SIGNALIZED INTERSECTIONS

Traffic signals manage traffic flow by separating and allocating time to specific movements. They can reduce conflicts between motor vehicles, transit vehicles, bicyclists, and pedestrians. Traffic signal design, which includes detection, phasing, timing, and equipment, should provide a safe and predictable environment for all users, especially the most vulnerable.

Conventional traffic engineering practice focuses on reducing delay to motor vehicles and improving vehicle throughput at signalized intersections. However, traffic signal timing and phasing should consider delay and safety impacts to all users. Traffic signals should be designed to meet the needs of all users through the use of appropriate detection, cycle lengths, phasing, interval timings, and equipment. Additionally, designers should consider the unique operating characteristics of each expected user type throughout the signal design and process of determining the most appropriate signal timing.

It is particularly important to evaluate potential conflicts between turning motorists with pedestrians and bicyclists where left-turns are permissive (i.e., vehicles can turn left on a circular green indication). In a 2015 study, the City of Seattle found that the most significant crash type for pedestrians and bicyclists was a turning motorist crossing their path. At signalized intersections, left-turning motorists accounted for 26 percent of bicyclist crashes and 49 percent of pedestrian crashes. Right turning motorists accounted for 24 percent of bicyclist crashes and 21 percent of pedestrian crashes at signalized intersections. For more information, refer to the design topic on **Turning Vehicles.**

KEY DESIGN FLEXIBILITY

According to **MUTCD**, a traffic signal design should consider pedestrian and bicyclist needs:

"The design and operation of traffic control signals shall take into consideration the needs of pedestrian as well as vehicular traffic."

2009, Sec. 4D.03

"On bikeways, signal timing and actuation shall be reviewed and adjusted to consider the needs of bicyclists."

2009, Sec. 9D.02

OTHER RESOURCES

"Elements, such as crosswalk treatments, signal location, and signal timing, should account for pedestrians and other roadway users."

AASHTO Ped Guide 2004, p. 49

"Actuated traffic signals should detect bicycles; otherwise, a bicyclists may be unable to call a green signal…Various technologies are available for detecting bicycles."

AASHTO Bike Guide 2012, p. 4-47

"Vehicle stops and delay may be less important than transit and pedestrians priority in a CBD, as well as other existing or developing areas with significant pedestrian, bicycle, and transit activity. The practitioner needs to make appropriate adjustments to the traffic signal timing process to account for the operating environment and user priorities."

Transportation Research Board. *NCHRP Report 212: Signal Timing Manual.* 2015, pp. 1-2–1-3

"Urban applications for traffic control devices expand to a multimodal transportation system, not just providing for vehicular traffic."

ITE Traffic Control Devices Handbook, p. 206

APPLYING DESIGN FLEXIBILITY

Pedestrians and bicyclists have a fundamental need to cross roads safely and efficiently at signalized intersections. There is a great deal of inherent flexibility in signal design and there are many new advances that have a positive impact on pedestrian and bicyclist safety at signalized intersections. This resource covers several of these strategies. However, this is a complex area of roadway design and other reference manuals and guidebooks should be consulted for more information, including **MUTCD 2009**, **AASHTO Pedestrian Guide 2004**, **AASHTO Bike Guide 2012**, **NACTO Urban Street Design Guide 2013**, and **NCHRP Report 212: Signal Timing Manual 2015**.

The conventional vehicle-based approach to evaluating signalized intersections may involve relatively high traffic projections, emphasize the peak hour, and focus on minimizing motor vehicle delay. This approach can result in relatively poor conditions for bicyclists and pedestrians. Designers may use qualitative measures to assess non-motor-vehicle-oriented operational objectives to consider in the evaluation process. For more information, refer to the design topic on **Road Diets and Traffic Analysis**.

PEDESTRIAN CONSIDERATIONS

The needs of all pedestrians should be taken into account when designing traffic signals at intersections where they can be expected to cross. Pedestrian safety, comfort, and convenience at intersections is fundamentally impacted by several major design decisions:

CYCLE LENGTH

When pedestrians are faced with long delays, they are more likely to ignore signals entirely and cross the road when they perceive a gap in traffic. Therefore, strategies to reduce overall cycle length are particularly important for pedestrian safety. In addition to reducing cycle lengths, designers should also consider using half-cycle lengths, particularly during off-peak hours. Cycle lengths also have similar implications for bicyclists. The **NACTO Urban Street Design Guide** recommends cycle lengths between 60–90 seconds for urban areas **(2013, p. 131)**.

PEDESTRIAN SIGNAL HEADS

Pedestrians need to be able to see signal indications (walking person/upraised hand or green/yellow/red) to know when it is safe to cross. An engineering study should be completed to determine if pedestrian signal heads and countdown displays are needed. Factors include signal phasing, intersection geometry complexity, and visibility of vehicular signal indications **(MUTCD 2009, Sec. 4E.03–4E.07)**. Pedestrian signals must be accessible to people with disabilities. For more information, refer to the design topic on **Accessibility**.

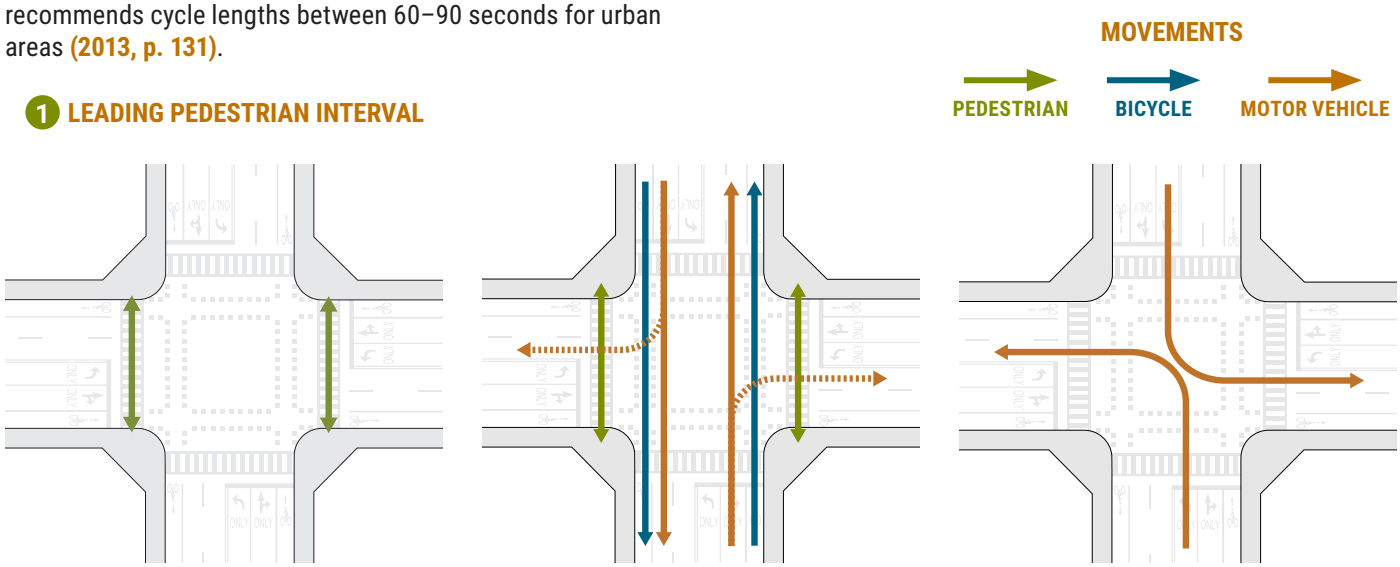
AUTOMATIC PEDESTRIAN PHASES

At locations with high pedestrian volumes, pedestrians should not be required to push a button to call the pedestrian phase. Studies show that only about 50 percent of pedestrians actually press the push buttons. This is because in locations with longer pedestrian delays and without automatic pedestrian phases, pedestrians may have the impression that the push button is either non-responsive or malfunctioning. All intersections regardless of whether the pedestrian phase is automatic or requires actuation must be accessible for people with disabilities. This commonly means that accessible push-buttons are installed in locations with automatic pedestrian phases. For more information, refer to design topic on **Accessibility**.

PROTECTED CROSSING PHASES

Allowing drivers to turn right or left during a pedestrian WALK signal is a frequent cause of crashes between pedestrians and drivers. Often drivers do not realize they are required to yield to pedestrians in these situations and fail to do so. Dedicated right- and left- turning phases and exclusive pedestrians phases can improve pedestrian safety. Designers should conduct an engineering study to determine if this is an appropriate solution.

1 LEADING PEDESTRIAN INTERVAL



MAJOR STREET PEDESTRIANS

MAJOR STREET PEDESTRIANS, BICYCLES, THROUGH & RIGHTS

MAJOR STREET LEFTS

LEADING PEDESTRIAN INTERVAL

A leading pedestrian interval 1 typically gives pedestrians "a 3–7 second head start when entering an intersection" before the vehicle phase **(NACTO Urban Street Design Guide 2013, p. 128)**. This can increase the visibility of pedestrians and reduce conflicts. The **MUTCD** says that leading pedestrian intervals "may be used to reduce conflicts between pedestrians and turning vehicles" **(2009, Sec. 4E.06)**.

EXCLUSIVE PEDESTRIAN PHASE

Also known as a pedestrian scramble or Barnes Dance, an exclusive pedestrian phase occurs when all pedestrians may cross while all vehicular traffic is stopped. This treatment may be considered where there are relatively high volumes of pedestrians, equal desire lines in all directions, higher turning vehicle movements, or at intersections with restricted sight distance or complex intersection geometry. This treatment "can produce a safer operation over conventional phasing, but delay for both pedestrians and motorists is always higher than conventional signal timing" **(AASHTO Pedestrian Guide 2004, p. 103)**. This increase in delay for pedestrians may result in pedestrians crossing with concurrent vehicular movements. Designers should consider whether pedestrians could also be able to cross with concurrent vehicular movements. In some scenarios, a leading pedestrian interval may be a more appropriate solution. If a diagonal crossing is used, designers must consider how a person with a visual disability would know that they could cross diagonally.

RIGHT TURN ON RED

Right Turn on Red (RTOR) introduces pedestrian safety concerns because drivers scanning for gaps in traffic on their left may not look for pedestrians on their right. Drivers are likely to encroach into the crosswalk while watching oncoming vehicles, further eroding pedestrian safety and comfort. These conflicts can be reduced by restricting RTOR movements. The **FHWA Pedestrian Safety Guide and Countermeasure Selection System** suggests that "prohibiting RTOR should be considered where exclusive pedestrian phases or high pedestrian volumes are present" **(2013)**.

Right Turn on Red should be prohibited where bicyclists wait in front of motor vehicles, such as at bike boxes and two-stage turn queue boxes (both are subject to experimentation). Designers should also consider prohibiting RTOR where bicycle movements may be unexpected, such as at crossings of contra-flow or two-way separated bike lanes.

SIGNAL TIMING FOR BICYCLISTS

Bicycles have different operating speeds, acceleration rates, and deceleration rates than motor vehicles. Adjustments to minimum green times, clearance intervals, and extension times can allow bicyclists to clear the intersection before opposing traffic is released **(AASHTO Bike Guide 2012, p. 4-22)**. At locations with high vehicular speeds and long crossing distances, bicyclists are more likely to have different signal timing needs than motor vehicles.

If used in combination with bicycle detection and permitted by the controller, bicycle-specific timing parameters can be employed for the specific times when a bicycle is present. If bicycle detection is not available, the bicycle-timing needs should be incorporated into the overall signal timing settings in the controller. The **AASHTO Bike Guide 2012** provides additional details on bike detection and signal timing.

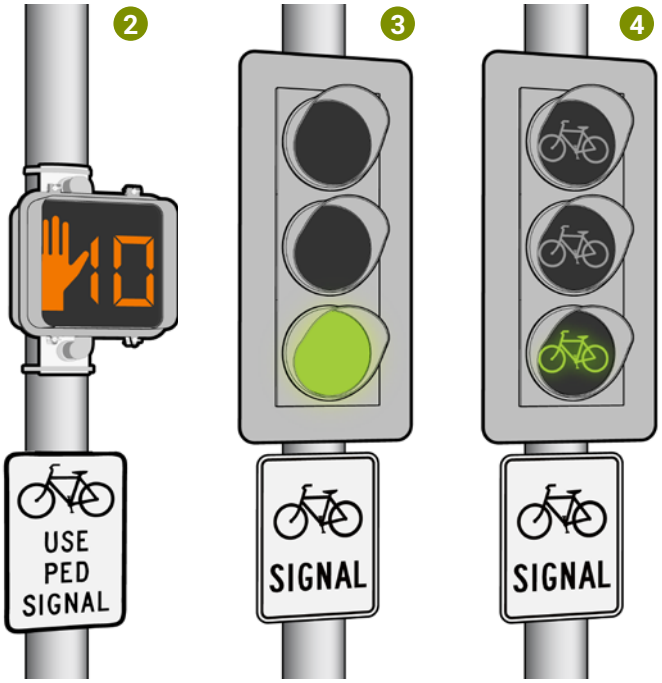
BICYCLE SIGNALS

On-road bicyclists typically use the same traffic signals as vehicles. However, at intersections where bicyclists cannot see vehicle signal faces or where bicyclists have a separate directional movement, phase, or interval, designers should consider alternate signalization options. The BIKES USE PED SIGNAL sign 2 **(MUTCD R9-5)** "may be used where the crossing of a street by bicyclists is controlled by pedestrian signal indications" **(MUTCD 2009, Sec. 9B.11)**. However, a bicycle signal 3 is more suitable as it can be timed for bicyclist speeds increasing the time a bicyclist may legally enter the roadway compared to a pedestrian signal. The **MUTCD** instructs that 8-inch circular signal indications may be used "in a signal face installed for the sole purpose of controlling a bikeway or a bicycle movement" and can be installed without requesting approval **(2009, Sec. 4D.07)**. In December 2013, FHWA issued an Interim Approval for the Optional Use of Bicycle Signal Faces. 4 A bicycle signal face may only be used with a protected phase. Designers should request permission from FHWA before installing a bicycle signal face.

ADDITIONAL SIGNAL CONSIDERATIONS

For additional information on other topics related to traffic signal design, such as signal priority for transit services and emergency vehicles, see **NCHRP Report 212: Signal Timing Manual 2015**.

BIKE SIGNALIZATION ALTERNATIVES



CASE STUDIES

2ND AVENUE PROTECTED PEDESTRIAN/BICYCLE PHASE
SEATTLE, WA

In 2014, the Seattle Department of Transportation (SDOT) implemented a two-way separated bike lane on 2nd Avenue. Designers used dedicated left-turn phasing to eliminate conflicts between left-turning vehicles and bicyclists and pedestrians. The project also included RTOR restrictions at conflicting cross streets and created a bicycle facility that is phase-separated at signalized intersections along the corridor. This project is the first phase of a multi-phased effort to create a comprehensive, connected network of separated bike lanes into and through downtown Seattle. Data collected in October 2014 indicated an 85-percent motorist compliance and 92-percent bicyclist compliance rate.

LEADING PEDESTRIAN INTERVALS
WASHINGTON, DC

The District Department of Transportation (DDOT) has implemented leading pedestrian intervals at intersections throughout Washington, DC. Beginning with 20 intersections that have a history of crashes involving right-turning vehicles hitting pedestrians in the crosswalk while the WALK or flashing DON'T WALK signal indication was displayed. The program has expanded to over 130 intersections based on count data showing high pedestrian and turning-vehicle volumes and public feedback. DDOT is currently reviewing additional potential locations for leading pedestrian intervals as part of a signal optimization study, which will have evaluated all 1,650 signalized intersections in the District when complete.

VALENCIA STREET GREEN WAVE
SAN FRANCISCO, CA

The San Francisco Municipal Transportation Agency (SFMTA) implemented its first "green wave" on Valencia Street as a pilot project in 2011. The "green wave" is a coordinated signal system designed for bicyclists traveling at moderate speeds, rather than the traditional coordination plan designed for vehicle speeds. The Valencia Street coordination plan serves bicyclists traveling in both directions, and signs notify bicyclists that the signals are timed for the 13-mi/h speed. The "green wave" has an added traffic-calming benefit since motor vehicles benefit from traveling at the designated speed. In 2011, SFMTA made the Valencia Street Green Wave a permanent feature and has continued implementing the strategy on other bikeways throughout the city.

Source: Matt Johnson, Montgomery County Department of Transportation