

# PART 4

## Highway Traffic Signals

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## CHAPTER 4A. GENERAL

### Section 4A.01 Types

Support:

The following types and uses of highway traffic signals are discussed in Part 4: traffic control signals; pedestrian signals; emergency-vehicle traffic control signals; traffic control signals for one-lane, two-way facilities; traffic control signals for freeway entrance ramps; traffic control signals for movable bridges; lane-use control signals; flashing beacons; and in-roadway lights.

### Section 4A.02 Definitions Relating to Highway Traffic Signals

Standard:

The following technical terms, when used in Part 4, shall be defined as follows:

1. **Accessible Pedestrian Signal**—a device that communicates information about pedestrian timing in nonvisual format such as audible tones, verbal messages, and/or vibrating surfaces.
2. **Active Grade Crossing Warning System**—the flashing-light signals, with or without warning gates, together with the necessary control equipment used to inform road users of the approach or presence of trains at highway-rail grade crossings or highway-light rail transit grade crossings.
3. **Actuated Operation**—a type of traffic control signal operation in which some or all signal phases are operated on the basis of actuation.
4. **Actuation**—initiation of a change in or extension of a traffic signal phase through the operation of any type of detector.
5. **Approach**—all lanes of traffic moving towards an intersection or a midblock location from one direction, including any adjacent parking lane(s).
6. **Average Day**—a day representing traffic volumes normally and repeatedly found at a location, typically a weekday when volumes are influenced by employment or a weekend day when volumes are influenced by entertainment or recreation.
7. **Backplate**—see Signal Backplate.
8. **Beacon**—a highway traffic signal with one or more signal sections that operates in a flashing mode.

- 9. Conflict Monitor**—a device used to detect and respond to improper or conflicting signal indications and improper operating voltages in a traffic controller assembly.
- 10. Controller Assembly**—a complete electrical device mounted in a cabinet for controlling the operation of a highway traffic signal.
- 11. Controller Unit**—that part of a controller assembly that is devoted to the selection and timing of the display of signal indications.
- 12. Crosswalk**—(a) that part of a roadway at an intersection included within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs or in the absence of curbs, from the edges of the traversable roadway, and in the absence of a sidewalk on one side of the roadway, the part of a roadway included within the extension of the lateral lines of the sidewalk at right angles to the centerline; (b) any portion of a roadway at an intersection or elsewhere distinctly indicated as a pedestrian crossing by lines on the surface, which may be supplemented by a contrasting pavement texture, style, or color.
- 13. Cycle Length**—the time required for one complete sequence of signal indications.
- 14. Dark Mode**—the lack of all signal indications at a signalized location. (The dark mode is most commonly associated with power failures, ramp meters, beacons, and some movable bridge signals.)
- 15. Detector**—a device used for determining the presence or passage of vehicles or pedestrians.
- 16. Dual-Arrow Signal Section**—a type of signal section designed to include both a yellow arrow and a green arrow.
- 17. Emergency Beacon**—a special type of beacon used to warn and control traffic at an unsignalized location where emergency vehicles enter or cross a street or highway.
- 18. Emergency Vehicle Traffic Control Signal**—a special traffic control signal that assigns the right-of-way to an authorized emergency vehicle.
- 19. Flasher**—a device used to turn highway traffic signal indications on and off at a repetitive rate of approximately once per second.
- 20. Flashing**—an operation in which a highway traffic signal indication is turned on and off repetitively.

- 21. Flashing Mode**—a mode of operation in which at least one traffic signal indication in each vehicular signal face of a highway traffic signal is turned on and off repetitively.
- 22. Full-Actuated Operation**—a type of traffic control signal operation in which all signal phases function on the basis of actuation.
- 23. Highway Traffic Signal**—a power-operated traffic control device by which traffic is warned or directed to take some specific action. These devices do not include signals at toll plazas, power-operated signs, illuminated pavement markers, warning lights (see Section 6F.74), or steady-burning electric lamps.
- 24. In-Roadway Lights**—a special type of highway traffic signal installed in the roadway surface to warn road users that they are approaching a condition on or adjacent to the roadway that might not be readily apparent and might require the road users to slow down and/or come to a stop.
- 25. Intersection**—(a) the area embraced within the prolongation or connection of the lateral curb lines, or if none, the lateral boundary lines of the roadways of two highways that join one another at, or approximately at, right angles, or the area within which vehicles traveling on different highways that join at any other angle might come into conflict; (b) the junction of an alley or driveway with a roadway or highway shall not constitute an intersection.
- 26. Intersection Control Beacon**—a beacon used only at an intersection to control two or more directions of travel.
- 27. Interval**—the part of a signal cycle during which signal indications do not change.
- 28. Interval Sequence**—the order of appearance of signal indications during successive intervals of a signal cycle.
- 29. Lane-Use Control Signal**—a signal face displaying signal indications to permit or prohibit the use of specific lanes of a roadway or to indicate the impending prohibition of such use.
- 30. Lens**—see Signal Lens.
- 31. Louver**—see Signal Louver.
- 32. Major Street**—the street normally carrying the higher volume of vehicular traffic.

- 33. Malfunction Management Unit—same as Conflict Monitor.**
- 34. Minor Street—the street normally carrying the lower volume of vehicular traffic.**
- 35. Movable Bridge Resistance Gate—a type of traffic gate, which is located downstream of the movable bridge warning gate, that provides a physical deterrent to vehicle and/or pedestrian traffic when placed in the appropriate position.**
- 36. Movable Bridge Signal—a highway traffic signal installed at a movable bridge to notify traffic to stop during periods when the roadway is closed to allow the bridge to open.**
- 37. Movable Bridge Warning Gate—a type of traffic gate designed to warn, but not primarily to block, vehicle and/or pedestrian traffic when placed in the appropriate position.**
- 38. Pedestrian Change Interval—an interval during which the flashing UPRAISED HAND (symbolizing DONT WALK) signal indication is displayed. When a verbal message is provided at an accessible pedestrian signal, the verbal message is "wait."**
- 39. Pedestrian Clearance Time—the time provided for a pedestrian crossing in a crosswalk, after leaving the curb or shoulder, to travel to the far side of the traveled way or to a median.**
- 40. Pedestrian Signal Head—a signal head, which contains the symbols WALKING PERSON (symbolizing WALK) and UPRAISED HAND (symbolizing DONT WALK), that is installed to direct pedestrian traffic at a traffic control signal.**
- 41. Permissive Mode—a mode of traffic control signal operation in which, when a CIRCULAR GREEN signal indication is displayed, left or right turns are permitted to be made after yielding to pedestrians and/or oncoming traffic.**
- 42. Platoon—a group of vehicles or pedestrians traveling together as a group, either voluntarily or involuntarily, because of traffic signal controls, geometrics, or other factors.**
- 43. Preemption Control—the transfer of normal operation of a traffic control signal to a special control mode of operation.**
- 44. Pretimed Operation—a type of traffic control signal operation in which none of the signal phases function on the basis of actuation.**

- 45. Priority Control**—a means by which the assignment of right-of-way is obtained or modified.
- 46. Protected Mode**—a mode of traffic control signal operation in which left or right turns are permitted to be made when a left or right GREEN ARROW signal indication is displayed.
- 47. Pushbutton**—a button to activate pedestrian timing.
- 48. Pushbutton Locator Tone**—a repeating sound that informs approaching pedestrians that they are required to push a button to actuate pedestrian timing and that enables pedestrians who have visual disabilities to locate the pushbutton.
- 49. Ramp Control Signal**—a highway traffic signal installed to control the flow of traffic onto a freeway at an entrance ramp or at a freeway-to-freeway ramp connection.
- 50. Ramp Meter**—see Ramp Control Signal.
- 51. Red Clearance Interval**—an optional interval that follows a yellow change interval and precedes the next conflicting green interval.
- 52. Right-of-Way (Assignment)**—the permitting of vehicles and/or pedestrians to proceed in a lawful manner in preference to other vehicles or pedestrians by the display of signal indications.
- 53. Roadway Network**—a geographical arrangement of intersecting roadways.
- 54. Semiactuated Operation**—a type of traffic control signal operation in which at least one, but not all, signal phases function on the basis of actuation.
- 55. Separate Left-Turn Signal Face**—a signal face for controlling a left-turn movement that sometimes displays a different color of circular signal indication than the adjacent through signal faces display.
- 56. Shared Left-Turn Signal Face**—a signal face, for controlling both a left turn movement and the adjacent through movement, that always displays the same color of circular signal indication that the adjacent through signal face or faces display.
- 57. Signal Backplate**—a thin strip of material that extends outward from and parallel to a signal face on all sides of a signal housing to provide a background for improved visibility of the signal indications.
- 58. Signal Coordination**—the establishment of timed relationships between

**adjacent traffic control signals.**

- 59. Signal Face**—that part of a traffic control signal provided for controlling one or more traffic movements on a single approach.
- 60. Signal Head**—an assembly of one or more signal sections.
- 61. Signal Housing**—that part of a signal section that protects the light source and other required components.
- 62. Signal Indication**—the illumination of a signal lens or equivalent device.
- 63. Signal Lens**—that part of the signal section that redirects the light coming directly from the light source and its reflector, if any.
- 64. Signal Louver**—a device that can be mounted inside a signal visor to restrict visibility of a signal indication from the side or to limit the visibility of the signal indication to a certain lane or lanes, or to a certain distance from the stop line.
- 65. Signal Phase**—the right-of-way, yellow change, and red clearance intervals in a cycle that are assigned to an independent traffic movement or combination of movements.
- 66. Signal Section**—the assembly of a signal housing, signal lens, and light source with necessary components to be used for providing one signal indication.
- 67. Signal System**—two or more traffic control signals operating in signal coordination.
- 68. Signal Timing**—the amount of time allocated for the display of a signal indication.
- 69. Signal Visor**—that part of a signal section that directs the signal indication specifically to approaching traffic and reduces the effect of direct external light entering the signal lens.
- 70. Signal Warrant**—a threshold condition that, if found to be satisfied as part of an engineering study, shall result in analysis of other traffic conditions or factors to determine whether a traffic control signal or other improvement is justified.
- 71. Speed Limit Sign Beacon**—a beacon used to supplement a SPEED LIMIT sign.
- 72. Steady (Steady Mode)**—the continuous illumination of a signal indication for

**the duration of an interval, signal phase, or consecutive signal phases.**

- 73. Stop Beacon—a beacon used to supplement a STOP sign, a DO NOT ENTER sign, or a WRONG WAY sign.**
- 74. Traffic Control Signal (Traffic Signal)—any highway traffic signal by which traffic is alternately directed to stop and permitted to proceed.**
- 75. Vibrotactile Pedestrian Device—a device that communicates, by touch, information about pedestrian timing using a vibrating surface.**
- 76. Visibility-Limited Signal Face or Signal Section—a type of signal face or signal section designed (or shielded, hooded, or louvered) to restrict the visibility of a signal indication from the side, to a certain lane or lanes, or to a certain distance from the stop line.**
- 77. Walk Interval—an interval during which the WALKING PERSON (symbolizing WALK) signal indication is displayed. When a verbal message is provided at an accessible pedestrian signal, the verbal message is "walk sign."**
- 78. Warning Beacon—a beacon used only to supplement an appropriate warning or regulatory sign or marker.**
- 79. Yellow Change Interval—the first interval following the green interval during which the yellow signal indication is displayed.**



## **CHAPTER 4B. TRAFFIC CONTROL SIGNALS—GENERAL**

### **Section 4B.01 General**

#### **Standard:**

**A traffic control signal (traffic signal) shall be defined as any highway traffic signal by which traffic is alternately directed to stop and permitted to proceed.**

**Traffic shall be defined as pedestrians, bicyclists, ridden or herded animals, vehicles, streetcars, and other conveyances either singularly or together while using any highway for purposes of travel.**

#### **Support:**

Words such as pedestrians and bicyclists are used redundantly in selected sections of Part 4 to encourage sensitivity to these elements of "traffic."

Standards for traffic control signals are important because traffic control signals need to attract the attention of virtually every road user, including those who are older, those with impaired vision who meet legal requirements, as well as those who are fatigued or distracted, or who are not expecting to encounter a signal at a particular location. Standards for traffic control signals are also important because signals need to function reliably under a wide range of conditions including day and night, adverse weather, and visually complex surroundings.

### **Section 4B.02 Basis of Installation or Removal of Traffic Control Signals**

#### **Guidance:**

The selection and use of traffic control signals should be based on an engineering study of roadway, traffic (vehicular, pedestrian, and bicyclist), and other conditions.

#### **Support:**

A careful analysis of traffic operations, pedestrian and bicyclist needs, and other factors at a large number of signalized and unsignalized locations, coupled with engineering judgment, has provided a series of signal warrants, described in Chapter 4C, that define the minimum conditions under which installing traffic control signals might be justified.

#### **Guidance:**

Engineering judgment should be applied in the review of operating traffic control signals to determine whether the type of installation and the timing program meet the current requirements of traffic.

If changes in traffic patterns eliminate the need for a traffic control signal, consideration should be given to removing it and replacing it with appropriate alternative traffic control devices, if any are needed.

Option:

If the engineering study indicates that the traffic control signal is no longer justified, removal may be accomplished using the following steps:

- A. Determine the appropriate traffic control to be used after removal of the signal.
- B. Remove any sight-distance restrictions as necessary.
- C. Inform the public of the removal study, for example by installing an informational sign (or signs) with the legend TRAFFIC SIGNAL UNDER STUDY FOR REMOVAL at the signalized location in a position where it is visible to all road users.
- D. Flash or cover the signal heads for a minimum of 90 days, and install the appropriate stop control or other traffic control devices.
- E. Remove the signal if the engineering data collected during the removal study period confirms that the signal is no longer needed. Instead of total removal of the traffic control signal, the poles and cables may remain in place after removal of the signal heads for continued analysis.

### **Section 4B.03 Advantages and Disadvantages of Traffic Control Signals**

Support:

When properly used, traffic control signals are valuable devices for the control of vehicular and pedestrian traffic. They assign the right-of-way to the various traffic movements and thereby profoundly influence traffic flow.

Traffic control signals that are properly designed, located, operated, and maintained will have one or more of the following advantages:

- A. They provide for the orderly movement of traffic.
- B. They increase the traffic-handling capacity of the intersection if proper physical layouts and control measures are used, and if the signal timing is reviewed and updated (if needed) on a regular basis (such as every 2 years) to ensure that it satisfies current traffic demands.
- C. They reduce the frequency and severity of certain types of crashes, especially right-angle collisions.

- D. They are coordinated to provide for continuous or nearly continuous movement of traffic at a definite speed along a given route under favorable conditions.
- E. They are used to interrupt heavy traffic at intervals to permit other traffic, vehicular or pedestrian, to cross.

Traffic control signals are often considered a panacea for all traffic problems at intersections. This belief has led to traffic control signals being installed at many locations where they are not needed, adversely affecting the safety and efficiency of vehicular, bicycle, and pedestrian traffic.

Traffic control signals, even when justified by traffic and roadway conditions, can be ill-designed, ineffectively placed, improperly operated, or poorly maintained. Improper or unjustified traffic control signals can result in one or more of the following disadvantages:

- A. Excessive delay;
- B. Excessive disobedience of the signal indications;
- C. Increased use of less adequate routes as road users attempt to avoid the traffic control signals; and
- D. Significant increases in the frequency of collisions (especially rear-end collisions).

#### **Section 4B.04 Alternatives to Traffic Control Signals**

Guidance:

Since vehicular delay and the frequency of some types of crashes are sometimes greater under traffic signal control than under STOP sign control, consideration should be given to providing alternatives to traffic control signals even if one or more of the signal warrants has been satisfied.

Option:

These alternatives may include, but are not limited to, the following:

- A. Installing signs along the major street to warn road users approaching the intersection;
- B. Relocating the stop line(s) and making other changes to improve the sight distance at the intersection;
- C. Installing measures designed to reduce speeds on the approaches;
- D. Installing a flashing beacon at the intersection to supplement STOP sign control;
- E. Installing flashing beacons on warning signs in advance of a STOP sign controlled intersection on major- and/or minor-street approaches;

- F. Adding one or more lanes on a minor-street approach to reduce the number of vehicles per lane on the approach;
- G. Revising the geometrics at the intersection to channelize vehicular movements and reduce the time required for a vehicle to complete a movement, which could also assist pedestrians;
- H. Installing roadway lighting if a disproportionate number of crashes occur at night;
- I. Restricting one or more turning movements, perhaps on a time-of-day basis, if alternate routes are available;
- J. If the warrant is satisfied, installing multiway STOP sign control;
- K. Installing a roundabout; and
- L. Employing other alternatives, depending on conditions at the intersection.

#### **Section 4B.05 Adequate Roadway Capacity**

##### Support:

The delays inherent in the alternating assignment of right-of-way at intersections controlled by traffic control signals can frequently be reduced by widening the major roadway, the minor roadway, or both roadways. Widening the minor roadway often benefits the operations on the major roadway, because it reduces the green time that must be assigned to minor-roadway traffic. In urban areas, the effect of widening can be achieved by eliminating parking on intersection approaches. It is desirable to have at least two lanes for moving traffic on each approach to a signalized location. Additional width on the departure side of the intersection, as well as on the approach side, will sometimes be needed to clear traffic through the intersection effectively.

##### Guidance:

Adequate roadway capacity should be provided at a signalized location. Before an intersection is widened, the additional green time pedestrians need to cross the widened roadways should be considered to ensure that it will not exceed the green time saved through improved vehicular flow.

## **CHAPTER 4C. TRAFFIC CONTROL SIGNAL NEEDS STUDIES**

### **Section 4C.01 Studies and Factors for Justifying Traffic Control Signals**

#### **Standard:**

**An engineering study of traffic conditions, pedestrian characteristics, and physical characteristics of the location shall be performed to determine whether installation of a traffic control signal is justified at a particular location.**

**The investigation of the need for a traffic control signal shall include an analysis of the applicable factors contained in the following traffic signal warrants and other factors related to existing operation and safety at the study location:**

**Warrant 1, Eight-Hour Vehicular Volume.**

**Warrant 2, Four-Hour Vehicular Volume.**

**Warrant 3, Peak Hour.**

**Warrant 4, Pedestrian Volume.**

**Warrant 5, School Crossing.**

**Warrant 6, Coordinated Signal System.**

**Warrant 7, Crash Experience.**

**Warrant 8, Roadway Network.**

**The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal.**

#### **Support:**

Sections 8D.07 and 10D.05 contain information regarding the use of traffic control signals instead of gates and/or flashing light signals at highway-railroad grade crossings and highway-light rail transit grade crossings, respectively.

#### **Guidance:**

A traffic control signal should not be installed unless one or more of the factors described in this section are met.

A traffic control signal should not be installed unless an engineering study indicates that installing a traffic control signal will improve the overall safety and/or operation of the intersection.

A traffic control signal should not be installed if it will seriously disrupt progressive traffic flow.

The study should consider the effects of the right-turn vehicles from the minor-street

approaches. Engineering judgment should be used to determine what, if any, portion of the right-turn traffic is subtracted from the minor-street traffic count when evaluating the count against the above signal warrants.

Engineering judgment should also be used in applying various traffic signal warrants to cases where approaches consist of one lane plus one left-turn or right-turn lane. The site-specific traffic characteristics dictate whether an approach should be considered as one lane or two lanes. For example, for an approach with one lane for through and right-turning traffic plus a left-turn lane, engineering judgment could indicate that it should be considered a one-lane approach if the traffic using the left-turn lane is minor. In such a case, the total traffic volume approaching the intersection should be applied against the signal warrants as a one-lane approach. The approach should be considered two lanes if approximately half of the traffic on the approach turns left and the left-turn lane is of sufficient length to accommodate all left-turn vehicles.

Similar engineering judgment and rationale should be applied to a street approach with one lane plus a right-turn lane. In this case, the degree of conflict of minor-street right-turn traffic with traffic on the major street should be considered. Thus, right-turn traffic should not be included in the minor-street volume if the movement enters the major street with minimal conflict. The approach should be evaluated as a one-lane approach with only the traffic volume in the through/left-turn lane considered.

At a location that is under development or construction and where it is not possible to obtain a traffic count that would represent future traffic conditions, hourly volumes should be estimated as part of an engineering study for comparison with traffic signal warrants. A traffic control signal installed under projected conditions should have an engineering study done within 1 year of putting the signal into stop-and-go operation to determine if the signal is justified. If not justified, the signal should be taken out of stop-and-go operation or removed.

For signal warrant analysis, a location with a wide median, even if the median width is greater than 9 m (30 ft), should be considered as one intersection.

Option:

At an intersection with a high volume of left-turn traffic from the major street, the signal warrant analysis may be performed in a manner that considers the higher of the major-street left-turn volumes as the “minor-street” volume and the corresponding single direction of opposing traffic on the major street as the “major-street” volume.

Engineering study data may include the following:

- A. The number of vehicles entering the intersection in each hour from each approach during 12 hours of an average day. It is desirable that the hours selected contain the greatest percentage of the 24-hour traffic volume.

- B. Vehicular volumes for each traffic movement from each approach, classified by vehicle type (heavy trucks, passenger cars and light trucks, public-transit vehicles, and, in some locations, bicycles), during each 15-minute period of the 2 hours in the morning and 2 hours in the afternoon during which total traffic entering the intersection is greatest.
- C. Pedestrian volume counts on each crosswalk during the same periods as the vehicular counts in Paragraph B above and during hours of highest pedestrian volume. Where young, elderly, and/or persons with physical or visual disabilities need special consideration, the pedestrians and their crossing times may be classified by general observation.
- D. Information about nearby facilities and activity centers that serve the young, elderly, and/or persons with disabilities, including requests from persons with disabilities for accessible crossing improvements at the location under study. These persons might not be adequately reflected in the pedestrian volume count if the absence of a signal restrains their mobility.
- E. The posted or statutory speed limit or the 85th-percentile speed on the uncontrolled approaches to the location.
- F. A condition diagram showing details of the physical layout, including such features as intersection geometrics, channelization, grades, sight-distance restrictions, transit stops and routes, parking conditions, pavement markings, roadway lighting, driveways, nearby railroad crossings, distance to nearest traffic control signals, utility poles and fixtures, and adjacent land use.
- G. A collision diagram showing crash experience by type, location, direction of movement, severity, weather, time of day, date, and day of week for at least 1 year.
- H. Bicyclists may be counted as either vehicles or pedestrians.

The following data, which are desirable for a more precise understanding of the operation of the intersection, may be obtained during the periods specified in Paragraph B above:

- A. Vehicle-hours of stopped time delay determined separately for each approach.
- B. The number and distribution of acceptable gaps in vehicular traffic on the major street for entrance from the minor street.
- C. The posted or statutory speed limit or the 85th-percentile speed on controlled approaches at a point near to the intersection but unaffected by the control.
- D. Pedestrian delay time for at least two 30-minute peak pedestrian delay periods of an average weekday or like periods of a Saturday or Sunday.
- E. Queue length on stop-controlled approaches.

**Section 4C.02 Warrant 1, Eight-Hour Vehicular Volume****Support:**

The Minimum Vehicular Volume, Condition A, is intended for application at locations where a large volume of intersecting traffic is the principal reason to consider installing a traffic control signal.

The Interruption of Continuous Traffic, Condition B, is intended for application at locations where Condition A is not satisfied and where the traffic volume on a major street is so heavy that traffic on a minor intersecting street suffers excessive delay or conflict in entering or crossing the major street.

**Standard:**

**The need for a traffic control signal shall be considered if an engineering study finds that one of the following conditions exist for each of any 8 hours of an average day:**

- A. The vehicles per hour given in both of the 100 percent columns of Condition A in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection; or**
- B. The vehicles per hour given in both of the 100 percent columns of Condition B in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection.**

**In applying each condition the major-street and minor-street volumes shall be for the same 8 hours. On the minor street, the higher volume shall not be required to be on the same approach during each of these 8 hours.**

**Option:**

If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 70 km/h or exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 70 percent columns in Table 4C-1 may be used in place of the 100 percent columns.

**Guidance:**

The combination of Conditions A and B is intended for application at locations where Condition A is not satisfied and Condition B is not satisfied and should be applied only after an adequate trial of other alternatives that could cause less delay and inconvenience to traffic has failed to solve the traffic problems.

**Table 4C-1. Warrant 1, Eight-Hour Vehicular Volume**

<b>Condition A—Minimum Vehicular Volume</b>									
Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
<u>Major Street</u>	<u>Minor Street</u>	<u>100%<sup>a</sup></u>	<u>80%<sup>b</sup></u>	<u>70%<sup>c</sup></u>	<u>56%<sup>d</sup></u>	<u>100%<sup>a</sup></u>	<u>80%<sup>b</sup></u>	<u>70%<sup>c</sup></u>	<u>56%<sup>d</sup></u>
1.....	1.....	500	400	350	280	150	120	105	84
2 or more...	1.....	600	480	420	336	150	120	105	84
2 or more...	2 or more ...	600	480	420	336	200	160	140	112
1.....	2 or more ....	500	400	350	280	200	160	140	112

<b>Condition B—Interruption of Continuous Traffic</b>									
Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
<u>Major Street</u>	<u>Minor Street</u>	<u>100%<sup>a</sup></u>	<u>80%<sup>b</sup></u>	<u>70%<sup>c</sup></u>	<u>56%<sup>d</sup></u>	<u>100%<sup>a</sup></u>	<u>80%<sup>b</sup></u>	<u>70%<sup>c</sup></u>	<u>56%<sup>d</sup></u>
1.....	1.....	750	600	525	420	75	60	53	42
2 or more...	1.....	900	720	630	504	75	60	53	42
2 or more...	2 or more ...	900	720	630	504	100	80	70	56
1.....	2 or more ....	750	600	525	420	100	80	70	56

<sup>a</sup> Basic minimum hourly volume.

<sup>b</sup> Used for combination of Conditions A and B after adequate trial of other remedial measures.

<sup>c</sup> May be used when the major-street speed exceeds 70 km/h or exceeds 40 mph or in an isolated community with a population of less than 10,000.

<sup>d</sup> May be used for combination of Conditions A and B after adequate trial of other remedial measures when the major-street speed exceeds 70 km/h or exceeds 40 mph or in an isolated community with a population of less than 10,000.

**Standard:**

**The need for a traffic control signal shall be considered if an engineering study finds that both of the following conditions exist for each of any 8 hours of an average day:**

- A. The vehicles per hour given in both of the 80 percent columns of Condition A in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection; and**
- B. The vehicles per hour given in both of the 80 percent columns of Condition B in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection.**

**These major-street and minor-street volumes shall be for the same 8 hours for each condition; however, the 8 hours satisfied in Condition A shall not be required to be the same 8 hours satisfied in Condition B. On the minor street, the higher volume shall not be required to be on the same approach during each of the 8 hours.**

**Option:**

If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 70 km/h or exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 56 percent columns in Table 4C-1 may be used in place of the 80 percent columns.

**Support:**

It is intended that Warrant 1 be treated as a single warrant. If Condition A is satisfied, then the criteria for Warrant 1 is satisfied and Condition B and the combination of Conditions A and B are not applicable. Similarly, if Condition B is satisfied, then the criteria for Warrant 1 is satisfied and the combination of Conditions A and B is not applicable.

**Section 4C.03 Warrant 2, Four-Hour Vehicular Volume****Support:**

The Four-Hour Vehicular Volume signal warrant conditions are intended to be applied where the volume of intersecting traffic is the principal reason to consider installing a traffic control signal.

**Standard:**

**The need for a traffic control signal shall be considered if an engineering study finds that, for each of any 4 hours of an average day, the plotted points**

**representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher-volume minor-street approach (one direction only) all fall above the applicable curve in Figure 4C-1 for the existing combination of approach lanes. On the minor street, the higher volume shall not be required to be on the same approach during each of these 4 hours.**

Option:

If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 70 km/h or exceeds 40 mph or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 4C-2 may be used in place of Figure 4C-1.

#### **Section 4C.04 Warrant 3, Peak Hour**

Support:

The Peak Hour signal warrant is intended for use at a location where traffic conditions are such that for a minimum of 1 hour of an average day, the minor-street traffic suffers undue delay when entering or crossing the major street.

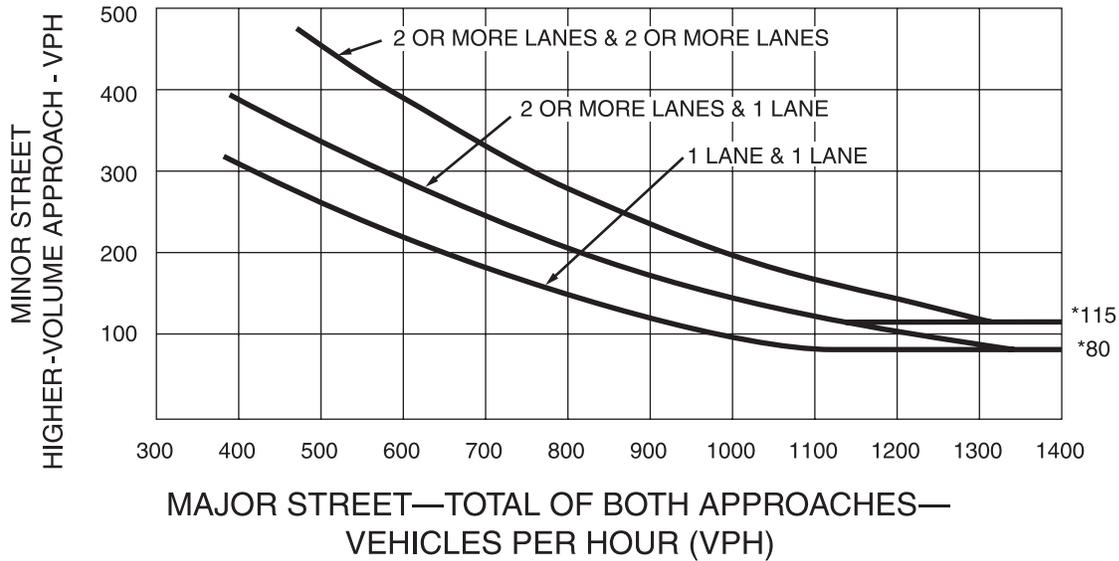
**Standard:**

**This signal warrant shall be applied only in unusual cases, such as office complexes, manufacturing plants, industrial complexes, or high-occupancy vehicle facilities that attract or discharge large numbers of vehicles over a short time.**

**The need for a traffic control signal shall be considered if an engineering study finds that the criteria in either of the following two categories are met:**

- A. If all three of the following conditions exist for the same 1 hour (any four consecutive 15-minute periods) of an average day:**
  - 1. The total stopped time delay experienced by the traffic on one minor-street approach (one direction only) controlled by a STOP sign equals or exceeds: 4 vehicle-hours for a one-lane approach; or 5 vehicle-hours for a two-lane approach, and**
  - 2. The volume on the same minor-street approach (one direction only) equals or exceeds 100 vehicles per hour for one moving lane of traffic or 150 vehicles per hour for two moving lanes, and**
  - 3. The total entering volume serviced during the hour equals or exceeds 650 vehicles per hour for intersections with three approaches or 800 vehicles per hour for intersections with four or more approaches.**

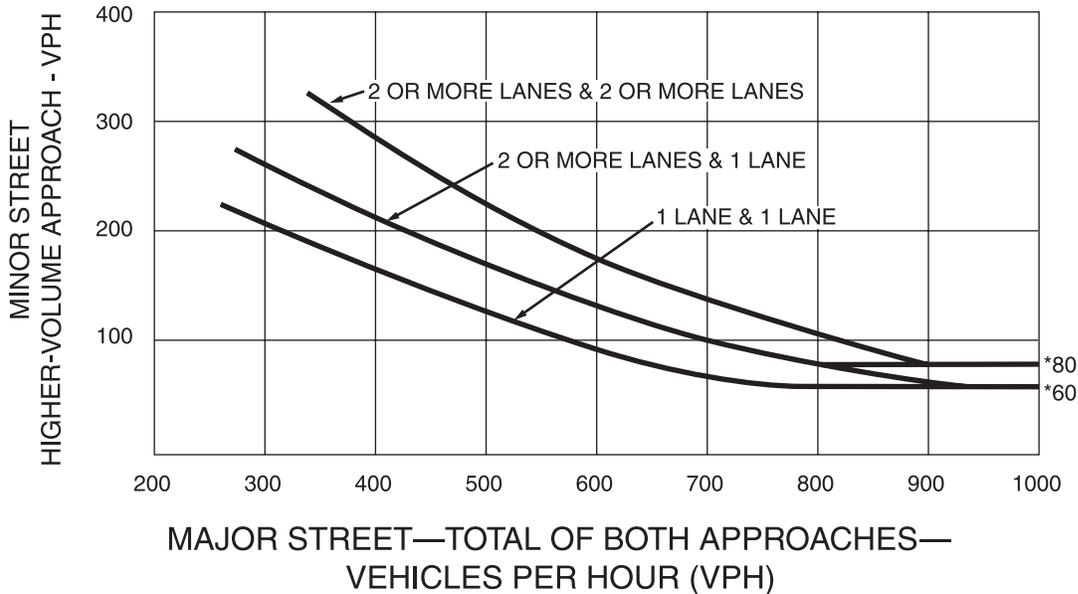
**Figure 4C-1. Warrant 2, Four-Hour Vehicular Volume**



\*Note: 115 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 80 vph applies as the lower threshold volume for a minor-street approach with one lane.

**Figure 4C-2. Warrant 2, Four-Hour Vehicular Volume (70% Factor)**

(COMMUNITY LESS THAN 10,000 POPULATION OR ABOVE 70 km/h OR ABOVE 40 mph ON MAJOR STREET)



\*Note: 80 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 60 vph applies as the lower threshold volume for a minor-street approach with one lane.

- B. The plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher-volume minor-street approach (one direction only) for 1 hour (any four consecutive 15-minute periods) of an average day falls above the applicable curve in Figure 4C-3 for the existing combination of approach lanes.**

Option:

If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 70 km/h or exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 4C-4 may be used in place of Figure 4C-3 to satisfy the criteria in the second category of the Standard.

#### **Section 4C.05 Warrant 4, Pedestrian Volume**

Support:

The Pedestrian Volume signal warrant is intended for application where the traffic volume on a major street is so heavy that pedestrians experience excessive delay in crossing the major street.

**Standard:**

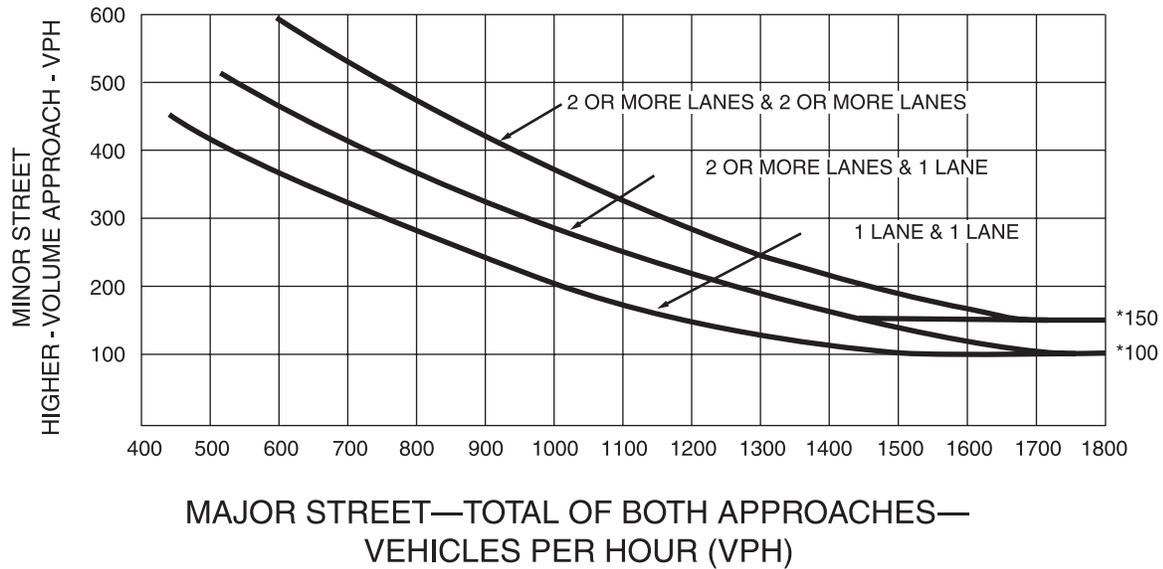
**The need for a traffic control signal at an intersection or midblock crossing shall be considered if an engineering study finds that both of the following criteria are met:**

- A. The pedestrian volume crossing the major street at an intersection or midblock location during an average day is 100 or more for each of any 4 hours or 190 or more during any 1 hour; and**
- B. There are fewer than 60 gaps per hour in the traffic stream of adequate length to allow pedestrians to cross during the same period when the pedestrian volume criterion is satisfied. Where there is a divided street having a median of sufficient width for pedestrians to wait, the requirement applies separately to each direction of vehicular traffic.**

**The Pedestrian Volume signal warrant shall not be applied at locations where the distance to the nearest traffic control signal along the major street is less than 90 m (300 ft), unless the proposed traffic control signal will not restrict the progressive movement of traffic.**

**If this warrant is met and a traffic control signal is justified by an engineering study, the traffic control signal shall be equipped with pedestrian signal heads**

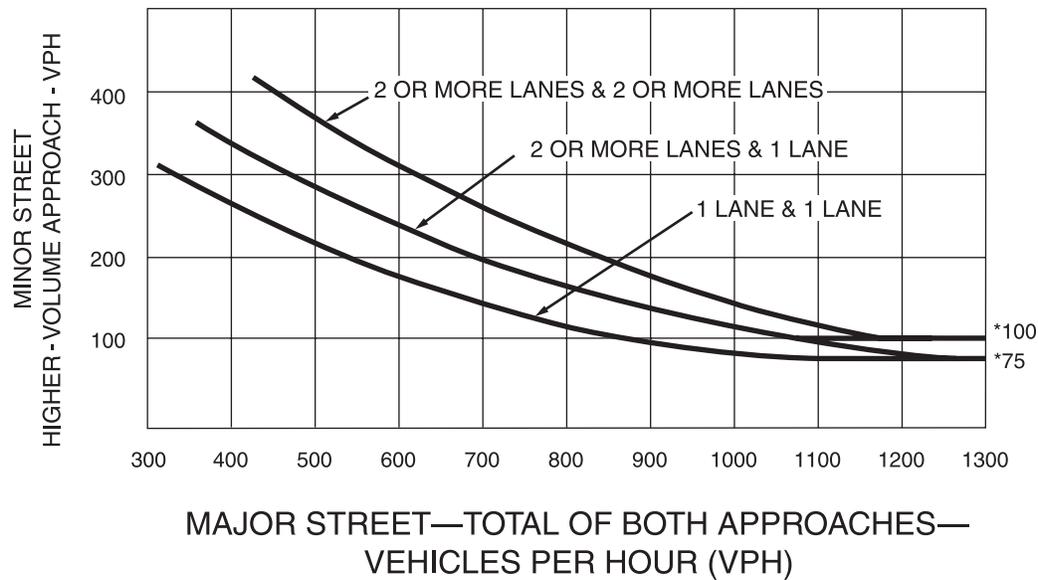
**Figure 4C-3. Warrant 3, Peak Hour**



\*Note: 150 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 100 vph applies as the lower threshold volume for a minor-street approach with one lane.

**Figure 4C-4. Warrant 3, Peak Hour (70% Factor)**

(COMMUNITY LESS THAN 10,000 POPULATION OR ABOVE 70 km/h OR ABOVE 40 mph ON MAJOR STREET)



\*Note: 100 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 75 vph applies as the lower threshold volume for a minor-street approach with one lane.

**conforming to requirements set forth in Chapter 4E.****Guidance:**

If this warrant is met and a traffic control signal is justified by an engineering study, then:

- A. If at an intersection, the traffic control signal should be traffic-actuated and should include pedestrian detectors. As a minimum, it should have semiactuated operation, but full-actuated operation with detectors on all approaches might also be appropriate.
- B. If at a nonintersection crossing, the traffic control signal should be pedestrian-actuated, parking and other sight obstructions should be prohibited for at least 30 m (100 ft) in advance of and at least 6.1 m (20 ft) beyond the crosswalk, and the installation should include suitable standard signs and pavement markings.
- C. Furthermore, if installed within a signal system, the traffic control signal should be coordinated.

**Option:**

The criterion for the pedestrian volume crossing the major roadway may be reduced as much as 50 percent if the average crossing speed of pedestrians is less than 1.2 m/sec (4 ft/sec).

A traffic control signal may not be needed at the study location if adjacent coordinated traffic control signals consistently provide gaps of adequate length for pedestrians to cross the street, even if the rate of gap occurrence is less than one per minute.

**Section 4C.06 Warrant 5, School Crossing****Support:**

The School Crossing signal warrant is intended for application where the fact that school children cross the major street is the principal reason to consider installing a traffic control signal.

**Standard:**

**The need for a traffic control signal shall be considered when an engineering study of the frequency and adequacy of gaps in the vehicular traffic stream as related to the number and size of groups of school children at an established school crossing across the major street shows that the number of adequate gaps in the traffic stream during the period when the children are using the crossing is less than the number of minutes in the same period (see Section 7A.03) and there are a**

**minimum of 20 students during the highest crossing hour.**

**Before a decision is made to install a traffic control signal, consideration shall be given to the implementation of other remedial measures, such as warning signs and flashers, school speed zones, school crossing guards, or a grade-separated crossing.**

**The School Crossing signal warrant shall not be applied at locations where the distance to the nearest traffic control signal along the major street is less than 90 m (300 ft), unless the proposed traffic control signal will not restrict the progressive movement of traffic.**

Guidance:

If this warrant is met and a traffic control signal is justified by an engineering study, then:

- A. If at an intersection, the traffic control signal should be traffic-actuated and should include pedestrian detectors. As a minimum, it should have semiactuated operation, but full-actuated operation with detectors on all approaches might also be appropriate.
- B. If at a nonintersection crossing, the traffic control signal should be pedestrian-actuated, parking and other sight obstructions should be prohibited for at least 30 m (100 ft) in advance of and at least 6.1 m (20 ft) beyond the crosswalk, and the installation should include suitable standard signs and pavement markings.
- C. Furthermore, if installed within a signal system, the traffic control signal should be coordinated.

#### **Section 4C.07 Warrant 6, Coordinated Signal System**

Support:

Progressive movement in a coordinated signal system sometimes necessitates installing traffic control signals at intersections where they would not otherwise be needed in order to maintain proper platooning of vehicles.

**Standard:**

**The need for a traffic control signal shall be considered if an engineering study finds that one of the following criteria is met:**

- A. **On a one-way street or a street that has traffic predominantly in one**

**direction, the adjacent traffic control signals are so far apart that they do not provide the necessary degree of vehicular platooning.**

- B. On a two-way street, adjacent traffic control signals do not provide the necessary degree of platooning and the proposed and adjacent traffic control signals will collectively provide a progressive operation.**

Guidance:

The Coordinated Signal System signal warrant should not be applied where the resultant spacing of traffic control signals would be less than 300 m (1,000 ft).

#### **Section 4C.08 Warrant 7, Crash Experience**

Support:

The Crash Experience signal warrant conditions are intended for application where the severity and frequency of crashes are the principal reasons to consider installing a traffic control signal.

**Standard:**

**The need for a traffic control signal shall be considered if an engineering study finds that all of the following criteria are met:**

- A. Adequate trial of alternatives with satisfactory observance and enforcement has failed to reduce the crash frequency; and**
- B. Five or more reported crashes, of types susceptible to correction by a traffic control signal, have occurred within a 12-month period, each crash involving personal injury or property damage apparently exceeding the applicable requirements for a reportable crash; and**
- C. For each of any 8 hours of an average day, the vehicles per hour (vph) given in both of the 80 percent columns of Condition A in Table 4C-1 (see Section 4C.02), or the vph in both of the 80 percent columns of Condition B in Table 4C-1 exists on the major-street and the higher-volume minor-street approach, respectively, to the intersection, or the volume of pedestrian traffic is not less than 80 percent of the requirements specified in the Pedestrian Volume warrant. These major-street and minor-street volumes shall be for the same 8 hours. On the minor street, the higher volume shall not be required to be on the same approach during each of the 8 hours.**

Option:

If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 70 km/h or exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 56 percent columns in Table 4C-1 may be used in place of the 80 percent columns.

#### **Section 4C.09 Warrant 8, Roadway Network**

Support:

Installing a traffic control signal at some intersections might be justified to encourage concentration and organization of traffic flow on a roadway network.

**Standard:**

**The need for a traffic control signal shall be considered if an engineering study finds that the common intersection of two or more major routes meets one or both of the following criteria:**

- A. The intersection has a total existing, or immediately projected, entering volume of at least 1,000 vehicles per hour during the peak hour of a typical weekday and has 5-year projected traffic volumes, based on an engineering study, that meet one or more of Warrants 1, 2, and 3 during an average weekday; or**
- B. The intersection has a total existing or immediately projected entering volume of at least 1,000 vehicles per hour for each of any 5 hours of a nonnormal business day (Saturday or Sunday).**

**A major route as used in this signal warrant shall have one or more of the following characteristics:**

- A. It is part of the street or highway system that serves as the principal roadway network for through traffic flow; or**
- B. It includes rural or suburban highways outside, entering, or traversing a city; or**
- C. It appears as a major route on an official plan, such as a major street plan in an urban area traffic and transportation study.**

## CHAPTER 4D. TRAFFIC CONTROL SIGNAL FEATURES

### Section 4D.01 General

#### Support:

The features of traffic control signals of interest to road users are the location, design, and meaning of the signal indications. Uniformity in the design features that affect the traffic to be controlled, as set forth in this Manual, is especially important for safe and efficient traffic operations.

Pavement markings (see Part 3) that clearly communicate the operational plan of an intersection to road users play an important role in the effective operation of traffic control signals. By designating the number of lanes, the use of each lane, the length of additional lanes on the approach to an intersection, and the proper stopping points, the engineer can design the signal phasing and timing to best match the goals of the operational plan.

#### Standard:

**When a traffic control signal is not in operation, such as before it is placed in service, during seasonal shutdowns, or when it is not desirable to operate the traffic control signal, the signal faces shall be covered, turned, or taken down to clearly indicate that the traffic control signal is not in operation.**

**A traffic control signal shall control traffic only at the intersection or midblock location where the signal faces are placed.**

**STOP signs shall not be used in conjunction with any traffic control signal operation, except in either of the following cases:**

- A. If the signal indication for an approach is a flashing red at all times; or**
- B. If a minor street or driveway is located adjacent to the area controlled by the traffic control signal, but does not require separate traffic signal control because an extremely low potential for conflict exists.**

#### Guidance:

Signalized midblock crosswalks should be located such that they are at least 30 m (100 ft) from side streets and driveways that are controlled by STOP signs or YIELD signs.

Pavement markings should be used at traffic control signal locations as provided in Part 3. If the road surface will not retain pavement markings, signs should be installed to provide the needed road user information.

Engineering judgment should be used to determine the proper phasing and timing for a traffic control signal. Since traffic flows and patterns change, phasing and timing should be reevaluated regularly and updated if needed.

#### **Section 4D.02 Responsibility for Operation and Maintenance**

Guidance:

Prior to installing any traffic control signal, the responsibility for the maintenance of the signal and all of the appurtenances, hardware, software, and the timing plan(s) should be clearly established. The responsible agency should provide for the maintenance of the traffic control signal and all of its appurtenances in a competent manner.

To this end the agency should:

- A. Keep every controller assembly in effective operation in accordance with its predetermined timing schedule; check the operation of the controller assembly frequently enough to ensure that it is operating in accordance with the predetermined timing schedule; and ensure that a record of all timing changes is maintained and that only authorized persons make timing changes;
- B. Clean the optical system of the signal sections and replace the light sources as frequently as experience proves necessary;
- C. Clean and service equipment and other appurtenances as frequently as experience proves necessary;
- D. Provide for alternate operation of the traffic control signal during a period of failure, using flashing mode or manual control, or manual traffic direction by proper authorities as might be required by traffic volumes or congestion, or by erecting other traffic control devices;
- E. Have properly skilled maintenance personnel available without undue delay for all emergency and lamp failure calls;
- F. Provide spare equipment to minimize the interruption of traffic control signal operation as a result of equipment failure;
- G. Provide for the availability of properly skilled maintenance personnel for the repair of all components; and
- H. Maintain the appearance of the signal displays and equipment.

### **Section 4D.03 Provisions for Pedestrians**

Support:

Chapter 4E contains additional information regarding pedestrian signals.

**Standard:**

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

**If engineering judgment indicates the need for provisions for a given pedestrian movement, signal faces conveniently visible to pedestrians shall be provided by pedestrian signal heads or a signal face for an adjacent vehicular movement.**

Guidance:

Safety considerations should include the installation, where appropriate, of accessible pedestrian signals (see Sections 4E.06 and 4E.09) that provide information in nonvisual format (such as audible tones, verbal messages, and/or vibrating surfaces).

Where pedestrian movements regularly occur, pedestrians should be provided with sufficient time to cross the roadway by adjusting the traffic control signal operation and timing to provide sufficient crossing time every cycle or by providing pedestrian detectors.

Option:

If it is desirable to prohibit certain pedestrian movements at a traffic control signal, a PEDESTRIANS PROHIBITED (R9-3) or No Pedestrian Crossing (R9-3a) sign may be used (see Section 2B.39).

### **Section 4D.04 Meaning of Vehicular Signal Indications**

Support:

The "Uniform Vehicle Code" (see Section 1A.11) is the primary source for the standards for the meaning of vehicular signal indications to both vehicle operators and pedestrians as set forth below, and the standards for the meaning of separate pedestrian signal indications as set forth in Section 4E.02.

**Standard:**

**The following meanings shall be given to highway traffic signal indications for vehicles and pedestrians:**

**A. Steady green signal indications shall have the following meanings:**

- 1. Traffic, except pedestrians, facing a CIRCULAR GREEN signal indication is permitted to proceed straight through or turn right or left except as such movement is modified by lane-use signs, turn prohibition signs, lane markings, or roadway design. But vehicular traffic, including vehicles turning right or left, shall yield the right-of-way to other vehicles, and to pedestrians lawfully within the intersection or an adjacent crosswalk, at the time such signal indication is exhibited.**
- 2. Traffic, except pedestrians, facing a GREEN ARROW signal indication, shown alone or in combination with another signal indication, is permitted to cautiously enter the intersection only to make the movement indicated by such arrow, or such other movement as is permitted by other signal indications shown at the same time. Such vehicular traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection.**
- 3. Unless otherwise directed by a pedestrian signal head, pedestrians facing any green signal indication, except when the sole green signal indication is a turn arrow, are permitted to proceed across the roadway within any marked or unmarked crosswalk. The pedestrian shall yield the right-of-way to vehicles lawfully within the intersection at the time that the green signal indication is first shown.**

**B. Steady yellow signal indications shall have the following meanings:**

- 1. Traffic, except pedestrians, facing a steady CIRCULAR YELLOW or YELLOW ARROW signal indication is thereby warned that the related green movement is being terminated or that a red signal indication will be exhibited immediately thereafter when vehicular traffic shall not enter the intersection.**
- 2. Pedestrians facing a steady CIRCULAR YELLOW or YELLOW ARROW signal indication, unless otherwise directed by a pedestrian signal head, are thereby advised that there is insufficient time to cross the roadway before a red signal indication is shown, and no pedestrian shall then start to cross the roadway.**

**C. Steady red signal indications shall have the following meanings:**

- 1. Vehicular traffic facing a steady CIRCULAR RED signal indication alone shall stop at a clearly marked stop line, but if there is no stop line, traffic shall stop before entering the crosswalk on the near side of the intersection; or if there is no crosswalk, then before entering the**

intersection, and shall remain stopped until a signal indication to proceed is shown, or as provided below.

Except when a sign is in place prohibiting a turn on red or a RED ARROW signal indication is displayed, vehicular traffic facing a CIRCULAR RED signal indication is permitted to enter the intersection to turn right, or to turn left from a one-way street into a one-way street, after stopping. Such vehicular traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection.

2. Vehicular traffic facing a steady RED ARROW signal indication shall not enter the intersection to make the movement indicated by the arrow and, unless entering the intersection to make another movement permitted by another signal indication, shall stop at a clearly marked stop line; but if there is no stop line, before entering the crosswalk on the near side of the intersection, or if there is no crosswalk, then before entering the intersection, and shall remain stopped until a signal indication permitting the movement indicated by such RED ARROW is shown.

When an R10-15 sign (see Section 2B.40) is in place permitting a turn on a RED ARROW signal indication, vehicular traffic facing a RED ARROW signal indication is permitted to enter the intersection to turn right, or to turn left from a one-way street into a one-way street, after stopping. Such vehicular traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection.

3. Unless otherwise directed by a pedestrian signal head, pedestrians facing a steady CIRCULAR RED or RED ARROW signal indication alone shall not enter the roadway.

**D. Flashing signal indications shall have the following meanings:**

1. **Flashing yellow**—When a yellow lens is illuminated with rapid intermittent flashes, vehicular traffic is permitted to proceed through the intersection or past such signal indication only with caution.
2. **Flashing red**—When a red lens is illuminated with rapid intermittent flashes, vehicular traffic shall stop at a clearly-marked stop line; but if there is no stop line, traffic shall stop before entering the crosswalk on the near side of the intersection; or if there is no crosswalk, at the point nearest the intersecting roadway where the driver has a view of

**approaching traffic on the intersecting roadway before entering the intersection. The right to proceed shall be subject to the rules applicable after making a stop at a STOP sign.**

- 3. Flashing RED ARROW and flashing YELLOW ARROW signal indications have the same meaning as the corresponding flashing circular signal indication, except that they apply only to vehicular traffic intending to make the movement indicated by the arrow.**

#### **Section 4D.05 Application of Steady Signal Indications**

##### **Standard:**

**When a traffic control signal is being operated in a steady (stop-and-go) mode, at least one lens in each signal face shall be illuminated at any given time.**

**A signal face(s) that controls a particular vehicular movement during any interval of a cycle shall control that same movement during all intervals of the cycle.**

**Steady signal indications shall be applied as follows:**

##### **A. A steady CIRCULAR RED signal indication:**

- 1. Shall be displayed when it is intended to prohibit traffic, except pedestrians directed by a pedestrian signal head, from entering the intersection or other controlled area. Turning after stopping is permitted as stated in Item C.1 of Section 4D.04.**
- 2. Shall be displayed with the appropriate GREEN ARROW signal indications when it is intended to permit traffic to make a specified turn or turns, and to prohibit traffic from proceeding straight ahead through the intersection or other controlled area, except in protected only mode turn signal faces, or in protected/permissive mode left-turn operation with separate left-turn signal faces (see Section 4D.06).**

##### **B. A steady CIRCULAR YELLOW signal indication:**

- 1. Shall be displayed following a CIRCULAR GREEN or straight-through GREEN ARROW signal indication in the same signal face.**
- 2. Shall not be displayed in conjunction with the change from the CIRCULAR RED signal indication to the CIRCULAR GREEN signal indication.**

3. Shall be followed by a **CIRCULAR RED** signal indication except that, when entering preemption operation, the return to the previous **CIRCULAR GREEN** signal indication shall be permitted following a **CIRCULAR YELLOW** signal indication (see Section 4D.13).
  4. Shall not be displayed to an approach from which drivers are turning left permissively unless one of the following conditions exists:
    - (a) A steady **CIRCULAR YELLOW** signal indication is also being shown simultaneously to the opposing approach;
    - (b) A separate left-turn signal face is provided and operated as described in Section 4D.06;
    - (c) Drivers are advised of the operation if it occurs regularly by the installation near the left-most signal head of a W25-1 sign (see Section 2C.54) with the legend **CAUTION ONCOMING GREEN EXTENDED**; or
    - (d) Drivers are advised of the operation if it occurs only occasionally, such as during a preemption sequence or because of the skipping of actuated phases, by the installation near the left-most signal head of a W25-2 sign (see Section 2C.54) with the legend **CAUTION ONCOMING GREEN MAY BE EXTENDED**.
- C. A steady **CIRCULAR GREEN** signal indication shall be displayed only when it is intended to permit traffic to proceed in any direction that is lawful and practical.
- D. A steady **RED ARROW** signal indication shall be displayed when it is intended to prohibit traffic, except pedestrians directed by a pedestrian signal head, from entering the intersection or other controlled area to make the indicated turn. Except as described in Item C.2 of Section 4D.04, turning on a steady **RED ARROW** signal indication shall not be permitted.
- E. A steady **YELLOW ARROW** signal indication:
1. Shall be displayed in the same direction as a **GREEN ARROW** signal indication following a **GREEN ARROW** signal indication in the same signal face, unless:
    - (a) The **GREEN ARROW** signal indication and a **CIRCULAR GREEN** (or straight-through **GREEN ARROW**) signal indication terminate simultaneously in the same signal face, or
    - (b) The green arrow is a straight-through **GREEN ARROW**.

2. Shall not be displayed in conjunction with the change from a **RED ARROW** signal indication to a **GREEN ARROW** signal indication.
  3. Shall not be displayed when any conflicting vehicular movement has a green or yellow signal indication or any conflicting pedestrian movement has a **WALKING PERSON** (symbolizing **WALK**) or flashing **UPRAISED HAND** (symbolizing **DONT WALK**) signal indication (see Section 4D.09).
  4. Shall be terminated by a **RED ARROW** signal indication for the same direction or a **CIRCULAR RED** signal indication except:
    - (a) When entering preemption operation, the return to the previous **GREEN ARROW** signal indication shall be permitted following a **YELLOW ARROW** signal indication.
    - (b) When the movement controlled by the arrow is to continue on a permissive mode basis during an immediately following **CIRCULAR GREEN** signal indication.
- F. A steady GREEN ARROW signal indication:**
1. Shall be displayed only to allow vehicular movements, in the direction indicated, that are not in conflict with other vehicles moving on a green or yellow signal indication or with pedestrians crossing in conformance with a **WALKING PERSON** (symbolizing **WALK**) or flashing **UPRAISED HAND** (symbolizing **DONT WALK**) signal indication (see Section 4D.09).
  2. Shall be displayed on a signal face that controls a left-turn movement when said movement is not in conflict with other vehicles moving on a green or yellow signal indication or with pedestrians crossing in conformance with a **WALKING PERSON** (symbolizing **WALK**) or flashing **UPRAISED HAND** (symbolizing **DONT WALK**) signal indication (see Section 4D.09). If U-turns are permitted from the approach and if drivers making a right turn from the conflicting approach to the left are simultaneously being shown a right-turn **GREEN ARROW** signal indication, drivers making a U-turn shall be advised of the operation by the installation near the left-turn signal face of a **U-TURN YIELD TO RIGHT TURN (R10-16)** sign (see Section 2B.40).
  3. Shall not be required on the stem of T-intersections or for turns from one-way streets.

**Option:**

Steady RED ARROW, YELLOW ARROW, and GREEN ARROW signal indications, if not otherwise prohibited, may be used instead of the corresponding circular signal indications at the following locations:

- A. On an approach intersecting a one-way street;
- B. Where certain movements are prohibited; and
- C. Where certain movements are physically impossible.

**Section 4D.06 Application of Steady Signal Indications for Left Turns****Support:**

Left-turning traffic is controlled by one of four modes as follows:

- A. Permissive Only Mode—turns made on the CIRCULAR GREEN signal indication after yielding to oncoming traffic and pedestrians;
- B. Protected Only Mode—turns made only when the left-turn GREEN ARROW signal indication is displayed;
- C. Protected/Permissive Mode—both modes occur on an approach during the same cycle; or
- D. Variable Left-Turn Mode—the operating mode changes among the protected only mode and/or the protected/permissive mode and/or the permissive only mode during different periods of the day.

**Option:**

In areas having a high percentage of elderly drivers, special consideration may be given to the use of protected only mode left-turn phasing, when appropriate.

**Standard:**

**The required left-turn signal faces and operation for an approach shall be determined by the selected mode of left-turn operation, as follows:**

- A. Permissive Only Mode—The signal indications for permissive only mode left turns shall be provided in either a shared signal face or a separate signal face. Any permissive only left-turn signal face that always simultaneously displays the same color of circular indication that the adjacent through signal face or faces display shall be considered to be a shared signal face, regardless of where the left-turn signal face is positioned and regardless of**

how many adjacent through signal faces are provided. Any permissive only left-turn signal face that sometimes displays a different color of circular signal indication than the adjacent through signal faces display shall be considered a separate signal face. The requirements for each type of signal face are as follows:

1. If a shared signal face is provided, it shall be considered an approach signal face and the signal indications for permissive only mode left turns shall be the same color as the signal indications for through traffic.
  2. If a separate left-turn signal face is provided for permissive only left turns, it shall meet the following requirements:
    - (a) During the permissive left-turn movement, the left-turn signal face shall display a CIRCULAR GREEN signal indication.
    - (b) If the CIRCULAR GREEN and CIRCULAR YELLOW signal indications in the left-turn signal face are visibility-limited from the adjacent through movement, the left-turn signal face shall not be required to simultaneously display the same color of circular signal indication as the signal faces for the adjacent through movement.
    - (c) If the CIRCULAR GREEN and CIRCULAR YELLOW signal indications in the left-turn signal face are visibility-limited from the adjacent through movement, the display of a CIRCULAR GREEN signal indication for a permissive left turn movement while the signal faces for the adjacent through movement display CIRCULAR RED signal indications and the opposing left-turn signal faces display left-turn GREEN ARROW signal indications for a protected left-turn movement shall be permitted.
    - (d) If the left-turn signal face does not simultaneously display the same color of circular signal indication as the signal faces for the adjacent through movement, a LEFT TURN YIELD ON GREEN (symbolic green ball) (R10-12) sign or a LEFT TURN SIGNAL—YIELD ON GREEN (symbolic green ball) (R10-21) sign (see Figure 2B-18) shall be used.
- B. Protected Only Mode—The left-turn signal face shall be capable of displaying one of the following sets of signal indications:
1. Left-turn RED ARROW, YELLOW ARROW, and GREEN ARROW signal indications only. At least one left-turn signal face shall be provided in addition to the two approach signal faces required in Section 4D.15 for the major movement. Only one of the three colors shall be

illuminated at any given time. A signal instruction sign shall not be required with this set of signal indications. If used, it shall be a **LEFT ON GREEN ARROW ONLY** sign (R10-5); or

2. **CIRCULAR RED, left-turn YELLOW ARROW, and left-turn GREEN ARROW** signal indications. At least one left-turn signal face shall be provided in addition to the two approach signal faces required in Section 4D.15 for the major movement. Only one of the three colors shall be illuminated at any given time. Unless the **CIRCULAR RED** signal indication is shielded, hooded, louvered, positioned, or designed such that it is not readily visible to drivers in the through lane(s), a **LEFT TURN SIGNAL** sign (R10-10) shall be used.
  3. **CIRCULAR RED, CIRCULAR YELLOW, CIRCULAR GREEN, and left-turn GREEN ARROW** signal indications. This four-section signal face shall be used only when the **CIRCULAR GREEN** and left-turn **GREEN ARROW** signal indications begin and terminate together. During each interval, the circular signal indication shall be the same color as the signal indication on the signal face(s) for the adjacent through traffic.
- C. **Protected/Permissive Mode**—The signal indications for protected/permissive mode left turns shall be provided in either a shared signal face or a separate signal face. Any protected/permissive left-turn signal face that always simultaneously displays the same color of circular signal indication that the adjacent through signal faces display shall be considered to be a shared signal face, regardless of where the left-turn signal face is positioned and regardless of how many adjacent through signal faces are provided. Any protected/permissive left-turn signal face that sometimes displays a different color of circular signal indication than the adjacent through signal faces display shall be considered to be a separate signal face. The requirements for each type of signal face are as follows:
1. If a shared signal face is provided, it shall be considered an approach signal face, and shall meet the following requirements:
    - (a) During the protected left-turn movement, the signal face shall simultaneously display a left-turn **GREEN ARROW** signal indication and a circular signal indication that is the same color as the signal indication for the adjacent through lane on the same approach as the protected left turn.

During the protected left-turn movement, the signal faces for through traffic on the opposing approach shall simultaneously display **CIRCULAR RED** signal indications.

- (b) During the permissive left-turn movement, all signal faces on the approach shall display **CIRCULAR GREEN** signal indications.
  - (c) All signal faces on the approach shall simultaneously display the same color of circular signal indications to both through and left-turn road users.
  - (d) A supplementary sign shall not be required. If used, it shall be a **LEFT TURN YIELD ON GREEN** (symbolic green ball) (R10-12) sign (see Figure 2B-18).
- 2. If a separate signal face is provided, it shall be considered a left-turn signal face, and shall meet the following requirements:
  - (a) During the protected left-turn movement, the left-turn signal face shall display a left-turn **GREEN ARROW** signal indication.

During the protected left-turn movement, the signal faces for through traffic on the opposing approach shall simultaneously display **CIRCULAR RED** signal indications.
  - (b) During the permissive left-turn movement, the left-turn signal face shall display a **CIRCULAR GREEN** signal indication.
  - (c) If the **CIRCULAR GREEN** and **CIRCULAR YELLOW** signal indications in the left-turn signal face are visibility-limited from the adjacent through movement, the left-turn signal face shall not be required to simultaneously display the same color of circular signal indication as the signal faces for the adjacent through movement.
  - (d) If the **CIRCULAR GREEN** and **CIRCULAR YELLOW** signal indications in the left-turn signal face are visibility-limited from the adjacent through movement, the display of a **CIRCULAR GREEN** signal indication for a permissive left-turn movement while the signal faces for the adjacent through movement display **CIRCULAR RED** signal indications and the opposing left-turn signal face displays a left-turn **GREEN ARROW** for a protected left-turn movement shall be permitted.
  - (e) If the left-turn signal face does not simultaneously display the same color of circular signal indication as the signal faces for the adjacent through movement, a **LEFT TURN SIGNAL—YIELD ON GREEN** (symbolic green ball) (R10-21) sign (see Figure 2B-18) shall be used.

**D. Variable Left-Turn Mode**—If the protected only mode occurs during one or more periods of the day, and the permissive only mode or the combined protected/permissive mode occurs during other periods of the day, the requirements of Paragraphs A, B, and C above that are appropriate to that mode of operation shall be met, subject to the following:

1. The **CIRCULAR GREEN** and **CIRCULAR YELLOW** signal indications shall not be displayed when operating in the protected only mode.
2. The left-turn **GREEN ARROW** and left-turn **YELLOW ARROW** signal indications shall not be displayed when operating in the permissive only mode.

Option:

Additional appropriate signal indications or changeable message signs may be used to meet the requirements for the variable left-turn mode.

#### **Section 4D.07 Application of Steady Signal Indications for Right Turns**

Support:

Right-turning traffic is controlled by one of four modes as follows:

- A. Permissive Only Mode—turns made on the **CIRCULAR GREEN** signal indication after yielding to pedestrians.
- B. Protected Only Mode—turns made only when the right-turn **GREEN ARROW** signal indication is displayed.
- C. Protected/Permissive Mode—both modes occur on an approach during the same cycle.
- D. Variable Right-Turn Mode—the operating mode changes among the protected only mode and/or the protected/permissive mode and/or the permissive only mode during different periods of the day.

**Standard:**

**The required right-turn signal faces and operation for an approach shall be determined by the selected mode of right-turn operation, as follows:**

- A. **Permissive Only Mode**—A separate signal indication or signal face for right turns shall not be required. The signal indication for permissive only mode right turns shall be the same color as the signal indication for adjacent through traffic, except that if the right turn is held to provide an exclusive

**pedestrian movement, a separate right-turn RED ARROW signal indication shall be provided.**

- B. Protected Only Mode—The right-turn signal face shall be capable of displaying one of the following sets of signal indications:**
- 1. Right-turn RED ARROW, YELLOW ARROW, and GREEN ARROW signal indications only. At least one right-turn signal face shall be provided in addition to the two approach signal faces required in Section 4D.15 for the major movement. Only one of the three colors shall be illuminated at any given time. A signal instruction sign shall not be required with this set of signal indications. If used, it shall be a RIGHT ON GREEN ARROW ONLY sign (R10-5a); or**
  - 2. CIRCULAR RED, right-turn YELLOW ARROW, and right-turn GREEN ARROW signal indications. At least one right-turn signal face shall be provided in addition to the two approach signal faces required in Section 4D.15 for the major movement. Only one of three colors shall be illuminated at any given time. Unless the CIRCULAR RED signal indication is shielded, hooded, louvered, positioned, or designed such that it is not readily visible to drivers in the through lane(s), a RIGHT TURN SIGNAL sign (R10-10R) shall be used.**
  - 3. CIRCULAR RED, CIRCULAR YELLOW, CIRCULAR GREEN, and right-turn GREEN ARROW signal indications. This four-section signal face shall be used only when the CIRCULAR GREEN and right-turn GREEN ARROW signal indications begin and terminate together. During each interval, the circular signal indication shall be the same color as the signal indication on the signal faces for the adjacent through traffic.**
- C. Protected/Permissive Mode—A separate signal face is not required for the right turn, but, if provided, it shall be considered an approach signal face, and shall meet the following requirements:**
- 1. During the protected right-turn movement, the signal face shall simultaneously display:**
    - (a) A right-turn GREEN ARROW signal indication, and**
    - (b) A circular signal indication that is the same color as the signal indication for the adjacent through lane on the same approach as the protected right turn.**

2. **During the permissive right-turn movement, all signal faces on the approach shall display a CIRCULAR GREEN signal indication.**
  3. **All signal faces on the approach shall simultaneously display the same color of circular signal indications to both through and right-turn road users.**
- D. Variable Right-Turn Mode—If the protected only mode occurs during one or more periods of the day, and the permissive only mode or the combined protected/permissive mode occurs during other periods of the day, the requirements of Paragraphs A, B, and C above that are appropriate to that mode of operation shall be met subject to the following:**
1. **The CIRCULAR GREEN and CIRCULAR YELLOW signal indications shall not be displayed when operating in the protected only mode.**
  2. **The right-turn GREEN ARROW and right-turn YELLOW ARROW signal indications shall not be displayed when operating in the permissive only mode.**

Option:

Additional appropriate signal indications or changeable message signs may be used to meet the requirements for the variable right-turn mode.

#### **Section 4D.08 Prohibited Steady Signal Indications**

**Standard:**

**The following combinations of signal indications shall not be simultaneously displayed on any one signal face:**

- A. CIRCULAR GREEN with CIRCULAR YELLOW.**
- B. CIRCULAR RED with CIRCULAR YELLOW.**
- C. CIRCULAR GREEN with CIRCULAR RED.**
- D. Straight-through GREEN ARROW with CIRCULAR RED.**

**The above combinations shall not be simultaneously displayed in different signal faces on any one approach unless one of the following conditions exists:**

- A. One of the signal faces is a turn signal controlling a protected only mode turn, and a LEFT (RIGHT) TURN SIGNAL sign (R10-10) (see Sections 4D.06 and 4D.07) is mounted adjacent to each such signal face, or**
- B. The signal faces are shielded, hooded, louvered, positioned, or designed so that the combination is not confusing to approaching road users.**

**A straight-through RED ARROW signal indication or a straight-through YELLOW ARROW signal indication shall not be displayed on any signal face, either alone or in combination with any other signal indication.**

#### **Section 4D.09 Unexpected Conflicts During Green or Yellow Intervals**

##### **Standard:**

**A steady GREEN ARROW or YELLOW ARROW signal indication shall not be displayed to vehicular movements that are in conflict with the following:**

- A. Other vehicles moving on a green or yellow signal indication, except for the situation regarding U-Turns described in Item F.2 of Section 4D.05. Vehicles departing in the same direction shall not be considered in conflict if, for each turn lane with moving traffic, there is a separate departing lane, and pavement markings or raised channelization clearly indicate which departure lane to use.**
- B. Pedestrians crossing in conformance with a WALKING PERSON (symbolizing WALK) or flashing UPRAISED HAND (symbolizing DONT WALK) signal indication.**

##### **Guidance:**

No movement that creates an unexpected crossing of pathways of moving vehicles or pedestrians should be allowed during any green or yellow interval, except when all three of the following conditions are met:

- A. The movement involves only slight conflict, and**
- B. Serious traffic delays are substantially reduced by permitting the conflicting movement, and**
- C. Drivers and pedestrians subjected to the unexpected conflict are effectively warned thereof by a sign.**

#### **Section 4D.10 Yellow Change and Red Clearance Intervals**

**Standard:**

**A yellow signal indication shall be displayed following every CIRCULAR GREEN or GREEN ARROW signal indication.**

**The exclusive function of the yellow change interval shall be to warn traffic of an impending change in the right-of-way assignment.**

**The duration of a yellow change interval shall be predetermined.**

**Guidance:**

A yellow change interval should have a duration of approximately 3 to 6 seconds. The longer intervals should be reserved for use on approaches with higher speeds.

**Option:**

The yellow change interval may be followed by a red clearance interval to provide additional time before conflicting traffic movements, including pedestrians, are released.

**Standard:**

**The duration of a red clearance interval shall be predetermined.**

**Guidance:**

A red clearance interval should have a duration not exceeding 6 seconds.

#### **Section 4D.11 Application of Flashing Signal Indications**

**Standard:**

**The light source of a flashing signal indication shall be flashed continuously at a rate of not less than 50 nor more than 60 times per minute. The illuminated period of each flash shall be not less than half and not more than two-thirds of the total flash cycle.**

**Flashing signal indications shall comply with the requirements of other Sections of this Manual regarding shielding or positioning of conflicting signal indications, except that flashing yellow signal indications for through traffic shall not be required to be shielded or positioned to prevent visual conflict for road users in separately controlled turn lanes.**

**The following applications shall apply whenever a traffic control signal is operated in the flashing mode:**

- A. Each approach or protected only mode turn movement that is controlled during steady mode (stop-and-go) operation shall display a signal indication during flashing operation.**
- B. All signal faces that are flashed on an approach shall flash the same color, either yellow or red, except that separate signal faces for protected only mode turn movements and separate signal faces for protected/permissive left-turn movements shall be permitted to flash a CIRCULAR RED or RED ARROW signal indication when the through signal indications are flashed yellow. Shared signal faces for protected/permissive left-turn movements shall not be permitted to flash a CIRCULAR RED signal indication when the through signal indications are flashed yellow.**
- C. The appropriate RED ARROW or YELLOW ARROW signal indication shall be flashed when a signal face consists entirely of arrow lenses.**
- D. If a signal face includes both circular and arrow signal lenses of the color that is to be flashed, only the circular signal indication shall be flashed.**

Guidance:

When a traffic control signal is operated in the flashing mode, a flashing yellow signal indication should be used for the major street and a flashing red signal indication should be used for the other approaches unless flashing red signal indications are used on all approaches.

#### **Section 4D.12 Flashing Operation of Traffic Control Signals**

**Standard:**

**Each traffic control signal shall be provided with an independent flasher mechanism that operates in compliance with Section 4D.11. The flashing operation shall not be terminated by removal or turn off of the controller unit or of the conflict monitor (malfunction management unit) or both.**

**When a traffic control signal is operated in the flashing mode:**

- A. Flashing yellow signal indications shall not be displayed for approaches with conflicting traffic movements, except for permissive left-turn movements.**
- B. At least one signal indication in each signal face on an approach shall be**

**flashed except in the following circumstance:**

**A single-section signal face consisting of a continuously-illuminated GREEN ARROW signal lens that is used alone to indicate a continuous movement in the steady (stop-and-go) mode shall remain continuously illuminated when the traffic control signal is operated in the flashing mode.**

**A manual switch, a conflict monitor (malfunction management unit) circuit, and, if appropriate, automatic means shall be provided to initiate the flashing mode.**

**The transition from steady (stop-and-go) mode to flashing mode, if initiated by a conflict monitor (malfunction management unit) or by a manual switch, shall be permitted to be made at any time.**

**Programmed changes from steady (stop-and-go) mode to flashing mode shall be made under either of the following circumstances:**

- A. At the end of the common major-street red interval (such as just prior to the start of the green in both directions on the major street), or**
- B. Directly from a steady CIRCULAR GREEN or GREEN ARROW signal indication to a flashing CIRCULAR YELLOW or YELLOW ARROW signal indication, respectively.**

**During programmed changes, no steady green signal indication or flashing yellow signal indication shall be terminated and immediately followed by a steady red or flashing red signal indication without first displaying the steady yellow signal indication.**

**Changes from flashing mode to steady (stop-and-go) mode shall be made under one of the following procedures:**

- A. Yellow-red flashing mode: Changes from flashing mode to steady (stop-and-go) mode shall be made at the beginning of the major-street green interval (when a green signal indication is shown to through traffic in both directions on the major street), or if there is no common major-street green interval, at the beginning of the green interval for the major traffic movement on the major street.**
- B. Red-red flashing mode: Changes from flashing mode to steady (stop-and-go) mode shall be made by changing the flashing red indications to steady red indications followed by appropriate green indications to begin the steady mode cycle. These green indications shall be the beginning of the major-street green interval (when a green signal indication is shown to through**

**traffic in both directions on the major street) or if there is no common major-street green interval, at the beginning of the green interval for the major traffic movement on the major street.**

Guidance:

When changing from the yellow-red flashing mode to steady (stop-and-go) mode, if there is no common major-street green interval, the provision of a steady red clearance interval for the other approaches before changing from a flashing yellow or a flashing red signal indication to a green signal indication on the major approach should be considered.

The steady red clearance interval provided during the change from red-red flashing mode to steady (stop-and-go) mode should have a duration of 6 seconds.

Support:

Section 4E.09 contains information regarding the operation of accessible pedestrian signal detector pushbutton locator tones during flashing operation.

### **Section 4D.13 Preemption and Priority Control of Traffic Control Signals**

Option:

Traffic control signals may be designed and operated to respond to certain classes of approaching vehicles by altering the normal signal timing and phasing plan(s) during the approach and passage of those vehicles. The alternative plan(s) may be as simple as extending a currently displayed green interval or as complex as replacing the entire set of signal phases and timing.

Support:

Preemption control (see definition in Section 4A.02) is typically given to trains, boats, emergency vehicles, and light rail transit.

Examples of preemption control include the following:

- A. The prompt displaying of green signal indications at signalized locations ahead of fire vehicles, police cars, ambulances, and other official emergency vehicles;
- B. A special sequence of signal phases and timing to provide additional clearance time for vehicles to clear the tracks prior to the arrival of a train; and
- C. A special sequence of signal phases to display a red indication to prohibit turning movements towards the tracks during the approach or passage of a train or transit vehicle.

Priority control (see definition in Section 4A.02) is typically given to certain nonemergency vehicles such as buses and light-rail vehicles.

Examples of priority control include the following:

- A. The displaying of early or extended green signal indications at an intersection to assist public transit vehicles in remaining on schedule; and
- B. Special phasing to assist public transit vehicles in entering the travel stream ahead of the platoon of traffic.

Some types or classes of vehicles supersede others when a traffic control signal responds to more than one type or class. In general, a vehicle that is more difficult to control supersedes a vehicle that is easier to control. Typically, the order of priority is: train, boat, heavy vehicle (fire vehicle, emergency medical service), light vehicle (police), light rail transit, rubber-tired transit.

**Standard:**

**During the transition into preemption control:**

- A. **The yellow change interval, and any red clearance interval that follows, shall not be shortened or omitted.**
- B. **The shortening or omission of any pedestrian walk interval and/or pedestrian change interval shall be permitted.**
- C. **The return to the previous steady green signal indication shall be permitted following a steady yellow signal indication in the same signal face, omitting the red clearance interval, if any.**

**During preemption control and during the transition out of preemption control:**

- A. **The shortening or omission of any yellow change interval, and of any red clearance interval that follows, shall not be permitted.**
- B. **A signal indication sequence from a steady yellow signal indication to a steady green signal indication shall not be permitted.**

**During priority control and during the transition into or out of priority control:**

- A. **The shortening or omission of any yellow change interval, and of any red clearance interval that follows, shall not be permitted.**
- B. **The shortening of any pedestrian walk interval below that time described in Section 4E.09 shall not be permitted.**

- C. The omission of a pedestrian walk interval and its associated change interval shall not be permitted unless the associated vehicular phase is also omitted or the pedestrian phase is exclusive.**
- D. The shortening or omission of any pedestrian change interval shall not be permitted.**
- E. A signal indication sequence from a steady yellow signal indication to a steady green signal indication shall not be permitted.**

Guidance:

When a traffic control signal that is returning to a steady mode from a dark mode (typically upon restoration from a power failure) receives a preemption or priority request, care should be exercised to ensure that vehicles or pedestrians are not misdirected into conflict with the vehicle making the request.

If a traffic control signal is installed near or within a highway-railroad grade crossing or if a highway-railroad grade crossing with active traffic control devices is within or near a signalized highway intersection, Chapter 8D should be consulted.

Traffic control signals operating under preemption control or under priority control should be operated in a manner designed to keep traffic moving.

Traffic control signals that are designed to respond under preemption or priority control to more than one type or class of vehicle should be designed to respond in the relative order of importance or difficulty in stopping the type or class of vehicle.

Option:

During the change from a dark mode to a steady mode under a preemption or priority request, the display of signal indications that could misdirect road users may be prevented by the following:

- A. Having the traffic control signal remain in the dark mode;
- B. Having the traffic control signal remain in the flashing mode;
- C. Altering the flashing mode;
- D. Executing the normal start-up routine before responding; and
- E. Responding directly to initial or dwell period.

A distinctive indication may be provided at the intersection to show that an emergency

vehicle has been given control of the traffic signal (see Section 11-106 of the "Uniform Vehicle Code").

Preemption or priority control of traffic signals may also be a means of assigning priority right-of-way to specified classes of vehicles at certain nonintersection locations such as on approaches to one-lane bridges and tunnels, movable bridges, highway maintenance and construction activities, metered freeway entrance ramps, and transit operations.

#### **Section 4D.14 Coordination of Traffic Control Signals**

Guidance:

Traffic control signals within 800 m (0.5 mi) of one another along a major route or in a network of intersecting major routes should be coordinated, preferably with interconnected controller units. However, signal coordination need not be maintained across boundaries between signal systems that operate on different cycle lengths.

Support:

For coordination with railroad-highway grade crossing signals, see Sections 4D.13 and 8D.07.

#### **Section 4D.15 Size, Number, and Location of Signal Faces by Approach**

Support:

Sections 4D.05, and 4D.16 through 4D.18 contain additional information regarding the design of signal faces.

**Standard:**

**There shall be two nominal diameter sizes for vehicular signal lenses: 200 mm (8 in) and 300 mm (12 in).**

**Three-hundred millimeter (12 in) signal lenses shall be used:**

- A. For signal indications for approaches (see definition in Section 4A.02) where road users view both traffic control and lane-use control signal heads simultaneously;**
- B. If the nearest signal face is between 35 m (120 ft) and 45 m (150 ft) beyond the stop line, unless a supplemental near-side signal face is provided;**
- C. For signal faces located more than 45 m (150 ft) from the stop line;**

**Table 4D-1. Minimum Sight Distance**

85th- Percentile Speed (km/h)	Minimum Sight Distance (meters)	85th- Percentile Speed (mph)	Minimum Sight Distance (feet)
30	50	20	175
40	65	25	215
50	85	30	270
60	110	35	325
70	140	40	390
80	165	45	460
90	195	50	540
100	220	55	625
		60	715

**D. For approaches to all signalized locations for which the minimum sight distance in Table 4D-1 cannot be met; and**

**E. For arrow signal indications.**

**A 200 mm (8 in) signal lens for a CIRCULAR RED signal indication shall not be used in combination with 300 mm (12 in) signal lens for a CIRCULAR GREEN signal indication or 300 mm (12 in) signal lens for a CIRCULAR YELLOW signal indication.**

Option:

Different sizes of signal lenses may be used in the same signal face or signal head, except for the prohibitions listed in the Standards in this Section.

Guidance:

Three-hundred millimeter (12 in) signal lenses should be used for all signal indications for the following:

- A. Approaches with 85th-percentile approach speeds exceeding 60 km/h (40 mph);
- B. Approaches where a traffic control signal might be unexpected;

- C. All approaches without curbs and gutters where only post-mounted signal heads are used; and
- D. Locations where there is a significant percentage of elderly drivers.

**Standard:**

**The signal faces for each approach to an intersection or a midblock location shall be provided as follows:**

- A. A minimum of two signal faces shall be provided for the major movement on the approach, even if the major movement is a turning movement.
- B. See Section 4D.06 for left-turn signal faces.
- C. See Section 4D.07 for right-turn signal faces.
- D. Except where the width of an intersecting roadway or other conditions make it physically impractical:
  - 1. A signal face installed to satisfy the requirements of Items B and C in this Standard, and at least one and preferably both of the signal faces required by Item A in this Standard shall be located:
    - (a) Not less than 12 m (40 ft) beyond the stop line.
    - (b) Not more than 55 m (180 ft) beyond the stop line unless a supplemental near side signal face is provided.
    - (c) As near as practical to the line of the driver's normal view, if mounted over the roadway.
  - 2. Where the nearest signal face is located between 45 and 55 m (150 and 180 ft) beyond the stop line, engineering judgment of the conditions, including the worst-case visibility conditions, shall be used to determine if the provision of a supplemental near side signal face would be beneficial.
  - 3. A signal face installed to satisfy the requirements of Items B and C in this Standard, and at least one and preferably both of the signal faces required by Item A in this Standard shall be located no higher than at a maximum height to the top of the signal housing mounted over a roadway of 7.8 m (25.6 ft) above the pavement (see Section 4D.17). For viewing distances between 12 m (40 ft) and 16 m (53 ft) from the stop line, the maximum mounting height to the top of the signal housing shall

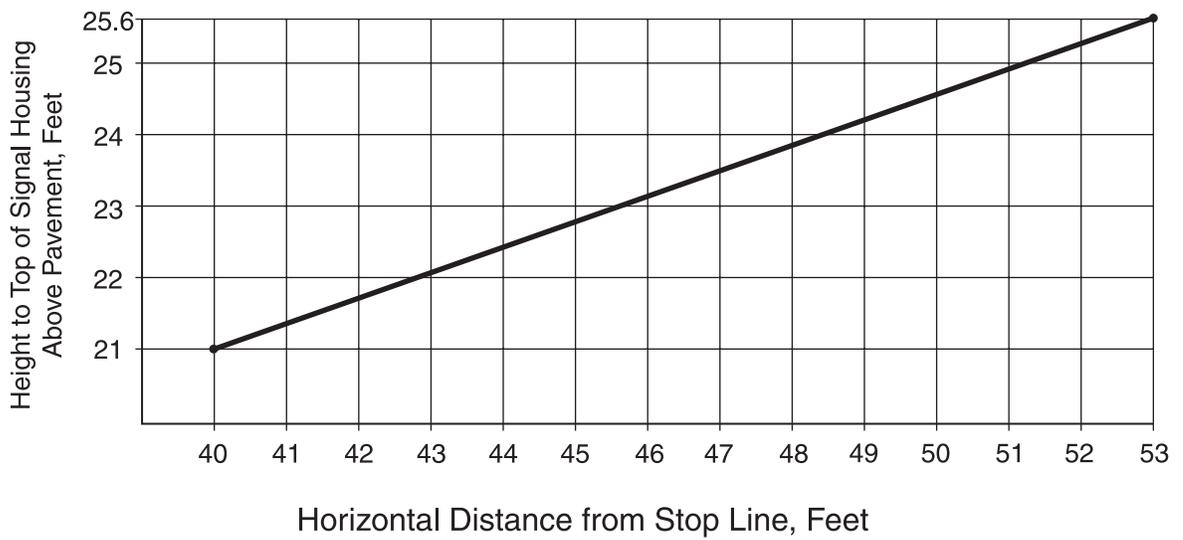
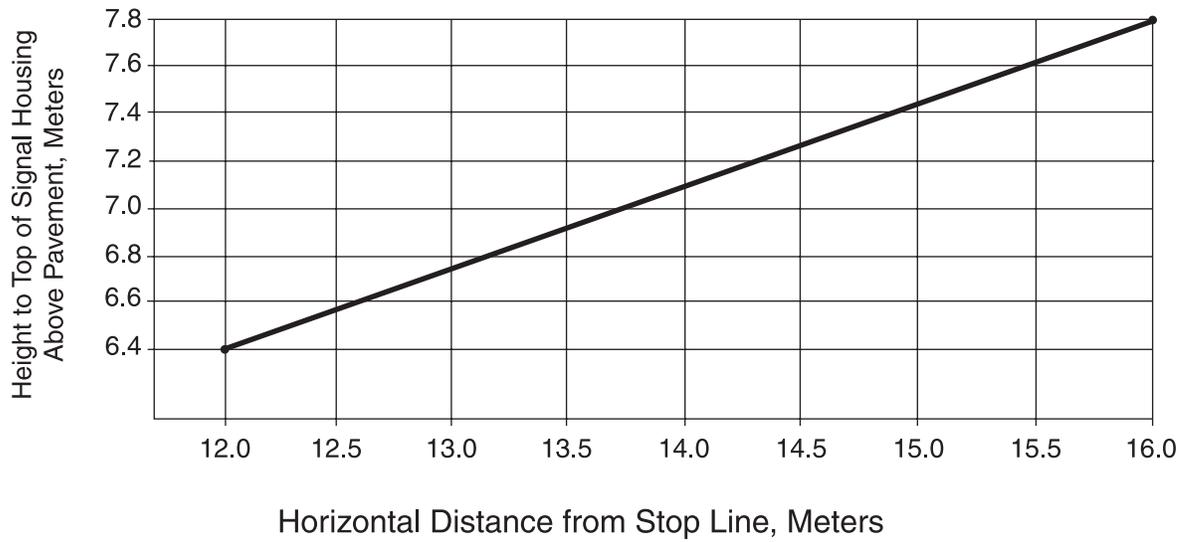
- be as shown on Figure 4D-1. (See Section 4D.17 for additional information regarding mounting heights.)
4. At least one and preferably both of the signal faces required by Item A in this Standard shall be located between two lines intersecting with the center of the approach at a point 3 m (10 ft) behind the stop line, one making an angle of approximately 20 degrees to the right of the center of the approach extended, and the other making an angle of approximately 20 degrees to the left of the center of the approach extended (see Figure 4D-2).
  5. If both of the signal faces required by Item A in this Standard are post-mounted, they shall both be on the far side of the intersection, one on the right and one on the left of the approach lane(s).
- E. If the minimum sight distance in Table 4D-1 cannot be met, a sign shall be installed to warn approaching traffic of the traffic control signal.
- F. Required signal faces for through traffic on any one approach shall be located not less than 2.4 m (8 ft) apart measured horizontally perpendicular to the approach between the centers of the signal faces.
- G. If more than one turn signal face is provided for a protected-mode turn and if one or both of the signal faces are located over the roadway, the signal faces shall be located not less than 2.4 m (8 ft) apart measured horizontally perpendicular to the approach between the centers of the signal faces.
- H. If supplemental signal faces are used, the following limitations shall apply:
1. Left-turn arrows shall not be used in near-right signal faces.
  2. Right-turn arrows shall not be used in far-left signal faces. A far-side median-mounted signal face shall be considered a far-left signal for this application.

Guidance:

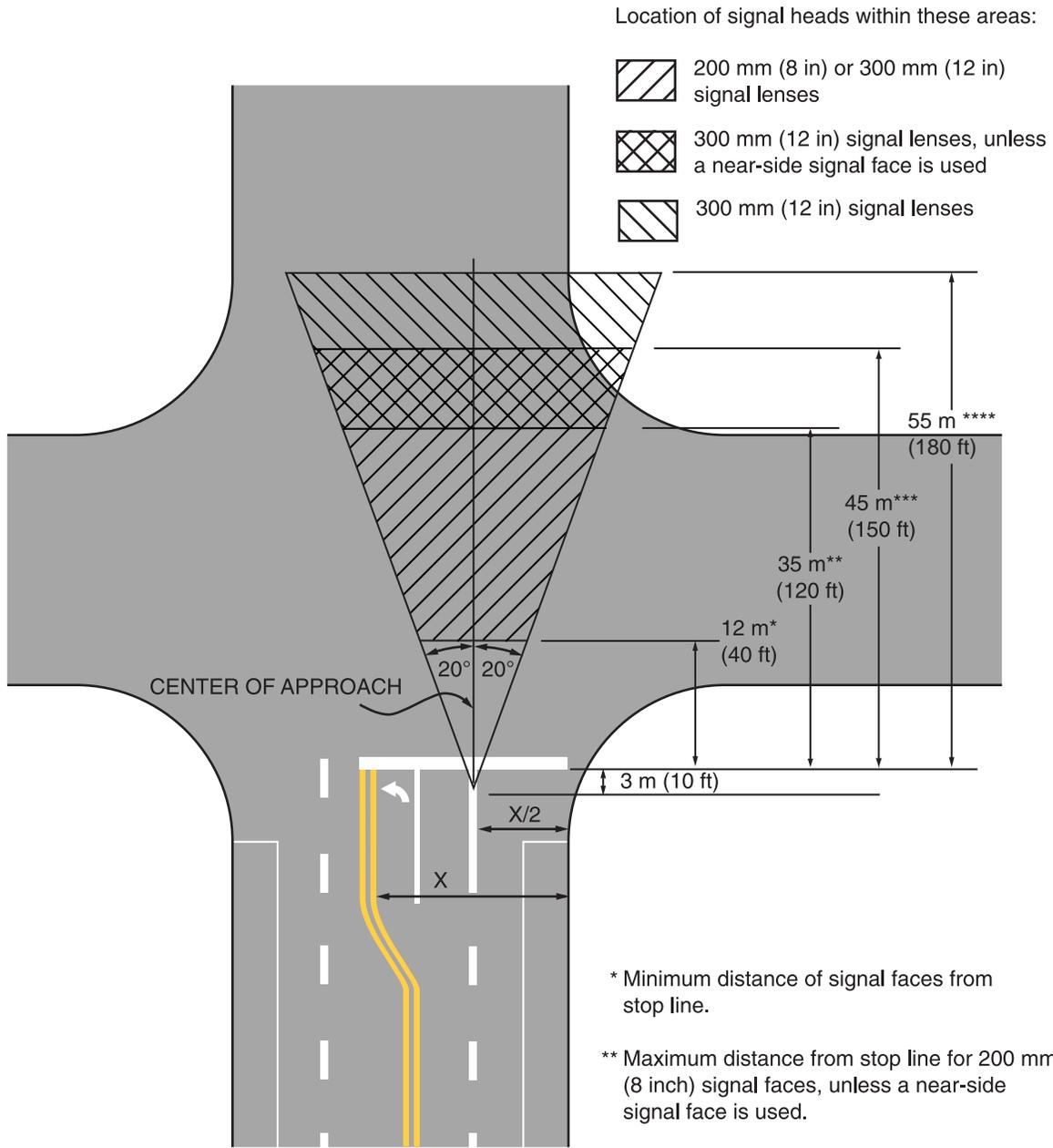
The two signal faces required for each approach should be continuously visible to traffic approaching the traffic control signal, from a point at least the minimum sight distance indicated in Table 4D-1 in advance of and measured to the stop line. This range of continuous visibility should be provided unless precluded by a physical obstruction or unless another signalized location is within this range.

If two or more left-turn lanes are provided for a separately controlled protected only mode left-turn movement, or if a left-turn movement represents the major movement

**Figure 4D-1. Maximum Mounting Height of Signal Faces Located Between 12 Meters (40 Feet) and 16 Meters (53 Feet) from Stop Line**



**Figure 4D-2. Horizontal Location of Signal Faces**



\* Minimum distance of signal faces from stop line.

\*\* Maximum distance from stop line for 200 mm (8 inch) signal faces, unless a near-side signal face is used.

\*\*\* Maximum distance from stop line for 200 mm (8 inch) signal faces when near-side supplemental signal face is used.

\*\*\*\* Maximum distance from stop line for 300 mm (12 inch) signal faces, unless a near-side supplemental signal face is used.

from an approach, two left-turn signal faces should be provided.

If two or more right-turn lanes are provided for a separately controlled right-turn movement, or if a right-turn movement represents the major movement from an approach, two right-turn signal faces should be provided.

Near-side signal faces should be located as near as practical to the stop line.

If a signal face controls a specific lane or lanes of an approach, its position should make it readily visible to road users making that movement.

Supplemental signal faces should be used if engineering judgment has shown that they are needed to achieve intersection visibility both in advance and immediately before the signalized location. If supplemental signal faces are used, they should be located to provide optimum visibility for the movement to be controlled.

At signalized midblock crosswalks, at least one of the signal faces should be over the traveled way for each approach.

Option:

If a sign is installed to warn approaching road users of the traffic control signal, the sign may be supplemented by a Warning Beacon (see Section 4K.03).

A Warning Beacon used in this manner may be interconnected with the traffic signal controller assembly in such a manner as to flash yellow during the period when road users passing this beacon at the legal speed for the roadway might encounter a red signal indication (or a queue resulting from the display of the red signal indication) upon arrival at the signalized location.

#### **Section 4D.16 Number and Arrangement of Signal Sections in Vehicular Traffic Control Signal Faces**

**Standard:**

**Each signal face at a signalized location shall have three, four, or five signal sections.**

**A single-section signal face shall be permitted at a traffic control signal if it consists of a continuously illuminated GREEN ARROW signal lens that is being used to indicate a continuous movement.**

**Arrows shall be pointed:**

- A. Vertically upward to indicate a straight-through movement;**
- B. Horizontally in the direction of the turn to indicate a turn at approximately or greater than a right angle; and**
- C. Upward with a slope at an angle approximately equal to that of the turn if the angle of the turn is substantially less than a right angle.**

The signal lenses in a signal face shall be arranged in a vertical or horizontal straight line, except that in a vertical array, signal lenses of the same color may be arranged horizontally adjacent to each other at right angles to the basic straight line arrangement. Such clusters shall be limited to two identical signal lenses or to two or three different signal lenses of the same color.

In each signal face, all red signal lenses in vertically arranged signal faces shall be located above, and in horizontally arranged signal faces shall be located to the left, of all yellow and green signal lenses.

If a CIRCULAR YELLOW signal lens is used, it shall be located between the red signal lens or lenses and all other signal lenses.

In vertically arranged signal faces, each YELLOW ARROW signal lens shall be located immediately above the GREEN ARROW signal lens to which it applies. If a dual-arrow signal section (capable of alternating between the display of a GREEN ARROW and a YELLOW ARROW signal indication) is used, the lenses shall be in the same position relative to other lenses as are the GREEN ARROW signal lenses in a vertically arranged signal face.

In horizontally arranged signal faces, the YELLOW ARROW signal lens shall be located immediately to the left of the GREEN ARROW signal lens. If a dual-arrow signal section (capable of alternating between the display of a GREEN ARROW and a YELLOW ARROW signal indication) is used, the dual left-turn arrow signal lens shall be located immediately to the right of the CIRCULAR YELLOW signal lens, the straight-through GREEN ARROW signal lens shall be located immediately to the right of the CIRCULAR GREEN signal lens, and the dual right-turn arrow signal lens shall be located to the right of all other signal lenses.

The relative positions of signal lenses within the signal face shall be as follows:

**A. In a vertically arranged signal face from top to bottom:**

**CIRCULAR RED**  
**Left-turn RED ARROW**  
**Right-turn RED ARROW**  
**CIRCULAR YELLOW**  
**CIRCULAR GREEN**  
**Straight-through GREEN ARROW**  
**Left-turn YELLOW ARROW**  
**Left-turn GREEN ARROW**  
**Right-turn YELLOW ARROW**  
**Right-turn GREEN ARROW**

**B. In a horizontally arranged signal face from left to right:**

**CIRCULAR RED**  
**Left-turn RED ARROW**  
**Right-turn RED ARROW**  
**CIRCULAR YELLOW**  
**Left-turn YELLOW ARROW**  
**Left-turn GREEN ARROW**  
**CIRCULAR GREEN**  
**Straight-through GREEN ARROW**  
**Right-turn YELLOW ARROW**  
**Right-turn GREEN ARROW**

**C. If adjacent signal indications in a signal face are not identical, their arrangement shall follow Items A or B above, as applicable.**

Option:

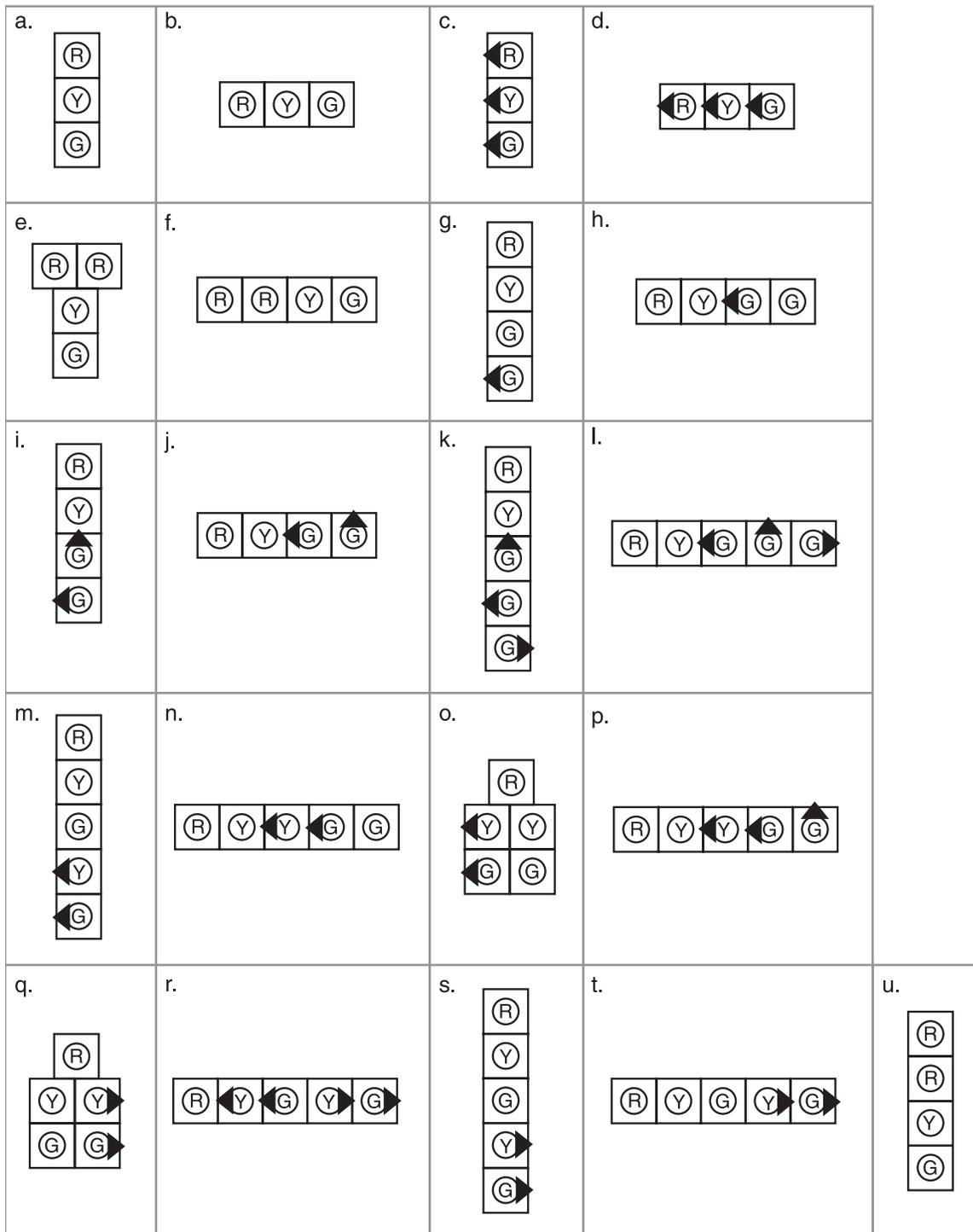
In a vertically arranged signal face, identical signal indications may be repeated in adjacent horizontal locations within the same signal face.

Horizontally arranged and vertically arranged signal faces may be used on the same approach provided they are separated to meet the lateral separation spacing required in Section 4D.15.

Support:

Figure 4D-3 illustrates some of the possible arrangements of signal lenses in signal faces.

**Figure 4D-3. Typical Arrangements of Signal Lenses in Signal Faces**



**Section 4D.17 Visibility, Shielding, and Positioning of Signal Faces****Standard:**

The primary consideration in signal face placement, aiming, and adjustment shall be to optimize the visibility of signal indications to approaching traffic. Road users approaching a signalized intersection or other signalized area, such as a midblock crosswalk, shall be given a clear and unmistakable indication of their right-of-way assignment.

The geometry of each intersection to be signalized, including vertical grades, horizontal curves, and obstructions as well as the lateral and vertical angles of sight toward a signal face, as determined by typical driver-eye position, shall be considered in determining the vertical, longitudinal, and lateral position of the signal face.

In cases where irregular street design necessitates placing signal faces for different street approaches with a comparatively small angle between their respective signal lenses, each signal lens shall, to the extent practical, be shielded or directed by signal visors, signal louvers, or other means so that an approaching road user can see only the signal lens(es) controlling the movements on the road user's approach.

The bottom of the signal housing and any related attachments to a vehicular signal face located over a roadway shall be at least 4.6 m (15 ft) above the pavement. The top of the signal housing of a vehicular signal face located over a roadway shall not be more than 7.8 m (25.6 ft) above the pavement.

Signal visors exceeding 300 mm (12 in) in length shall not be used on free-swinging signal heads.

The bottom of the signal housing (including brackets) of a vehicular signal face that is vertically arranged and not located over a roadway:

- A. Shall be at least 2.4 m (8 ft) but not more than 5.8 m (19 ft) above the sidewalk or, if there is no sidewalk, above the pavement grade at the center of the roadway.
- B. Shall be at least 1.4 m (4.5 ft) but not more than 5.8 m (19 ft) above the median island grade of a center median island if located on the near side of the intersection.

The bottom of the signal housing (including brackets) of a vehicular signal face that is horizontally arranged and not located over a roadway:

- A. Shall be at least 2.4 m (8 ft) but not more than 6.7 m (22 ft) above the sidewalk or, if there is no sidewalk, above the pavement grade at the center of the roadway.**
- B. Shall be at least 1.4 m (4.5 ft) but not more than 6.7 m (22 ft) above the median island grade of a center median island if located on the near side of the intersection.**

**Signal heads mounted at less than 4.6 meters (15 feet) from the bottom of the housing and any related attachments at the side of a roadway with curbs shall have a horizontal clearance of not less than 0.6 m (2 ft) from the face of a vertical curb. If there is no curb, signal heads shall have a horizontal clearance of not less than 0.6 m (2 ft) from the edge of a shoulder.**

Guidance:

There should be legal authority to prohibit the display of any unauthorized sign, signal, marking, or device that interferes with the effectiveness of any official traffic control device (see Section 11-205 of the "Uniform Vehicle Code").

Signal visors should be used on signal faces to aid in directing the signal indication specifically to approaching traffic, as well as to reduce "sun phantom," which can result when external light enters the lens.

The use of signal visors, or the use of signal faces or devices that direct the light without a reduction in intensity, should be considered as an alternative to signal louvers because of the reduction in light output caused by signal louvers.

The use of a signal backplate for target value enhancement should be considered on signal faces viewed against a bright sky or bright or confusing backgrounds.

Support:

The use of backplates enhances the contrast between the traffic signals and their surroundings for both day and night conditions, which is also helpful to elderly drivers.

Option:

Special signal faces, such as visibility-limited signal faces, may be used such that the road user does not see signal indications intended for other approaches before seeing the signal indications for their own approach, if simultaneous viewing of both signal indications could cause the road user to be misdirected.

If the sight distance to the signal heads facing the approach is limited by horizontal or vertical alignment, supplemental signal faces aimed at a point on the approach at which the signal indications first become visible may be used.

**Section 4D.18 Design, Illumination, and Color of Signal Sections****Standard:**

**Each signal indication, except those used for pedestrian signal heads and lane-use control signals, shall be circular or arrow.**

**Letters or numbers shall not be displayed as part of a vehicular signal indication.**

**Each signal indication shall be independently illuminated.**

**Each circular signal indication shall emit a single color: red, yellow, or green.**

**Each arrow signal indication shall emit a single color: red, yellow, or green except that the alternate display (dual-arrow signal section) of a GREEN ARROW and a YELLOW ARROW signal indication, both pointing in the same direction, shall be permitted, provided that they are not displayed simultaneously.**

**The arrow, which shall show only one direction, shall be the only illuminated part of an arrow signal indication.**

**Except for the requirements of this section, the requirements of the "Standards for Vehicle Traffic Control Signal Heads" (see Section 1A.11) shall be met.**

**References to signal lenses in this section shall not be used to limit signal optical units to incandescent lamps within optical assemblies that include lenses.**

**Support:**

Research has resulted in signal optical units that are not lenses, such as, but not limited to, light-emitting diode (LED) traffic signal modules. Some units are practical for all signal indications, and some are practical for specific types such as visibility-limited signal indications.

**Guidance:**

The intensity and distribution of light from each illuminated signal lens should conform to the current "Standards for Vehicle Traffic Control Signal Heads" and "Traffic Signal Lamps" (see Section 1A.11).

If a signal indication is operated in the flashing mode for nighttime operation and the signal indication is so bright as to cause excessive glare, some form of automatic dimming should be used to reduce the brilliance of the signal indication.

**Standard:**

**The inside of signal visors (hoods), the entire surface of louvers and fins, and the front surface of backplates shall have a dull black finish to minimize light reflection and to increase contrast between the signal indication and its background.**

**Section 4D.19 Lateral Placement of Signal Supports and Cabinets**

## Guidance:

The following items should be considered when placing signal supports and cabinets:

- A. Reference should be made to the American Association of State Highway and Transportation Officials (AASHTO) "Roadside Design Guide" (see Section 1A.11) and to the Americans with Disabilities Act (ADA) (see the Department of Justice's ADA Standards for Accessible Design, 1991).
- B. Signal supports should be placed as far as practical from the edge of the traveled way without adversely affecting the visibility of the signal indications.

Where supports cannot be located based on the recommended AASHTO clearances, consideration should be given to the use of appropriate safety devices.

No part of a concrete base for a signal support should extend more than 100 mm (4 in) above the ground level at any point. This limitation does not apply to the concrete base for a rigid support.

- C. In order to minimize hindrance to the passage of persons with physical disabilities, a signal support or controller cabinet should not obstruct the sidewalk, or access from the sidewalk to the crosswalk.
- D. Controller cabinets should be located as far as practical from the edge of the roadway.
- E. On medians, the above minimum clearances for signal supports should be obtained if practical.

**Section 4D.20 Temporary Traffic Control Signals****Standard:**

**A temporary traffic control signal shall be defined as a traffic control signal that**

**is installed for a limited time period. A portable traffic control signal shall be defined as a temporary traffic control signal that is designed so that it can be easily transported and reused at different locations.**

Support:

A temporary traffic control signal is generally installed using methods that minimize the costs of installation, relocation, and/or removal. Typical temporary traffic control signals are for specific purposes, such as for one-lane, two-way facilities in temporary traffic control zones (see Chapter 4G), for a haul-road intersection, or for access to a site that will have a permanent access point developed at another location in the near future.

**Standard:**

**Advance signing shall be used when employing a temporary traffic control signal.**

**A temporary traffic control signal shall:**

- A. Meet the physical display and operational requirements of a conventional traffic control signal.**
- B. Be removed when no longer needed.**
- C. Be placed in the flashing mode when not being used if it will be operated in the steady mode within 5 working days; otherwise, it shall be removed.**
- D. Be placed in the flashing mode during periods when it is not desirable to operate the signal, or the signal heads shall be covered, turned, or taken down to indicate that the signal is not in operation.**

Guidance:

A temporary traffic control signal should be used only if engineering judgment indicates that installing the signal will improve the overall safety and/or operation of the location. The use of temporary traffic control signals by a work crew on a regular basis in their work area should be subject to the approval of the jurisdiction having authority over the roadway.

A temporary traffic control signal should not operate longer than 30 days unless associated with a longer-term temporary traffic control zone project.

For use of temporary traffic control signals in temporary traffic control zones, reference should be made to Section 6F.76.

**Section 4D.21 Traffic Signal Signs, Auxiliary**

**Support:**

Traffic signal signs are sometimes used at highway traffic signal locations to instruct or guide pedestrians, bicyclists, or drivers.

**Standard:**

**The minimum vertical and horizontal clearance of the total assembly of traffic signal signs (see Section 2B.40) shall conform to the provisions of Section 4D.17.**

**If used, illuminated traffic signal signs shall be designed and mounted in such a manner as to avoid glare and reflections that seriously detract from the signal indications. Traffic control signal faces shall be given dominant position and brightness to ensure their priority in the overall display.**

**Guidance:**

Traffic signal signs should be located adjacent to the signal face to which they apply.