Bicycle Facilities Adjacent to On-Street Parking:
A Review of Crash Data, Design Guidelines, and Bicyclist Positioning

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ABSTRACT

This paper reviews the available data on “dooring” crashes to determine their prevalence; bicycle facility design standards to determine how they account for the “door zone,” and observational data on bicyclist position with respect to car doors under different types of road markings. The conclusions are:

1. The full extent of the dooring problem is not known, since most data sources exclude this type of incident by definition.
2. The studies that do include door-opening incidents reveal that they are one of the most common causes of urban bicycle-motor vehicle collisions, accounting for 12% to 27% of the total.
3. Current guidelines for ordinary bike lanes insufficiently account for the door zone, as demonstrated by several studies that show most bicyclists using bike lanes adjacent to parking are not far enough away from parked cars to avoid a suddenly opened door.
4. A 3 ft buffer zone is described in the design guides as an essential component of separated bike lanes. Ordinary bike lanes have an equal need for a buffer. This disparity in the guidelines is the reason for the claimed superiority of separated lanes in terms of safety from opening doors.
5. Shared lane markings move some bicyclists away from the door zone, but many still ride within range of car doors, despite signs and markings encouraging them to ride in the center of the lane.

Recommendations for improvements to bike lane and shared lane marking standards are offered, along with other changes that could improve the understanding of the dooring problem and reduce its incidence.
INTRODUCTION
There has been a large increase in the number of marked bicycle lanes in American cities in the past two decades. Many of these facilities have been added in older urban areas, where arterials often have on-street parking. One of the motivations for marking bicycle lanes is to make bicyclists feel welcome on city streets. However, bicyclist organizations have routinely warned bicyclists about the danger of suddenly opened door of a parked car—a problem known as “dooring”—even when bicyclists are using bicycle lanes as intended. This paper reviews the available data on dooring crashes to determine their prevalence; bicycle facility design standards to determine how they account for the “door zone,” and observational data on bicyclist position with respect to car doors under different types of road markings. This paper is concerned only with parallel on-street parking. Angle on-street parking does not present a dooring hazard for bicyclists, although it does present a backing hazard, particularly with the more common back-out design.

PREVALENCE OF COLLISIONS WITH CAR DOORS
How frequently do bicyclists hit the opened door of a parked car? A recent paper argues that “past studies have shown that dooring crashes are a rare form of bicycle crash and are not relatively dangerous.” (1)

The main source of U.S. data on bicyclist crashes is the National Highway Traffic Safety Administration, which provides both a nationally representative sample of police-reported crashes and a complete inventory of road fatalities. However, both sources are restricted to crashes involving a motor vehicle in transport. Bicycles are not “motor vehicles” and parked motor vehicles are not “in transport.” Therefore, dooring collisions are excluded by definition from these databases, as well as from state databases and the Model Minimum Uniform Crash Criteria. (2) This exclusion may not be clear to data users: the NHTSA data includes the Pedestrian and Bicycle Crash Analysis Tool code for “Bicyclist Overtaking - Extended Door.” (2) A few crashes with this code sometimes appear in the data, giving the impression that dooring crashes are rare when in fact they are excluded by definition from the sample universe.

In 2011, the Illinois Department of Transportation announced that it would begin tracking dooring crashes, but IDOT has yet to release any public data on this crash type. (4) Denver recently conducted a bicyclist crash study based on state crash forms. The study found that only 1.7% of bicycle-motor vehicle (BMV) collisions involved dooring (5). However, the Colorado state crash reporting form specifically says that “A bicycle accident is not a traffic accident unless it involves a motor vehicle in motion, regardless of injury. When a cyclist is involved in an accident on a bicycle only, and is injured, it is not a traffic accident. . . . When a cyclist collides with a parked vehicle, it is not a traffic accident.” (3)

Despite the lack of regularly collected data, it is possible to give an indication of the prevalence of dooring using the few studies that have looked at data from police, EMS, or hospitals, rather than from standard motor vehicle crash reports; eight of these are summarized in Table 1. Dooring was the first, second, or third largest crash type in most of these studies, bested only by motorist turns. Dooring should therefore be viewed as a highly significant BMV crash type, at least in areas with on-street parking.
TABLE 1 Dooring Crashes as a Share of Bicycle-Motor Vehicle (BMV) Crashes

<table>
<thead>
<tr>
<th>Place</th>
<th>Data Type</th>
<th>% of BMV Crashes</th>
<th>Data Years</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boston</td>
<td>Police Reports¹</td>
<td>13%</td>
<td>2009-2012</td>
<td>1,645</td>
</tr>
<tr>
<td>Boston</td>
<td>EMS Reports¹</td>
<td>12%</td>
<td>2009-2012</td>
<td>1,337</td>
</tr>
<tr>
<td>Cambridge</td>
<td>Police Reports</td>
<td>20%</td>
<td>2004-2009</td>
<td>539</td>
</tr>
<tr>
<td>New York City</td>
<td>Hospital</td>
<td>16%</td>
<td>2008-2011</td>
<td>382</td>
</tr>
<tr>
<td>New York City</td>
<td>Police Reports</td>
<td>16%</td>
<td>2011</td>
<td>300</td>
</tr>
<tr>
<td>Toronto</td>
<td>Police Reports</td>
<td>12%</td>
<td>1997-1998</td>
<td>2,572</td>
</tr>
<tr>
<td>Vancouver</td>
<td>Insurance-Reported Crashes</td>
<td>15%</td>
<td>2007-2012</td>
<td>2,994</td>
</tr>
<tr>
<td>Vancouver and</td>
<td>Hospital¹</td>
<td>27%</td>
<td>2008-2009</td>
<td>690</td>
</tr>
<tr>
<td>Toronto</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ The universe of crashes was adjusted to eliminate incidents not involving a collision with a moving or parked motor vehicle. Sources in order of listing: (4) (5) (6) (7) (9) (10) (11)

MECHANISM AND SEVERITY OF INJURY FROM OPENING DOORS

There are several ways in which a suddenly opening door can cause injuries. The bicyclist could come into contact with the door, which presents a sharp edge that could produce a cutting injury. If the bicyclist hits the center of the door with force, he or she could break the window glass. Contact with the door is almost certain to cause a fall, which can produce injuries via a collision with the asphalt. A bicyclist who falls can end up suddenly in the path of an approaching motor vehicle, with no time for the driver to stop; these incidents can be fatal. Even a small overlap between the end of the bicycle handlebars and the open door can cause the front wheel to turn suddenly to the right, which will immediately send the bicycle and rider to the left, into the path of approaching traffic.

With regard to injury severity, the Toronto study observed that for dooring crashes, “the injuries sustained were often more severe than average” and concluded that, combined with its frequency, “this type of crash would appear to be a very serious concern for urban cyclists.” (9) Transport for London reports that cyclists hit by car doors (or swerving to avoid them) tied for the second largest category of serious bicyclist injuries in London, representing about twice as many serious injuries as cases of bicyclists hit from the rear. (12) Finally, an analysis of the Boston Police Department data conducted by this author found that in 58% of dooring cases, the bicyclist was either transported in an ambulance or sought other medical treatment—essentially the same percent as for motorist overtaking collisions, in which 54% received medical treatment other than at the scene. (4)

PREVENTING COLLISIONS WITH CAR DOORS

There are several ways dooring collisions can be prevented. Automobile occupants should look before opening a door: 41 states and the District of Columbia require this by statute. However, after dark an approaching bicyclist failing to use a required headlight can be difficult to see. Even if most motorists look, apparently sufficient numbers do not, based on the data presented in the previous section, despite the legal requirement.
It is sometimes argued that the bicyclist should be responsible for stopping in time. When a door opens, in
stopping sight distance is a function of the bicyclist’s speed and the distance between the bicyclist and an
open door. Since a door can be opened very quickly, there is no speed at which a bicyclist can be sure to
avoid a suddenly opened door. If the bicyclist can see that a car is unoccupied, he or she can be sure that
there is no dooring hazard. But seeing inside vehicles is not reliable: many have tinted glass that make
this impossible, nor is it possible at night. In one case, a bicyclist was struck when a driver lying on his
side kicked open the car door (13).

Almost all bicycle safety materials produced by states, cities, and advocacy groups recommend that
bicyclists always stay a door’s width away from parked cars, often specifying a distance of three or four
feet. Despite this advice, there are several reasons that bicyclists frequently ride too close to parked cars:

- The door threat is invisible, until a door suddenly opens. Other threats (moving cars, double-
parked cars) are more obvious.
- When traffic is slow or stopped, bicyclists are tempted to pass between the parked cars and the
stopped cars, which may be particularly hazardous because a person exiting a parked car in this
situation may assume no traffic could be approaching.
- When lanes are narrow, riding a safe distance away from parked cars may mean that there is no
room for a motorist to pass without changing lanes. Bicyclists may be reluctant to keep this
distance because of the threat of harassment from motorists who do not understand why the
bicyclist is not keeping further right.

All but six states require bicyclists to keep as close to the right edge of the roadway as “practicable” or
“safe” (depending on the specific wording). Most of these statutes include an exception that permits
bicyclists to leave the right edge “when reasonably necessary to avoid conditions including, but not
limited to, fixed or moving objects, parked or moving vehicles, bicycles, pedestrians, animals, surface
hazards, or substandard width lanes that make it unsafe to continue along the right hand curb or edge.”
While it is obvious that an open door constitutes a “condition” under this exemption, it is less obvious that
the exemption applies to the possibility of a suddenly opening door. When Long Beach (Calif.) sought
permission from the California Traffic Control Devices Committee to experiment with an enhanced
shared lane marking designed to encourage bicyclists to ride outside the door zone, “committee members
had concerns over a California Vehicle Code provision that requires bicyclists to ride as far to the right as
is reasonably safe.” (14)

How Far From the Curb Must Bicyclists Ride to be Outside of the Door Zone?

Studies of bicyclist position on the roadway typically measure the distance from bicycle tire to curb. To
determine if the bicyclist is outside the door zone one must also estimate the distance from the parked car
to the curb, the width of the parked car, the reach of an open door at its furthest extent, and the width of
the bicycle or rider. The AASHTO Guide uses 2.5 ft as the operating space needed by a bicycle and rider.
(15) To account for the width beyond the tire one must add half of this amount or 1.25 ft. Most passenger
cars are just under 6 feet wide, but many pickup trucks are 6.7 feet wide (larger trucks can be as wide as
8.5 feet). Given that most jurisdictions permit parking up to 1 foot from the curb, 7 feet is a reasonable
figure to use for the outside edge of the parked car. For the width of an open door at its greatest extent
some studies have used as little as 2.5 feet. However doors on coupes can be as wide as 3.75 feet, as
confirmed by a 2014 NCHRP study of bicycle lane widths discussed below. If the door reaches no further
than 9.5 feet from the curb, the bicycle tire should be no closer than 11 feet from the curb. However in the worst case of a car parked 1 foot from the curb with a 3.75 foot door fully extended, the bicycle wheel should be 13 feet from the curb. In practice bicyclists can adjust their position slightly when they observe poorly parked vehicles ahead; therefore a wheel position 12 feet from the curb is sufficient.

**DESIGN GUIDELINES FOR BICYCLE FACILITIES ADJACENT TO ON-STREET PARKING**

A summary of the guidelines relating to bicycle facilities adjacent to parking from different guide books is shown in Table 2. The American Association of State Highway and Transportation Officials *Guide for the Development of Bicycle Facilities Fourth Edition* (2012) the following minimum dimensions: 5 foot bike lane adjacent to a 7 foot parking lane. (15) The *Guide recommends* a wider parking lane (8 feet) and/or a wider bike lane (6 or 7 feet), particularly when there is high parking turnover. The Fourth Edition discusses buffers, either between the bike lane and the travel lane or between the bike lane and the parking lane, but provides no recommendation for buffers, nor guidelines for their width.

The National Association of City Transportation Officials *Urban Bikeway Design Guide* echoes AASHTO’s guidelines for bike lanes adjacent to parking. (16) The NACTO *Guide* adds a facility type, “buffered bike lane,” and states that it “encourages bicyclists to ride outside of the door zone when [the] buffer is between parked cars and [the] bike lane.” The NACTO *Guide* provides no guidance on the width of the buffer, but states that it can be considered part of the bike lane width.

**TABLE 2 Widths of Bicycle Facilities Adjacent to Parking, Minimum and Recommended**

<table>
<thead>
<tr>
<th>Type</th>
<th>Use</th>
<th>Facility (ft)</th>
<th>Buffer (ft)</th>
<th>Parking Lane (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bike Lane</td>
<td>1-way</td>
<td>AASHTO</td>
<td>5</td>
<td>6 to 7</td>
</tr>
<tr>
<td>Bike Lane</td>
<td>1-way</td>
<td>NACTO</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Separated Bike Lane</td>
<td>1-way</td>
<td>NACTO</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Separated Bike Lane</td>
<td>1-way</td>
<td>FHWA</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Separated Bike Lane</td>
<td>1-way</td>
<td>MassDOT</td>
<td>5</td>
<td>6.5</td>
</tr>
<tr>
<td>Separated Bike Lane</td>
<td>2-way</td>
<td>NACTO</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Separated Bike Lane</td>
<td>2-way</td>
<td>FHWA</td>
<td>12</td>
<td>ns</td>
</tr>
<tr>
<td>Separated Bike Lane</td>
<td>2-way</td>
<td>MassDOT</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Sidepath</td>
<td>2-way</td>
<td>AASHTO</td>
<td>12</td>
<td>8</td>
</tr>
</tbody>
</table>

Notes: Min=minimum, Rec=recommended, ns=not stated.

The AASHTO *Guide* recommends against placing bike lanes between parked cars and the curb; prior to the Fourth Edition, the AASHTO *Guide* prohibited such placement. The NACTO *Guide* provides guidelines for these facilities, which it calls “cycle tracks;” the FHWA *Separated Bike Lane Planning and Design Guide* changes the name to “separated bike lanes.” (17) The NACTO *Guide* refers to a “desired” buffer of 3 feet between a separated bike lane and a parking lane; the FHWA *Guide* expresses this more
strongly as “a minimum 3 ft buffer should be used.” Another source, the MassDOT Separated Bike Lane Planning and Design Guide, recommends a 6-foot buffer but adds that “street buffers may be narrowed to a minimum of 2 ft. in constrained conditions.” (18)

The NACTO Guide says that a separated bike lane “reduces risk of ‘dooring’ compared to a bike lane.” The FHWA Guide states that “a minimum buffer width of 3 feet is required to allow for the opening of doors and other maneuvers.” Where a separated bike lane is adjacent to on-street parking, the 3-foot buffer is the key element that reduces the risk of dooring. There is now a discrepancy between the guidance for separated bike lanes, which necessarily include a buffer zone from parked cars, and ordinary bike lanes adjacent to parking, which do not. The minimum width of the bike lane itself is the same five feet in both cases: under current design guidelines a separated bike lane needs a minimum of 8 feet (5 ft lane plus 3 ft buffer) whereas an ordinary bike lane requires only 5 feet.

BICYCLIST POSITIONING WITH ON-STREET PARKING

There are a number of studies that have examined how bicyclist position in relation to parked cars is affected by bike lanes of various dimensions and by shared lane markings placed at various distances from the curb.

Effect of Bicycle Lanes on Bicyclist Position

A 1999 study of bicycle lanes next to on-street parking found that “Bicyclists tended to center themselves in the middle of the [bike lane] in the presence of a parked motor vehicle.” (20) The study’s only concern was the distance between bicyclists and moving traffic, not the distance between bicyclists and parked cars, despite the fact that 6 of the 8 observed conflicts at one of the two study sites involved parking. The bike lanes studied were 4.5 to 5 feet wide, and the parking lanes seem to be 7 to 8 feet wide (the width was not stated). Because the observed bicyclists were typically centered in the bike lanes, they were generally within 10 feet of the curb, well within the reach of a fully extended door. No data was provided about bicyclist position prior to installation of the bike lanes.

A 2005 study of Hampshire Street in Cambridge, Mass. looked at the effect of a) separating the 22 ft travel and parking lane into a 10 ft travel lane and a 12 ft parking lane; b) adding a bike lane symbol in the parking lane; and c) adding a lane line separating the bike lane from the parking lane positioned 7 feet from the curb. (21) The study found that compared to the baseline with a center line stripe only, “cyclists rode 2.8 inches farther from parked cars with the lane line alone, 2 inches farther with the lane line plus bike lane symbol, and 2.4 inches farther with the full bike lane.” These differences were small, and, more to the point, did not change the baseline situation of most bicyclists riding within the door zone, which in this situation would require riding outside the bike lane. In the words of the study, “for cyclists to travel completely outside the full door zone, the left handle bar would be in the travel lane. Cyclists may not have felt comfortable riding with a portion of their bicycle in a relatively narrow travel lane of 10 feet.”

A 2009 study of bicycle lanes and wide outside lanes adjacent to on-street parking in three Texas cities found that, comparing similar-width sites, bicyclists ride closer to parked cars where there is a wide outside lane (20 ft) compared to a 7 foot bicycle lane and 13 foot travel lane. (26) However, even in the bike lane case, a significant number of bicyclists were in the door zone (within 3.5 feet of parked cars). Moreover, at locations with a bike lane of only 5 feet, about ¾ of bicyclists were within the door zone.
Where there was a marked buffer separating the bike lane from the parking lane, as on San Jacinto Blvd and 30th Street in Austin, the study finds that no bicyclists rode within the door zone, as shown in Figure 1.

The National Cooperative Highway Research Program commissioned a major study of bicycle lane widths which included three locations with on-street parking in Cambridge, Mass. and Chicago, Ill. (23) The study found that “for parking lanes 7- to 9-ft wide, based on the 95th-percentile parked vehicle displacement and assuming an open door width of 45 in., the open door zone width of parked vehicles extends approximately 11 ft from the curb.” The authors suggest that “the design of the bike lane should encourage bicyclists to ride outside of this door zone area and should account for the width of the bicyclist.”

At the experimental sites the total width from curb to outside lane line (travel lane, bike lane, parking lane combined) varied between 22 and 24 feet (compared to 22 ft on Hampshire Street and as much as 28 ft in the Austin cases). Several different lane configurations were tested at each of the locations. At the Cambridge location, the existing 5 ft bike lane was reconfigured by adding a small (1 to 1.5 ft) buffer to the parked cars, narrowing the bike lane, and keeping the total width constant at 5 ft. At the Chicago sites, there were two separate experiments:

- Widen the parking lane from 7 to 8 to 9 feet while narrowing the bike lane to 6, 5, and 4 feet, keeping a constant 13 ft width of the parking and bike lane combined.
• Narrow the travel lane to 10 feet and narrow the bike lane to 4 feet in order to create a 2-ft hashed buffer between the bike lane and the parking lane.

In terms of the first set of experiments, the study found that “drivers park their vehicles closer to the curb as the parking lane narrows from 9 ft to 7 ft; however, the results are not statistically different.” Changing the dividing line between parking lane and bike lane did not move bicyclists away from parked cars. However, “when a buffer was provided between a bike lane and a parking lane, bicyclists positioned themselves further away from the door zone of parked vehicles.” But, “for parking lanes widths of between 7 and 9 ft and a buffer space of only 1 to 2 ft, a sizable portion (40% to 60%) of bicyclists may still position themselves within the door zone of parked vehicles. Thus, when adjacent to narrow parking lanes, it is desirable to provide a wider buffer space up to a maximum of 4 ft.”

In summary, the research findings on bicyclist positioning with bike lanes adjacent to parking show that:

• With minimal bicycle lane dimensions (5 ft bike lane adjacent to 7 ft parking lane), almost all bicyclists ride within the door zone.
• Widening the bike lane helps only minimally to reduce door-zone riding.
• The most dramatic reduction in door zone riding was when a 3 ft buffer was placed between the bike lane and the parking lane. In this configuration, bicyclists centered in the bike lane are completely outside the door zone.

Effect of Shared Lane Markings (SLMs) on Bicyclist Position

The shared lane marking, appearing for the first time in the 2009 Edition of the Manual of Uniform Traffic Control Devices, has multiple purposes, one of which is to “assist bicyclists with lateral positioning in a shared lane with on-street parallel parking in order to reduce the chance of a bicyclist's impacting the open door of a parked vehicle.” (19) To keep bicyclists out of the door zone, the MUTCD requires that the center of the 3.5 ft-wide SLM be positioned at least 11 feet from the curb where there is on-street parking. A review of the literature produced six studies of the effect of SLMs on bicyclist positioning at locations with on-street parking (see Table 3).

A San Francisco study found that on average bicyclists moved 8 inches away from parked cars after the placement of SLMs centered in 11 ft travel lanes adjacent to parking lanes. (18) The study also reported that bicyclists, measured at the location of the bicycle tire, averaged 4 feet from parked cars after placement of the markings. The study also reported that bicyclists averaged only 2.9 feet from parked cars when motorists were overtaking. The share of bicyclists riding outside the door zone was not reported.

A Cambridge study considered the effects of adding SLMs to a section of Massachusetts Avenue which in the before condition had a 21-ft combined parking and travel lane and an 11-ft travel lane in each direction. (24) The experiment involved adding SLMs centered 10 feet from the curb (one foot less than the MUTCD requirement). The study found that the mean bicyclist distance from parked cars did not change: 43.0 inches before adding the markings and 42.9 inches after (these figures are a weighted average of observations with and without motorists passing, calculated using Table 1 of the source). The study also reported the distance from the wheel of the parked motor vehicle to the curb. Assuming the average parked motor vehicle is 70 inches wide, bicyclists averaged 10.2 feet from the curb both before and after installation of SLMs, within range of car doors.
A study in Austin, Texas evaluated the placement of SLMs on several multi-lane roadways. (29) SLMs were placed 11 feet from the curb on Dean Keeton Street, a road with a 22 foot shared parking and travel lane and an 11 foot travel lane. The share of bicyclists observed outside the door zone increased from 20% before the markings to 46% after (calculated based on a weighted average of those observed with motorists overtaking and without, as reported in Table 1 and Figure 17 in the source). On Guadalupe Street SLMs were centered in the right-hand lane, about 13.5 feet from the curb, since the right lane was considered too narrow for a bicyclist to share with a motor vehicle. The study reported that the percent of bicyclists riding in the center of the lane (between 4.4 and 6.6 feet from the parked cars) increased from 31% to 42%.

The City of Long Beach, California installed shared lane markings on 2nd Street, a four-lane boulevard with on-street parking in a business district with heavy parking use and slow travel speeds. (17) In the before condition, the left lane line of the right-hand travel lane was 18.5 feet from the curb and parking Ts were marked at approximately 7.5 feet from the curb. In the after condition, the lane dimensions were unchanged but SLMs were added with the center of the marking 14 feet from the curb, centered in the 11-foot travel lane. A green strip, 5.5 feet wide with its right edge 11 feet from the curb, was painted continuously in the center of the right-hand lane. “Bikes in Lane” signs were also installed. The share of roadway bicyclists outside the door zone increased from only 15% before the installation to 44% immediately afterwards. At the same time, the share of bicyclists using the sidewalk decreased from 43% to 26%. The initial design had SLMs only at the beginning of each 200-foot block, but in April 2010, a second SLM was added near the end of each block. A few months after this change new counts found that the share of roadway bicyclists outside the door zone had increased to 55% and the share of sidewalk bicyclists had decreased to 21%. Total bicyclist volume increased 94% over the before conditions.

Another study looked at the installation of SLMs on Washington Avenue in Miami Beach. (30) This site has one 8-foot parking lane and two 11-foot travel lanes in each direction and a posted speed limit of 30 mph. The SLMs were placed in the middle of the right-hand travel lane about 13.5 feet from the curb. The report says that “the City felt that normal spacing of 11 feet from curb next to parked vehicles would not allow enough room for motor vehicles to pass bicycles in the lane next to parking.” The results showed that on average “the spacing between bicycles and parked vehicles increased by about 10.5 inches.” The percent of bicyclists “near the center of the lane” increased from 12% to 35%. The study noted that some bicyclists rode within the door zone to pass slow or stopped motor vehicles.

The most recent study examined bicyclist positioning on 40th Street in Oakland, Calif. (27) The before conditions were two 12 foot travel lanes and an 8 foot parking lane in each direction with no bicycle-specific markings (Phase 1). In the first part of the experiment, SLMs were added centered in the right-most travel lane in each direction (14 ft from the curb), and Bicycles May Use Full Lane signs were posted (Phase 2). After three months, the SLMs were highlighted with green pavement coloring (Phase 3). The lane width dimensions remained unchanged. The edge of the green painted area was 11 feet from the curb. An analysis of bicyclist positions recorded by video cameras found that the mean bicyclist distance from the curb, with no motor vehicles nearby, increased from 9.0 ft to 9.6 ft with the regular SLM and to 11.1 ft with the enhanced SLM. When there were motor vehicles nearby, the mean spacing went from 8.6 ft to 8.8 ft with the regular SLM and to 9.9 ft with the enhanced SLM.
### TABLE 3 Bicyclist Positioning with and Without SLMs

<table>
<thead>
<tr>
<th>Street Name</th>
<th>City</th>
<th>Travel + Parking Lane (ft)</th>
<th>Center of SLM (ft from curb)</th>
<th>Bicyclists to Parked Cars (ft)</th>
<th>Bicyclists to Curb (ft)</th>
<th>Change vs. base (in)</th>
<th>% Outside of Door Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>various</td>
<td>San Francisco</td>
<td>17 to 22</td>
<td>-</td>
<td>3.3</td>
<td>na</td>
<td>-</td>
<td>na</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>11</td>
<td>6.0</td>
<td>na</td>
<td>8.4</td>
<td>na</td>
</tr>
<tr>
<td>Massachusetts Ave</td>
<td>Cambridge</td>
<td>21</td>
<td>-</td>
<td>3.6</td>
<td>na</td>
<td>-</td>
<td>na</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>3.6</td>
<td>na</td>
<td>-0.1</td>
<td>na</td>
</tr>
<tr>
<td>Dean Keeton Street, WB</td>
<td>Austin</td>
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<td>na</td>
<td>na</td>
<td>-</td>
<td>20%</td>
</tr>
<tr>
<td>Guadalupe Street, SB</td>
<td>Austin</td>
<td>19</td>
<td>1.5</td>
<td>4.4</td>
<td>11.1</td>
<td>-</td>
<td>31%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>13.5</td>
<td>6.6</td>
<td>11.5</td>
<td>4.4</td>
<td>42%</td>
</tr>
<tr>
<td>2nd Street</td>
<td>Long Beach</td>
<td>18.5</td>
<td>14(^a)</td>
<td>na</td>
<td>na</td>
<td>-</td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>13.5</td>
<td>3.1</td>
<td>na</td>
<td>-</td>
<td>12%</td>
</tr>
<tr>
<td></td>
<td>Miami Beach</td>
<td>19</td>
<td>14(^b)</td>
<td>na</td>
<td>na</td>
<td>10.5</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>14(^c)</td>
<td>4.0</td>
<td>na</td>
<td>10.5</td>
<td>35%</td>
</tr>
<tr>
<td>40th Street</td>
<td>Oakland</td>
<td>20</td>
<td>-</td>
<td>na</td>
<td>8.8</td>
<td>-</td>
<td>3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>14(^b)</td>
<td>9.4</td>
<td>6.3</td>
<td>7%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>14(^c)</td>
<td>10.6</td>
<td>21.2</td>
<td>31%</td>
<td></td>
</tr>
</tbody>
</table>

Notes: \(a\). Also green painted area 11 ft from the curb and “Bikes in Lane” signs. \(b\). Also Bicycles May Use Full Lane signs. \(c\). Also green painted area 11.5 ft from the curb and “Bicycles May Use Full Lane” signs. SLM=Shared Lane Marking, \(-\)=not applicable, na=not available, WB=westbound, SB=southbound. Due to variation in original sources, “outside of door zone” is measured at 10.5 ft from curb for Dean Keeton St, 11.4 ft for Guadalupe St, 11 ft for Second St and Washington St, and 11.5 ft for 40th St. Sources: \((18), (28), (29), (17), (30), (31)\)

The following conclusions can be made from these studies:

- Only 10% to 30% of bicyclists ride outside the door zone when there are narrow lanes next to on-street parking. Shared lane markings can increase this to 30% to 50%, but in most cases more than half the bicyclists were still in the door zone.
- SLMs are more effective when centered in the travel lane, 13-14 feet from the curb.
- Enhanced SLMs, combined with May Use Full Lane signs, increase the share of bicyclists outside the door zone.

The modest effects of SLMs on pulling bicyclists away from parked cars may reflect the strong social pressures for bicyclists to stay out of the way of motor vehicles. Roadway design changes could be supplemented by eliminating statutes that require bicyclists to have an excuse to leave the right edge of the road, retraining police officers, educating the public, and passing and enforcing laws prohibiting harassment of bicyclists.

The AASHTO minimum dimensions currently permit a 5 ft bike lane next to a 7 ft parking lane. However, the data shows that virtually all bicyclists will ride in the door zone in this configuration. One possible alternative is a mixed traffic lane with a SLM adjacent to a marked door-zone buffer. The cross section for each travel direction would be a 7 ft parking lane, 3 ft marked buffer zone, and a 10 to 12 ft...
CONCLUSIONS AND RECOMMENDATIONS
This paper has reviewed the available evidence and found that:

1. The full extent of the dooring problem is not known, since most data sources exclude this type of incident by definition.
2. The studies that do include door-opening incidents reveal that they are one of the most common causes of urban bicycle-motor vehicle collisions, accounting for 12% to 27% of the total.
3. Current guidelines for ordinary bike lanes insufficiently account for the door zone, as demonstrated by several studies that show most bicyclists using bike lanes adjacent to parking are not far enough away from parked cars to avoid a suddenly opened door.
4. A 3 ft buffer zone is described in the design guides as an essential component of separated bike lanes. Ordinary bike lanes have an equal need for a buffer. This disparity in the guidelines is the reason for the claimed superiority of separated lanes in terms of safety from opening doors.
5. Shared lane markings move some bicyclists away from the door zone, but many still ride within range of car doors, despite signs and markings encouraging them to ride in the center of the lane.

Based on the findings, the following recommendations are offered:

1. Provide a disclaimer on all reports about bicyclist crashes that are derived from NHTSA and state databases that most bicyclist crashes are excluded by definition from the data: specifically, incidents involving parked motor vehicles and those not involving any motor vehicles.
2. Begin a discussion with NHTSA and the Governors Highway Safety Association about changing the Uniform Crash Criteria to include bicyclist crashes using the same rules as for motor vehicle crashes.
3. Revise bicycle facility guidelines to include a marked 3 ft buffer whenever a bike lane is installed adjacent to parked vehicles.
4. Where there is insufficient room for a bike lane and a door zone buffer, experiment with instead using a door zone buffer with a shared lane marking in a travel lane.
5. Revise the shared lane marking standard to require that it be centered in the shared lane.
6. Increase motorist awareness of the need for bicyclists to stay away from the door zone, backed up by appropriate laws and enforcement. Repeal laws that create an expectation that bicyclists have an additional duty, beyond the same one that applies to all road users, to keep to the extreme right edge of the road.
1 REFERENCES


20. FHWA. Separated Bike Lane Planning and Design Guide. 2015.


Research, U. of Texas at Austin, Austin, TX, 2010.
