

CHAPTER 4D. DESIGN FEATURES OF TRAFFIC CONTROL SIGNALS

Section 4D.01 General

Support:

01 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 the safety and efficiency of operations.

02 Traffic control signals can be operated in pretimed, semi-actuated, or full-actuated modes. For isolated (non-interconnected) signalized locations on rural high-speed highways, full-actuated mode with advance vehicle detection on the high-speed approaches is typically used. These features are designed to reduce the frequency with which the onset of the yellow change interval is displayed when high-speed approaching vehicles are in the “dilemma zone” such that the drivers of these high-speed vehicles find it difficult to decide whether to stop or proceed.

Standard:

03 **The design and operation of traffic control signals shall take into consideration the needs of all modes of traffic including access and safety.**

04 **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.**

Guidance:

05 *If a cover is placed over a traffic control signal face that is not in operation and that has a yellow retroreflective strip along the perimeter of its signal backplate (see Paragraph 21 in Section 4D.06), the entire signal face, including the backplate, should be covered. If a traffic control signal face that is not in operation and that has a yellow retroreflective strip along the perimeter of its signal backplate is turned, the turned signal face should be oriented such that the yellow backplate border will not reflect light back to road users on any of the approaches to the intersection.*

Support:

06 Seasonal shutdown is a condition in which a permanent traffic control signal is turned off or otherwise made non-operational during a particular season when its operation is not justified. This might be applied in a community where tourist traffic during most of the year justifies the permanent signalization, but a seasonal shutdown of the signal during an annual period of lower tourist traffic would reduce delays; or where a major traffic generator, such as a large factory, justifies the permanent signalization, but the large factory is shut down for an annual factory vacation for a few weeks in the summer.

Standard:

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

Guidance:

08 *Midblock crosswalks should not be signalized if they are located within 300 feet from the nearest traffic control signal, unless supported by an engineering study or engineering judgment that indicates safe and efficient operation of the closely-spaced traffic control signals can be achieved.*

09 *Midblock crosswalks should not be signalized if they are located within 100 feet from side streets or driveways that are controlled by STOP signs or YIELD signs, unless supported by an engineering study or engineering judgment that considers restricting turning movements from the side street or driveway to eliminate conflicts with pedestrian and bicyclist movements.*

10 *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.*

11 *Traffic control signals within ½ mile of one another along a major route or in a network of intersecting major routes should be coordinated, preferably with interconnected controller units. Where traffic control signals that are within ½ mile of one another along a major route have a jurisdictional boundary or a boundary between different signal systems between them, coordination across the boundary should be considered.*

Support:

12 Signal coordination need not be maintained between control sections that operate on different cycle lengths.

13 Sections 4F.19, 4Q.03, and 8D.09 contain information about coordination of traffic control signals with grade

crossing signals and movable bridge signals.

Section 4D.02 Provisions for Pedestrians

Support:

01 Chapter 4I contains additional information regarding pedestrian control features, Chapter 4J contains additional information regarding pedestrian hybrid beacons, and Chapter 4K contains additional information regarding accessible pedestrian signals and detectors.

Standard:

02 **Pedestrian signal heads shall be used in conjunction with vehicular traffic control signals under any of the following conditions, unless the pedestrian crossing is prohibited:**

- A. **If the basis for traffic signal installation was justified by an engineering study and meeting either Warrant 4, Pedestrian Volume or Warrant 5, School Crossing (see Chapter 4C);**
- B. **If an exclusive pedestrian signal phase or a leading pedestrian interval (LPI) is provided with all conflicting vehicular movements being stopped;**
- C. **At an established signalized school crossing; or**
- D. **Where there are existing pedestrian accommodations and engineering judgment determines that multi-phase signal indications (such as split-phase timing) would tend to confuse or cause conflicts with pedestrians using a crosswalk guided only by vehicular signal indications.**

Guidance:

03 *Pedestrian signal heads should be installed for each marked crosswalk at a location controlled by a traffic control signal.*

04 *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.*

05 *Where certain pedestrian movements are prohibited at a traffic control signal location, a No Pedestrian Crossing (R9-3) sign (see Section 2B.57) should be used if it is impracticable to provide a barrier or other physical feature to physically discourage the pedestrian movements.*

Support:

06 Accessible pedestrian signals (see Chapter 4K) that provide information in non-visual formats (such as audible tones and/or speech messages, and vibrating surfaces) enhance safety and accessibility at signalized crossings for pedestrians with vision disabilities.

Option:

07 Pedestrian signal heads may be used under other conditions based on engineering judgment.

Section 4D.03 Provisions for Bicyclists

Standard:

01 **At installations where visibility-limited signal faces are used, signal faces shall be adjusted so bicyclists for whom the indications are intended can see the signal indications. If the visibility-limited signal faces cannot be aimed to serve the bicyclist, then separate signal faces (see Chapter 4H) shall be provided for the bicyclist.**

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

Option:

03 Where it is desired to provide separate signal indications to control bicyclist movements at a traffic control signal, bicycle signal faces may be used (see Chapter 4H).

Support:

04 Sections 9B.02, 9B.11, 9B.20, 9B.22, 9E.02, 9E.06, 9E.07, 9E.08, 9E.11, 9E.12, and 9E.15 contain additional provisions regarding bicyclist movements and actuation at traffic control signals.

05 **The Guide for the Development of Bicycle Facilities (2024), published by the American Association of State Highway and Transportation Officials (AASHTO), and the Urban Bikeway Design Guide (2025), published by the National Association of City Transportation Officials (NACTO), provide guidance on the recommended practices regarding additional provisions of traffic signals for the bicyclists.**

Section 4D.04 Provisions for Transit Vehicles

Option:

01 Where it is desired to provide separate signal indications to control transit vehicles at a traffic control signal, LRT signal indications may be used at intersections where special signal phases are used for transit vehicles (see Section 8D.15).

Section 4D.05 Number of Signal Faces on an Approach

Standard:

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

- If a signalized motor vehicle through movement exists on an approach, a minimum of two primary signal faces shall be provided for the through movement. ~~Except for single-lane approaches~~, if a signalized motor vehicle through movement does not exist on an approach, a minimum of two primary signal faces shall be provided for the signalized motor vehicle turning movement that is considered to be the major movement from the approach (also see Section 4F.16). **Single lane approaches shall have two signal faces per movement.**
- See Sections 4F.02 through 4F.08 for left-turn (and U-turn to the left) signal faces.
- See Sections 4F.09 through 4F.15 for right-turn (and U-turn to the right) signal faces.

Option:

02 Where a movement (or a certain lane or lanes) at the intersection never conflicts with any other signalized vehicular or pedestrian movement, a continuously-displayed single-section GREEN ARROW signal indication may be used to inform road users that the movement is free-flow and does not need to stop.

Support:

03 In some circumstances where the through movement never conflicts with any other signalized vehicular or pedestrian movement at the intersection, such as at T-intersections with appropriate geometrics and/or pavement markings and signing, an engineering study might determine that the through movement (or certain lanes of the through movement) can be free-flow and not signalized.

Guidance:

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

05 *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 or more primary right-turn signal faces should be provided.*

Support:

06 Locating primary signal faces overhead on the far side of the intersection has been shown to ~~provide safer~~ **improve** operation by reducing intersection entries late in the yellow interval and by reducing red signal violations, as compared to post-mounting signal faces at the roadside or locating signal faces overhead within the intersection on a diagonally-oriented mast arm or span wire. On approaches with two or more lanes for the through movement, one signal face per through lane, centered over each through lane, has also been shown to ~~provide safer operation~~ **be effective in reducing excessive red signal violations.**

Guidance:

07 *If the posted or statutory speed limit or the 85th-percentile speed on an approach to a signalized location is 45 mph or higher, signal faces should be provided as follows for all new or reconstructed signal installations **where there is a documented pattern of excessive red signal violations** (see Figure 4D-1):*

- The minimum number and location of primary (non-supplemental) signal faces for through traffic should be provided in accordance with Table 4D-1.*
- If the number of overhead primary signal faces for through traffic is equal to the number of through lanes on an approach, one overhead signal face should be located approximately over the center of each through lane.*
- Except for shared left-turn and right-turn signal faces, any primary signal face required by Sections 4F.02 through 4F.16 for a mandatory turn lane should be located overhead approximately over the center of each mandatory turn lane.*
- All primary signal faces should be located on the far side of the intersection.*

- E. In addition to the primary signal faces, one or more supplemental pole-mounted or overhead signal faces should be considered to provide added visibility for approaching traffic that is traveling behind large vehicles.
- F. All signal faces should have backplates.

08 This layout of signal faces should also be considered for any major urban or suburban arterial street with four or more lanes and for other approaches with speeds of less than 45 mph.

Section 4D.06 Visibility, Aiming, and Shielding of Signal Faces

Guidance:

01 The visibility of signal indications to approaching traffic should be the highest priority for signal face placement and aiming.

02 Road users approaching a signalized intersection or other signalized area, such as a midblock crosswalk, should be given a clear and unmistakable indication of whether they are being directed to stop or permitted to proceed.

03 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, should be considered in determining the vertical, longitudinal, and lateral position of the signal face.

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

05 The two primary signal faces required as a minimum for each approach should be continuously visible to traffic approaching the traffic control signal, from a point at least the minimum sight distance provided in Table 4D-2 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.

06 If approaching traffic does not have a continuous view of at least two signal faces for at least the minimum sight distance shown in Table 4D-2, a sign (see Section 2C.35) should be installed to warn approaching traffic of the traffic control signal.

Option:

07 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 4S.03).

08 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.

09 If the sight distance to the signal faces for an 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.

Guidance:

10 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.

11 If supplemental signal faces are used, they should be located to provide optimum visibility for the movement to be controlled.

12 In cases where irregular street design necessitates placing signal faces for different street approaches with a comparatively small angle between their respective signal indications, each signal indication should, to the extent practical, be visibility-limited by signal visors, signal louvers, or other means so that an approaching road user's view of the signal indication(s) controlling movements on other approaches is minimized.

Standard:

13 Signal visors exceeding 12 inches in length shall not be used on free-swinging signal faces.

Guidance:

14 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.

15 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.

Option:

16 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, especially if

simultaneous viewing of both signal indications could cause the road user to be misdirected.

Guidance:

17 *If the posted or statutory speed limit or the 85th-percentile speed on an approach to a signalized location is 45 mph or higher, signal backplates should be used on all of the signal faces that face the approach. Signal backplates should also be considered for use on signal faces on approaches with posted or statutory speed limits or 85th-percentile speeds of less than 45 mph where sun glare, bright sky, and/or complex or confusing backgrounds indicate a need for enhanced signal face target value.*

Support:

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

Standard:

19 **If backplates are used, ancillary legends of any kind that identify the purpose or operation of the signal face shall not be placed on the backplate.**

20 **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.**

Option:

21 A yellow retroreflective strip with a minimum width of 1 inch and a maximum width of 3 inches may be placed along the perimeter of the face of a signal backplate to project a rectangular appearance at night.

Section 4D.07 Lateral Positioning of Signal Faces

Standard:

01 **At least one and preferably both of the minimum of two primary signal faces required for the through movement (or the major turning movement if there is no through movement) on the approach shall be located between two lines intersecting with the center of the approach at a point 10 feet 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. The signal face that satisfies this requirement shall simultaneously satisfy the longitudinal placement requirement described in Section 4D.08 (see Figure 4D-2).**

02 **If both of the minimum of two primary signal faces required for the through movement (or the major turning movement if there is no through movement) on the approach 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).**

03 **The required signal faces for through traffic on an approach shall be located not less than 8 feet apart measured horizontally perpendicular to the approach between the centers of the signal faces.**

04 **If more than one separate turn signal face is provided for a turning movement and if one or both of the separate turn signal faces are located over the roadway, the signal faces shall be located not less than 8 feet apart measured horizontally perpendicular to the approach between the centers of the signal faces.**

Guidance:

05 *If horizontally-arranged or clustered signal faces are used, the minimum 8-foot horizontal separation between the two signal faces should be measured from the center of the right-most signal indication in the signal face on the left to the center of the left-most signal indication in the signal face on the right.*

06 *Except as provided in Paragraph 7 of this Section, for signal faces located over the roadway, separate turn signal faces should be located at least 8 feet from the nearest traffic signal face for a different movement on the same approach measured horizontally perpendicular to the approach between the centers of the signal faces.*

Option:

07 For modifications to existing traffic signals, the minimum horizontal separation between a separate turn signal face and the nearest traffic signal face for a different movement may be reduced to 3 feet.

Guidance:

08 *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.*

Support:

09 Section 4D.05 contains additional provisions regarding lateral positioning of signal faces for approaches having a

posted or statutory speed limit or an 85th-percentile speed of 45 mph or higher.

Guidance:

10 *If a mandatory left-turn, right-turn, or U-turn lane is present on an approach and if a primary separate turn signal face controlling that lane is mounted over the roadway, the primary separate turn signal face should not be positioned any farther to the right than the extension of the right-hand edge of the mandatory turn lane or any farther to the left than the extension of the left-hand edge of the mandatory turn lane.*

Support:

11 Supplemental turn signal faces mounted over the roadway are not subject to the positioning recommendations in Paragraph 10 of this Section.

Guidance:

12 *For new or reconstructed signal installations, on an approach with a mandatory turn lane(s) for a permissive left-turn (or U-turn to the left) movement, signal faces that display a CIRCULAR GREEN signal indication should not be post-mounted on the far-side median or mounted overhead above the mandatory turn lane(s) or the extension of the lane(s).*

Standard:

13 **If supplemental post-mounted signal faces are used, the following limitations shall apply:**

- A. **Left-turn arrows and U-turn arrows to the left shall not be used in near right signal faces that are located to the right of the through and/or right-turn lanes.**
- B. **Right-turn arrows and U-turn arrows to the right shall not be used in far left signal faces that are located to the left of the through and/or left-turn lanes. A far-side median-mounted signal face shall be considered a far left signal face for this application.**

Section 4D.08 Longitudinal Positioning of Signal Faces

Standard:

01 Except where the width of an intersecting roadway or other conditions make it physically impractical, the signal faces for each approach to an intersection or a midblock location shall be provided as follows:

- A. A signal face installed to satisfy the requirements for primary left-turn signal faces (see Sections 4F.02 through 4F.08) and primary right-turn signal faces (see Sections 4F.09 through 4F.15), and at least one and preferably both of the minimum of two primary signal faces required for the through movement (or the major turning movement if there is no through movement) on the approach shall be located:
 1. No less than 40 feet beyond the stop line, and
 2. No more than 180 feet beyond the stop line unless a supplemental near-side signal face is provided.
- B. The primary signal faces that are used to satisfy the requirements of Item A shall simultaneously satisfy the lateral placement requirement described in Section 4D.07 (see Figure 4D-2).

Guidance:

02 Where the nearest signal face is located between 150 and 180 feet beyond the stop line, engineering judgment of the conditions, including the worst-case visibility conditions, should be used to determine if the provision of a supplemental near-side signal face would be beneficial.

03 Supplemental near-side signal faces should be located as near as practicable to the stop line.

Support:

04 Section 4D.05 contains additional provisions regarding longitudinal positioning of signal faces for approaches having a posted or 85th-percentile speed of 45 mph or higher.

Section 4D.09 Mounting Height of Signal Faces

Standard:

01 **The bottom of the signal housing and any related attachments to a vehicular signal face located over any portion of a highway that can be used by motor vehicles shall be at least 15 feet above the pavement.**

Guidance:

01a *The bottom of the signal housing and any related attachments to a vehicular signal face located over a roadway should be at least 17 feet. Refer to Caltrans' Standard Plans publication. See Section 1A.05 for information regarding this publication.*

Standard:

02 **The bottom of the signal housing (including brackets) of a vehicular signal face that is vertically arranged or**

horizontally arranged and not located over a roadway:

- A. Shall be a minimum of 8 feet above the sidewalk or, if there is no sidewalk, above the pavement grade at the center of the roadway.
- B. Shall be a minimum of 4.5 feet above the median island grade of a center median island if located on the near side of the intersection.

Guidance:

03 The top of the signal housing of a vehicular signal face located over any portion of a highway that can be used by motor vehicles should not be more than 25.6 feet above the pavement.

04 For viewing distances between 40 and 53 feet from the stop line, the maximum mounting height to the top of the signal housing of a vehicular signal face located over any portion of a highway that can be used by motor vehicles should be as shown in Figure 4D-3.

05 The bottom of the signal housing (including brackets) of a vehicular signal face that is vertically arranged and not located over a roadway or shoulder (see Figures 4E-2, 4F-3, 4F-4, 4F-6, 4F-10, 4F-11, 4F-13, and 4F-15):

- A. Should be a maximum of 19 feet above the sidewalk or, if there is no sidewalk, above the pavement grade at the center of the roadway.
- B. Should be a maximum of 19 feet above the median island grade of a center median island if located on the near side of the intersection.

06 The bottom of the signal housing (including brackets) of a vehicular signal face that is horizontally arranged and not located over a roadway or shoulder (see Figures 4E-2, 4F-3, 4F-4, 4F-6, 4F-10, 4F-11, 4F-13, and 4F-15):

- A. Should be a maximum of 22 feet above the sidewalk or, if there is no sidewalk, above the pavement grade at the center of the roadway.
- B. Should be a maximum of 22 feet above the median island grade of a center median island if located on the near side of the intersection.

Section 4D.10 Lateral Offset (Clearance) of Signal Faces

Guidance:

01 Signal faces mounted at the side of a roadway at less than 15 feet from the bottom of the housing and any related attachments should have a horizontal offset of not less than 2 feet from the face of a vertical curb, or if there is no curb, not less than 2 feet from the edge of a shoulder.

Section 4D.11 Temporary and Portable Traffic Control Signals

Support:

01 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 4O), 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. Portable traffic signals are temporary traffic signals.

02 Because a portable traffic control signals is considered to be a type of temporary traffic control signal, the provisions for temporary traffic control signals are also applicable to portable traffic control signals.

02a Refer to Section 6P.01 and Typical Application 14 Haul Road Crossing (Figure 6P-14(CA) and related Notes) when using a temporary traffic control signal at haul road crossings.

Standard:

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

04 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; and
- C. Except as provided in Paragraph 5 of this Section, be placed in the flashing mode during periods when it is not desirable to operate the signal in the steady mode, or the signal heads shall be covered, turned, or taken down to indicate that the signal is not in operation.

Option:

05 If the temporary traffic control signal is capable of being operated in a semi-actuated mode, such that green signal indications are continually shown to major-street traffic except when responding to a minor-street approach vehicle call,

it may be operated in a semi-actuated mode instead of being placed in a flashing mode.

Guidance:

06 *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.*

07 *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.*

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

09 *Section 6L.01 contains information about the use of temporary traffic control signals in temporary traffic control zones.*

Support:

10 Refer to FHWA's List of Known Errors for error in labeling Paragraph 9. Refer to Section 1A.04 for more details.

Option:

11 One-way traffic control signals may utilize semi- or fully-traffic-actuated controller units, or may be manually controlled.

Section 4D.101(CA) Permissive Left-Turn Phasing

Guidance:

01 *When a protected-permissive or permissive-protected left-turn phasing operation is used for a signal system, no information sign is necessary.*

Standard:

02 **If a sign is used, it shall be a LEFT TURN YIELD ON GREEN (Green Ball symbol) (R10-12) sign.**

Option:

03 Public agencies having jurisdiction may use an Activated Blank-Out message sign on local roads in place of the R10-12 sign on their local roads that are not part of an intersection with a State highway.

Standard:

04 **The Activated Blank-Out sign shall say LEFT TURN YIELD in at least 6 inch high letters. The light source shall be designed and constructed so that when illuminated, the message shall be white and remain dark when not in use. The message shall be illuminated only when the green permissive ball is lighted.**

05 **The following apply to permissive left-turn phasing:**

1. This operation shall not be initiated where the left turn collision warrant is satisfied.
2. Both directions of through traffic shall be terminated simultaneously except where opposing left turns or opposing U-turns are prohibited.

Guidance:

3. Signal faces should not be placed in a median facing a left turn lane.

- The signal face is provided with some type of visibility control so that the indications are not visible to traffic in the left turn storage lane; or
- A LEFT TURN YIELD ON GREEN (symbolic circular green) (R10-12) sign is installed below the said signal face.

Support:

4. Signs are not required for this operation unless U-turns are to be prohibited.

Section 4D.102(CA) Review of Traffic Signal Operations

Guidance:

01 *All traffic signals should be periodically reviewed for proper operation. The traffic signal operation should be observed during morning and evening peak traffic periods and during off-peak periods. If an operating deficiency is observed, the reason for the deficiency should be determined. If there is a malfunction, Maintenance unit should be notified, and after corrective work is done, further surveillance should be conducted to be sure no deficiency remains. If a need for a design change is observed, an analysis should be made to determine what improvement might be necessary to improve the design.*

02 *Improvements to consider are:*

1. *Timing of:*
 - a. Maximums or Force Offs
 - b. Gap Interval
 - c. Offsets

- d. Cycle Length*
- 2. *Time-of-Day or Traffic Responsive Settings*
- 3. *Signal Phasing or Phase Sequence*
- 4. *Type of Operation*
- 5. *Coordination of Signals*
- 6. *Signs, Striping and/or Pavement Markings*
- 7. *Roadway Improvements*

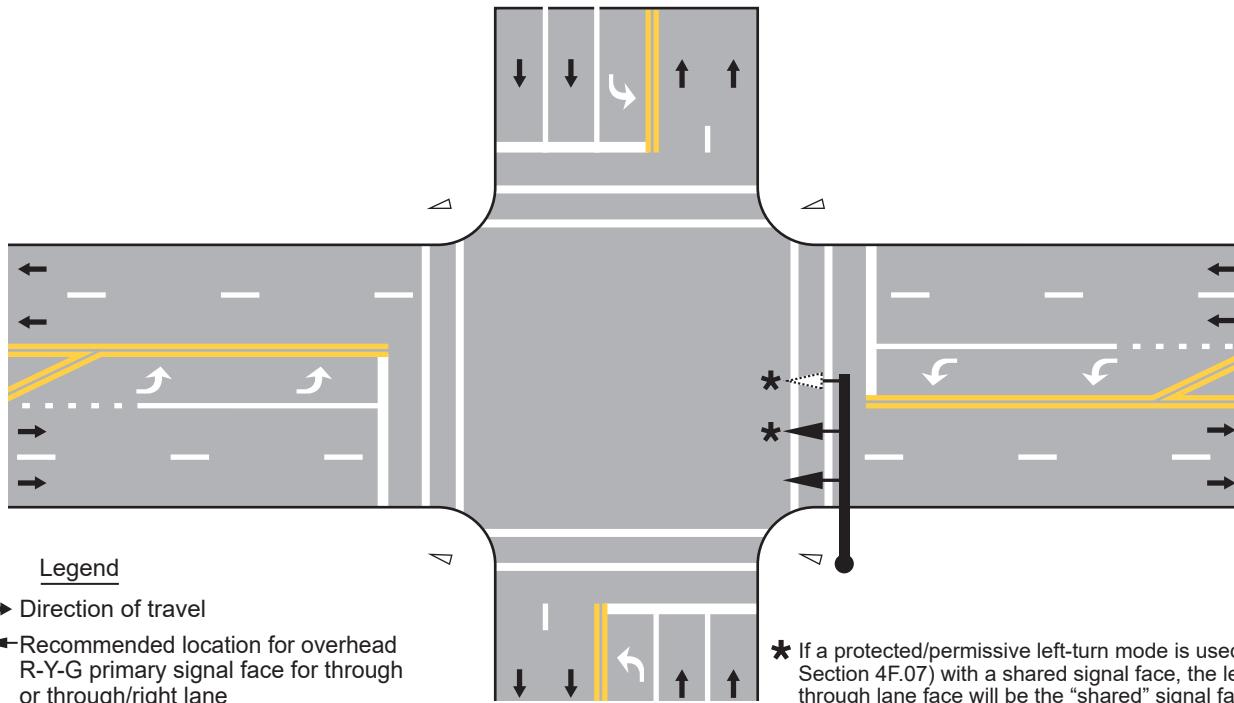
Standard:

03 **Timing and phasing of traffic signals and any subsequent changes in timing shall be approved by the public agency having jurisdiction. Timing records shall be kept by the agency responsible for the maintenance and/or operation and be readily available to the maintenance and traffic operations staffs and other agencies, where appropriate.**

Support:

04 Aids for timing are shown in Tables 4D-102(CA) and 4D-103(CA).

Figure 4D-1. Recommended Vehicular Signal Faces for Approaches with Posted, Statutory, or 85th-Percentile Speed of 45 mph or Higher
(Where there are Excessive Red Signal Violations)



Notes:

1. Signal faces for only one direction and only one possible set of geometrics (number of lanes, etc.) are illustrated. If there are fewer or more than two through lanes on the approach, see Table 4D-1.
2. Any primary left-turn and/or right-turn signal faces, as determined by Sections 4F.02 through 4F.15, should be overhead for each mandatory turn lane.
3. One or more pole-mounted or overhead supplemental faces should be considered, based on the geometrics of the approach, to maximize visibility for approaching traffic.
4. All signal faces should have backplates.

Figure 4D-2. Lateral and Longitudinal Location of Primary Signal Faces

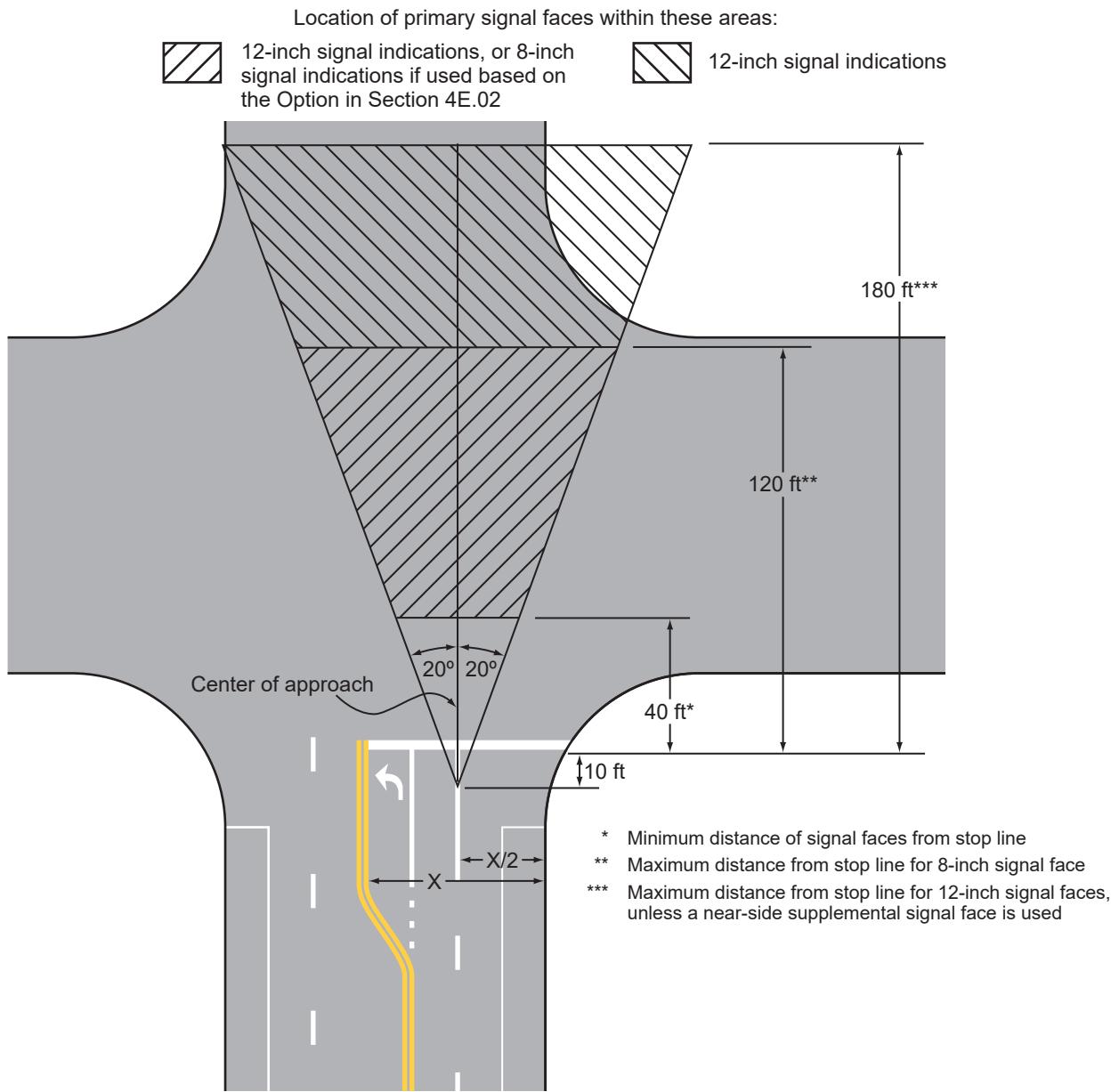


Figure 4D-3. Maximum Mounting Height of Signal Faces that Are Located between 40 Feet and 53 Feet from the Stop Line

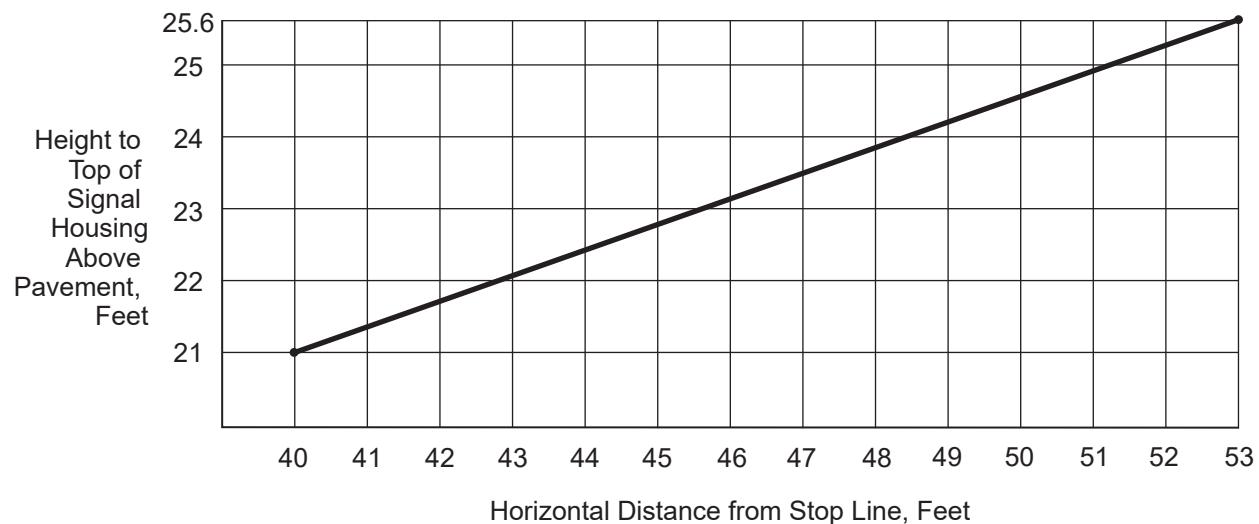


Table 4D-1. Recommended Minimum Number of Primary Signal Faces for Through Traffic on Approaches with Posted, Statutory, or 85th-Percentile Speed of 45 mph or Higher

Number of Through Lanes on the Approach	Total Number of Primary Through Signal Faces for the Approach*	Minimum Number of Overhead-Mounted Primary Through Signal Faces for the Approach
1	2	1
2	2	1
3	3	2**
4 or more	4 or more	3**

Notes:

* A minimum of two through signal faces is always required (see Section 4D.05). These recommended numbers of through signal faces may be exceeded. Also, see cone of vision requirements otherwise indicated in Section 4D.07.

** If practical, all of the recommended number of primary through signal faces should be located overhead.

Table 4D-2. Minimum Sight Distance for Signal Visibility

85th-Percentile Speed	Minimum Sight Distance
20 mph	175 feet
25 mph	215 feet
30 mph	270 feet
35 mph	325 feet
40 mph	390 feet
45 mph	460 feet
50 mph	540 feet
55 mph	625 feet
60 mph	715 feet

Note: Distance in this table are derived from stopping sight distance plus an assumed queue length for shorter cycle lengths (60 to 75 seconds).

Table 4D-101 (CA). Minimum Yellow Change Interval Timing

Yellow Time = $\frac{\text{Detector Setback Distance}}{\text{Speed}}$
$T = \frac{D}{V} = \text{The minimum yellow change interval (sec)}$
$V = \text{Speed (ft/sec)}$
$d = \text{Deceleration Rate (10 ft/sec}^2\text{)}$
$t_R = \text{Reaction Time (1 sec)}$
$\text{Reaction Distance} = Vt_R$
$\text{Deceleration Distance} = \frac{1}{2}dt^2 \text{ or } \frac{1}{2}Vt \text{ or } \frac{V^2}{2d}$
$D = \text{Detector Setback} = \text{Deceleration Distance} + \text{Reaction Distance} = \frac{V}{2d} + Vt_R$
$T = \frac{\frac{V^2}{2d} + Vt_R}{V}$
$T = \frac{V}{2d} + t_R$

a – For Speed determined by 85th Percentile

SPEED (Determined by 85 th Percentile Speed)*	MINIMUM YELLOW INTERVAL
mph	Seconds
25 or less	3.0
30	3.2
35	3.6
40	3.9
45	4.3
50	4.7
55	5.0
60	5.4
65	5.8

*See Section 4F.17 Standard under paragraph 13c

b – For Posted or Prima Facie Speed

POSTED SPEED OR UNPOSTED PRIMA FACIE SPEED	MINIMUM YELLOW INTERVAL*
mph	Seconds
15	3.0
20	3.2
25	3.6
30	3.7
35	4.1
40	4.4
45	4.8
50	5.2
55	5.5
60 or higher	5.9

*Speed values for Table 4D-101.b(CA) are inclusive of the 7 mph added for speeds equal to 30 mph or higher and 10 mph for speeds equal to or lower than 25 mph for determining the minimum values of the yellow intervals.

Table 4D-102 (CA). Traffic Signal Timing Analysis Chart

Number of Cars	Min. Time in Seconds Req. for Cars	Length of Stopped Queue	Length of Moving Queue	Moving Queue Time (Bond Width in Seconds)	NUMBER OF VEHICLES PER HOUR LANE AT INDICATED CYCLE LENGTH									
					50 Sec.	60 Sec.	70 Sec.	80 Sec.	90 Sec.	100 Sec.	120 Sec.	150 Sec.	180 Sec.	240 Sec.
1	4	25	0	2	70	60	50	45	40	35	30	25	20	15
2	7	50	88	4	145	120	100	90	80	70	60	50	40	30
3	9	75	176	6	215	180	150	135	120	110	90	70	60	45
4	11	100	264	8	290	240	205	180	160	145	120	95	80	60
5	13	125	352	10	360	360	255	225	200	180	150	120	100	175
6	15	150	440	12	430	420	310	270	240	215	180	145	120	90
7	17	175	528	14	505	480	360	315	280	250	210	170	140	105
8	19	200	616	16	575	540	410	360	320	290	240	190	160	120
9	21	225	704	18	650	600	460	405	360	320	270	215	180	135
10	23	250	792	20	720	660	510	450	400	360	300	240	200	150
11	25	275	880	22	790	720	560	495	440	400	330	265	220	165
12	27	300	968	24	865	780	610	540	480	430	360	290	240	180
13	29	325	1056	26	935	840	665	585	520	470	390	315	260	195
14	31	350	1144	28	1020	900	715	630	560	500	420	340	280	210
15	33	375	1232	30	1080	960	765	675	600	540	450	365	300	225
16	35	400	1320	32	1150	1020	815	720	640	580	480	385	320	240
17	37	425	1408	34	1225	1080	865	765	680	610	510	410	340	255
18	39	450	1496	36	1295	1140	920	810	720	650	540	430	360	270
19	41	475	1584	38		1200	970	855	760	680	570	455	380	285
20	43	500	1672	40		1260	1020	900	800	720	600	480	400	300
21	45	525	1760	42		1320	1070	945	840	760	630	505	420	315
22	47	550	1848	44		1380	1120	990	880	790	660	530	440	330
23	49	575	1936	46		1140	1175	1035	920	830	690	550	460	345
24	51	600	2024	48			1225	1080	960	860	720	575	480	360
25	53	625	2112	50			1275	1125	1000	900	750	600	500	375
26	55	650	2200	52			1325	1170	1040	930	780	625	520	390
27	57	675	2288	54			1375	1215	1080	960	810	650	540	405
28	59	700	2376	56			1430	1260	1120	990	840	670	560	420
29	61	725	2464	58				1305	1160	1020	870	700	580	435

Table 4D-103 (CA). Signal Operations - Vehicular Speed

SECONDS		10	15	20	25	30	35	40	45	50	55	60
mph	Ft/s	DISTANCE TRAVELED IN FEET										
1	1.46	14.6	21.9	29.3	36.6	44.0	51.3	58.6	66.0	73.3	80.6	88.0
2	2.93	29.3	44.0	58.6	73.3	88.0	102.6	117.3	132.0	146.6	161.3	176.0
3	4.40	44.0	66.0	88.0	110.0	132.0	154.0	176.0	198.0	220.0	242.0	264.0
4	5.86	58.6	88.0	117.3	146.6	176.0	205.3	234.6	264.0	293.3	322.6	352.0
5	7.30	73.0	110.0	147.0	183.0	220.0	257.0	293.0	330.0	367.0	403.0	440.0
10	14.60	146.0	220.0	293.0	366.0	440.0	513.0	587.0	660.0	733.0	807.0	880.0
15	22.00	220.0	330.0	440.0	550.0	660.0	770.0	880.0	990.0	1,100.0	1,210.0	1,320.0
20	29.30	293.0	440.0	587.0	733.0	880.0	1,027.0	1,173.0	1,320.0	1,467.0	1,613.0	1,760.0
25	36.70	367.0	550.0	733.0	917.0	1,100.0	1,283.0	1,467.0	1,650.0	1,833.0	2,017.0	2,200.0
30	44.00	440.0	660.0	880.0	1,100.0	1,320.0	1,540.0	1,760.0	1,980.0	2,200.0	2,420.0	2,640.0
35	51.30	513.0	770.0	1,027.0	1,283.0	1,540.0	1,797.0	2,053.0	2,310.0	2,567.0	2,823.0	3,080.0
40	58.70	587.0	880.0	1,173.0	1,467.0	1,760.0	2,053.0	2,347.0	2,640.0	2,933.0	3,227.0	3,520.0
45	66.00	660.0	990.0	1,320.0	1,650.0	1,980.0	2,310.0	2,640.0	2,970.0	3,300.0	3,630.0	3,960.0
50	73.30	733.0	1,100.0	1,467.0	1,833.0	2,200.0	2,567.0	2,933.0	3,300.0	3,667.0	4,033.0	4,400.0
55	80.70	807.0	1,210.0	1,613.0	2,017.0	2,420.0	2,823.0	3,227.0	3,630.0	4,033.0	4,437.0	4,840.0
60	88.00	880.0	1,320.0	1,760.0	2,200.0	2,640.0	3,080.0	3,520.0	3,960.0	4,400.0	4,840.0	5,280.0
65	95.30	953.0	1,430.0	1,907.0	2,383.0	2,860.0	3,337.0	3,813.0	4,290.0	4,767.0	5,243.0	5,720.0
70	102.70	1,027.0	1,540.0	2,053.0	2,567.0	3,080.0	3,593.0	4,107.0	4,620.0	5,133.0	5,647.0	6,160.0
75	110.00	1,100.0	1,650.0	2,200.0	2,750.0	3,300.0	3,850.0	4,400.0	4,950.0	5,500.0	6,050.0	6,600.0
80	117.30	1,173.0	1,760.0	2,347.0	2,933.0	3,520.0	4,107.0	4,693.0	5,280.0	5,867.0	6,453.0	7,040.0
85	124.70	1,247.0	1,870.0	2,493.0	3,117.0	3,740.0	4,363.0	4,987.0	5,610.0	6,233.0	6,858.0	7,480.0
90	132.00	1,320.0	1,980.0	2,640.0	3,300.0	3,960.0	4,620.0	5,280.0	5,940.0	6,600.0	7,260.0	7,920.0
95	139.30	1,393.0	2,090.0	2,787.0	3,483.0	4,180.0	4,877.0	5,573.0	6,270.0	6,967.0	7,663.0	8,360.0
100	146.70	1,467.0	2,200.0	2,933.0	3,667.0	4,400.0	5,133.0	5,867.0	6,600.0	7,333.0	8,067.0	8,800.0
105	154.00	1,540.0	2,310.0	3,080.0	3,850.0	4,620.0	5,390.0	6,160.0	6,930.0	7,700.0	8,470.0	9,240.0
110	161.30	1,613.0	2,420.0	3,227.0	4,033.0	4,840.0	5,647.0	6,453.0	7,260.0	8,067.0	8,873.0	9,680.0
115	168.60	1,686.0	2,530.0	3,373.0	4,217.0	5,060.0	5,903.0	6,747.0	7,590.0	8,434.0	9,277.0	10,120.0
120	176.00	1,760.0	2,640.0	3,520.0	4,400.0	5,280.0	6,160.0	7,040.0	7,920.0	8,800.0	9,680.0	10,560.0