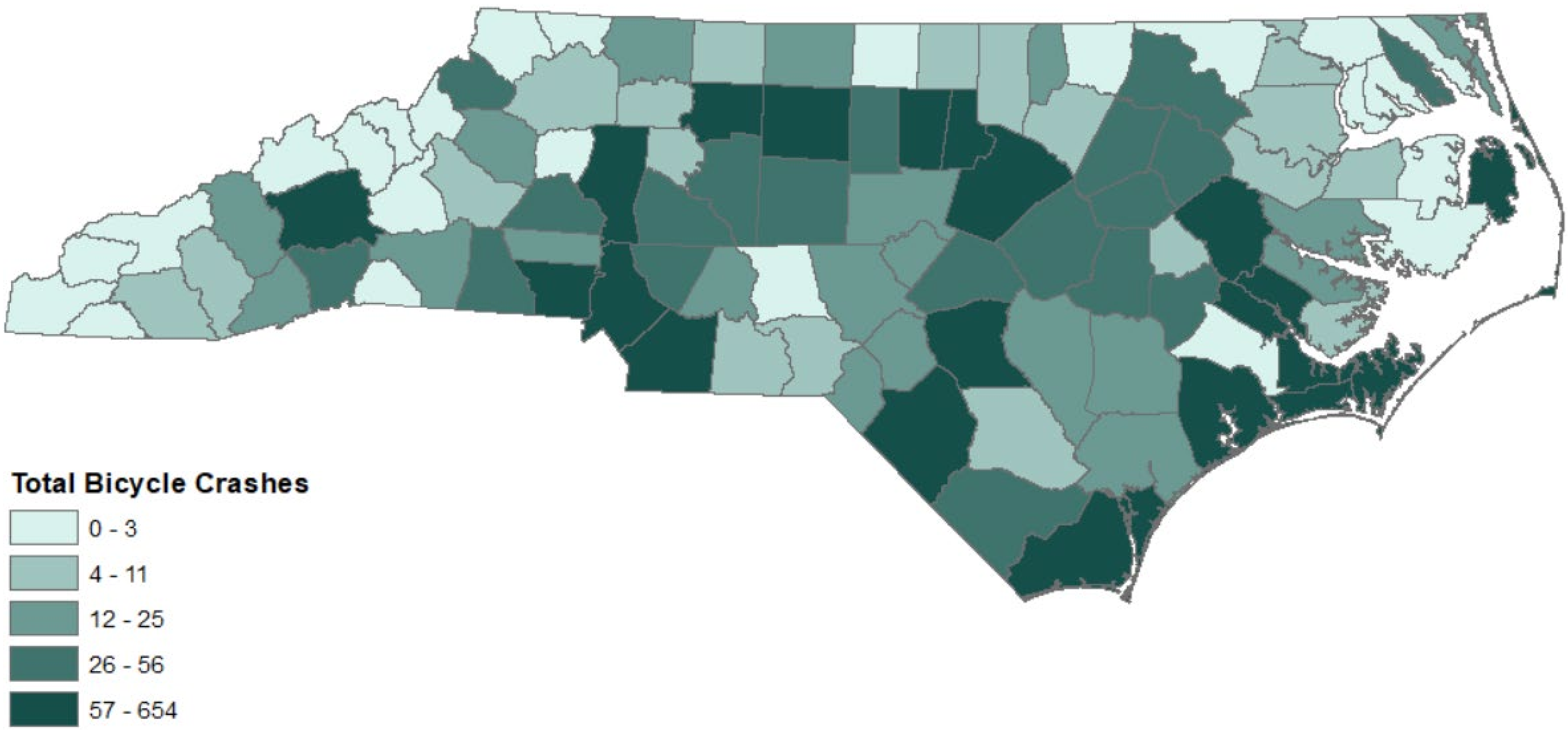

Figure 12 Total bicycle crashes by NC County

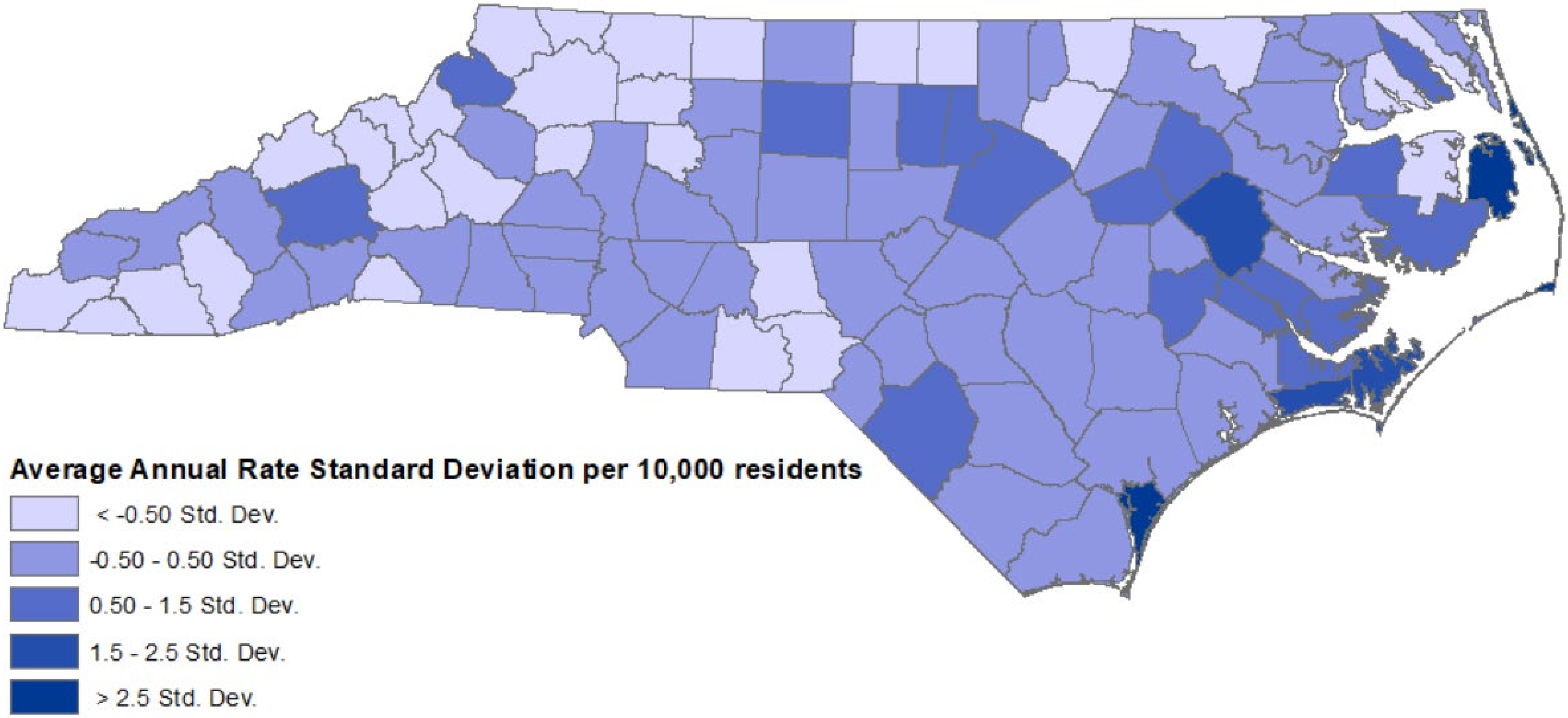

Figure 13 Standard deviation of average annual rate of total bicycle crashes per 10,000 residents

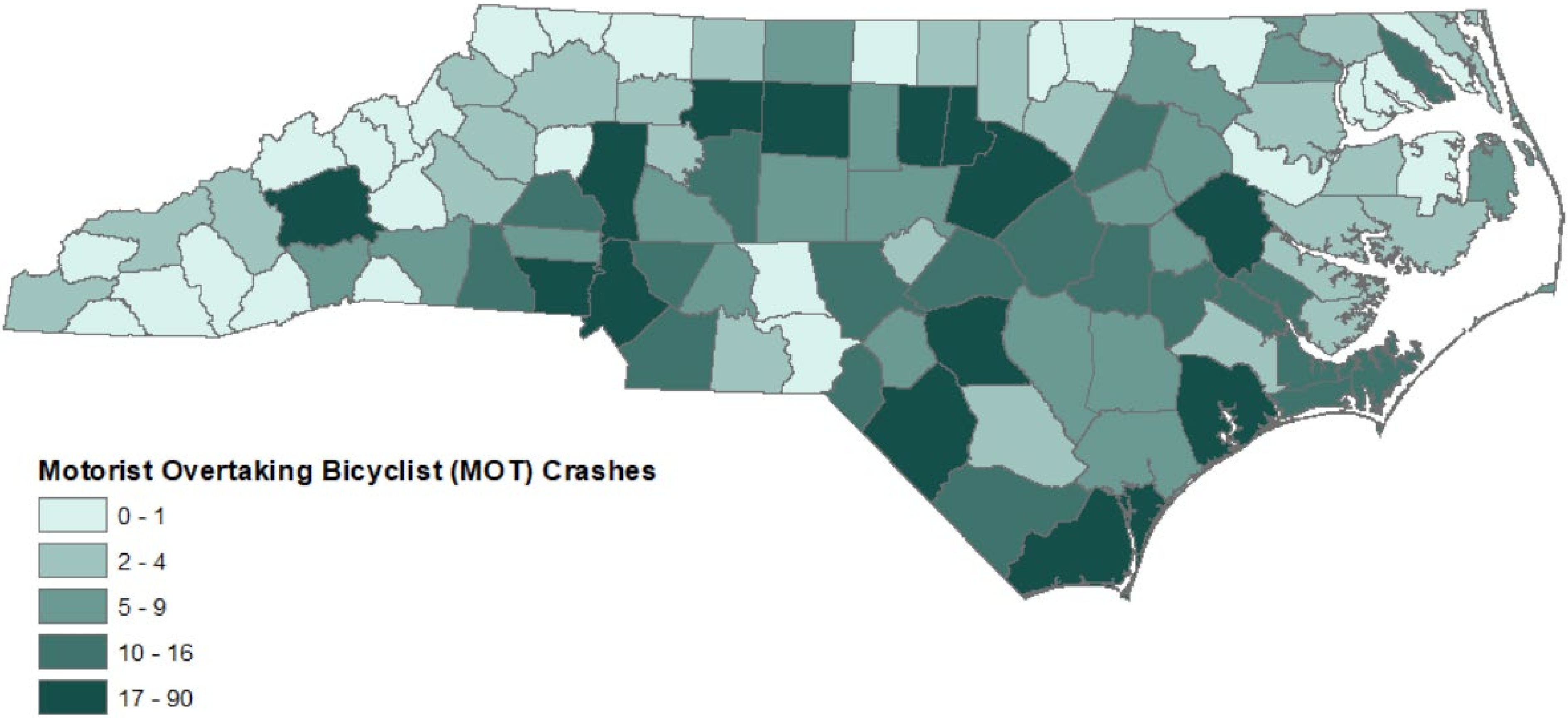

Figure 14 *Motorist Overtaking Bicyclist* crashes by County

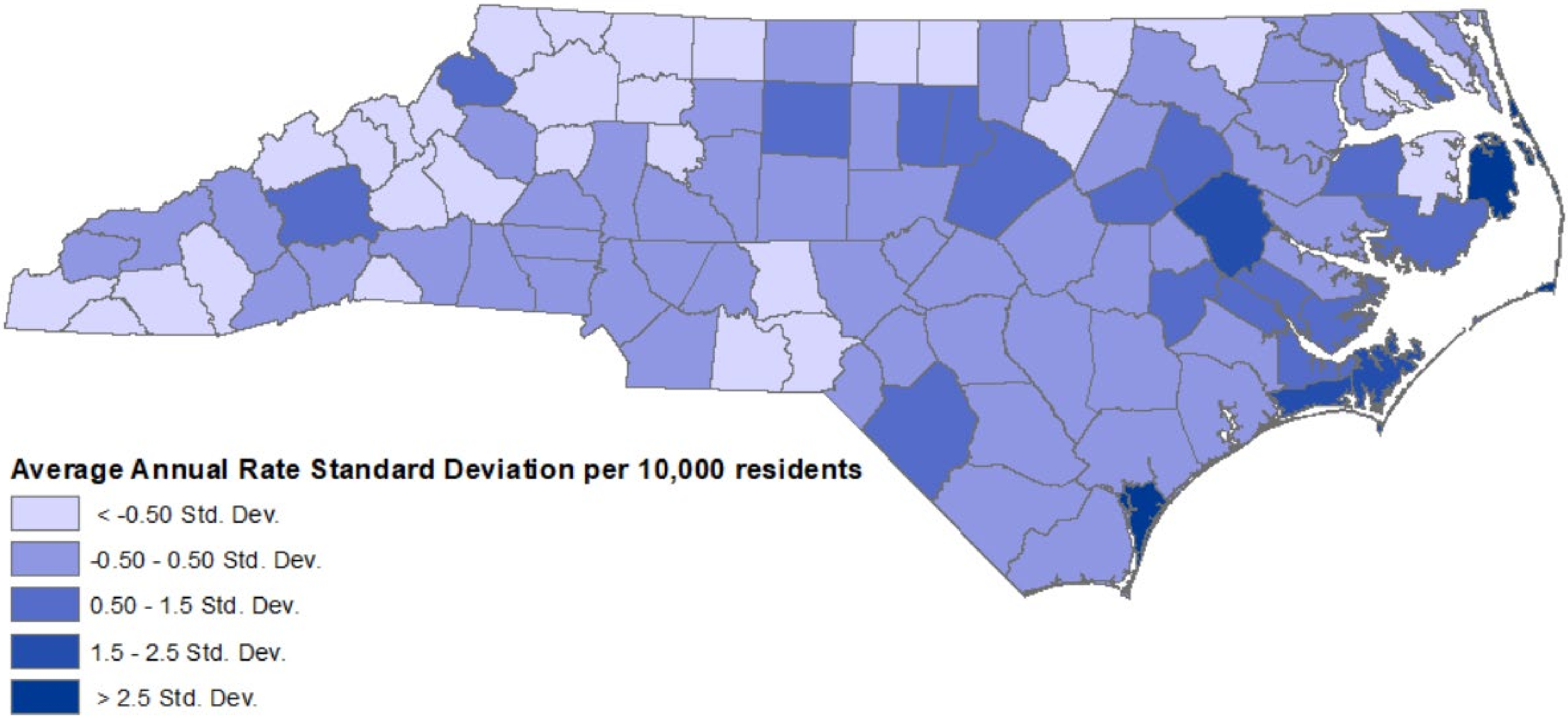

Figure 15 Standard deviation for *Motorist Overtaking Bicyclist* crashes per 10,000 residents

Figure 16 Map of NC Counties