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# Bicycle Signals in the United States:

## An Inventory, Typical Use Cases, and Research Gaps

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Many communities across the United States are working to promote bicycling by improving the comfort and safety for bicyclists. The interactions between modes at signalized intersections present challenges for traffic engineers and designers, especially in busy urban settings. Bicycle signals can be used at intersections to control the movement of bicycles when geometric or operational conditions dictate that their movements be separated in time for safety or other reasons. Bicycle signals typically consist of a signal with green, yellow, and red bicycle symbols in the face. They have been standard tools in the European and Asian bicycling networks for some time.

The first application of a bicycle signal in the United States is believed to have been in 1994 at the intersection of Russell Boulevard and Sycamore Lane in Davis, CA, USA.[1] Sometime later, bicycle signals with the bicycle symbol in the face were included in the 2002 update to the *California Traffic Manual* and subsequently adopted in the California *Manual on Uniform Traffic Control Devices* (MUTCD).[2,3] Nationally, the MUTCD contained provisions for circular signal indications to control bicycle movements.[4*] The 2011 NACTO *Urban Bikeway Design Guide* highlighted the applicability of bike signals, publishing information on their use in 10 American cities and applications in Canada, Europe, and Asia. In 2013, the Federal Highway Administration (FHWA) issued *Interim Approval for Optional Use of a Bicycle Signal Face* that allows the use of bicycle symbols in the signal face with several restrictions.[5] The most notable restriction is that the bicycle signal face can only be used in scenarios where there is no conflicting motor vehicle movements, which can limit the ability for pratictioners to comply with the provisions of the IA-16.

Before IA-16, bicycle signals were in use at at more than 40 intersections in a select number of jurisdictions.[6] In recognition of growing use, the National Cooperative Highway Research Program (NCHRP) funded a research effort to summarize and synthesize the U.S. experience with bicycle signals using the bicycle symbol in the face. This updated inventory identified more than 500 intersections in 61 jurisdictions with a bicycle signal on one or more approaches. The research also identifed research gaps related explicitly to road user comprehension and compliance and develop research needs statements (RNS). The full report can be accessed on the NCHRP website as Web-Only Document 273.[7] The following sections describe the results of the literature review, an inventory of existing uses of bicycle signal faces, agency interviews, and identified research gaps.

## Review of Existing Research

The use of green, yellow, and red bicycle symbols in signal faces (and other traffic control devices) is a widespread practice internationally. Figure 1 shows a small sample of the consistency of bicycle signal faces. While the symbols are very similar, there is a variation on other design details. For example, smaller near-side signal faces are more common elsewhere than the United States. The faces from Shanghai, China, and Utrecht, Netherlands include an arrow in the bicycle symbol face indicating the allowed bicycle movement.

In the U.S. context, the bicycle signal housing, backplates, and mounting practices are similar, and often identical to, motor vehicle signals. The signal face with the bicycle symbol is often the only uniquely distinguishing feature.[**] Human factors principles suggest that road user confusion might be possible with this design approach. In contrast, pedestrian or light rail transit signals use different shapes and colors that distinguish them from vehicular signals. While the literature review identified some anecdotal evidence of road user's confusion (primarily due to lack of separation between vehicular and bicycle traffic signal faces), none of the published evaluation reports found evidence of significant user confusion. Importantly, the review of the literature found no published studies that directly evaluated visibility or comprehension of the bicycle signal face or the transferability of design assumptions from motor vehicle users. In other words, questions such as at what distance can the symbol be seen in various lens sizes and what movements road users assume as allowable from the symbol have not been formally researched.

## Bicycle Signal Inventory

The research developed an extensive inventory of bicycle signals. The locations of bicycle signals were identified by starting with an existing list maintained by the bicycle technical committee of the National Committee on Uniform Traffic Control Devices (NCUTCD). The list was supplemented with responses to an online survey distributed by the research team to Transportation Research Board committees and Association of Pedestrian and Bicycle Professionals (APBP) channels. A total of 511 intersections were inventoried where the use of the bicycle symbol in the signal face on at least one approach was verified. For most installations (86 percent), current Google Streetview images were available and were the primary source for data collection. Using the measurement tool in Google Maps and an open-source software to scale images, the research team collected data for each approach


London, United Kingdom — Lima, Peru — Shanghai, China — Utrecht, Netherlands

*Figure 1 Examples of International Bicycle Signal Faces.*

* MUTCD Section 4D.07 allows new 8 inch circular signal indications for the "sole purpose of controlling a bikeway or a bicycle movement" and 9D.02 describes requirements for visibility-limited faces and reviewing timing on bikeways. No other specific guidance is provided.

** IA-16 does require use of the "R10-10b Bicycle Signal" sign.

such as the number of bicycle faces, mounting heights, distance from the stop line, use of arrows, lens diameter, use of colored housing or backplates, presence of visibility restricted louvers, and other data elements. The history option in Google Street View (when available) or agency data, the year of installation was determined for 80 percent of the inventory.

As would be expected, the inventory documented an increasing number of installations of bicycle signals after IA-16 was issued in 2013. The states with the most intersections with bicycle signals were New York (156), California (70), Illinois (40), Washington (51), Oregon (33), and Texas (26), with large cities in these states being the primary adopters. The map in Figure 2 shows the location of intersections. Table 1 highlights the cities with 10 or more intersections in the inventory.[***]

Detailed signal timing was challenging to obtain. Instead, the research team assessed the primary purpose of using the signal control for bicycles by inspection of the geometry and placement of the signals. A partial summary of this assessment is presented in Table 2. Many of the intersections in the inventory are part of a corridor, where signal control and design are replicated at multiple intersections. As a result, frequency summaries partially reflect repeated designs. The most common bicycle signal uses are to facilitate the contra-flow movement of a two-way bicycle lane and to provide separation when the bicycle lane is placed left of a left-turn lane or right of a right-turn lane. Other typical use cases include controlling bicycle movements at connections to two-way facilities or paths, controlling contra-flow and diagonal bicycle movements, left turns, and crossings for multiuse paths. In many of these applications, the bicycle signal face was not visible to drivers in motor vehicles.

Table 3 summarizes the number of signal heads, lens diameter, and visibility distance per approach. Visibility distance from the stop line to the signal face was measured using Google Maps. Though IA-16 only requires a second signal face for intersections when the primary signal face is more than 120 feet (ft.) (36.6 meters [m]) from the stop line and suggests a second signal face for more than 80 ft. (24.4 m), many installations used two signal heads for bicycles even when the distances to the stop bar were less than 120 ft. Two-thirds of the lenses with the bicycle symbol in the inventory were 8 inches. The selection of lens size did not have an apparent relationship with visibility distance. IA-16 also allows optional use of a 4-inch nearside signal. There were only a few locations identified with 4-inch heads (mostly in Portland, OR as the research team had direct knowledge of these locations) because the data collection approach made it difficult to identify these smaller signal heads optimally placed for viewing by persons on a bicycle.

*** At the time of the inventory the research team was aware of signal faces in Hawaii (mostly along South King Street in Honolulu) but was unable to obtain further details.

Table 4 presents the summary of the horizontal and vertical distance between the far-side primary bicycle signal face and the nearest vehicular signal face, rounded to the nearest foot. The horizontal offset was measured between the edge (either the signal housing or the backplate) of the bicycle signal face to the nearest motor vehicle signal face. No protocol for the vertical separation measurement was found, so the distance was measured from the top edge of the bicycle signal face to the bottom edge of the motor vehicle signal. IA-16 suggests that a bicycle signal face be separated vertically or horizontally from the nearest motor vehicle traffic signal face for the same approach by at least 3 ft. (0.9 m). Most of the signal faces in the inventory met the horizontal and vertical separation from vehicular signal heads recommended in IA-16.

To make the inventory available to practitioners and researchers in an easy-to-use format, the research team posted the data collected from the project, including the map of signals online.[8] Data for each intersection are posted in a sheet format and include most of the categories described in this section. The map interface includes direct links to the Streetview image of the bicycle signal face. The site includes a link to report new signal faces and the map includes locations identified after the end of the project.

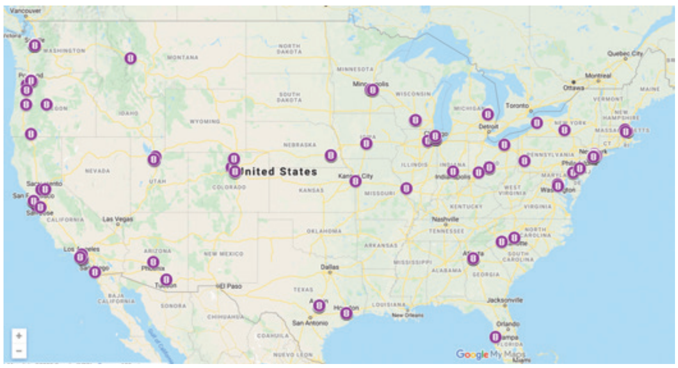


*Figure 2. Map of Intersections with Bicycle Signal Faces.*

*Table 1. Jurisdictions with Ten or More Intersections with Bicycle Signal Faces*

| City | Number of Intersections | City | Number of Intersections |
|---|---|---|---|
| Atlanta, GA | 17 | Long Beach, CA | 18 |
| Austin, TX | 16 | Los Angeles, CA | 17 |
| Boston, MA | 12 | Minneapolis/St. Paul, MN | 14 |
| Chicago, IL | 32 | New York City, NY | 154 |
| Denver, CO | 14 | Portland, OR | 25 |
| Houston, TX | 10 | San Francisco, CA | 24 |
| Lincoln, NE | 10 | Seattle, WA | 51 |

*Table 2. Summary of Typical Use Cases Identified for Bicycle Signal Faces.*

| | | | | |
|---|---|---|---|---|
| **Sample Application Image**<br>Source: Google, C. Monsere, Toole Design Group, P. Singleton |  |  |  |  |
| | Los Angeles, CA | Chicago, IL | Portland, OR | Portland, OR |
| **Number of Intersections and Context of Bicycle Signal Control** | 129 - Bicycle Lane to the Left of a Left-Turn Lane<br>41 - Bicycle Lane to the Right of a Right-Turn Lane | 69 - Two-Way Bicycle Lane on One-Way Street<br>41 - Two-Way Bicycle Lane on Two-Way Street | 36 - Multiuse Path Crossings<br>17 - Bicycle-Only Connections to Parks, Train Stations, or Center Bike Lanes<br>15 - Connection to a Multiuse Path<br>14 - Contra-Flow Bicycle Lane | 11 - Diagonal Crossing<br>10 - Bicycle Left Turns |

*Table 3. Number of Signal Heads, Lens Diameter, and Visibility Distance per Approach.*

| Lens diameter | Number of bicycle signal heads | Number of Approaches by Visibility Distance (ft.) | | | |
|---|---|---|---|---|---|
| | | ≤80 | >80 and ≤120 | >120 | Total |
| 12-inch | 1 | 19 | 36 | 4 | 59 |
| | 2 | 14 | 22 | 4 | 40 |
| | 3 | 1 | - | - | 1 |
| 12-inch Subtotal | | 34 | 58 | 8 | 100 |
| 8-inch | 1 | 67 | 72 | 1 | 140 |
| | 2 | 80 | 89 | 8 | 177 |
| | 3 | | 6 | - | 6 |
| 8-inch Subtotal | | 147 | 167 | 9 | 323 |
| **Total** | | **181** | **225** | **17** | **423** |

*Table 4 Number of Signal Heads by Horizontal and Vertical Separation Category*

| Horizontal Separation Category (ft.) | Number of Approaches by Vertical Separation Category (ft.) | | | |
|---|---|---|---|---|
| | ≤3 | >3 and ≤8 | >8 | Total |
| <3 | 53 | 7 | - | 60 |
| >3 and ≤8 | 15 | 13 | - | 28 |
| >8 | 77 | 98 | 7 | 182 |
| **Total** | **145** | **118** | **7** | **270** |

## Agency Interviews

The research team interviewed agency staff to capture their experience with bicycle traffic signals. Interviews consisted of 25 questions that explored bicycle signal use, road user understanding, lens visibility and conspicuity, placement of the bicycle signal face, operations, and research needs. The research team sent recruiting emails to individuals at agencies with significant experience with bicycle signals. The research team interviewed 21 agencies, including six state departments of transportation (California, Delaware, Maryland, Minnesota, Oregon, and District of Columbia), 14 city agencies (Akron, OH; Atlanta, GA; Austin, TX; Cambridge, MA; Chicago, IL; Denver, CO; Lincoln, NE; Minneapolis, MN; Seattle, WA; Houston, TX; Los Angeles, CA; New York, NY; Portland, OR; San Francisco, CA), and one county (Hennepin, MN). Many interviews included multiple professionals at the agency.

The majority of the agencies either did not receive or were not aware of any reports of driver confusion with bicycle signals. The few reports of driver confusion stemmed from lack of familiarity with new installations of bicycle signals and intersection or corridor operations, or improper placement of bicycle signals. In one case, confusion was eliminated when new signal poles allowed the separation of faces. In other cases, confusion diminished with experience. Most agencies were not aware of any bicycle-motor vehicle crashes at locations with bicycle signals. About thirty-eight percent of the agencies interviewed undertook public education efforts to improve user expectancy and comprehension. While some agencies felt that additional research is warranted on lens visibility and conspicuity (52 percent) and size (76 percent), only 38 percent felt that design refinements to the bicycle symbol itself in the lens needed additional research. The interviews suggest that agency practice guided many of the decisions on lens size. For example, New York City, NY uses almost exclusively 8-inch lenses and had 175 intersections in the sample. About 40 percent of the agencies reported that they were using visibility restricting devices to shield the bicycle signal face from the view of persons driving and were using or plan to use 4-inch bicycle signal heads.

While most agencies reported following the guidance set by IA-16, a majority (57 percent) of the agencies stated that the IA-16's requirement of limiting bike signals to scenarios where there is no conflicting motor vehicle movements had limited their ability to use bicycle signals. One agency stated that research on the relative need or safety benefit of this requirement is critical, citing long delays that result to all users when only movements without conflicts are required. Some agencies have interpreted the guidance to limit the use of leading bike intervals (LBIs) and there are current RTEs to implement them. Other RTEs are active for applications with conflicting movements that do not comply with IA-16. A number of agencies indicated that they found the IA-16 requirement of providing at least 3 ft. of separation between bicycle and motor vehicle signal heads to be challenging to implement on existing poles.

While not the focus of the interview, a need was expressed for improved guidance and research on current practices for yellow change and red clearance intervals and determining if longer intervals increase safety and tradeoffs associated with signal timing and phasing strategies for bicycles (i.e., exclusive phasing, LBI, delayed turn).

## Research Gaps Identified

A synthesis of the results from the literature review, inventory, and interviews identified three research needs about the road user's understanding of bicycle symbols in the signal face. In priority order, the research needs identified were:

- Optimal methods to communicate allowable, protected, or permissive movements to bicyclists at signalized intersections.
- Evaluation of size, placement, and orientation of bicycle signal faces on bicyclist and driver comprehension and compliance.
- Guidance on visibility and detection of bicycle symbols in signal faces by lens size and distance.

Full text of NCHRP research needs statements were drafted and are being submitted to the relevant AASHTO committees for consideration in the research funding cycle.

## Conclusion

Bicycle signals are an useful tool for controlling the movements of bicycles in unique situations and for separating bicycle movements when needed for safety or operations. This study documented an increasing number of installations of bicycle signals in a wide range of U.S. jurisdictions, especially after Interim Approval 16 was issued in 2013. A wide range of applications were identified, including use on two-way bicycle facilities, locations with heavy vehicle turning traffic (either left or right), connecting bicycle facilities to shared-use paths, contra-flow bicycle lanes, left-turns, and others. The interviews with agencies identified positive results and challenges with implementing IA-16 in some situations. The effort suggests more research is warranted on bicycle signal faces, bicycle symbols, and the appropriate traffic control design for permissive movements by bicyclists. **itej**

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