North Carolina
Bicycle Crash Types
2008 - 2012

Prepared for

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

Prepared by

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Contents

Figures

Tables

Introduction and Purpose

During the five year period of 2008-2012, an average of 978 bicycle-motor vehicle crashes were reported to the North Carolina Division of Motor Vehicles each year. On average, 22 bicyclists were killed and many more were injured each year.

This report summarizes bicycle-motor vehicle crash type information developed for 2008-2012 for the entire State. UNC Highway Safety Research Center staff reviewed diagrams and narratives and other details on copies of all 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 in the State's crash database. The results of analyzing the crash type data and other elements are summarized in the tables, figures, and text in the following sections.

The 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 diagnosis and other procedures are necessary before implementing treatments at any location. Additional information on person, environmental, and roadway factors is provided in the companion *North Carolina Bicycle Crash Facts* summary report.

Background on Crash Typing

The information from the State crash report forms and reported by public safety officials across the State is stored in electronic crash databases. Analysis of these data can provide information on *where* pedestrian-motor vehicle crashes occur (city street, two-lane roadway, intersection location, etc.), *when* they occur (time of day, day of week, etc.), and *to whom* they occur (age of victim, gender, level of impairment, etc.). Reported crash data were compiled and used to describe such bicycle-motor vehicle crash characteristics for the companion, *North Carolina Bicycle Crash Facts* summary report.

However, the data contained in the crash database provides little information about the actual sequence of events leading to crashes between motor vehicles and bicyclists. The development of effective countermeasures to help prevent and reduce the severity of these crashes is limited by insufficient detail about the events or types of bicycle-related crashes in typical electronic crash databases.

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 has precipitating actions, 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. 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, Tsai, Thomas, and Hunter updated this tool in 2006 in a project sponsored by the Federal Highway Administration (FHWA). 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 (Hunter, Thomas, and Stutts, 2006). Another FHWA tool that can assist with diagnosing problems is the Bicycle Road Safety Audit Guidelines and Prompt Lists.

Crash Events and Description

Crash Location

Table 1 shows the frequency and percentage of bicycle crashes by the general crash location of the bicyclist as determined during the crash typing process. Nearly half (49%) of the collisions occurred in non-intersection (i.e., mid-block) sections along streets and roadways. These include crashes that occurred at or related to non-signalized commercial and private driveways. Another 43% occurred at intersections (i.e., within the motor vehicle stop bars or pedestrian crosswalks), and 4% were intersection-related (i.e., close enough that an intersection maneuver such as slowing traffic may have led to the crash). About 4% occurred in non-roadway locations (typically parking lots).

Table 1. NC bicycle-motor vehicle crashes by location type.

Crash Location	2008	2009	2010	2011	2012	Total
Intersection	461	350	411	448	466	2,136
	44.2[1]	42.2	42.5	43.6	45.5	43.7 [2]
Intersection-Related	28	32	55	65	89	269
	2.7	3.9	5.7	6.3	8.7	5.5
Non-Intersection	501	402	463	469	437	2,272
	48.1	48.5	47.9	45.6	42.7	46.5
Non-Roadway	47	42	37	46	31	203
	4.5	5.1	3.8	4.5	3	4.2
Unknown Location	5	3	0	0	1	9
	0.5	0.4	0	0	0.1	0.2
Total	1,042	829	966	1,028	1,024	4,889
	21.3 [3]	17	19.8	21	20.9	

[1] Row percent of column total
[2] Row total percent of total
[3] Column percent of row total

Figure 1 shows how the proportion of crash location types vary from rural to urban crash locations in NC, and may also vary from city to city, depending on how closely-spaced intersections are, and other factors. Non-intersection crash locations make up a higher percentage, nearly 70 percent, of the total bicycle crashes in rural areas but account for about 37 percent of crashes in urban areas. Non-roadway (parking lot crashes) are understandably a lower percentage (<3 percent) of crashes in rural areas than in urban areas (5 percent). Intersections and crashes near intersections account for 58 percent of urban area crashes and 28 percent of those in rural areas.

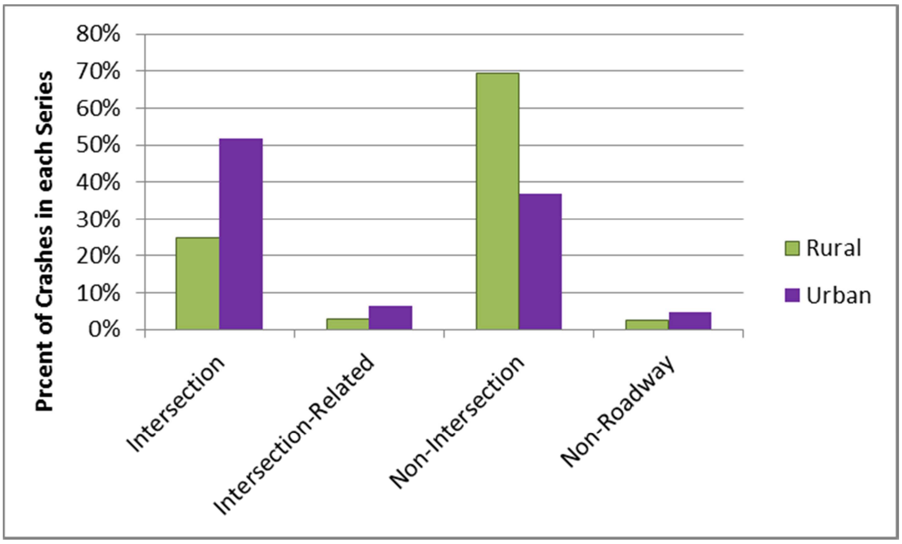


Figure 1. Percentages of NC rural and urban bicycle crashes by location type, 2008-2012 (n = 1,451 rural, 3,438 urban crashes).

Statewide, however, urban intersection locations accounted for 36 percent of all bicycle-motor vehicle crash locations (1,777/4,899; Table 2). Table 2 shows the combined distributions for rural and urban locations for all five years. Urban, intersection locations accounted for the next highest number of crashes among rural/urban combined with location type. However, because many more bicycle crashes in rural areas occur at non-intersection locations (1,008 compared with 359 at rural intersections), in total, non-intersection roadway locations account for the larger numbers across the State.

Table 2. Crash Location type by Rural or Urban Area Type, 2008-2012.

Crash Location Type by Rural / Urban	Rural	Urban	Total
Intersection	359	1,777	2,136
	24.7 [1]	51.7	43.7 [2]
Intersection-Related	45	224	269
	3.1	6.5	5.5
Non-Intersection	1,008	1,264	2,272
	69.5	36.8	46.5
Non-Roadway	36	167	203
	2.5	4.9	4.2
Unknown Location	3	6	9
	0.2	0.2	0.2
Total	1,451	3,438	4,889
	29.7 [3]	70.3	

[1] Row percent of column total
[2] Row total percent of total
[3] Column percent of row total

In addition to greater total numbers of crashes at all non-intersection locations across the state, the rate of fatal and serious injuries for bicyclists struck along these road sections is twice as high (10 percent) as the rate for those struck at intersection locations (5 percent of the total struck). (Note that Figure 2 shows only crashes that were indicated to result in at least possible injury.) In part, the higher fatalities resulting from non-intersection crashes reflect that a large percentage of bicyclists are struck at non-intersection locations in rural areas, as already shown, where speeds are typically higher, travel lanes are typically shared, and rural roadway sections often have no paved shoulders or supplemental lighting.

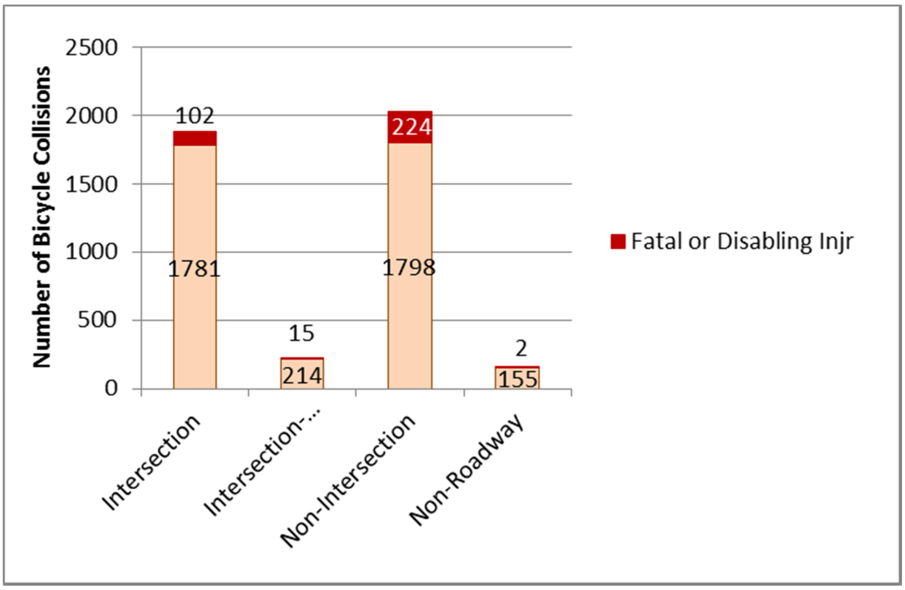


Figure 2. Bicyclist injury severity by location type, 2008-2012.

Bicyclist Position

Table 3 shows the initial position of the (primary) bicyclist involved the crash and indicates that 66% of the bicyclists were on a street in a lane shared with motor vehicle traffic just prior to the crash. On average, 16% were on a sidewalk, crosswalk, or driveway crossing just prior to the collision. According to data available in crash reports, bicyclists were riding on paved shoulders or bicycle lanes about 5% of the time prior to their collisions. About 2% were on a driveway or alley before any maneuvers such as the bicyclist riding out into a street, or a motor vehicle turning in. Another 5% were in other non-roadway areas such as parking lots. Unfortunately, we lack data on exposure, or amounts of riding on these different facility types. The initial position of the bicyclist was unknown/unable to be determined in about 3 percent of the crashes.

Table 3. Bicyclist position prior to the crash, NC bicycle-motor vehicle crashes.

Bicyclist Position	2008	2009	2010	2011	2012	Total
Travel Lane	635	547	674	701	691	3,248
	60.9 [1]	66	69.8	68.2	67.5	66.4 [2]
Bike Lane / Paved Shoulder	71	37	58	47	51	264
	6.8	4.5	6	4.6	5	5.4
Sidewalk / Crosswalk / Driveway Crossing	179	124	148	173	170	794
	17.2	15	15.3	16.8	16.6	16.2
Multi-use Path	7	3	6	7	7	30
	0.7	0.4	0.6	0.7	0.7	0.6
Driveway / Alley	18	16	25	24	17	100
	1.7	1.9	2.6	2.3	1.7	2
Non-Roadway	63	50	37	57	54	261
	6	6	3.8	5.5	5.3	5.3
Other	8	5	5	5	3	26
	0.8	0.6	0.5	0.5	0.3	0.5
Unknown	61	47	13	14	31	166
	5.9	5.7	1.3	1.4	3	3.4
Total	1,042	829	966	1,028	1024	4,889
	21.3 [3]	17	19.8	21	20.9	

[1] Row percent of the column (yearly) total
[2] Row total percent of total
[3] Column percent of the total

Bicyclist Direction of Travel

Table 4 shows that 62% of the bicyclists were riding with traffic (i.e., in the same direction as traffic). About 23 percent were riding opposed or facing traffic, however, which is essentially unchanged from the percentage mentioned during the previous five-years analysis (for 2006-2010). The percentage riding opposed to traffic was 27% when including only applicable crashes on the roadway network for which direction was known. Direction was considered not applicable for parking lot, driveway, and other off-road locations. Bicyclist travel direction was not applicable or unknown/not determinable for about 15% of the crashes.

Riding facing traffic is against the rules of the road and may contribute to crash occurrence since bicyclists are approaching from an unexpected direction.

Table 4. Bicyclist travel direction in NC bicycle-motor vehicle crashes.

Bicyclist Direction	2008	2009	2010	2011	2012	Total
With Traffic	628	503	612	658	640	3041
	60.3 [1]	60.7	63.4	64	62.5	62.2 [2]
Facing Traffic	252	175	212	212	255	1106
	24.2	21.1	21.9	20.6	24.9	22.6
Not Applicable	118	123	111	138	95	585
	11.3	14.8	11.5	13.4	9.3	12
Unknown	44	28	31	20	34	157
	4.2	3.4	3.2	1.9	3.3	3.2
Total	1042	829	966	1028	1024	4,889
	21.3 [3]	17	19.8	21	20.9	

[1] Row percent of column total
[2] Row total percent to total
[3] Column total percent of row total

Individual Crash Types

Table 5 shows a complete listing of all the individual crash types generated by the coding for each of the five years, and totals for all five years. (Nine of the crashes during this period lacked sufficient information to be typed even to a general location type.) The table shows the 78 different ways bicycle-motor vehicle collisions can occur, including various turning and merging maneuvers in traffic, overtaking events, ride outs and drive outs, bicyclists and motorists losing control of their vehicle, motorists intentionally striking bicyclists, unusual circumstances, and parking lot/non-roadway events, etc. The names are reasonably self-explanatory, but more details as to the meaning of each crash type are available on the software web page, in the manual that accompanies in the software.

There is some year-to-year variability in the frequencies and proportions of each crash type, especially those with smaller numbers. Much of this variation is likely explained by chance, but some variation is potentially attributable to changes in behaviors including effects of roadway treatments or education and enforcement measures.

Table 5. NC bicycle crash types by year.

Crash Type	2008	2009	2010	2011	2012	Total
Motorist Turning Error - Left Turn	7	4	3	4	8	26
	0.7 [1]	0.5	0.3	0.4	0.8	0.5 [2]
Motorist Turning Error - Right Turn	1	1	2	4	0	8
	0.1	0.1	0.2	0.4	0	0.2
Motorist Turning Error - Other	0	1	1	1	1	4
	0	0.1	0.1	0.1	0.1	0.1
Bicyclist Turning Error - Left Turn	2	0	1	3	3	9
	0.2	0	0.1	0.3	0.3	0.2
Bicyclist Turning Error - Right Turn	3	0	5	2	3	13
	0.3	0	0.5	0.2	0.3	0.3
Bicyclist Turning Error - Other	0	1	1	0	0	2
	0	0.1	0.1	0	0	0
Bicyclist Lost Control - Mechanical Problems	15	7	9	10	16	57
	1.4	0.8	0.9	1	1.6	1.2
Bicyclist Lost Control – Oversteering, Improper Braking, Speed	3	0	0	4	0	7
	0.3	0	0	0.4	0	0.1
Bicyclist Lost Control - Alcohol / Drug Impairment	1	0	1	2	1	5
	0.1	0	0.1	0.2	0.1	0.1
Bicyclist Lost Control - Surface Conditions	0	3	1	0	0	4
	0	0.4	0.1	0	0	0.1
Bicyclist Lost Control - Other / Unknown	9	11	8	10	7	45
	0.9	1.3	0.8	1	0.7	0.9
Motorist Lost Control - Mechanical Problems	1	0	1	0	0	2
	0.1	0	0.1	0	0	0
Motorist Lost Control – Oversteering, Improper Braking, Speed	1	1	1	0	1	4
	0.1	0.1	0.1	0	0.1	0.1
Motorist Lost Control - Alcohol / Drug Impairment	0	0	0	1	0	1
	0	0	0	0.1	0	0
Motorist Lost Control - Surface Conditions	0	0	2	0	0	2
	0	0	0.2	0	0	0
Motorist Lost Control - Other / Unknown	4	6	9	7	15	41
	0.4	0.7	0.9	0.7	1.5	0.8
Motorist Drive Out - Sign-Controlled Intersection	116	81	82	102	97	478
	11.1	9.8	8.5	9.9	9.5	9.8
Bicyclist Ride Out - Sign-Controlled Intersection	22	9	22	25	9	87
	2.1	1.1	2.3	2.4	0.9	1.8
Motorist Drive Through - Sign-Controlled Intersection	10	5	10	2	5	32
	1	0.6	1	0.2	0.5	0.7
Bicyclist Ride Through - Sign-Controlled Intersection	53	36	41	39	64	233
	5.1	4.3	4.2	3.8	6.3	4.8
Multiple Threat - Sign-Controlled Intersection	1	0	0	0	0	1
	0.1	0	0	0	0	0

Crash Type	2008	2009	2010	2011	2012	Total
Sign-Controlled Intersection - Other / Unknown	17	10	7	6	7	47
	1.6	1.2	0.7	0.6	0.7	1
Motorist Drive Out - Right Turn on Red	18	7	9	12	23	69
	1.7	0.8	0.9	1.2	2.2	1.4
Motorist Drive Out - Signalized Intersection	2	9	17	11	8	47
	0.2	1.1	1.8	1.1	0.8	1
Bicyclist Ride Out - Signalized Intersection	3	6	13	20	9	51
	0.3	0.7	1.3	1.9	0.9	1
Motorist Drive Through - Signalized Intersection	5	7	2	6	2	22
	0.5	0.8	0.2	0.6	0.2	0.4
Bicyclist Ride Through - Signalized Intersection	22	12	19	25	31	109
	2.1	1.4	2	2.4	3	2.2
Bicyclist Failed to Clear - Trapped	8	2	1	4	6	21
	0.8	0.2	0.1	0.4	0.6	0.4
Bicyclist Failed to Clear - Multiple Threat	2	2	0	0	2	6
	0.2	0.2	0	0	0.2	0.1
Signalized Intersection - Other / Unknown	33	19	16	12	43	123
	3.2	2.3	1.7	1.2	4.2	2.5
Bicyclist Failed to Clear - Unknown	0	2	1	0	0	3
	0	0.2	0.1	0	0	0.1
Crossing Paths - Uncontrolled Intersection	7	8	9	10	14	48
	0.7	1	0.9	1	1.4	1
Crossing Paths - Intersection - Other / Unknown	2	23	25	16	13	79
	0.2	2.8	2.6	1.6	1.3	1.6
Motorist Left Turn - Same Direction	7	13	11	10	5	46
	0.7	1.6	1.1	1	0.5	0.9
Motorist Left Turn - Opposite Direction	56	53	84	83	87	363
	5.4	6.4	8.7	8.1	8.5	7.4
Motorist Right Turn - Same Direction	48	34	41	47	41	211
	4.6	4.1	4.2	4.6	4	4.3
Motorist Right Turn - Opposite Direction	5	7	5	7	3	27
	0.5	0.8	0.5	0.7	0.3	0.6
Motorist Drive In / Out - Parking	2	0	0	0	1	3
	0.2	0	0	0	0.1	0.1
Motorist Right Turn on Red - Same Direction	0	0	2	4	0	6
	0	0	0.2	0.4	0	0.1
Motorist Right Turn on Red - Opposite Direction	0	1	0	0	0	1
	0	0.1	0	0	0	0
Motorist Turn / Merge - Other / Unknown	2	1	0	1	1	5
	0.2	0.1	0	0.1	0.1	0.1
Bicyclist Left Turn - Same Direction	59	29	60	54	32	234
	5.7	3.5	6.2	5.3	3.1	4.8
Bicyclist Left Turn - Opposite Direction	8	3	6	5	7	29
	0.8	0.4	0.6	0.5	0.7	0.6
Bicyclist Right Turn - Same Direction	12	8	15	13	8	56
	1.2	1	1.6	1.3	0.8	1.1
Bicyclist Right Turn - Opposite Direction	3	1	1	0	3	8
	0.3	0.1	0.1	0	0.3	0.2

Crash Type	2008	2009	2010	2011	2012	Total
Bicyclist Ride Out - Parallel Path	14	5	8	14	10	51
	1.3	0.6	0.8	1.4	1	1
Motorist Overtaking - Undetected Bicyclist	38	26	30	30	17	141
	3.6	3.1	3.1	2.9	1.7	2.9
Motorist Overtaking - Misjudged Space	44	42	55	57	37	235
	4.2	5.1	5.7	5.5	3.6	4.8
Motorist Overtaking - Bicyclist Swerved	19	28	22	21	33	123
	1.8	3.4	2.3	2	3.2	2.5
Motorist Overtaking - Other / Unknown	75	88	74	82	119	438
	7.2	10.6	7.7	8	11.6	9
Bicyclist Overtaking - Passing on Right	2	4	1	8	5	20
	0.2	0.5	0.1	0.8	0.5	0.4
Bicyclist Overtaking - Passing on Left	1	0	3	4	1	9
	0.1	0	0.3	0.4	0.1	0.2
Bicyclist Overtaking - Parked Vehicle	2	2	8	4	5	21
	0.2	0.2	0.8	0.4	0.5	0.4
Bicyclist Overtaking - Extended Door	1	1	2	0	4	8
	0.1	0.1	0.2	0	0.4	0.2
Bicyclist Overtaking - Other / Unknown	6	8	7	5	6	32
	0.6	1	0.7	0.5	0.6	0.7
Head-On - Bicyclist	28	11	21	20	23	103
	2.7	1.3	2.2	1.9	2.2	2.1
Head-On - Motorist	3	2	4	5	4	18
	0.3	0.2	0.4	0.5	0.4	0.4
Head-On - Unknown	4	0	1	2	1	8
	0.4	0	0.1	0.2	0.1	0.2
Parallel Paths - Other / Unknown	11	11	8	10	5	45
	1.1	1.3	0.8	1	0.5	0.9
Bicyclist Ride Out - Residential Driveway	14	11	16	20	13	74
	1.3	1.3	1.7	1.9	1.3	1.5
Bicyclist Ride Out - Commercial Driveway / Alley	8	6	10	9	8	41
	0.8	0.7	1	0.9	0.8	0.8
Bicyclist Ride Out - Other Midblock	21	20	16	26	20	103
	2	2.4	1.7	2.5	2	2.1
Bicyclist Ride Out - Midblock - Unknown	18	26	5	6	13	68
	1.7	3.1	0.5	0.6	1.3	1.4
Motorist Drive Out - Residential Driveway	8	5	3	4	3	23
	0.8	0.6	0.3	0.4	0.3	0.5
Motorist Drive Out - Commercial Driveway / Alley	59	25	39	63	60	246
	5.7	3	4	6.1	5.9	5
Motorist Drive Out - Other Midblock	7	7	12	8	3	37
	0.7	0.8	1.2	0.8	0.3	0.8
Motorist Drive Out - Midblock - Unknown	3	4	4	1	1	13
	0.3	0.5	0.4	0.1	0.1	0.3
Multiple Threat - Midblock	5	4	3	5	2	19
	0.5	0.5	0.3	0.5	0.2	0.4
Crossing Paths - Midblock - Other / Unknown	4	2	8	1	3	18
	0.4	0.2	0.8	0.1	0.3	0.4

Crash Type	2008	2009	2010	2011	2012	Total
Bicycle Only	0	1	1	1	0	3
	0	0.1	0.1	0.1	0	0.1
Motorist Intentionally Caused	3	4	3	0	1	11
	0.3	0.5	0.3	0	0.1	0.2
Bicyclist Intentionally Caused	0	1	0	0	0	1
	0	0.1	0	0	0	0
Backing Vehicle	5	4	9	5	10	33
	0.5	0.5	0.9	0.5	1	0.7
Play Vehicle-Related	0	0	0	1	0	1
	0	0	0	0.1	0	0
Unusual Circumstances	3	0	1	1	1	6
	0.3	0	0.1	0.1	0.1	0.1
Non-Roadway	47	42	37	46	31	203
	4.5	5.1	3.8	4.5	3	4.2
Unknown Approach Paths	14	13	11	7	8	53
	1.3	1.6	1.1	0.7	0.8	1.1
Unknown Location	5	3	0	0	1	9
	0.5	0.4	0	0	0.1	0.2
Total	1,042	829	966	1,028	1,024	4,889
	21.3 [3]	17	19.8	21	20.9	

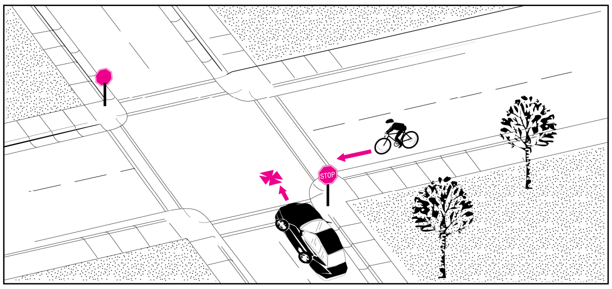
[1] Row percent of the column (yearly) total
[2] Row total percent of the total
[3] Column total percent of the total

Table 6 shows the top ten most frequently occurring types of bicycle-motor vehicle crashes for all five years combined. Together, these ten types accounted for 57% of all of NC's bicycle collisions. These types could therefore be among the priorities for targeting safety treatments. Other crash types, some closely related to the top ten also account for sizable numbers and may be targets for similar measures or others. The resources mentioned in the Background and at the end of this report, provide further guidance for selecting appropriate treatments.

Table 6. Top ten most frequent NC bicycle crash types, 2008-2012.

Rank	Crash Type	Total	Percent of NC Total
1	Motorist Drive Out - Sign-Controlled Intersection	478	9.8%
2	Motorist Overtaking - Other / Unknown	438	9.0%
3	Motorist Left Turn - Opposite Direction	363	7.4%
4	Motorist Drive Out - Commercial Driveway / Alley	246	5.0%
5	Motorist Overtaking - Misjudged Space	235	4.8%
6	Bicyclist Left Turn - Same Direction	234	4.8%
7	Bicyclist Ride Through - Sign-Controlled Intersection	233	4.8%
8	Motorist Right Turn - Same Direction	211	4.3%
9	Non-Roadway	203	4.2%
10	Motorist Overtaking - Undetected Bicyclist	141	2.9%
	Subtotal for top ten types for frequency	2782	56.9%

Among the top ten types, crashes in which the motorist and bicyclist were initially on parallel paths before any turns or other maneuvers that led to the crash (nos. 2, 3, 5, 6, 8, and 10) accounted for about 33 percent. Crashes in which the motorist and bicyclist were initially on crossing or perpendicular paths (nos. 1, 4, and 7) accounted for about 20 percent, with non-roadway types of crashes such as in parking lots or on public or private driveways accounted for about 4 percent of total crashes.



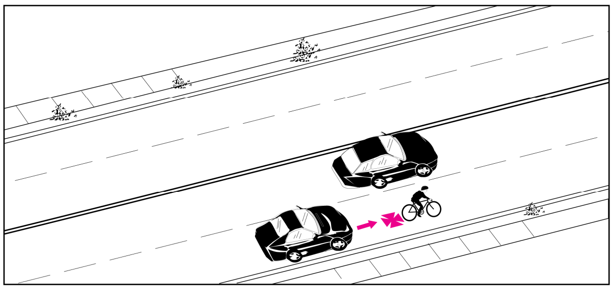
The most frequent event coded over this time period, **Motorist Drive Out – Sign-Controlled Intersection,** refers to a motorist who apparently obeyed a stop sign but then drove out into the path of the bicyclist. In 57% of the crashes of this type, bicyclists were riding wrong-way (facing against traffic) and therefore may have contributed to the crash by coming from an unexpected direction where the driver was less likely to notice them before pulling out.

Potential Countermeasures. Intersection improvements include providing mini-roundabouts or roundabouts, narrowing curb radii to reduce turning speeds, improving lighting, improving sight distance and visibility. Motorist and bicyclist education are also among the important countermeasures for this crash type. In addition, bicyclists may be uncomfortable riding on the roadway sections leading up to the intersection or there may be limited connectivity to paths or other bicycle origins/destinations. Cyclists using the sidewalk were at least three times as likely to be riding wrong-way compared to those riding on a travel lane on the roadway before their crash. (About half of all wrong-way cyclists were on the sidewalk.) Therefore measures that improve the overall bicycle level or quality of service on roadway sections, making it more appealing for riders to ride on the road in the correct direction of traffic, may help reduce this crash type.

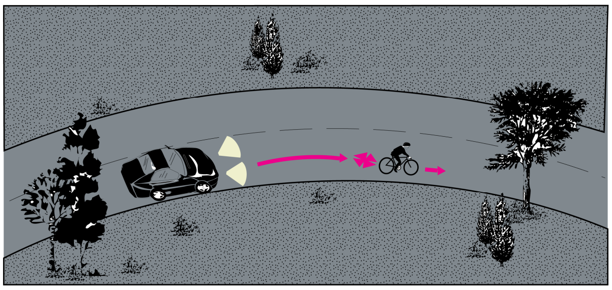
Cyclists riding on multi-use paths (which may be adjacent sidepaths intended for two-way riding), may also come from an unexpected direction when motorists cross these paths. Care should be taken in designing such junctions and providing for safe interactions.

Motorist Overtaking – Other/Unknown, the second most frequent crash type, describes events where the motorist and bicycle were on parallel paths in the same direction, but there was no information to indicate whether the motorist misjudged the space needed to pass, failed to detect the bicyclist, or the bicyclist swerved into the path of the motorist. There were very few cases (only five instances out of 438 crashes) where the bicyclist was indicated to be traveling in the wrong direction.

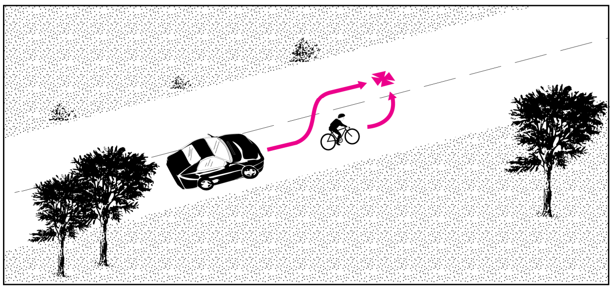
There are three other types of **Motorist Overtaking** crashes; two others are also in the top ten list: **Misjudged Space** (no. 5) implies that the motorist misjudged the space or distance needed to safely pass the bicyclist.



Motorist Overtaking - Undetected Bicyclist (no. 10) signifies crashes in which the motorist apparently did not see the bicyclist ahead until it was too late to avoid a crash.



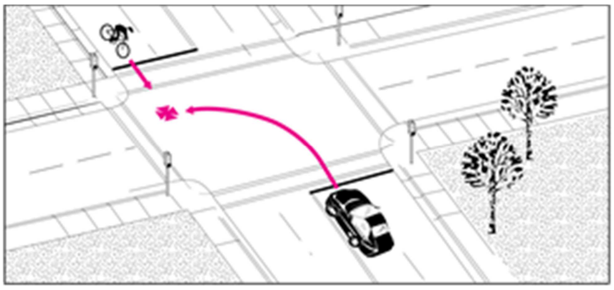
In addition, the 11th most frequent type (not shown in the table) was **Motorist Overtaking - Bicyclist Swerved**, which accounted for 123 crashes. This crash type describes cases where the bicyclist suddenly swerved (apparently not an intentional merge or turn) into the path of the overtaking motorist. This type accounted for another 3% of crashes statewide.



Thus, these four motorist overtaking crash types combined accounted for 19% of all of NC's bicycle-motor vehicle collisions. Treatments would be similar for all three types.

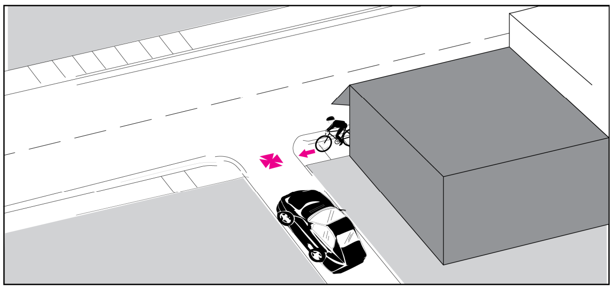
Potential Countermeasures. Providing for sufficient sight distance for the speed of traffic, separated space to ride such as wide shoulders or bike lanes (or even separated facilities), and keeping shoulders or lanes clear of debris and well-maintained are countermeasures that can help to address overtaking crash types. These crash types can be severe, particularly when motorized speeds are high. If separate space (paved shoulders, lanes, or path) or adequate sight distance cannot be provided, then it is important to consider whether speed limits should be lower, and to control traffic speeds so that overtaking motorists have sufficient sight distance and time to react to any slower vehicles ahead, including bikes. 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 tried.

Motorist Left Turn – Opposite Direction (#3 in the list) involves events where the motorist turns left at an intersection or driveway in front of an oncoming bicyclist.



These types of crashes may occur on multi-lane roads when the motorist's view of the bicyclist is block by other traffic lanes, or the driver may fail to look for or notice an oncoming bicyclist. About 78 percent of these occurred at intersections; 22 percent at driveways. The vast majority (95 percent) of bicyclists involved in this collision type were riding in the correct direction - with traffic - at the time of the crash.

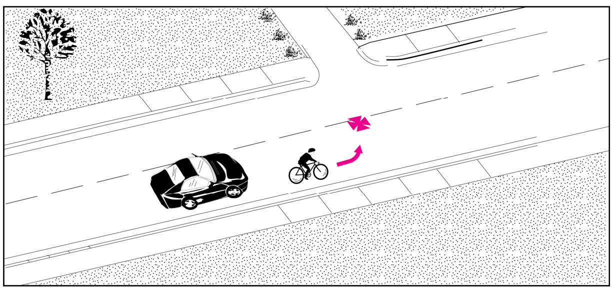
Potential Countermeasures. Providing protected-only left-turn phasing at signalized locations, restricting left turns at midblock locations, reducing conflicting movements by providing roundabouts (especially one-lane) at intersections, are among potential treatments for these types of collisions. Again, motorist education, which could include the use of MUTCD-approved regulatory or warnings signs (such as Yield when Turning or Watch for Bikes types of signs) could potentially help to reduce this crash type, at least at the locations where implemented. However, signs may lose effectiveness over the longer term.



Motorist Drive Out - Commercial Driveways (#4 in list) involves motorists driving out at these locations and failing to yield right-of-way to approaching bicyclists. As was the case with motorist drive outs at sign-controlled junctions, this type also has an over-representation (74% of the cases) of bicyclists traveling from the motorist's right, facing against traffic. Again, about half of all such cyclists are also riding on sidewalks or paths.

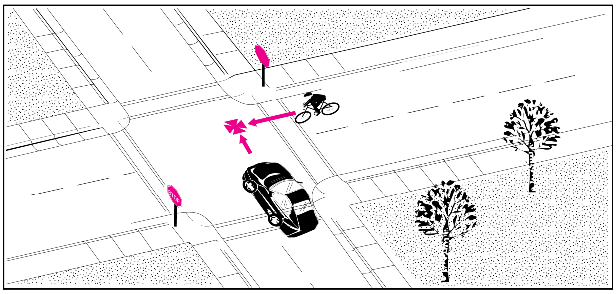
Potential Countermeasures. Sight distance issues may be contributing factors at driveways and should be addressed. In addition, driveway design and narrow turning radii can help to ensure that drivers stop and yield before pulling out. Measures that improve bicyclists' comfort on the road, as well as training and education of cyclists are also needed.s Drivers should be reminded to look both ways before pulling out. If bicyclists use sidewalks for riding in neighborhoods, or before roadway or other improvements are in place, they should be trained to ride like pedestrians, slowly, and watching for traffic at each junction.

Bicyclist left turn – Same Direction (#6) involves a bicyclist traveling along the right side of the roadway (usually) in the same direction as a motor vehicle and turning or merging left in front of, or into the side of, the motor vehicle traveling in the same direction. The rider fails to see or yield to a



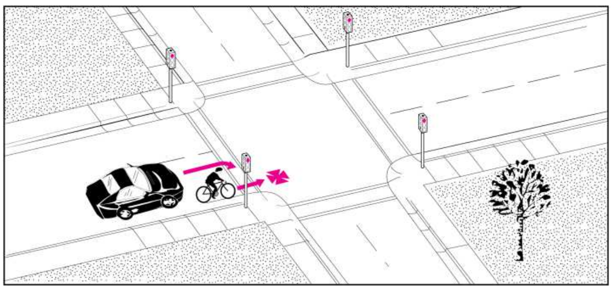
motorist coming from behind. This crash type could also involve a bicyclist riding out from a sidewalk or path beside the road. Speed of overtaking vehicles may be a factor in this group of crashes. The motorist also may not see the bicyclist, or may not suspect that the bicyclist will turn in front in time to react.

Potential Countermeasures. A variety of countermeasures may help reduce the occurrence of this crash type, specific to the situation. Bicyclists should be educated to use proper hand signals and check behind before changing position, and use lights at night. Motorists should be encouraged to allow ample space and be alert for when bicyclists may need to merge or turn. Speed enforcement and other efforts to control traffic speeds may also be needed. Special facilities or designs may be warranted in certain circumstances, such as if there are many bicyclists needing to merge to make left turns for a particular destination.



The 7th most frequent collision type over this time period, **Bicyclist Ride Through – Sign-Controlled Intersection**, is typically an event where the bicyclist ignored the sign controlling the bicyclist's direction. A lack of on-road bicycling experience, failure to notice the sign or look for conflicting traffic, a lack of sufficient gaps in traffic or a misjudgment of the available gap, or a reluctance to lose momentum are factors that could be present in such a crash type. Wrong-way riding (present in about 15% of the cases) could increase the chances that a bicyclist would not notice the traffic control.

Potential Countermeasures. In addition to educational/training measures, intersection treatments such as improved sight distance, implementing roundabouts or mini-roundabouts, installing a signal with bike detection, or providing alternate routes for bicyclists, are improvements that may be warranted to safely accommodate bicyclist traffic, depending on the road and area type. Bicycle boulevards, described in BIKESAFE, is a measure that could be tried to provide a priority route for bicyclists where they do not have to stop as frequently.



Eighth on the list, **Motorist Right Turn – Same Direction** involves motorists passing and turning right (sometimes known as the "right-hook") in front of bicyclists who were traveling along the same roadway (or an adjacent path or walkway) in the same direction.

Potential Countermeasures. Conspicuous bike lanes combined with bike boxes or advance stop bars at intersections may be appropriate in some situations to allow bicyclists to proceed to the front of the queue at signalized locations. Turn and through lane design and merge areas, intersection markings, narrower curb radii, and other treatments may be suitable, depending on the context. BIKESAFE describes some of these treatments. The *Guide for the Development of Bicycle Facilities* available from AASHTO, and the NACTO Urban Bikeway Design Guide are other resources.

The 9th most frequent crash type is a catch-all category for all **Non-Roadway** collisions that were reported (image not shown). This type means the crash occurred off the roadway network and typically refers to parking lot crashes, but may also include crashes on public and private driveways and other off-roadway areas.

Bicyclist Age Group and Crash Type (group)

Although all ages can be involved in virtually any type of crash, there are patterns of association by age group. Children and young adults are more often involved in riding out at sign and signal-controlled intersections as well as riding out from midblock locations. (See Table 7 in the Appendix for a table of age group by crash type interactions.) As with pedestrians, the youngest bicyclists are over-represented in back-over crashes and other crashes in non-roadway areas. When cycling, adults tend to be over-represented in crashes where the motorist turned across their path, or pulled out at an intersection or midblock location.

Countermeasures. Educational messages, training and enforcement could focus on the most common types of errors and situations that lead to the most common types of collisions, targeted by age group.

Children should also be closely supervised by parents and other caregivers, provided safe places to ride and to learn safe cycling, and taught about hazards when riding on driveways or around any motor vehicle, even those that seem parked. Adults also need to ride with youngsters and provide training as they learn to ride on paths and neighborhood streets when they mature enough to ride in these locations. If taught to ride on sidewalks, young riders should be coached to ride slowly and watch for traffic turning in and out at driveways, give way to pedestrians, and to obey traffic controls at intersections, regardless of where they ride. Young riders should also be taught to observe all traffic rules and regulations as they progress to riding on streets as well as to watch out for common types of conflicts. More information on behavioral countermeasures is available in Countermeasures That Work (NHTSA, 2011).

Education and enforcement efforts toward motorists should target safe driving around bicyclists and reinforce both motorists and bicyclists following traffic laws. Motorists need to understand and apply safe passing maneuvers, to watch out for bicyclists before making turns, and to obey all traffic controls.

Both children and adults should be encouraged to properly use safety helmets when riding to help prevent injuries in crashes. Helmet use is required by law Statewide for children 15 and younger when riding on public thoroughfares.

For complete crash type definitions, see the PBCAT Manual 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 data specific to those locations would need to be examined. Identification of the specific problems and treatments should include site visits, such as through interdisciplinary roadway safety audits before any

treatments are selected or implemented. See the Bicycle Road Safety Audit Guidelines and Prompt Lists for more information (Nabors et al., 2012).

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

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Appendix

Table 7. Crash type (group) involvement by age group of bicyclists, 2008-2012.

Percentages are the row percentage (crash type) of the column (age group) total. Gray highlights show over-represented categories.

Crash Type by Bicyclist Age	5 or less	6 to 10	11 to 15	16 to 19	20 - 29	30 - 59	60 +	Total
Backing Vehicle	6.4%	1.5%	0.2%	0.8%	1.0%	0.5%	0.3%	0.7%
Bicyclist Failed to Yield - Midblock	29.8%	25.2%	11.1%	7.6%	3.3%	2.7%	3.4%	6.2%
Bicyclist Failed to Yield - Sign-Controlled Intersection	12.8%	24.0%	14.5%	7.0%	3.5%	2.9%	4.4%	6.6%
Bicyclist Failed to Yield - Signalized Intersection	0.0%	0.6%	6.0%	6.4%	4.1%	3.5%	1.3%	3.9%
Bicyclist Left Turn / Merge	0.0%	4.2%	9.0%	9.2%	3.8%	3.9%	8.4%	5.4%
Bicyclist Overtaking Motorist	0.0%	0.3%	1.1%	1.6%	3.1%	1.7%	2.2%	1.8%
Bicyclist Right Turn / Merge	0.0%	2.4%	2.6%	1.8%	0.7%	1.2%	0.3%	1.3%
Crossing Paths - Other Circumstances	6.4%	7.5%	6.9%	8.0%	6.6%	5.9%	3.4%	6.4%
Head-On	4.3%	1.2%	2.4%	2.1%	3.3%	2.5%	3.8%	2.6%
Loss of Control / Turning Error	2.1%	7.2%	6.2%	4.3%	3.7%	4.5%	5.3%	4.7%
Motorist Failed to Yield - Midblock	2.1%	0.9%	4.2%	6.4%	9.3%	7.2%	4.1%	6.5%
Motorist Failed to Yield - Sign-Controlled Intersection	0.0%	2.1%	7.2%	10.2%	10.7%	12.2%	15.3%	10.4%
Motorist Failed to Yield - Signalized Intersection	0.0%	0.9%	2.1%	2.0%	4.2%	2.7%	4.1%	2.8%
Motorist Left Turn / Merge	2.1%	0.3%	3.1%	4.9%	13.2%	10.0%	8.8%	8.4%
Motorist Overtaking Bicyclist	4.3%	4.2%	11.3%	14.8%	14.4%	27.1%	24.7%	19.2%
Motorist Right Turn / Merge	0.0%	1.2%	2.4%	4.3%	7.2%	5.6%	5.9%	5.0%
Non-Roadway	25.5%	12.3%	5.5%	4.1%	4.0%	2.1%	2.8%	4.2%
Other / Unknown - Insufficient Details	2.1%	1.8%	2.0%	1.8%	0.9%	1.2%	0.3%	1.3%
Other / Unusual Circumstances	2.1%	0.0%	0.0%	0.6%	0.7%	0.6%	0.0%	0.4%
Parallel Paths - Other Circumstances	0.0%	2.1%	2.1%	2.1%	2.0%	2.3%	1.3%	2.1%
Parking / Bus-Related	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

*Note that Unknown ages were omitted for presentation.

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