Database improvements for motor vehicle/bicycle crash analysis

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ABSTRACT

Background Bicycling is healthy but needs to be safer for more to bike. Police crash templates are designed for reporting crashes between motor vehicles, but not between vehicles/bicycles. If written/drawn bicycle-crash-scene details exist, these are not entered into spreadsheets.

Objective To assess which bicycle-crash-scene data might be added to spreadsheets for analysis.

Methods Police crash templates from 50 states were analysed. Reports for 3350 motor vehicle/bicycle crashes (2011) were obtained for the New York City area and 300 cases selected (with drawings and on roads with sharrows, bike lanes, cycle tracks and no bike provisions). Crashes were redrawn and new bicycle-crash-scene details were coded and entered into the existing spreadsheet. The association between severity of injuries and bicycle-crash-scene codes was evaluated using multiple logistic regression.

Results Police templates only consistently include pedal-cyclist and helmet. Bicycle-crash-scene coded variables for templates could include: 4 bicycle environments, 18 vehicle impact-points (opened-doors and mirrors), 4 bicycle impact-points, motor vehicle/bicycle crash patterns, in/out of the bicycle environment and bike/relevant motor vehicle categories. A test of including these variables suggested that, with bicyclists who had minor injuries as the control group, bicyclists on roads with bike lanes riding outside the lane had lower likelihood of severe injuries (OR, 0.40, 95% CI 0.16 to 0.98) compared with bicyclists riding on roads without bicycle facilities.

Conclusions Police templates should include additional bicycle-crash-scene codes for entry into spreadsheets. Crash analysis, including with big data, could then be conducted on bicycle environments, motor vehicle potential impact points/doors/mirrors, bicycle potential impact points, motor vehicle characteristics, location and injury.

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From 2000 to 2013, the number of commuting bicyclists in the USA increased by 61.6%.[1] This may be due in part to the health benefits of bicycling[2–13] and the desire for a cleaner environment.[14–18] While the health benefits outweigh the risks, including crashes,[9] many individuals may still choose not to bicycle due to risk.[19] If environments were safer for bicyclists, perhaps more individuals would bicycle.[20] Having accurate crash data about bicyclists would be useful, especially since accurate motor vehicle crash (MVC) data produced better roadways and safer motor vehicles which, in turn, resulted in decreased crash-related morbidity and mortality.[21–23]

Police have recorded bicycle crashes since the introduction of the bicycle in 1890 when crashes were written in police journals.[24 25] Crash reports are now entered by police officers on a state crash report template that includes spaces for a written description of the crash and free drawn diagrams plus boxes for coded information. Some of the data on the template, including the coded information, is later entered by a police officer or a staff person into a spreadsheet about that individual crash. The information requested on the template, and thus the data entered later into the spreadsheet, focuses primarily on crashes between motor vehicles.[26]

Diagrammatically, a motor vehicle most closely resembles a rectangle while a bicycle most closely resembles a line (figure 1). Consequently, the points of impact could be very different when two motor vehicles collide versus when a motor vehicle and a bicycle collide. For example, in a crash between a bicycle and a motor vehicle, a bicycle could strike an opened car door or a side mirror, or come alongside a motor vehicle in a narrow space between the motor vehicle and the road's edge. To describe a bicycle crash in a useful way, police crash report templates should be modified to include bicycle-crash-scene reporting fields. The current state crash report template does include a category for pedal cyclist/bicyclist, who is considered a non-motorist, but there are very few codes specific to bicyclists. Bicycle-crash-scene details can be found in the written crash description and drawing on the template but these details are not coded for entry into a spreadsheet. Therefore, when analyses require large existing data sets and the combining of many reports, bicycle-crash-scene details are not available.

Many state police are now entering crash reports into an electronic tablet, allowing the information to be automatically transferred, thus lessening errors from manual entry and improving timeliness. Advances are also being made through the Model Minimum Uniform Crash Criteria (MMUCC), a minimum and standardised data set for MVCs that describes the motor vehicles, people involved and environments.[27] The Federal government, state agencies, local government officials, engineers, hospitals and researchers have proposed combining electronic data into the Crash Outcome Data Evaluation System (CODES) that includes police crash data, emergency medical services reports, hospital records and insurance claims.[28] As these advances are being made and big data are being generated, perhaps the crash report entered into the electronic tablet could include a drop-down bike-only template with bicycle-crash-scene spreadsheet-coded data points. The issue then becomes what might be most informative as bicycle-crash-scene coded data in a spreadsheet.

No study has analysed police templates and crash report text/drawings to determine if the templates

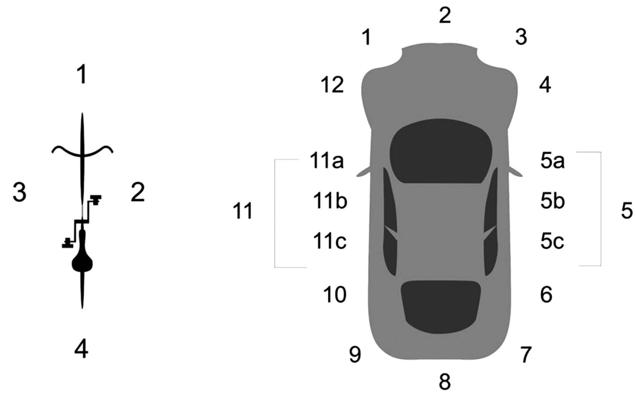

Figure 1 Bicycle and vehicle points of impact coding.

could be improved to more fully report motor vehicle/bicycle crashes. Therefore, this study first explored what bicycle-crash-scene coded information is in the existing state and MMUCC templates. Second, using police text and drawings from 300 motor vehicle/bicycle crashes in New York City (NYC), crashes were redrawn using Google street view and the vehicle identification number (VIN) studied to investigate what additional variables to consider as bicycle-crash-scene coded data. These new bicycle-crash-scene variables were added to the original spreadsheet crash file of 300 crashes and analysed to demonstrate the value of these new variables. If detailed and bicycle-crash-scene motor vehicle/bicycle crash information could be entered into a spreadsheet as coded data, combined with the other data in a spreadsheet (CODES),[28] and used as part of the Pedestrian and Bicycle Crash Analysis Tool[29] and bicycle road safety audits,[30] the results might better inform changes to environments, motor vehicles, and bicycles to lower motor vehicle/bicycle crashes and severity of injury.

METHODS

State and MMUCC crash report templates were studied and data in motor vehicle/bicycle crash report text and drawings in NYC analysed to determine which bicycle-crash-scene data might be informative to add as spreadsheet coded variables to police crash report templates to use in the analysis for improving safety.

Crash report template content comparisons

Crash templates were obtained from the individual state Departments of Motor Vehicles, state websites, and websites with templates.[31 32] The templates studied for requested information (ie, what information was requested for the fill-in-the blank spaces and the small boxes for which there were codes) included 49 full crash templates dated 2000–2013, 2 full crash templates dated 1988–1991 and the MMUCC template. Then, the state templates were compared to identify what bicycle-crash-scene information was requested, or not, on each state template.

Motor vehicle/bicycle crashes in NYC selected for analysis (300 cases)

Full crash reports of 3350 motor vehicle/bicycle crashes in the NYC area for the year 2011 were obtained that had x/y coordinates (crash location) from the New York State Department of Transportation (NYSDOT). Using the geographical codes available in the spreadsheet file, we first identified the motor vehicle/bicycle crashes only in NYC (n=1080). With a bicycle facilities map for NYC, a map was generated designating the roads with four different bicycle environments ((1) roads; (2) sharrows—bike stencil designations on the street; (3) bike lanes; and (4) cycle tracks—barrier protected, bicycle exclusive paths beside sidewalks) and crash locations were superimposed on this map.

From NYSDOT, full copies of reports were requested for 46 crashes on sharrows (all sharrow crashes), 79 crashes on roads with cycle tracks (all cycle track crashes), 188 crashes on roads with bike lanes (all bike lane crashes) and, using a probability sampling programme, 188 crashes on roads with no bike facilities to match the number of crashes on roads with bike lanes (n=501 crashes). NYSDOT sent us 600 full crash reports (private information redacted) to better guarantee that we would have 300 crash reports with diagrams (83 out of the 600 crash reports had no crash diagrams). The maximum of 300 crashes was due to the significant amount of time involved in the reanalysis of each crash. For analysis, the selected crashes included all the crashes on roads with sharrows (n=44), all the crashes on roads with cycle tracks (n=65), and using a probability sampling programme, a random sample of crashes on roads with bike lanes (n=95) and a random sample of the crashes on roads without bicycle provisions (n=96).

Motor vehicle/bicycle crashes redrawn for impact, turns, and in or out of environment

Using the text and drawings in the crash reports and Google street views, each of the 300 motor vehicle/bicycle crashes were redrawn including streets and their directions, number of lanes, presence of parking, bicycle environment if one existed, motor vehicle/s location and bicycle location (figure 2). Then, an X was drawn to identify the impact location on the motor vehicle and the bicycle and a Google street view saved of the crash scene.

From the state templates and the web, the variety of diagrams was collected that depicted the turning direction and impact location (head-on crash with two arrows pointing towards each other) and similar turns/impact diagrams merged. The different turn/impact diagrams were matched to the 300 redrawn crash drawings (that had included the vehicle and bicycle turning directions), grouping all similar diagrams most relevant to motor vehicle/bicycle crash turns to achieve a manageable number (10). For example, if only two of the 300 bike crash scenarios were related to a turn/impact diagram, those two cases were merged with another similar scenario (figure 3).

The location of the bicyclist was also determined in relation to a bicycle environment, if an environment existed. These variables then included if the bicyclists were: (1) on a road with no designated bicycle environment; (2) on a road with sharrows; (3) in a street with bike lanes and inside the bike lane; (4) in a street with bike lanes but outside the lane; (5) in a street with cycle tracks and inside the cycle track; and (6) in a street with cycle tracks but outside the cycle track. The 300 redrawn vehicle/bicycle crashes then provided the following for each crash: (1) motor vehicle impact point; (2) bicycle impact point; (3) vehicle and bicycle turning directions (crash patterns); and (4) bicyclist's location and in or out of a bicycle environment.

VINs and motor vehicle configuration

The first 11 digits in the 17 motor vehicle code VIN were requested for the 300 crashes to reveal general motor vehicle characteristics but not owner identity. Using the digits and pictures of the motor vehicles from the web, the motor vehicle types were recategorised into bicycle crash/relevant characteristics based on an expert determination ((1) car sedan; (2) car

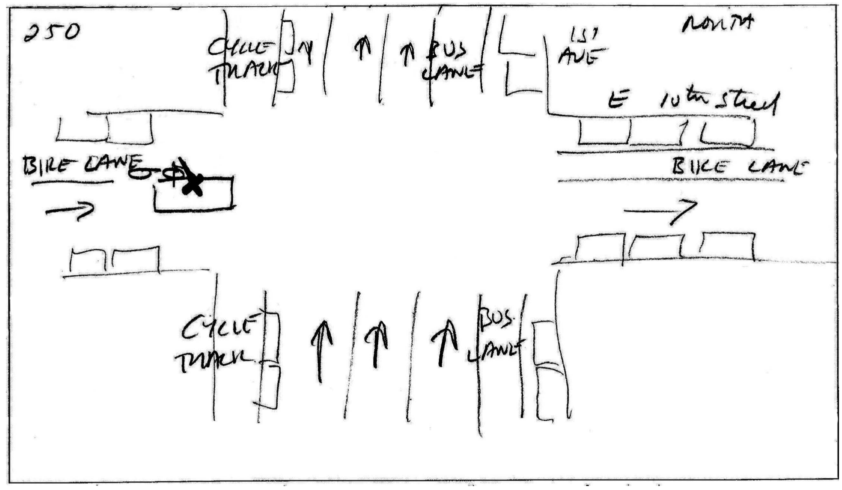

Figure 2 Drawing of vehicle/bicycle crash. The diagram shows a one way street north with three lanes of traffic (up arrow symbol), a bus lane, a cycle track, and on both sides parallel parked cars (□). The diagram also shows a one way street east with one lane of traffic (right pointing arrow symbol), a bike lane, and parallel parked cars on both sides (□). The vehicle is drawn as a rectangle and the bicycle crashed into the opened back door on the driver's side.

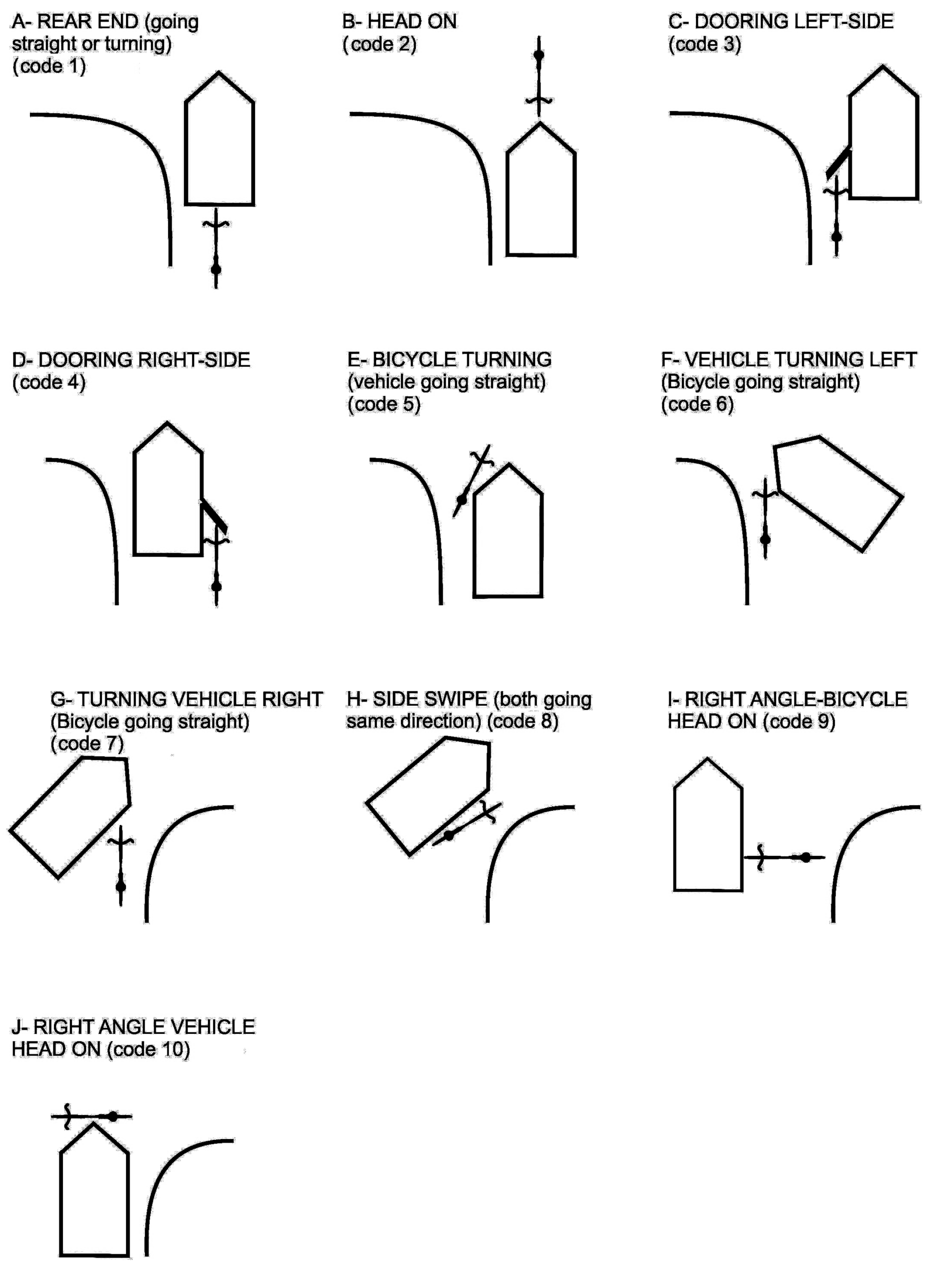

Figure 3 Crash patterns coding (turn/impact).

sport utility vehicle (SUV); (3) hatchback; (4) van; (5) pick-up truck; (6) medium truck; (7) large truck; and (8) bus). This content could then be used in the analysis to determine if one type of vehicle was more likely to be involved in a crash with a bicycle.

Content in the different motor vehicle/bicycle crash report formats

From the NYSDOT the crash reports in all three formats were obtained that are available to the public. These reports include: (1) original police report with the text and diagram (private information redacted); (2) spreadsheet; and (3) shorter typed report. Having the three formats allowed us to determine and compare the level of detail in each of the formats.

Statistical analysis

Analysis was conducted using the new bicycle-crash-scene variables that were entered into the existing spreadsheet for the 300 NYC vehicle/bicycle crashes. This analysis provided the opportunity to begin to assess if having these bicycle-crash-scene variables might be worthwhile. Frequency of motor vehicle impact point, bicycle impact point, bicycle environments, bicycling inside or outside of the environments, motor vehicle type, and crash patterns (turn/impact diagrams) were analysed. Because the existing spreadsheet included the variables, as reported by the police, of bicyclists with minor injuries and bicyclists with severe injuries and it would be time-consuming to obtain bike counts for all the streets studied in NYC, bicyclists with minor injuries were used as the control group and bicyclists with severe injuries/fatalities as the case group. Based on injuries/fatalities, the groups then included: Group 1 (control group)—Minor injury included non-incapacitating injuries (n=99); and Group 2 (case group)—Severe injury included incapacitating injuries, possible injuries and killed (n=191). Variables were compared based on injury type by t test for quantitative variables and χ^2 tests for qualitative variables. Logistic regression was also performed for independent variables which had been estimated as strongly affecting injury; ORs with 95% CIs were reported. Two models were constructed to examine the association between motor vehicle potential impact points, in/out (whether the crash happened inside or outside a bike lane or cycle track) and injury severity. Model 1A and 1B are unadjusted models. In Model 2A, potential confounders were adjusted including age (years), gender, road surface condition (dry, wet, muddy, snow/ice, slush, flooded water, other), crash pattern, motor vehicle type (motorcycle, car/van/pick-up truck, bus, bicycle, pedestrian, other, unknown), light condition (daylight, dawn, dusk, dark-road lighted, dark-road unlighted) and intersection. We did a sensitivity analysis by excluding crashes for which the vehicle in the existing spreadsheet was listed as unknown (Model 1B and 2B). Thus, Model 2B did not include possible hit-and-run crashes in which the vehicle driver would have left the scene. All analyses used SPSS V.21 (Chicago, Illinois, USA).

RESULTS

Analysis of the state police and MMUCC crash templates and 300 motor vehicle/bicycle crashes in NYC (impact points, crash patterns, in/out of environment, VINs and content in report formats) revealed motor vehicle/bicycle specific crash variables that, as spreadsheet-coded data, could be useful for analysis.

Existing crash report templates

Content analysis of state police templates indicated that pedalcyclist (labelled under non-motorist Vehicle #2) and helmet (except for three states with motorcycle helmet) were standard, but other bicycle-crash-scene categories were not consistently included (table 1). Motor vehicle drawings ranged from having 8 to 16 potential impact points but did not include opened doors or side mirrors. States with a motorcycle/pedal cyclist drawings included Nevada (eight potential impact points), Arizona (six potential impact points), and North and South Carolina (four potential impact points). Only a few states included pedal-cyclist action, location, reflective clothing, lighting, direction or manoeuvre. Some states are issuing electronic citations using an online template, but some did not include a bicycle category. The standardised MMUCC included a motor vehicle drawing (12 potential impact points), a motorcycle drawing (12 potential impact points), reflective clothing and lighting. Of the templates that listed bicycle facilities, only bike lanes or shared use paths were included.

Motor vehicle/bicycle crashes in NYC selected for analysis

Three hundred vehicle/bicycle crashes in NYC that included drawings were redrawn, studied and analysed to test if having bicycle-crash-scene variables to enter into crash spreadsheets might be informative for analysing vehicle/bicycle crashes.

Motor vehicle/bicycle crashes redrawn for in/out of environment, impact points and turns

Though bicycle environments may exist, bicyclists do not have to ride in these facilities unless a side path law exists (must ride in a parallel bicycle environment). Based on the new bicycle-crash-scene codes, numbers of minor or severe crashes differ (table 2).

For the bicycle, four potential impact points were identified because of the difficulty in discerning from the crash report more than four potential impact points (figure 1). For motor vehicles, 18 possible impact points were identified (including *a* for mirror and *b* and *c* for opened doors). The bicycle front (side 1) and the motor vehicle front (side 2) had the greatest frequency of crash and injury severity (table 2). A test was conducted to assess the usefulness of having these new bicycle-crash-scene data entered into the existing spreadsheet. In Model 2B (that did not include possible hit-and-runs and that had bicyclists who had minor injuries as the control group), bicyclists on roads with bike lanes who were riding outside the lane had lower likelihood of severe injuries (OR, 0.40, 95% CI 0.16 to 0.99) compared with bicyclists riding on roads without bicycle facilities (table 3).

Under the merged similar turns/impact diagrams most likely in a motor vehicle/bicycle crash, the 300 crash drawings were sorted. For example, all head-on motor vehicle/bicycle crashes were together. (figure 3). The highest frequencies for motor vehicle/bicycle crashes were motor vehicles turning left and sideswipe (motor vehicle and bicycle same direction) (table 2).

VINs and motor vehicle configuration

VINs and pictures of the motor vehicles allowed for classification of eight different types of motor vehicles and sedans, which can include taxis, that were most involved with crashes and severely injured bicyclists (table 2).

Content in the different motor vehicle/bicycle crash report formats

Data about the NYC motor vehicle/bicycle crashes can be requested in spreadsheet form but for bicycle-crash-scene data, only body type (bicyclist), vehicle type (bicycle) and helmet are coded for spreadsheet entry. The typed crash report can also be

Table 1 State templates and inclusion of bicycle information

State (date of most recent report)	Pedal cyclist code	Potential impact point of motor vehicle	Potential impact point of bicycle	Pedal cycle-specific location code	Pedal cycle-specific action code	Pedal cycle clothing or light code	Pedal cycle sobriety/physical condition	Helmet code	Bike-specific path of travel in diagram and bike manoeuvre
Alabama (1991)	Yes	11 (8 sides)	No	Yes	Yes	Constraining clothing	No	No (motor cycle)	No
Alaska (2001)	Yes	9 (8 sides)	No	No	No	No	No	Yes	No
Arizona (2008)	Yes	14 (8 sides)	No	Yes	No	No	No	Yes	No
Arkansas (2000)	Yes	10 (8 sides)	No	No	No	No	No	Yes	No
California (2003)	Yes	No	No	No	No	No	No	Yes	No
Colorado (2006)	Yes	20 (16 sides)	No	No	No	No	No	Yes	No
Connecticut (2001 and 1994)	Yes	No	No	No	No	High visibility clothing (1994)	No	Yes (1994)	No
Delaware (1988)	Yes	15 (12 sides)	No	No	No	No	No	No (motor cycle)	No
District of Columbia (2011)	Yes	18 (12 sides)	No	No	No	No	No	No	No
Florida (2001)	Yes	20 (14 sides)	No	No	No	No	No	Yes	No
Georgia (2003)	Yes	15 (12 sides)	No	No	No	No	No	Yes	No
Hawaii (1996)	Yes	10 (8 sides)	No	Yes	Yes	No	No	No	No
Idaho (2011)	Yes	14 (12 sides)	No	Yes	Yes	No	No	Yes	No
Illinois (2009)	Yes	12 (8 sides)	No	Yes	Yes	Constraining clothing, reflective material, light	No	Yes	No
Indiana (2003)	Yes	10 (8 sides)	No	No	No	No	No	Yes	No
Iowa (2001)	Yes	10 (8 sides)	No	Yes	Yes	Reflective clothing, light	No	Yes	No
Kansas (2009)	Yes	22 (16 sides)	No	No	No	Reflective clothing	No	No (motor cycle)	No
Kentucky (2000)	Yes	None	No	No	No	No	No	Yes	No
Louisiana (2005)	Yes	17 (12 sides)	No	No	No	No	No	Yes	No
Maine (2010)	Yes	12 sides	No motorcycle	Yes	Yes and manoeuvres	No	No	Yes	Yes manoeuvre
Maryland (2006)	Yes	23 (16 sides)	No	No	No	Clothing not visible	Yes	Yes	No
Massachusetts (2012)	Yes	9 (8 sides)	No	Yes	Yes	Reflective clothing Lighting	No	Yes	Yes
Michigan (2010)	Yes	10 (8 sides)	No	No	No	No	No	Yes	No
Minnesota (2008)	Yes	12 (8 sides)	No	No	Yes	No	No	Yes	No
Mississippi	Yes	18 (16 sides)	No	No	No	Reflective clothing	No	Yes	No
Missouri (2012)	Yes	19 (14 sides)	No	No	No	No	No	Yes	No
Montana	Yes	No diagram	No	Yes	No	No	No	Yes	No
Nebraska (2011)	Yes	10 (8 sides)	No	No	No	No	No	Costume helmet	No
Nevada (2004)	Yes	10 (8 sides)	Yes 8 sides	Yes (lane, route, path)	No	Reflective clothing Lighting	No	Yes	No
New Hampshire (2013)	Yes	17 (14 sides)	No	No	Yes	No	No	Yes	No
New Jersey (2010)	Yes	14 (12 sides)	No	No	Yes	No	No	Yes	No
New Mexico (1997)	Yes	14 (12 sides)	No	No	Yes	No	Yes	No	No
New York (2004)	Yes	14 (12 sides)	No	Yes	Yes	No	No	Yes	No

Continued

Table 1 Continued

State (date of most recent report)	Pedal cyclist code	Potential impact point of motor vehicle	Potential impact point of bicycle	Pedal cycle-specific location code	Pedal cycle-specific action code	Pedal cycle clothing or light code	Pedal cycle sobriety/physical condition	Helmet code	Bike-specific path of travel in diagram and bike manoeuvre
North Carolina (2009) (1999)	Yes	21 (16 sides)	4 sides bike (1999)	Yes (1999)	Yes (1999)	No	No	Yes (1999)	Yes—line (1999)
North Dakota (2009)	Yes	9 (8 sides)	8 sides (motor cycle)	No	No	No	No	Yes	No—line for motor cycle
Ohio (2012)	Yes	11 (8 sides)	No	Yes	Yes	Reflective clothing Lighting	No	Yes	No
Oklahoma (2007)	Yes	14 (12 sides)	No	No	No	No	No	Yes	No
Oregon (2011 Insurance report) (1998 police form)	Yes	Motor vehicle diagram	No	No	Yes	Reflective clothing Lighting	Yes	Yes	Yes
Pennsylvania (2009) (Insurance report)	No	14 (12 sides)	No	No	No	No	No	No—Motor Cycle	No
Rhode Island (2012) (Insurance report)	Yes	No	No	No	No	No	No	No	No
South Carolina (2001) and (2005 Insurance report)	Yes	11 (8 sides)	4 sides (2001)	No	No	Reflective clothing 2001 Lighting 2001	No	Yes 2001	No
South Dakota (2003)	Yes	14 (12 sides)	No	Yes	No	Reflective clothing Lighting	No	Yes	No
Tennessee (2000)	Yes	10 (8 sides)	No	No	No	No	No	Yes	No
Texas (2010)	Yes	12 sides	No	Yes	No	No	No	Yes	No
Utah (2005)	Yes	14 (12 sides)	No	Yes	Yes	No	No	Yes	No
Vermont (2012)	Yes	12 (8 sides)	No	Yes	Yes	No	No	Yes	No
Virginia (2007)	Yes	13 (12 sides)	No	No	No	No	No	Yes	No
Washington (2006)	Yes	10 (8 sides)	No	Yes	Yes	Reflective clothing	No	Yes	No
West Virginia (2007)	Yes	14 (12 sides)	12 sides (motor cycle)	No	No	Reflective clothing Lighting	No	Yes	No
Wisconsin (1996)	Yes	10 (8 sides)	No	No	No	No	No	Yes	No
Wyoming (2007)	Yes	14 (12 sides)	No	No	No	No	No	Yes	No
MMUCC (Model Minimum Uniform Crash Criteria (2012)	Yes	12 sides	12 sides (motor cycle)	Yes	Yes	Reflective clothing Lighting	No	Yes	No

Table 2 Frequency of minor and severe injuries based on new bicycle-crash-scene codes*

	Minor injury (n)‡	Severe injury (n)§	Total injury (n)	
Bicycle environments†				
No bike facility	33	62	95	
Sharrows	14	30	44	
Bike lane (bicyclist inside the lane)	11	22	33	88 (total)
Bike lane (bicyclist outside the lane)	23	32	55	
Cycle track (bicyclist inside the lane)	8	14	22	63 (total)
Cycle track (bicyclist outside the lane)	10	31	41	
Bicycle potential impact points¶	Minor Injury (n)	Severe Injury (n)	Total Injury(n)	Ratio of all cases (%)
Front	54	95	149	51.6
Right side	16	34	50	17.3
Back	5	8	13	4.5
Left side	23	54	77	26.6
Motor vehicle Potential impact Points				
1 (left front)	7	23	30	10.3
2 (front)	17	35	52	17.9
3 (right front)	10	21	31	10.7
4 (right/right front)	11	17	28	9.6
5 (general ride door side)	8	17	25	8.6
5a (right mirror)	5	8	13	4.5
5b (right front door)	1	4	5	1.7
5c (right back door)	6	15	21	7.2
6 (right/right back)	4	3	7	2.4
7 (right back)	1	0	1	0.3
8 (back)	3	2	5	1.7
9 (left back)	0	1	1	0.3
10 (left/left back)	1	3	4	1.4
11 (general left door side)	4	4	8	2.6
11a (left mirror)	2	1	3	1.0
11b (left front door)	3	5	8	2.8
11c (left back door)	3	12	15	5.2
12 (left/left front)	13	20	33	11.4
Crash patterns (turn/impact)				
Rear end	7	6	13	4.4
Head-on	2	6	8	2.8
Dooring left-side	7	17	24	8.3
Dooring right-side	6	17	23	8.0
Bicycle turning	3	14	17	5.9
Motor vehicle turning left	20	28	48	16.6
Motor vehicle turning right	14	16	30	10.4
Sideswipe	19	33	52	18.0
Right angle—bicycle head-on	12	23	35	12.1
Right angle—motor vehicle head-on	9	30	39	13.5
Vehicle type				
Sedan	42	79	121	53.8
Sport utility vehicle (SUV)	2	14	16	7.1
Hatchback	20	34	54	24
Van	6	14	20	8.9
Pick-up truck	0	4	4	1.8
Medium truck	1	3	4	1.8
Large truck	2	1	3	1.3
Bus	2	1	3	1.3

*All of the specific variables could not be generated for all of the 300 bicycle crashes.
†Bicycle environments selected based on equitability among the environments and thus not a random sample.
‡Minor injury—non-incapacitating injuries.
§Severe injury—incapacitating injuries, possible injuries or killed.
¶Bicycle potential impact points, motor vehicle potential impact points, motor vehicle types and crash patterns could all equally be impacted in the four different bicycle environments.

obtained but this is a text version of the spreadsheet information. The original redacted crash report with text and drawings (if the crash was drawn) can be requested. With this full crash report and Google street view, the scenario, though time-consuming, can be redrawn to reveal motor vehicle-side impact, bicycle-side impact, if the bicyclist was most likely riding in the bicycle facility, or the unique motor vehicle/bicycle turning directions. These bicycle-crash-scene data then have to be

Table 3 OR and 95% CIs for severe injuries according to in/out of bicycle facility and motor vehicle side impact

	Number of severe injuries	Number of total injuries	Included 'unknown' vehicle variable (included possible hit-and-runs) Model 1A	Model 2A*	Number of severe injuries	Number of total injuries	Excluded 'unknown' vehicle variable (did not include possible hit-and-runs) Model 1B	Model 2B†
In/Out	**191**	**290**			**150**	**225**		
No bicycle facility	62	95	1	1	53	74	1	1
Sharrows	30	44	1.14 (0.53 to 2.44)	1.18 (0.51 to 2.73)	23	33	0.91 (0.37 to 2.24)	0.95 (0.35 to 2.59)
Riding inside bike lane	22	33	1.06 (0.46 to 2.46)	1.20 (0.46 to 3.13)	15	25	0.59 (0.23 to 1.53)	0.57 (0.19 to 1.70)
Riding outside bike lane	32	55	0.74 (0.37 to 1.46)	0.59 (0.28 to 1.25)	23	39	0.57 (0.25 to 1.28)	**0.40 (0.16 to 0.98)****
Riding inside cycle track	14	22	0.93 (0.36 to 2.45)	0.91 (0.31 to 2.68)	11	19	0.54 (0.19 to 1.54)	0.60 (0.19 to 1.93)
Riding outside cycle track	31	41	1.65 (0.72 to 3.78)	1.45 (0.60 to 3.54)	25	35	0.99 (0.41 to 2.41)	0.83 (0.31 to 2.18)
Motor vehicle side	**190**	**289**			**149**	**224**		
2 (Reference) (front vehicle)	35	52	1	1	24	36	1	1
1 (left front vehicle)	23	30	1.60 (0.57 to 4.45)	2.14 (0.66 to 6.96)	20	23	3.33 (0.82 to 13.48)	4.66 (0.93 to 23.45)
3 (right front vehicle)	21	31	1.02 (0.39 to 2.64)	1.20 (0.41 to 3.52)	14	22	0.88 (0.29 to 2.66)	1.00 (0.28 to 3.64)
4 (right/right front vehicle)	17	28	0.75 (0.29 to 1.95)	1.09 (0.34 to 3.53)	12	20	0.75 (0.24 to 2.32)	0.90 (0.21 to 3.78)
5,11 (general door potential impact points)	21	33	0.85 (0.34 to 2.12)	0.92 (0.28 to 3.05)	18	28	0.90 (0.32 to 2.54)	0.96 (0.23 to 3.92)
6 (right/right back vehicle)	3	7	0.36 (0.07 to 1.81)	0.52 (0.08 to 3.49)	2	5	0.33 (0.05 to 2.27)	0.58 (0.06 to 6.06)
7, 8, 9 (vehicle back potential impact points)	2	6	0.24 (0.04 to 1.46)	0.14 (0.01 to 1.91)	1	4	0.17 (0.02 to 1.78)	0.08 (0.004 to 1.77)
10 (left/left back vehicle)	3	4	1.46 (0.14 to 15.07)	1.26 (0.10 to 16.48)	3	4	1.50 (0.14 to 16.00)	1.07 (0.07 to 16.32)
12 (left/left front vehicle)	20	33	0.75 (0.30 to 1.85)	0.94 (0.30 to 3.01)	16	27	0.73 (0.26 to 2.05)	0.81 (0.21 to 3.14)
5a, 5b, 5c, 11a, 11b, 11c‡	45	65	1.09 (0.50 to 2.39)	0.98 (0.24 to 4.04)	39	55	1.22 (0.49 to 3.01)	1.73 (0.32 to 9.32)

*Model 2A was adjusted for age (years), gender, road surface condition (dry, wet, muddy, snow/ice, slush, flooded water, other), crash pattern, motor vehicle type (motorcycle, car/van/pick-up truck, bus, bicycle, pedestrian, other, unknown), light condition (daylight, dawn, dusk, dark-road lighted, dark-road unlighted) and intersection.
†Model 2B was adjusted for age (years), gender, road surface condition (dry, wet, muddy, snow/ice, slush, flooded water, other), crash pattern, motor vehicle type (motorcycle, car/van/pick-up truck, bus, bicycle, pedestrian, other), light condition (daylight, dawn, dusk, dark-road lighted, dark-road unlighted) and intersection.
‡5a=right mirror; 5b=right front opened door; 5c=right back opened door; 11a=left mirror; 11b=left front opened door; 11c=left back opened door.
**P<0.05. The bold is for level of significance 0.05.

entered into the existing spreadsheet to conduct an analysis more focused on the bicyclist.

DISCUSSION

Fifty-one state crash report templates and the MMUCC template were analysed and pedal-cyclist/bicyclist and helmet are the only bicycle-relevant information consistently entered as coded data into the state spreadsheet about each crash. To conduct more analysis, full crash reports with the text and drawings were obtained and redrawn using Google street view. This process was labour-intensive, the extracted variables were only available to this team, and the Google street views changed during the analysis as some of the cycle tracks were under construction.

Because improvements are being made to crash reporting, bicyclist-crash-scene variables could be coded on a police electronic tablet with a drop-down template for motor vehicle/bicycle crashes and uploaded automatically into the state spreadsheet database. Our research suggests that new bicycle-crash-scene variables might be informative for analysis including: 4 bicycle environments (roads, sharrows, bike lanes and cycle tracks); 18 motor vehicle potential impact points including opened car doors and mirrors; 4 bicycle potential impact points; whether in or out of the bicycle environment; 10 bicycle-crash-scene patterns (turn/impact); and motor vehicle types relevant to bicyclists. Having these new variables revealed higher crash frequency on motor vehicle fronts, bicycle fronts, no bike facility, sedan and as sideswipes.

Compared with bicyclists hitting the back of the motor vehicle, opened motor vehicle doors and mirrors resulted in higher risk of severe injury and, compared with riding on roads without bicycle facilities, riding on roads with bike lanes but not riding on the lane resulted in lower risk of severe injury. These analyses were possible because the new bicycle variables were entered into the existing spreadsheet that already contained the categories for minor and severe/fatal injuries. While studying circumstances surrounding crashes using bicycle counts is valuable,[33–36] collecting bicycle counts can be difficult, especially if counts are needed on all streets involved. If these new bicycle-crash-scene variables were entered into the existing spreadsheets, bicycling could be analysed with minor injuries as the control and severe injuries as the case. Though not as ideal as a comparison between no injury and injury, using the data in the spreadsheet at least enables a comparison between minor injury and severe injury.

Entering new bicycle-crash-scene variables can be worthwhile because in the USA the focus has been on bike lanes[37 38] while recent research has suggested the safety of cycle tracks.[33 34 39–41] With bicycle-crash-scene spreadsheet codes, associations could be found between environments plus motor vehicle/bicycle potential impact points, motor vehicles and injuries, especially when merged with big data including emergency medical services, insurance, etc.[28 42] These bicycle-crash-scene data are informative because, unlike a motor vehicle, a bicyclist can be negatively impacted by opened car doors[43] or by the direction of travel or turning of a motor vehicle.[36 44–46] Additionally, before a crash 11% of car drivers saw the bicyclist while 68% of the bicyclists saw the car.[47] If environments and crash patterns were coded for motor vehicle/bicyclist crashes, intersections might be better understood and designed to lessen the looked-but-failed-to-see-errors.[48–50] Better data leading to better analysis would also inform bicyclist and driver education efforts.[44 51]

With bicycle-crash-scene spreadsheet codes, access to and use of data would be improved. Now, a research team can request the VIN's first 11 digits but this information is then only available to that team. Current codes include the chassis size, yet many vehicle descriptors are less relevant to bicycle safety. Motor vehicles have been improved to protect the occupants[23] and perhaps, with the 11 digit VIN more widely available and different motor vehicle categories, motor vehicles could also be designed to better protect bicyclists.

Adding bicycle categories has been recommended but with fewer specifics. Researchers in Minnesota only recommended the addition of on-street and off-street bicycle facilities.[52] Analysis of bicycle crash types in North Carolina (2006–2010) suggested the addition of environments but only bike lanes or multiuse paths were recommended in the study for the North Carolina Department of Transportation.[53] Because having no side path law means a bicyclist could ride in the road, cycle track or lane, a code could identify whether the bicyclist was in or out of that facility.

Since the invention of the bicycle in 1890, transportation research has focused on motor vehicle risk[54] yet the bicyclist is far more vulnerable.[55–57] Multiple data sets are available to study MVCs,[58 59] and multiple data sets should be available to study bicycle crashes. Safety should not be the sole responsibility of the bicyclist and their choice of location for riding or clothing while riding.[60] Besides a code for helmet, a bicycle light should be coded[61 62] along with other bicycle-crash-scene codes to help design the safest environment.[63] With the advantages of coded bicycle-crash-scene data identified, moderation will still be necessary. North Carolina bicycle and pedestrian crash data were analysed and 78 crash types developed.[53] When at a crash scene, police might be less willing or unable to enter multiple codes, but a bicycle-crash-scene drop-down menu on an electronic table may serve as a useful tool.

LIMITATIONS

Recent crash templates were not available from all states, yet some older templates included useful information, such as a motorcycle/pedal cycle with four potential impact points. Crash details were analysed from NYC, a unique urban environment. The analysis involved only 300 crashes, due to complexity in redrawing, and only crashes with drawings were analysed. Due to the need to understand the four different bicycle environments, the analysis was not a random sample of all motor vehicle/bicycle crashes, but the maximum number of crashes in the different environments to equalise sample sizes. Bicycle counts would have been ideal for the four environments, but this would have been a large undertaking in NYC. Minor and severe injuries had been identified by the police but these data allowed minor injuries to serve as the control. The sample size limited power in each variable, however, the data allowed inferences to be drawn about the value of bicycle-crash-scene variables being coded for inclusion in the spreadsheet.

CONCLUSION

The motor vehicle resembles a rectangle while a bicycle resembles a line, making motor vehicle/bicycle crashes different. Data can be found in the full police crash report, yet obtaining and extracting the information is labour-intensive, data are sometimes available only to the researchers, and Google street views change. Therefore, the Federal and State officials responsible for creating the state crash report templates could consider inclusion of bicycle-crash-scene spreadsheet coded variables that could be entered electronically on a tablet with a drop-down template for bicycle crashes only. Variables worthy of consideration include: 4 bicycle environments; 18 car potential impact points (including 4 opened door locations and side mirrors); 4 bicycle potential impact points; turning directions appropriate for motor vehicle/bicycle interactions; in or out of the bicycle environment; and motor vehicle categories relevant to bicyclists. More coded variables could be considered in future research, especially as combinations with big data.

What is already known on the subject

- Many states are making changes to the crash report templates, but the emphasis still is on motor vehicles.
- Detailed information is available in individual reports' text and drawing, yet, it takes considerable time to analyse.
- Google street views are useful, however, in years to come the view may change, eliminating identification of that bicycle environment.

What this study adds

- Motor vehicle/bicycle crash variables that could be entered into a spreadsheet include 4 bicycle environments, 18 motor vehicle potential impact points (opening doors and mirrors), 4 bicycle potential impact points, 10 bicycle-crash-scene patterns, in/out of the bicycle environment and motor vehicle types relevant to bicyclists.
- With these new data, analysis could determine that, compared with bicyclists hitting the back of motor vehicles, motor vehicle doors and mirrors posed a greater risk of severe injury.
- With these new data, analyses could determine that, compared with riding on roads without bicycle facilities, riding on roads with bike lanes but not riding in the lane had lower likelihood of severe injury.

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