Traffic Signals Manual

Texas Department of Transportation

Revised June 2020

Manual Notice 2020-1

From: Michael A. Chacon, P.E., Traffic Safety Division

Manual: *Traffic Signals Manual*

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Purpose

The purpose of this manual notice is to advise users of the *Traffic Signals Manual* that the manual has been revised to include new and updated information on the installation and operation of traffic signals on the state highway system.

Contents

The contents of the *Traffic Signals Manual* have changed as follows:

Removed Chapter 4, Section 5 pertaining to Red Light Cameras on State ROW. Effective June 2, 2019, per HB 1631, 86th Texas Legislature, local authorities are no longer permitted to install or operate photographic traffic signal enforcement systems, or red light cameras, on streets under their jurisdiction, including state right-of-way. This legislation rendered the information on installation and design of these systems obsolete.

Review

The TxDOT General Counsel Division (GCD) and Compliance Division (CMP) reviewed the draft, and approved the revision made to this manual.

Contact

Address questions concerning content of the revised manual to David Valdez, P.E., of the Traffic Engineering Section of the Traffic Safety Division at 512-416-2642, or by email at David.Valdez@txdot.gov.

Archives

Past manual notices are available in a PDF archive.

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Chapter 1 — Introduction

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Section 1 — Overview

Scope of this Manual

This manual is a guide and reference for the handling of requests for traffic signals on the designated State Highway System, including installations financed by federal funds and installed off the numbered State Highway System.

This manual describes the steps necessary for the installation of traffic signals from project inception through construction and final disposition of records.

Traffic Signal Policy

The State Highway and Public Transportation Commission (now known as the Texas Transportation Commission) approved TxDOT's current policy on highway traffic signals under Commission Minute Order No. 85777 dated May 27, 1987. The current policy, as published in the *Texas Administrative Code* at 43 TAC, § 25.5, states that TxDOT:

- may install, maintain, and operate traffic signals on the state highway system in unincorporated areas when requested by anyone and provided that the location or locations meet one or more of the warrants for highway traffic signals contained in the current *Texas Manual on Uniform Traffic Control Devices* (*TMUTCD*).
- may install, maintain, and operate traffic signals on the state highway system in incorporated cities of less than 50,000 population (latest federal census) when requested by the city council, mayor, or city manager, and on frontage roads and at interchanges of freeways of the State Highway System within incorporated cities and provided that the location or locations meet one or more of the warrants for highway traffic signals contained in the current *TMUTCD* and that the city enters into an agreement setting forth the responsibilities of each party.
- is responsible for authorizing traffic signals to be installed at locations on the State Highway System other than freeways in incorporated cities of 50,000 or more population (latest federal census) provided that the location or locations meet one or more of the warrants for highway traffic signals contained in the current *TMUTCD*. (NOTE: The cost of installation, operation, and maintenance of these signals is the responsibility of the city, except that TxDOT may provide for the installation of traffic signals when the installation is financed in part with federal-aid funds and the city enters into an agreement setting forth the responsibilities of each party. (See the *Negotiated Contracts Procedures Manual* for details.)
- may install, maintain, and operate traffic signals on state highway frontage roads in all areas, provided the locations meet at least one of the *TMUTCD* warrants. (NOTE: The maintenance and operation of these signals may be contracted out to cities.)

The Texas Manual on Uniform Traffic Control Devices (TMUTCD)

Section 544.001 of the Texas Transportation Code requires TxDOT to adopt a manual and specifications for a uniform system of traffic control devices for use on streets, roads, and highways within the state. The uniform system must correlate with and, so far as possible, conform to the system then current as approved by the Federal Highway Administration (FHWA) and set forth in the *National Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD)*. The *Texas Manual on Uniform Traffic Control Devices (TMUTCD)* basically follows the national *MUTCD*, except where the national standards conflict with state law or where modifications are necessary to more closely fit Texas conditions. The Texas Transportation Commission originally adopted the 2011 TMUTCD with Minute Order No. 112903 on November 17, 2011. The Commission adopted the current version, *2011 TMUTCD, Version 2*, with Minute Order No. 113938 on May 12, 2014, as referenced in 43 TAC, § 25.1. References to the TMUTCD throughout this manual refer to the 2011 TMUTCD, Revision 2.

Using the TMUTCD

The *TMUTCD* is referenced throughout this manual. The *TMUTCD* contains the standards and basic principles governing the design and usage of traffic control devices in Texas. The provisions of the *TMUTCD* apply to all streets and highways in the state, including those under the jurisdiction of cities and counties. It should be the governing document on any question regarding the application of traffic control devices.

Part 4 of the *TMUTCD* provides detailed information and guidelines on traffic signal applications, including minimum warrants required for traffic signal installation. Readers are urged to consult the for information and topics not covered in this manual, which only provides additional information specific to TxDOT operations.

The TMUTCD can be found on TxDOT's Traffic Safety Division web page, or linked in the previous section.

Traffic Signal Agreements

Agreements of various kinds are often required for traffic signal installations. For information on when traffic signal agreements are required and how they are handled, see the *Negotiated Contracts Procedures Manual*.

Traffic Signal Project Process Overview

Before proceeding to construction, a traffic signal project on the state highway system progresses through the following stages:

1. Someone, either inside or outside TxDOT, requests the signal installation.
2. The district acknowledges the request.
3. The district or city conducts a traffic study to determine if the signal is warranted and justified.
4. The district or city designs the installation.

Section 2 — Traffic Safety Division Support

TRF Support Functions

The Traffic Safety Division (TRF) supports district signal design and operation activities. Support is available in the following areas:

- plan, specification, and estimate (PS&E) review
- operational matters, such as traffic signal phasing and timing
- technical issues (such as controllers and detectors), including:
  - writing and maintaining equipment specifications
  - performing equipment inspection and testing for department purchased and district contract jobs
  - consulting with districts regarding traffic signal design applications
- field support, including system installation and troubleshooting.

Signal System Analysis

TRF can provide system analysis for:

- arterial signal timing
- diamond interchange controllers
- arterial and network timing optimization
- arterial and network analysis
- capacity analysis.

Specification Writing and Maintenance

TRF writes and maintains technical specifications for traffic signal equipment for use on contract jobs and for equipment purchased through the Support Services Division (SSD) Regional Supply Center. TRF also assists districts in developing technical specifications for one-time or district-wide use for items not covered by the standard specifications.

Specifications for which TRF is responsible include:

- traffic signal controllers, Malfunction Management Units (MMU) and cabinets
- signal hardware, such as Backup Battery Units (BBU)/Uninterruptable Power Supply (UPS) units

- closed loop systems, and
- vehicle detectors.

NOTE: For all items that have statewide specifications available, these standard specifications should be used.

Section 3 — Equipment Acquisition

Acquisition Methods

Districts can acquire traffic signal equipment by any of the following methods:

- through the Support Services Division (SSD) Regional Supply Center
- through small purchases
- through blanket orders
- through construction contracts.

Explanations of each of these methods follow.

Acquisition through SSD Regional Supply Center

Equipment obtained through the SSD Regional Supply Center provides uniformity and quick purchase time. This is the most economical way to purchase equipment because warehouse stock is purchased in larger quantities. Districts may order equipment from the Regional Distribution Centers by submitting an "Inter-Unit Transfer" request through the PeopleSoft Inventory module, or by submitting an "EPRO REQ" through the "Purchasing" module in PeopleSoft. The NIGP # will be required for each item requested.

Acquisition through Small Purchase

Equipment not stocked in the general warehouse can be obtained through either a small purchase or a blanket order. The small purchase is most useful and practical for infrequently purchased items (items purchased once or twice a year). Three bids are required for small purchases over $5,000, unless a sole source purchase justification is submitted to the Procurement Division (PRO). Purchases of equipment over $25,000 are handled as an Open Market purchase by the Comptroller of Public Accounts (CPA).

Acquisition through Blanket Order

Blanket orders can be established for more commonly purchased items (equipment purchased on a small purchase basis several times a year). This type of purchase procedure also promotes equipment uniformity. Blanket purchases are made through PRO, and delivery is made directly to the district requesting the equipment. Pre-established Blanket Purchase Orders generally allow for a shorter delivery time.

Acquisition through Construction Contract

Traffic signal equipment may be acquired through construction contracts by any of the following three means:

- The contractor may supply the traffic signal equipment.
- The state may furnish the traffic signal equipment. With this method, the state purchases the traffic signal equipment through the general warehouse, small purchase, or blanket order and provides the equipment to the contractor for installation. This method will also require that a Public Interest Statement (PIS) be submitted to TRF for approval. The PIS must include justification as to why it is in the public's best interest that TxDOT provide the signal equipment.
- When a traffic signal is being installed in a city, the city may supply the traffic signal equipment to the contractor for installation. If the city wishes to be compensated for providing the equipment, a PIS must be submitted to TRF for approval.

Coordinating First Time Purchases with TRF

Whenever new traffic signal equipment is purchased for the first time, the purchase should be coordinated with the TRF Traffic Management Section (TRF-TM) to ensure that all TxDOT districts and divisions become aware of the experiences with and testing done on the product. This coordination helps maintain uniformity across the state and reduces duplication of effort between districts and divisions.

Equipment Testing

Equipment must undergo environmental testing by TRF-TM as specified. Equipment that is not on a prequalified list must also go through functional testing at either the district or by TRF-TM. This testing is in addition to the environmental testing.

If the equipment is supplied by the state through the PRO purchasing system, it has already been through both the functional and environmental tests. Such equipment is also purchased in larger quantities and can provide significant cost savings.

Product Prequalification

The equipment testing performed by TRF-TM includes the evaluation of new products and testing products for prequalification. Prequalification reduces the time required to test pre-shipment samples and the duplication of effort between the districts and division.

Equipment for Contract Jobs

Equipment on contracted projects can be supplied by the contractor, state, or city.

If the equipment is supplied by the contractor, it must be thoroughly checked to verify that it meets all pertinent specifications. Prequalification of traffic signal equipment does not eliminate the need for testing. Testing is the only assurance that the equipment will function as specified when it is installed at the intersection.

Chapter 2 — Requests for Traffic Signals

Contents:

Section 1 — Sources of Requests

Introduction

Requests for traffic signal installations may originate from either of the following sources:

- routine operations within the district
- special requests from outside the district or the department.

From Within the District. TxDOT personnel should be sufficiently aware of conditions on all highways in their respective districts in order to initiate requests through the district traffic engineer for studies at locations where the need for an installation appears evident.

From Outside the District. A request for a traffic signal installation may be initiated by any of the following parties outside of the district:

- a private citizen
- a private organization
- a public organization
- a city
- a county
- a division or section of TxDOT
- another state agency.

Requests from Unincorporated Areas

Individuals. In unincorporated areas, requests from individuals and public or private organizations should be by letter or email, preferably with a description of the perceived problem.

Counties. Requests from a county should be by official letter from the county judge, or by resolution of the county commissioner’s court.

Requests from Incorporated Areas

At locations in incorporated areas, requests should be made through the proper city authority, such as the city council, mayor, or city manager. The request should be forwarded in the form of a letter to the TxDOT district. The letter should be accompanied by:

- a description of the perceived problem
- a condition diagram, crash collision diagram, or other applicable reports

- traffic volume data obtained from the city's traffic engineering department.

Requests from Private Organizations

Occasionally, traffic signals are installed at intersections of private driveways with state routes. A private driveway intersecting a state route requires a driveway permit. The issuance of a driveway permit should be contingent on TxDOT's approval of an impact study of the area to be developed. This impact study should include a traffic signal study. If TxDOT determines that the proposed development will create enough traffic to cause undue traffic delays and hazards, then the district notifies the private organization that a traffic signal must be installed before the driveway is opened to the public.

If a traffic signal is authorized at a private driveway, the private driveway should have sufficient channelization, acceleration and deceleration lanes, or pavement markings at the intersection.

Funding. TxDOT does not fund the installation of traffic signals for private driveways intersecting state routes. The private organization must fund the installation of the traffic signal through a third party agreement.

Section 2 — Action on Requests

Districts Act on Requests

When a request for a traffic signal installation is received by TxDOT, it must be acted upon by the appropriate district. If the request is received by any office other than the district office responsible for the location, it should be forwarded to the appropriate district for handling.

Acknowledgment of Request

Should a district office or the Traffic Safety Division (TRF) receive the request initially, the requesting party or agency should be informed, by letter, that the request has been received and is being studied.

Process Overview

After acknowledging receipt of a signal request, the district does the following:

1. The district conducts a traffic engineering study (if the city has not already provided this information) to determine if the location meets one of the signal justification warrants in the *Texas Manual on Uniform Traffic Control Devices (TMUTCD)*. (See Chapter 3 of this manual for a description of the traffic study.)
2. If the traffic study shows that the location meets at least one of the warrants for traffic signal installation (as described in the *TMUTCD*), the district then decides, based on engineering judgment, if the installation of a traffic signal would be in the best interest of the public. If the location does not meet at least one warrant, the request is denied.
3. If the traffic signal installation is deemed appropriate, the district traffic section then forwards its recommendation and a Traffic Signal Authorization Request form (described in Chapter 5 of this manual) to the district engineer for final approval and signature.
4. If the signal installation is approved, the district then determines who is responsible for the installation of the signal (based on the "Traffic Signal Policy" outlined in Chapter 1, Section 1, of this manual). If funding, installation, maintenance, or operation of the proposed signal will involve an entity other than TxDOT, the district must determine if a written agreement is required. Traffic signal agreements are covered in the *Negotiated Contracts Procedures Manual*.

Chapter 3 — Traffic Studies

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Section 1 — Overview

Introduction

A traffic study consists of a comprehensive investigation of existing physical and operating conditions. Analysis of the study data provides insight into possible remedial measures, if any. Remedial measures may include various traffic control measures, such as speed zoning, channelization, signing, traffic signals, safety lighting, or a combination of these. This chapter pertains only to traffic studies which may result in the installation of traffic signals.

Responsibility

TxDOT is responsible for conducting traffic studies on numbered state routes, locations within incorporated cities with populations less than 50,000, and on interstate frontage roads. Incorporated cities with populations greater than 50,000 should conduct their own traffic studies.

Districts should conduct traffic studies (as described throughout this chapter) and submit them to the district engineer for review and approval.

Costs

Normally the costs for conducting traffic studies are absorbed into the operations of the districts. However, traffic study costs for federal-aid projects are reimbursable by the Federal Highway Administration (FHWA) if a control section job number has been assigned by the Transportation Planning and Programming Division (TPP).

Required Information

A complete traffic study for a proposed traffic signal or flashing beacon installation requires the collection of sufficient data on the physical, traffic, and operational characteristics of the intersection. Examples of the types of data typically collected are:

- condition diagram (covered in Chapter 3, Section 2)
- location map (covered in Chapter 3, Section 3)
- photographs (covered in Chapter 3, Section 3)
- crash data (covered in Chapter 3, Section 4)
- vehicular and pedestrian traffic counts (covered in Chapter 3, Section 5)
- approach speeds (covered in Chapter 3, Section 6)
- Traffic Survey Count Analysis Form (covered in Chapter 3, Section 7)

- intersection delay study (covered in Chapter 3, Section 8).

When the traffic signal study is complete, the information is tabulated and checked against the traffic signal warrants set forth in the *Texas Manual on Uniform Traffic Control Devices (TMUTCD)*. The district traffic section supervisor then makes a recommendation to the district engineer using the Traffic Signal Authorization Request form (as described in Chapter 5 of this manual).

Warrant Analysis Data

It is common to first analyze warrants requiring data that is easier to collect. If a signal does not meet any of these warrants, then the more difficult data is collected and the other warrants are analyzed. The following table shows the suggested phased data collection and associated warrants.

Suggested Phased Data Collection and Associated Warrants

Phase	Warrants
Phase 1 — Volume Warrants	◆ Warrant 1: Eight Hour Vehicular Volume ◆ Warrant 2: Four Hour ◆ Warrant 3: Peak Hour
Phase 2 — Crash Warrant	◆ Warrant 7: Crash Experience
Phase 3 — Signal Operation Warrants	◆ Warrant 6: Coordinated Signal System ◆ Warrant 8: Roadway Network
Phase 4 — Railroad Warrants	◆ Warrant 9: Intersection Near a Grade Crossing
Phase 5 — Pedestrian Warrants	◆ Warrant 4: Pedestrian Volume ◆ Warrant 5: School Crossing.

In addition to meeting the minimum criteria for one or more of these warrants, an engineering study must also indicate that installing a traffic signal would improve the safety and/or operation of the intersection without disrupting the progressive flow of traffic. Simply meeting a warrant does not necessitate the installation of a traffic signal.

Recommending Against Installation

When the district's traffic study indicates that a traffic signal is not needed, the district should notify the requesting party, by letter, that a traffic signal installation is not recommended. In unusual cases, the district may wish to submit their traffic study to TRF for review and comment prior to notifying the requesting party of the study results.

Section 2 — Condition Diagram

Introduction

A study should be made of existing conditions at the study location and along each approach to it. Where the location is open to traffic, the study should include existing traffic control devices (signs, signals, markings, speed zones, etc.).

Information Sources

The condition diagram should provide a complete presentation of the physical layout of the study location as it currently exists.

Plan Sheets from Prior Projects. Final construction plan sheets from prior projects may be used as a basis for the condition diagram.

Additional Necessary Information

The following items should be included in the condition diagram:

- north cardinal direction
- highway and intersection design features, including:
  - pavement edges, curbs, and shoulders (unpaved or paved)
  - widths of approaches
  - approach grades
  - channelization
  - parking conditions and restrictions
  - bus stops
  - safety lighting or continuous lighting
  - posted speed limit for all approaches
  - any other roadway features which may affect traffic operations
- roadside development, including:
  - sight distance restrictions (trees, bushes, advertising and other signs, poles, fences, bridge, and guard rails)
  - off street parking
  - driveway locations
  - utility and other poles

  - adjacent land use
  - any other pertinent features
- traffic control devices, such as:
  - signs
  - traffic signals (type, face locations, etc.)
  - distance to adjacent traffic signals within one mile (indicate if none)
  - pavement markings
  - any other traffic control devices
  - railroad crossing and type of control
  - distance to railroad from traffic signal.

Section 3 — Location Map and Photographs

Location Map

A city or area location map should be prepared to show the relationship of the proposed installation to other traffic signals, highways, business areas, and traffic generators.

Photographs

Photographs should be made of all approaches to an intersection, ramp, or any other location being studied for a traffic signal. Generally, only one photograph is necessary for each approach if the photograph is taken from a position approximating that of a passenger car driver approaching the intersection. This would normally be from 150 to 300 feet from the study location. More than one photograph may be required for a particular approach to fully illustrate problems at the location. Peripheral features may also be helpful in defining any operational problems.

The location and approach view direction of each photograph should be indicated on the photograph itself.

Section 4 — Crash Data

Introduction

Crash data is obtained through the Crash Records Information System (CRIS). Each district has personnel with access rights to CRIS. TxDOT employees should contact their district's CRIS personnel to obtain this data.

NOTE: Requests for CRIS Information from non-TxDOT personnel are subject to statutory requirements and should be handled by the Crash Data and Analysis Section of the Traffic Safety Division (TRF).

Section 5 — Vehicle and Pedestrian Traffic Counts

Introduction

Up-to-date traffic and pedestrian volume counts reflect the characteristics of traffic. These volume counts, when compared to the established warrants, help determine the appropriate type of traffic control device, if any.

Types of Counts

A volume count analysis may use the following types of counts:

- vehicle counts at existing locations
- estimated counts at locations under construction and projected counts for future locations
- pedestrian counts
- school pedestrian counts.

Discussions of each of these types of counts follow.

Volume counts should be shown on the Traffic Survey Count Analysis Sheet (discussed in Section 7 of this chapter) for review in the office following the field work.

Vehicle Counts at Existing Locations

A vehicle count at an existing location should include the number of vehicles entering the location on each approach. Counts are recorded as vehicles cross the stop bar and enter the intersection. Tallies should be recorded for each quarter hour for the duration of the count. Ideally, counts are conducted on a “representative day” (defined later). The duration of the count should be 16 consecutive hours. This time span should contain the greatest percentage of traffic during the 24-hour time period. Traffic patterns, such as when the highest vehicle and pedestrian volumes occur, should help determine the beginning and ending times for the count. These patterns may vary from one location to the next.

Representative Day. A representative day is normally an average, mid-week day, such as Tuesday, Wednesday, or Thursday. Monday or Friday may be acceptable if traffic volumes are representative of a mid-week day. Local knowledge of commercial habits, such as early closings or evening shopping, is essential in choosing a truly representative day. Under unusual conditions when recreational traffic is significant, traffic counts taken on weekends may be compared against the accepted warrants.

Counting Techniques

With passenger or commercial vehicles, manual turning movement counts are always preferable, as they provide both the basic data for justification as well as detailed guidance for design.

Recording Manual Counts

Manual traffic counts may be recorded on the Vehicle Volume Summary Sheet (See Appendix A of this manual).

Estimated and Projected Counts

For locations under construction or not yet in existence, the Transportation Planning and Programming Division (TPP) estimates the anticipated average daily traffic (ADT) volumes at the district's request. To aid TPP in making such an estimate, 24-hour machine counts should be made along each approach open to traffic. An up-to-date map of the area and a layout of the location as it will be constructed should also be provided. (If construction will be staged and the location opened to traffic in increments, layouts at various stages of construction are recommended.) If a major traffic generator (shopping center, industrial plant, recreational facility, school, etc.) is in operation (or expected) within a 0.5 mile radius of the location, the information should be included in the request to TPP.

Using the projected ADT volumes, the following general guidelines can be used to obtain an estimate of vehicle count data:

The maximum 8-hour volume is generally between 50 percent and 60 percent of the ADT, with the average being approximately 52 percent. In an urban area with a high ADT, the percentage is generally between 55 and 60 percent.

The average hourly volume of the maximum 8-hour volume is generally between 6 percent and 8 percent of the ADT (maximum 8-hour volume divided by eight.)

The lowest hourly volume (eighth highest hour) of the maximum 8-hour volume is generally between 5 percent and 6 percent of the ADT with an average value of approximately 5.5 percent. It is also approximately 80 percent of the average hourly volume or 10 percent of the maximum 8-hour volume. This value is the basis for comparing the anticipated volumes with the volume warrants for signalization found in the *Texas Manual on Uniform Traffic Control Devices* (TMUTCD).

The lowest hourly volume (eighth highest hour) for a “grid system” of existing signals within a city is assumed to be 5 percent of the ADT.

The peak hour volume (highest hour) is generally between 6 percent and 10 percent of the ADT. The lower values are generally found on roadways with low volumes. The average value is approximately 8.4 percent of the ADT.

Pedestrian Counts

Pedestrian volume counts for each cross walk should be made during the same period as the vehicle volume count. Tallies should be recorded for each quarter hour for the duration of the count.

Pedestrian counts are not required in sparsely settled rural areas or at other locations where it is apparent that pedestrian movement is negligible. The signal installation must comply with the latest version of the Americans with Disabilities Act and the Texas accessibility standards.

Forms. The Pedestrian Volume Summary Sheet can be used to record pedestrian counts in the field (See Appendix A).

School Pedestrian Counts

School pedestrian counts should be made on a normal school day during the hours of greatest crossing activity. Obtaining the necessary count information for a school crossing study involves:

- counting the number of vehicles
- determining the length and spacing of gaps in the traffic stream
- measuring the width of the street
- counting the number of pedestrians crossing the street during each gap in the traffic stream.

Other factors to be considered at the crossing are:

- the 85th percentile speed
- crash history
- existing pavement markings, signing and channelization
- the age of school children.

Forms. The necessary forms with instructions for conducting a school pedestrian count are:

- Pedestrian Group Size Study (See Appendix A)
- Pedestrian Delay Time Study (See Appendix A)

For procedures for Determination of Need for Traffic Control at School Crossings, see Appendix B of this manual.

Section 6 — Approach Speeds

Introduction

When installing or upgrading a traffic signal, it should be verified that the posted speeds on each of the approaches to the location are still appropriate for current traffic conditions. For details regarding the necessity for 85th percentile speed rechecks, see the *Procedures for Establishing Speed Zones* manual.

Where approaches are controlled by a STOP sign or traffic signal at the time of the study, the speed check must be conducted far enough away from the location to obtain a speed not affected by the sign or signal. As per *Procedures for Establishing Speed Zones*, speed check stations should be located midway between signals or 0.2 miles from any signal, whichever is less, to ensure an accurate representation of speed patterns.

Section 7 — Traffic Survey Count Analysis

Count Data Processing

Vehicle and pedestrian count data must be tabulated and checked against established traffic signal warrants. The vehicle data is recorded on the Vehicle Volume Summary Sheet. The pedestrian data is recorded on the Pedestrian Volume Summary Sheet.

The tabulation and checking can be accomplished manually or by using an automated system.

Manual Method. Manual tabulation is accomplished by transferring the data to the Traffic Survey — Count Analysis Form (discussed under the following subheading).

Automated Methods. Traffic count data may be transferred into an automated system for tabulation and checking against warrants. Districts may use commercially available software for this purpose. Also available for use is a traffic signal warrant excel worksheet developed by TxDOT personnel. A copy of this Excel file can be provided by the Traffic Safety Division upon request.

The Traffic Survey — Count Analysis Form

The Traffic Survey — Count Analysis Form is used to compare the data from the traffic study with the accepted signal warrants. The form shows the following information:

- location data (major and minor street, control and section, etc.)
- date of survey
- 85th percentile speed on major street
- accepted traffic signal warrants
- vehicle and pedestrian volumes for the eight highest, **non-overlapping** hours of the day, as determined from the vehicle and pedestrian counts.

This form shows both rural and urban warrants; therefore, the warrants applied should be indicated on the form (See Appendix A).

Section 8 — Intersection Delay Study

Introduction

To meet the delay portion of the requirements for Warrant 3, “Peak Hour,” a delay study must be performed at the subject intersection. Typically, an intersection delay study is conducted at intersections or major driveways where congestion problems exist. This study is considered as a detailed investigation of the stopped-time delay conditions at an intersection being evaluated for signalization.

Time of Study

The intersection delay study should be performed during periods of congestion. Typically, the peak delay occurs during the peak hour, which can be identified from the traffic counts. The peak delay may occur during the major street’s peak hour or during the minor street’s peak hour, so care should be taken when determining the study time period. In some cases, both time periods need to be studied to determine the peak delay hour. It may be desirable to start the delay study 30 minutes before the beginning of the peak hour and end it 30 minutes afterwards to ensure that the peak delay is recorded.

Equipment

Unless the district has a delay meter, the intersection delay data is usually collected manually. In most cases, one observer is required for each intersection approach being evaluated. In some cases, traffic volumes are too heavy for one person to handle alone, and a second observer is used.

Each observer needs

- a stop watch or wristwatch with a second hand
- a clipboard and paper to record the delay data.

Form

The Intersection Delay Study Field Sheet can be used to record the data. (See Appendix A).

Procedure

Performing a delay study involves counting the vehicles stopped in the intersection approach at successive intervals.

Selecting the Interval. The typical duration for the interval is 15 seconds. Other values can be selected; however, if a larger interval is selected, the amount of overestimation of delay increases. Conversely, if a smaller interval is selected, the amount of overestimation of delay is lower, but the amount of data collected increases. So the 15 second interval represents a good compromise.

Preparing the Form. Before the start of the study, the identifying information is entered in the appropriate places on the Intersection Delay Study Form. The first column is completed to indicate the starting times in minutes for the indicated succession of sampling intervals.

Counting and Recording. When the starting time arrives, the observer counts and records the number of vehicles stopped on the approach for each observation time indicated. As a vehicle arrives, it is recorded on the "Total Number of Vehicles" section in the column corresponding to the 15 second interval when the vehicle arrived. For example, if a vehicle arrived at 8:00.08 am, it is recorded in the column "+ 0 sec." If this same vehicle is still waiting at the stop line at 8:00.15 am, it is recorded in the column "+ 15 sec." Thus, a vehicle is counted more than once in the delay determination if it is stopped during more than one sampling time.

A separate tabulation of the approach volume is made for each time period by classifying vehicles as stopped or not stopping. (Note: the vehicles not stopping column is typically used for a delay study of an existing signalized intersection.) The number of stopping vehicles is always equal to or less than the total number of vehicles stopped on the approach for a specific time interval, because vehicles can be delayed for more than one sampling period.

Study Results

Each vehicle counted in the delay study is assumed to be stopped for the duration of the selected interval (typically 15 seconds). Each column is added up in each of the subtotal blocks, and the total is recorded in the "Total" block. The total number of vehicles delayed is then multiplied by the interval (15 seconds) to get total vehicle-seconds of delay. Then the highest four consecutive 15 minute time periods are added together. This sum is then divided by 3600 to convert the value to vehicle-hours of delay. The result is then used to determine if the delay portion of Warrant 3, "Peak Hour," is met.

Chapter 4 — Operational Considerations

Contents:

Section 1 — Overview

Introduction

How a traffic signal will be operated and maintained needs to be considered along with the initial design and installation. This chapter covers several operational considerations, including coordination, preemption, and flashing operation. How a traffic signal interacts with adjacent signals, railroads, and emergency vehicles is important to the effectiveness of the transportation system.

Equipment Repair

Failed equipment should be repaired by qualified personnel only. If the equipment is still under the manufacturer's warranty, it should be sent to the manufacturer for repair. To minimize down time, spare units should be kept in stock for use while equipment is shipped for repair.

Section 2 — Coordinated Operation

Introduction

Traffic signals can operate at an independent intersection or as part of a coordinated system. The traffic signals can be set up to operate in the fully actuated mode, in fixed time mode, or in a flashing mode of operation. How a signal is operated determines its effectiveness in reducing delay and increasing safety. Signal operation also influences public acceptance.

Coordinating Operations with Other Jurisdictions

The operation of TxDOT traffic signals often crosses jurisdictional boundaries. For this reason, it is often necessary to connect or operate TxDOT traffic signals with signals and control devices maintained and operated by other jurisdictions.

Agreements. If coordination across jurisdictional boundaries is accomplished by synchronizing time clocks (time-based coordination), then no agreement is necessary. If the coordination involves one jurisdiction operating (setting the timing) or maintaining (opening a cabinet for maintenance purposes), then a formal agreement between the entities is required. For information on agreements, see the *Negotiated Contracts Procedures Manual*.

Advantages of Coordinated Operation

Traffic signal systems are designed to minimize delay. An individual intersection operates most efficiently when it is allowed to respond to traffic demand in a fully actuated mode. Fully actuated operation allows the traffic signal to adjust the cycle length and phase split times on a cycle-by-cycle basis.

At all intersections, vehicles tend to group into “platoons.” Once a platoon is established, delay can be reduced by keeping the platoon moving through adjacent signals. The coordination of traffic signals (operating more than one signal in a system) can provide smooth progression along an arterial.

Drawbacks of Coordinated Operation

Operating traffic signals in a coordinated mode does have some drawbacks. The coordination of the system may further delay some minor traffic movements.

Determining Effectiveness of a Coordinated Operation

Several factors determine how effective a coordinated traffic signal system can be. These factors should be considered when determining if a signal should be operated independently in a fully actuated mode or as part of an arterial system. These factors include:

- distance between intersections
- system design speed and posted speed
- required cycle length
- required pedestrian phases.

Section 3 — Preemption

Preemption by Railroad Equipment

Traffic signals near railroad grade crossings can be connected to the railroad equipment to initiate a traffic signal preemption sequence. The railroad installs sensors on the tracks that send an electrical input to the traffic signal controller as the train passes over the sensors.

When To Use. Preemption of a traffic signal by the railroad signals is required if the traffic signal is at an intersection that is within 200 feet of a railroad grade crossing. Preemption should be considered wherever traffic may back up over the crossing due to traffic signals or other traffic congestion.

Traffic signal preemption requires an agreement with the railroad. For more information on railroad agreements and preemption, see the *Rail-Highway Operations Manual*.

Types of Railroad Preemption. Preemption of a traffic signal by railroad equipment may be either “simultaneous” or “advance.” These terms, which are used by the railroads, are explained in the *Rail-Highway Operations Manual*.

Preemption by Emergency Vehicles

Various mechanisms may be used to preempt traffic signals so that emergency vehicles are provided with safe right-of-way as soon as practical. This type of preemption is typically used at intersections adjacent to fire stations and on commonly traveled routes. Communication with the traffic signals may be provided by direct wire, modulated light, or radio. The agency requesting the preemption is normally responsible for supplying the interconnect and any additional hardware required for the preemption. Agreements are not required.

Multiple preemptions are allowed at the same location. Priority must be given to each preempt. Railroad preemption always overrides emergency vehicle preemption.

Section 4 — Flashing Operation

Introduction

All traffic signals are programmed to operate in the flash mode for emergencies. Signals may also operate in maintenance flash, railroad preemption flash, or scheduled operational flash modes.

The type of flash used (all-red or yellow-red) must be considered carefully. Driver expectation is an important factor. Drivers are conditioned to react to situations through their experiences. Mixing the types of flash can confuse drivers if they are accustomed to the all-red flash. The benefits of operating a mixed color flash must be weighed against the disadvantages. Violation of driver expectation can be a disadvantage of a mixed color flash.

Refer to the *Texas Manual on Uniform Traffic Control Devices* (TMUTCD) for specific instructions on flashing operations.

Malfunction Flash

Malfunction flash mode is used when the conflict monitor senses a malfunction. Malfunction flash should use all-red flash exclusively.

Maintenance Flash

Maintenance flash mode can be programmed for the operation of the intersection during routine maintenance. Yellow-red flash can be used if the main street traffic is significantly more than the minor street traffic.

Railroad Preemption Flash

When a traffic signal is preempted by a train, flashing operation may be used while the train is going through the crossing. Either all-red flash or yellow-red flash can be used.

Scheduled Flash

Traffic signals can operate in scheduled flash mode as a time-of-day operation (nighttime flash). Nighttime flash can reduce delay at intersections operating in the fixed time mode. Scheduled flash mode typically uses the yellow-red flash type operation. Nighttime flash should not be used at fully actuated intersections unless all other intersections in the area operate nighttime flash. Again, driver expectation is a major factor in this decision.

Left-Turn Flash

When a traffic signal has left-turn signal heads the type of flash operation must be considered. If using an all-red flash operation, the left-turn signal heads should flash red. If using a yellow-red flash operation, the left-turn signal indication should flash red for both the yellow flash direction and the red flash direction.

Chapter 5 — Traffic Signal Projects

Contents:

Section 1 — Overview

Introduction

This chapter explains traffic signal project funding and programming, methods of construction, submission requirements, and project construction. The submissions consist of information gathered during the traffic study and include various forms, graphs, sketches, plans, and other justification data.

Authorization Request Form

Districts use the Traffic Signals Authorization Request Form (See Appendix A) to recommend the type of traffic signal control to install at a particular location, the method of accomplishing the work, the warrants upon which the authorization was based, and the funding source. When executed by the district, the form also serves as:

- authorization for the existence of the signal **and**
- authorization to do the work under certain programs where work authority has not been previously granted.

Districts are authorized to program projects directly with the Transportation Planning and Programming Division (TPP). In order to obtain a valid control-section-job (CSJ) number to establish a project, the district must submit a signed Traffic Signal Authorization Form to TPP.

Signature Requirements. The following officials' signatures are required on the Authorization Request Form:

- recommendations by district traffic section
- approval by the district engineer.

Disposition of Paperwork. TxDOT policy requires districts to keep all relevant paperwork in their files. Traffic engineering data need **not** be submitted to TRF.

Recommending Against Installation

When the district's traffic study indicates that a traffic signal is not needed, the district should notify the requesting party, by letter, that a traffic signal installation is not recommended. In unusual cases, the district may wish to submit their traffic study to TRF for review and comment prior to notifying the requesting party of the study results.

Removal of Traffic Signals

Although the original installation of a traffic signal may be based on the satisfaction of one or more warrants and other factors, changes in traffic flow over time may reduce the effectiveness of traffic signal control. When this occurs, it may be appropriate to remove a traffic signal. The *TMUTCD* provides the following guidance regarding the removal of traffic signals:

"If the engineering study indicates that the traffic control signal is no longer justified, and a decision is made to remove the signal, removal should be accomplished using the following steps:

1. Determine the appropriate traffic control to be used after removal of the sign.
2. Remove any sight distance restrictions as necessary.
3. Inform the public of the removal study.
4. Flash or cover the signal heads for a minimum of 90 days, and install the appropriate stop control or other traffic control devices.

Remove the signal if the engineering data collected during the removal study period confirms that the signal is no longer needed."

Before determining to remove a traffic signal, keep in mind that it is possible that a signalized intersection that does not meet any of the warrants will meet at least one warrant after the signal is removed (due to increases in crashes, delay, or traffic patterns). Therefore, the removal of a traffic signal requires engineering judgment.

Due to the expense associated with the removal and possible re-installation of a traffic signal, the following steps should be followed prior to the removal of a traffic signal:

1. The traffic signal should be placed in flashing operation reflecting two-way or multi-way stop control, as appropriate.
2. If, after an extended period of flashing operation, intersection operation and safety is acceptable, the signal should be deactivated and STOP signs should be installed on the appropriate approaches. Signal deactivation can be accomplished by covering the signal heads, turning them face down, or removing the signal heads completely. Signal related signing should be removed from the intersection. The signal poles, mast arms, and span wire should be left in place.
3. After an extended period of acceptable sign control operation, the signal poles, mast arms, and span wire should be removed.

NOTE: TRF may be consulted for guidance when removal of a traffic signal is being considered.

City Traffic Signal Installation Using Local Funds

When a city of 50,000 or greater population (latest federal census) desires to install a traffic signal using local funds within its corporate limits on a highway of conventional design which is on the state highway system, TxDOT must conduct a traffic study to determine

- if there is a need
- if warrants are met
- if the proposed installation should be authorized.

When the district engineer approves the project by signing the Traffic Signal Authorization Form, the district should then forward a copy of the signed authorization form to the city to serve as their record of approval for the proposed traffic signal installation.

Project Cancellations or Change

If for any reason the work from an approved project is not to be performed or the method of performing the work is to be changed (such as from state forces to contract or vice versa), the district should advise the Transportation Planning and Programming Division (TPP).

Section 2 — Traffic Signal Projects Funding

Introduction

This section covers projects installed by the state, which includes all projects using state administered funds. Depending on the type of project, construction may be accomplished using state forces, contract forces, or city forces. These projects generally fall under the following categories:

- highway safety projects funded through the Highway Safety Improvement Program (HSIP)
- other federal-aid projects funded through:
  - Interstate Construction
  - National Highway System
  - Surface Transportation Program
  - Congestion Mitigation and Air Quality Improvement
- projects funded under state construction programs
- projects funded under state maintenance programs
- projects funded using third party funding (such as city, county, or private entity).

Program choice is often dependent on the scope of the proposed work and whether or not the installation is urgently needed.

Programming

HSIP Projects. Highway safety projects are funded under the Highway Safety Improvement Program (HSIP). For more information on the HSIP, contact the Safety Engineering Group of the Traffic Safety Division (TRF).

Other Federal Aid Projects. Districts should program all proposed federal-aid projects and assign preliminary control-section-job (CSJ) numbers prior to conducting traffic studies. Once the project is programmed, all costs incurred in performing the traffic study should be charged to a project CSJ number for the purpose of documentation for federal reimbursement.

State Funded Construction Projects. Districts obtain work authority for projects funded under state construction programs by programming them through the Transportation Planning and Programming Division (TPP). It is not advisable to program state forces for these projects. Although work authority is provided through an approved program, financing comes from the district's maintenance budget.

Construction program funds are applied only to contract work.

State Funded Maintenance Projects. Installation of traffic signals can be accomplished using maintenance funds. A maintenance contract can be let to purchase and install traffic signals. Maintenance funds may also be used to purchase equipment, and state, city, or county forces can be used for installation.

Agreements

See the *Negotiated Contracts Procedures Manual* for information on securing and processing traffic signal agreements.

Third-Party Funding. When securing funds from a private entity to install a traffic signal, a three-party agreement is necessary. The third party in these agreements must be the relevant city or county. For details concerning content and execution of these agreements, contact the Contract Services Division (CSD).

Method of Construction

All projects financed using federal-aid funds should be let to contract unless there are valid reasons to provide other methods of construction, such as state or city forces. Projects may be constructed by state or city forces if it can be justified to the FHWA that this method of construction is cost effective and in the public interest. The district should be aware that any force account items provided by the state will be charged to the district maintenance budget. Federal reimbursement for these items is not applied back into the district's account, but is placed in TxDOT's general revenue accounts. City force account work, however, is paid initially from state construction funds, which are reimbursed directly by federal funds, because the city is considered to be a contractor for the state.

State Funded Construction Projects. State funded construction projects should go through the construction letting process.

Letting

Contract letting, which includes the advertising, preparation of proposals, furnishing of proposals to prospective bidders, etc., and preparation of the contract award or rejection by Commission minute is handled in Austin.

Construction

Once a project is let to contract, the Construction Division (CST) issues an "Authorization to Begin Work" or "Work Order Authorization" upon award of the contract by the Commission and the signing of the contract.

Shop Drawings

Traffic Signal Poles. Shop drawings for non-standard traffic signal poles should be submitted to the project engineer. The project engineer reviews the shop drawings for general design features and then forwards them to the Bridge Division (BRG) for review and approval of the structural design, fabrication, and erection details.

Lighting Poles. If the poles are to be fabricated in accordance with the RIP standard, no shop drawings are required. If the poles are non-standard (including Aluminum material vs Steel), shop drawings and calculations should be submitted to BRG_ShopPlanReview@txdot.gov in accordance with the Guide to Electronic Shop Drawing Submittal.

Changes on Contract Projects

Change Orders. If it becomes necessary to change design, correct errors in plans, modify specifications, or extend project limits and the total value of the change order is greater than $100,000, then a change order request must be submitted to the Construction Division (CST) (see the *Construction Contract Administration Manual* for details). Change order requests involving force account items on contract projects should also be submitted to CST.

Supplemental Agreements. A supplemental agreement is required to pay the contractor for any necessary extra work on a unit basis. In most cases, a change order request is also required. The supplemental agreement should be submitted to CST.

Changes on City Force Projects

Change Orders. If, on a project constructed by city forces, it becomes necessary to make substantial design changes, correct errors in plans, or extend project limits on a project, the district should submit a change order request to CST.

Supplemental Funds. If it becomes apparent that the project will overrun the authorized funds, a request for additional funds should be made.

Project Administration

For additional details on managing a contract for a construction project, refer to the *Construction Contract Administration Manual*.

Section 3 — Plan Requirements for PS&E

Introduction

This section describes the sheets that should accompany submissions of plans, specifications, and estimates (PS&Es). Depending on the type and size of a project, some of the sheets described may be combined or eliminated. For additional information, see the Design Division's *PS&E Preparation Manual*.

Data for Plan Preparation

The basic data used in preparing the plans can be found on the condition diagram and the design layout sketch submitted with the recommendations. These sheets plus additional information, such as the exact location of all utilities, should be available when preparing the detailed plans.

Affected Utilities. Negotiations with affected utilities must be started upon approval to begin plans for a project so that any utility adjustments can be made promptly when work begins.

Survey Data and Photographs. All survey data should be kept in a neat and detailed form so it can be referred to at any time. By detailing all information and obtaining photographs of the location and special features, unnecessary trips to the location may be eliminated. For this reason, adequate time should be devoted to project surveys and photographs.

Title Sheet

The title sheet must contain the following information:

- title describing the location and type of installation (for example: "Work Consisting of Installation of a Full Traffic-Actuated Traffic Signal")
- area map (county, city or both) with the location of the installation circled and noted as "LOCATION OF PROPOSED WORK"
- project limits, control-section-job (CSJ) number, project length
- index of sheets, including sheet number and title (can be separate sheet)
- spaces for the following officials' signatures:
  - city or county officials, as applicable
  - engineer responsible for the preparation of the plans
  - district engineer
  - director, Design Division (DES)
  - FHWA division administrator, as applicable.

Estimate and Quantity Sheet

The estimate and quantity sheet is necessary only for state financed contract projects and federally financed projects.

This sheet should list all bid items for the project. The list should consist of:

- the estimated bid item quantities, showing a breakdown by control and section and the total for the entire project
- the specification item number as well as the descriptive code number and alternate number (if applicable)
- the bid item description (for example: "Installation of Highway Traffic Signals") and the unit of measurement (for example: LS., EA, etc.).

This sheet should also show any state or city force account items and any materials to be furnished to the contractor by the state.

Condition Diagram Sheet

The condition diagram (described in Chapter 3, Section 2 of this manual), which is included with the submission of the district's recommendations, must also be included in the project plans.

Plan Sheets

The plan sheets must provide a detailed, dimensioned layout of the location. North must be toward the top or left edge of the sheets. Plan sheets must include the following:

- **existing conditions** which include parking, signing, striping, traffic signals, lighting, etc.
- **existing utilities**, including indication of ownership as well as a detailed location with respect to roadway and depth below or height above the surface. If usage is to be made of any part of the utility, notes about such usage are to be included. If there are a large number of utilities, a separate utilities sheet should be provided to show their locations.
- **proposed highway improvements** (design, geometrics, pavement type, etc.). Design and operational considerations for traffic signals are addressed in Chapter 4 of this manual. Safety lighting design is covered in the *Highway Illumination Manual*.
- **proposed installation**, including the exact location of all major items of equipment, such as poles, foundation, luminaries, conduit, signal heads and faces, ground boxes, detectors, controllers, etc. shown in detail.
- **proposed additional traffic control**, such as striping, stop lines, signs, etc.
- **proposed signing layout,** including location, sign nomenclature, and size for all signs to be removed, added, or remain in their current location.

Elevation Sheets

The elevation sheets should show elevation views for all above ground equipment.

Traffic Signal Elevation Sheets. Traffic signal elevation sheets should include the dimensioned views of proposed mast arm and span wire mounted signal assemblies, above ground detectors, post or bracket mounted signal assemblies, and other similar items. Elevation views of proposed signal equipment should show the exact location of the equipment with respect to the existing roadway and all surrounding facilities. The sheets should also show the following information, when pertinent to the particular elevation view:

- sign locations and legends
- overhead utility installations located with respect to proposed signal equipment
- horizontal and vertical roadway clearances

Utilities Elevation Sheets. Utilities should be checked in detail, and those requiring adjustment should be noted on the utilities elevation sheet, with additional sheets prepared showing proposed relocation.

Detail Sheets

Standard sheets prepared by the Design Division (DES) and the Traffic Safety Division (TRF) and special detail sheets prepared by the district should include sufficient detail to adequately describe all of the following applicable items:

- poles:
  - signal
  - power
  - luminaire
  - pedestal
- ground boxes
- wiring diagrams
  - cable termination (signal, power, and illumination)
  - detector termination
- conduit and conductor tables
- detectors
  - induction loop
  - accessible pedestrian push button
  - other (radar, microwave, acoustic, infrared, VIVDS)

- concrete foundations:
  - controller
  - poles
- down-guys (including anchors)
- vehicle and pedestrian signal head mounting details (vertically or horizontally mounted with or without backplate)
  - span wire
  - mast arm
  - pedestal or post top
  - short bracket
- phasing sheet showing:
  - signal location
  - signal indications
  - phasing diagram (see Figure 5-1)
  - flashing operations
  - preemption operation (when applicable)
- work area protection, including any or all of the following:
  - standard barricade and construction sheets and traffic control plan prepared by the Traffic Safety Division (TRF)
  - construction detour and barricade location sheets
  - plan notes pertaining to work zone and sequence of work, if applicable.

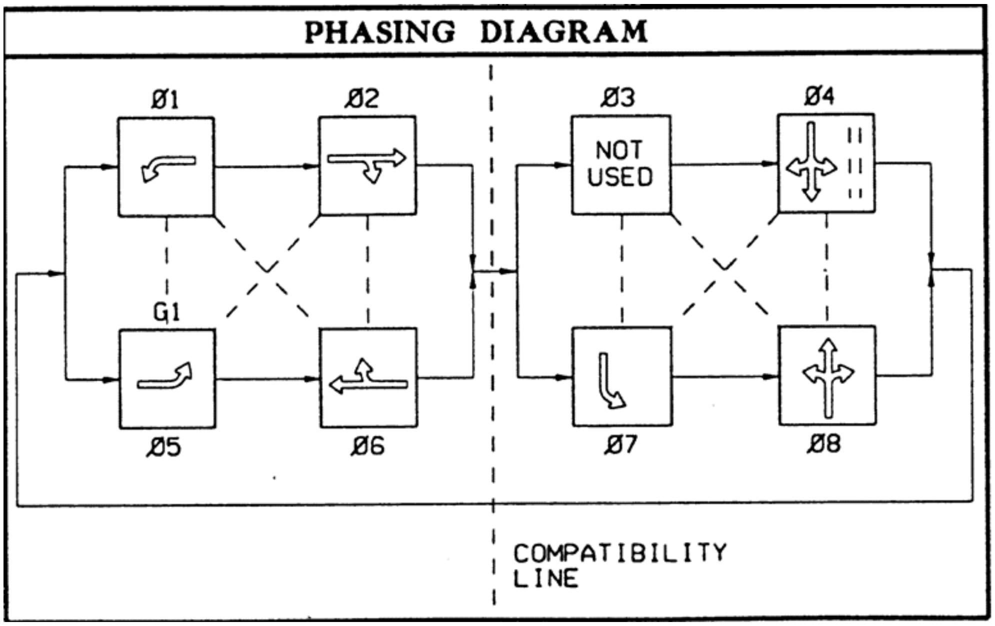


Figure 5-1. Typical phasing diagram.

Specifications

The specifications submitted with each set of project plans for a state financed contract project or for any federally financed project must be adequate to provide for the purchase of all necessary equipment to be installed as well as other materials which must be used in completing the installation. The manner and method of installation must also be addressed. Reference should be made to the TxDOT's *Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges*, as applicable.

Occasionally special specifications are needed to procure equipment or define items of work not explicitly covered by the standard specifications. As existing specifications evolve through a history of use, special provisions to these specifications are developed to reflect any changes to current practice or special need. Contact TRF for the latest versions of the special specifications.

PS&E Paperwork

PS&E paperwork may include, but is not limited to the following:

- PS&E submission data
- general notes
- specification list
- estimate.

For information on all paperwork that needs to be submitted with a PS&E package, see the Design Division's *PS&E Preparation Manual*.

Section 4 — Accessible Pedestrian Signals Guidelines

Purpose

The purpose of this section is to provide guidelines for the installation of Accessible Pedestrian Signals (APS).

Definition

An APS is a device that communicates information about pedestrian signal timing in non-visual format such as audible tones, verbal messages, and/or vibrating surfaces - Texas Manual on Uniform Traffic Control Devices (TMUTCD).

Background

In June of 2002, the U.S. Access Board released a draft document entitled *Draft Guidelines for Public Rights-Of-Way*. These draft guidelines required APS systems at all new signalized intersections where pedestrian signals are installed. In July 2011, the *Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way*, also known as the PROWAG, was issued. The PROWAG also included requirements for APS to be installed where pedestrian signals are provided.

The Americans with Disabilities Act (ADA) requires that when pedestrian facilities are provided, they must be usable by all pedestrians. While the PROWAG has not been finalized by the U.S. Access Board nor adopted by the U.S. Department of Justice or U.S. Department of Transportation, it does provide a useful framework to meet our obligations to make our programs, services and activities in the public right-of-way readily accessible and usable by all individuals, including those with disabilities. The Federal Highway Administration (FHWA) stresses that the draft guidelines should be considered as best practices and the state of practice and should be followed regarding issues not covered by the existing ADA standards.

The following recommended practice is based on the above mentioned draft guidelines that were developed through the FHWA.

Recommended Practice

Until such time that further rules or regulations are provided by the U.S. Department of Transportation (USDOT), FHWA, U.S. Department of Justice (USDOJ), the U.S. Access Board, the Texas Department of Licensing and Regulation (TDLR), the American Association of State Highway Transportation Officials (AASHTO), or others, the installation of APS will be in accordance with the guidance that follows. This recommended practice is subject to change and will be updated as needed. Additionally, the Intersection Prioritization Tool Worksheets (See Appendix C) based on National Cooperative Highway Research Program (NCHRP) Project 3-62 should be utilized to evaluate signalized intersections for the need of APS based on comparative need. Priority to install APS systems will also depend on whether the signalized intersection is considered to be part of new construction, part of a modification project, or an existing installation as defined below.

- **New Construction -** New construction of traffic signals is considered either the installation of a new traffic signal at a previously non-signalized intersection or substantial replacement of a traffic signal. If pedestrian signals are installed, the traffic signal shall be designed and equipped with APS for all crosswalks that are to be equipped with pedestrian signals. Installation of APS will not be considered at intersection approaches where an engineering study has determined that pedestrian signals are to be prohibited. However, the designer should take into consideration that a non-visual format to prohibit pedestrian crossing (some sort of physical means of prohibiting the crossing such as railing, heavy vegetation, etc.) should be provided in addition to crossing prohibition signs.
- **Traffic Signal Modifications -** Traffic Signal Modifications are considered to be the modification of an existing traffic signal at an intersection. If there are existing pedestrian signals, or pedestrian signals are being added as part of the installation, the design shall include the installation of APS. Installation of APS will not be considered where pedestrian crossings are physically prohibited. Minor signal modifications, such as installation of left-turn signal heads, modification of existing signal phasing, or installation of vehicle detection systems that do not require substantial reworking of the intersection signal poles or wiring would not require a redesign of the intersection as mentioned above. The PROWAG states that existing pedestrian signals shall comply with APS requirements "when the signal controller and software are altered, or the signal head is replaced."
- **Existing Traffic Signals -** TxDOT districts will schedule an evaluation of all existing signalized crosswalks at signalized intersections under their jurisdiction. Evaluations will include completion of the Intersection Prioritization Tool worksheet. Crosswalks should be evaluated to determine a priority for the installation of APS. The scores should be arranged in order from the highest to the lowest. Crosswalks with scores in the top 50 percent and associated with a specific request should be considered high priority. Districts shall develop a plan for installation of APS at all intersections with existing pedestrian signals based on the order established by the determined priority. Additionally, evaluations will be made when there is a written request for a specific intersection(s). Evaluations that result in a high priority or are associated with a specific request should be scheduled to have APS installed. At the completion of the high priority or specific request projects, the district should review the plan and move toward completing all APS installation.
- **Engineering Judgment -** Based on the engineer's judgment, a higher priority may be given to the installation of APS at a crosswalk than an initial evaluation of the crosswalk would indicate.

Engineering Study for APS

An engineering study of signalized intersections for each TxDOT district is needed to determine priority for providing APS at pedestrian signals. The Intersection Prioritization Tool should be completed by engineering staff. However, the study may include the input of an Orientation and Mobility Specialist. The Texas Workforce Commission, Vocational Rehabilitation Services, can be a good point of contact for consultants on orientation and mobility. TxDOT districts should develop a plan for upgrading pedestrian signals based on the priority established by the engineering study.

The TMUTCD provides the following information on the APS study:

"**Guidance:** If a particular signalized location presents difficulties for pedestrians who have visual disabilities to cross the roadway, an engineering study should be conducted that considers the needs of pedestrians in general, as well as the information needs of pedestrians with visual disabilities. The engineering study should consider the following factors:

- Potential demand for accessible pedestrian signals;
- A request for accessible pedestrian signals;
- Traffic volumes during times when pedestrians might be present, including periods of low traffic volumes or high turn-on-red volumes;
- The complexity of traffic signal phasing (such as split phases, protected turn phases, leading pedestrian intervals, and exclusive pedestrian phases); and
- The complexity of intersection geometry."

Research information indicates other considerations to study. According to the NCHRP publication *Accessible Pedestrian Signals - A Guide to Best Practices*:

"Too little traffic is as great a problem to pedestrians who are blind, as is too much traffic. In the absence of APS, blind pedestrians must be able to hear a surge of traffic parallel to their direction of travel in order to know when the walk interval begins. Locations that may need APS include those with:

- intersections with vehicular and/or pedestrian actuation
- very wide crossings
- major streets at intersections with minor streets having very little traffic
- t-shaped intersections
- non-rectangular or skewed crossings
- high volumes of turning vehicles
- split phase signal timing
- exclusive pedestrian phasing, especially where right-turn-on-red is permitted

- a leading pedestrian interval.

Where these conditions occur, it may be difficult for pedestrians who are visually impaired or blind to determine the onset of the walk interval by listening for the onset of parallel traffic, or to obtain usable orientation and directional information about the crossing from cues that are available."

There are potential traffic conflicts associated with signalized pedestrian crossings to be aware of whether audible APS systems are installed or not. These include: vehicles still clearing the intersection when the audible signal comes on, vehicles that fail to stop for the red light, motorists who stop and make a right turn on red while watching to the left and failing to notice pedestrians on their right, and vehicles that may turn right or protected on the same phase as the pedestrian.

Adjustments to vehicular phases and allowable movements, including prohibiting right turn on red, may need to be incorporated into the overall intersection operation. It may even be questionable whether the audible signal interferes with the sight impaired traveler's ability to listen for these possible conflicts. These potential conflicts require that due caution be used when crossing a street whether there is an audible signal or not. Speech messages should never indicate that it is safe to cross, but rather that a walk light is on.

Design Considerations

The draft Americans with Disabilities Act *Revised Draft Guidelines for Accessible Public Rights-of-Way* include specific requirements for pedestrian signals and a comprehensive list that the designer should review.

The TMUTCD, Section 4E. "Pedestrian Control Features" also covers many of the design requirements of APS systems. As with any traffic control device, the TMUTCD should be reviewed when designing accessible pedestrian signals. For example, the TMUTCD indicates that the push buttons should be separated by 10 feet and located near the curb ramp they serve, preferably at the landing for the curb ramp.

The APS units require mounting with proper orientation to direct pedestrians across the street.

The *Accessible Pedestrian Signals - A Guide to Best Practices*, which was developed by the NCHRP, is very comprehensive in regard to all aspects of APS. It goes into extensive detail regarding all aspects of APS and is recommended as a reference for APS design considerations.

APS have undergone several advancements throughout the years. The most current devices are the push button integrated systems. With these systems, the speaker, push button, and vibro-tactile arrow are all contained in the push button housing. Placement of the push button/APS is critical to the proper operation of the system. The pedestrian uses the arrow on the APS for orientation in crossing the street. The button stations serving adjacent crosswalks at the same corner require separation so that the user can tell which crossing is being served with a walk indication. The APS provides a locater tone and "walk" tone; the cuckoo and chirp tones are no longer considered effective. These systems have the capability to adjust to ambient noise levels and can be configured so that they are only discernible from a specific distance from the intersection, posing less of a noise issue for the surrounding environment. In consideration of the above, it is critical in design to locate the pushbuttons and crosswalks such that the installation of APS will be effective.

Specifications

When specifying an APS, it is necessary to know what will be needed at the crossing. It is recommended that a push button integrated APS system be specified. These systems have all the TMUTCD required features such as locater tones, volume control, vibro-tactile arrows, etc. Contact TRF for assistance with specifications.

References

2011 Texas Manual on Uniform Traffic Control Devices (TMUTCD)

July 26, 2011, *Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way* (U.S. Access Board)

NCHRP 3-62 Accessible Pedestrian Signals: Synthesis and Guide to Best Practice

Texas Accessibility Standards

Transportation Research Record, Journal of the Transportation Research Board, No. 1982, pp. 13-20, titled, “Development of Intersection Prioritization Tool for Accessible Pedestrian Signal Installation”

Accessible Pedestrian Signals - A Guide to Best Practices, Developed under the sponsorship of the National Cooperative Highway Research Program (http://www.apsguide.org/index.cfm).

Intersection Prioritization Tool Worksheet

The Intersection Prioritization Tool provided through the link and available from the Traffic Safety Division was recreated from National Cooperative Highway Research Program (NCHRP) 3-62 research. The worksheets are a product of NCHRP 3-62 and are published in the *Transportation Research Record, Journal of the Transportation Research Board*, No. 1982, pp. 13-20, entitled “Development of an Intersection Prioritization Tool for Accessible Pedestrian Signal Installation”. The Intersection Prioritization Tool consists of two worksheets.

- The Intersection Worksheet accounts for intersection characteristics and layout, signalization type, and location related to transit facilities, facilities for the visually impaired, and major pedestrian attractions.

- The Crosswalk Worksheet accounts for the individual crossing characteristics. Each crossing at the intersection is rated based on several factors including:
  - crossing width
  - speed limit
  - geometrics
  - pedestrian signal control
  - vehicle signal control
  - off-peak traffic presence
  - availability of alternative APS
  - requests for APS installation.

The Intersection Prioritization Tool provides a method of scoring individual crossings for relative crossing difficulty to visually impaired individuals. This provides a method to compare crossings for priority for installation of APS systems. In general, if one crossing generates a high priority, it would be desirable to provide APS for all crossings at the intersection.

The detailed instructions on the correct method for filling out and completing the worksheets are available on the internet at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w117a_appendix-d.pdf.

Section 5 — Uninterruptible Power Supply/Battery Back-up (UPS/BBU) System

Purpose

The purpose of this section is to provide guidelines for the installation of uninterruptible power supply/battery backup (UPS/BBU) systems at signalized intersections.

Definition

An uninterruptible power supply/battery backup (UPS/BBU) system provides emergency power to connected equipment by supplying power from a separate source (batteries) when utility power is not available. The system may also function as a power conditioner and/or voltage regulation device. UPS/BBU systems consist of an enclosure or cabinet, the batteries, the power inverter/ conditioner, a battery charger (usually integral to the inverter), and automatic and manual bypass switches.

Background

The Texas Department of Transportation (TxDOT) started installing LED signal lamps at signalized intersections around the mid 1990's. Initially, TxDOT decided to utilize LED signal lamps because they were expected to last longer than incandescent lamps and would not require re-lamping on a yearly basis. Additionally, the LED lamps save in power consumption when compared to incandescent lamps. The installation of LED signal lamps, which use approximately 20 watts or less per indication as compared to incandescent light bulbs at 150 watts, made the installation of UPS/BBU systems more practicable.

Most signalized intersections using LED lamps operate at 400-600 watts, and in a power outage situation, can be powered by four 12-volt batteries for up to four to six hours.

TxDOT has installed UPS/BBU systems at signalized intersections on a limited basis since about 2002. The installation of UPS/BBU systems has become more common and can be found at locations on the state system that are maintained by local governments.

Initially, most of the intersections chosen were at locations that experienced reoccurring power issues. Power issues can damage signal equipment, impair video detection equipment performance, or cause traffic signals to go dark. Some examples of power issues include failures (blackouts), voltage sags and surges, brown outs (under voltages), and over voltages. Power failures require TxDOT maintenance and signal technicians to respond to emergency calls, place the traveling public in less orderly traffic control situations, and result in increased delays, auto emissions, driver frustration, and possibly crashes.

Installing UPS/BBU systems at locations where there have been power issues helps reduce down time and electrical damage to equipment. A signalized intersection that is equipped with UPS/BBU can continue to operate through short-term power losses. Maintaining the green, yellow, and red signal operation through power outages is very beneficial in reducing problems with congestion, substantial delay, and safety. UPS/BBU systems at intersections with preemption for emergency vehicles or railroad crossings are also extremely beneficial.

Recommended Practice

UPS/BBU systems are not currently required at signalized intersections; however, the 2011 *Texas Manual on Uniform Traffic Control Devices* (TMUTCD), provides guidance that “Except for traffic control signals interconnected with light rail transit systems, traffic control signals with railroad preemption or coordinated with flashing-light signal systems should be provided with a back-up power supply.” Even though back-up power is not currently required, there are many locations that can benefit from the installation of battery backup systems.

The decision to install UPS/BBU systems is at the discretion of each district, but should be based on a study of conditions at the proposed intersection. In deciding whether to install a UPS/BBU system at an intersection, there should be an evaluation of the conditions at the intersection. Installation of UPS/BBU systems should be based on a priority established by the characteristics or conditions at the location. Locations where UPS/BBU systems are most beneficial include:

- intersections with unique geometry such as wide medians, conflicting left turns that require lead-lag operation, protected-only left-turn operation, or split phasing where right-of-way assignment is difficult for a four-way stop operation
- intersections over capacity with heavy directional traffic flow
- intersections with a history of signal malfunction due to power quality or reliability issues
- intersections on high volume roads (total volume of all approaches in excess of 20,000 ADT)
- intersections with rail preemption
- intersections with emergency preemption, or intersections near fire stations (within 1200 ft.)
- intersections with signal repair response time in excess of 30 minutes
- intersections with 1320 ft. proximity to another intersection with UPS/BBU
- intersections that are part of a coordinated system, or are part of a corridor that functions as a major arterial in an urbanized area
- intersections with high speed approaches.

Intersections that consistently experience trouble with utility line power, have railroad interconnect for preemption, or have a unique geometry, are high in priority. Intersections that rarely have utility power issues and/or have simple geometry would be considered low priority and would not be good candidates for a UPS/BBU system. A UPS Guidelines Worksheet is available from the Traffic

Safety Division that can be used to develop intersection priority for installation of UPS/BBU systems. Not all intersections will have all the conditions listed, and in some cases, the engineer may consider the relative importance of the conditions at the intersection a higher priority than listed on the spreadsheet.

Documentation detailing the criteria for the installation that was considered should be maintained by district traffic operations for each location where a UPS/BBU system is installed.

Installation of UPS/BBU for new traffic signal locations should be identified during the initial design development process.

Design Considerations

To be eligible for a UPS/BBU system, the intersection must be equipped with LED traffic signal indications.

Installation of UPS/BBU requires determining where to install the unit in the intersection. The UPS/BBU system will normally be provided with its own cabinet that will house the inverter, batteries, and auxiliary equipment. Cabinets can be provided for installation on the side of the signal cabinet or a separate base mount. In some cases, the inverter/charger and auxiliary equipment can be installed in the signal cabinet with the batteries located in a separate cabinet or ground box. However, this is not recommended, as signal cabinets do not have room for all the equipment and it can require wiring modification to the signal cabinet.

In determining whether to install the cabinet to the side of the signal cabinet or base mounted, the traffic signal cabinet base should be evaluated to ensure it is structurally adequate and there is adequate area for access by technicians. Additionally, there should be no obstruction to sidewalks and pedestrian walkways. Base mounted cabinets located in low areas that may be subject to storm water may need a cabinet extension to elevate the cabinet and prevent possible exposure to high water.

Maintenance Considerations

UPS/BBU systems require maintenance. In order to ensure that UPS/BBU systems operate properly when needed, units should be checked periodically. Batteries should be inspected and replaced when needed. Additionally, all ancillary equipment in the cabinet (i.e. fans, lights, circuit breakers, charging circuits, temperature sensors) should also be checked periodically for proper operation.

Removal of UPS/BBU

The decision to remove UPS/BBU at a specific location should be made by the district's engineer responsible for traffic signals and district traffic operations.

Section 6 — Flashing Yellow Arrow Display for Left-Turn Operations

Purpose

The purpose of this section is to provide guidance on the requirements for the design, use and operation of signalized left-turn operations resulting from the adoption of the 2011 *Texas Manual on Uniform Traffic Control Devices* (TMUTCD). These guidelines apply specifically to signalized left-turn operations and were first implemented on April 17, 2012.

Background

The 2011 TMUTCD contains several changes that affect the design and operation of traffic signals. These changes include the addition of a Flashing Yellow Arrow (FYA) display for permissive left-turn operations. While a 5-section signal face with a circular green may still be used in a shared left-turn signal face, the use of a circular green indication in a separate left-turn signal face for permissive left turns has been prohibited. The flashing yellow arrow (or flashing red arrow) is now the only allowable indication for a permissive left/right-turn in a separate left/right-turn signal face.

Information provided in this section is for guidance and comes from Part 4 of the TMUTCD.

Signal Face Types

Definitions of a Shared Left-Turn Signal Face and a Separate Left-Turn Signal Face as outlined in the TMUTCD are presented below.

- **Shared Left-Turn Signal Face:** A signal face that controls both a turn movement and the adjacent through movement and always displays the same color of circular signal indication that the adjacent through signal face or faces display.
- **Separate Turn Signal Face:** A signal face that exclusively controls a turn movement and that displays signal indications that are applicable only to the turn movement.

Modes of Operation

Left-turning traffic is controlled by one of four modes as follows: protected only, protected permissive, permissive only, or variable by time of day.

- **Permissive-Only Mode.** Turns are allowed on a CIRCULAR GREEN signal indication, a flashing left-turn YELLOW ARROW signal indication, or a flashing left-turn RED ARROW signal indication after yielding to pedestrians, if any, and/or opposing traffic, if any. If a separate signal section is provided for the left-turn lane, the signal face will need to be as shown in TMUTCD Figure 4D-7 and will require modification to the controller cabinet to provide the Flashing Yellow Arrow (FYA) operation. Alternatively, the approach can be provided with signal faces as illustrated in TMUTCD Figure 4D-6, without need for cabinet modification.

- **Protected-Only Mode.** Turns are allowed only when a left-turn GREEN ARROW signal indication is displayed. Signal indications for protected-only mode left turns in a separate signal face are required to be 3-section signal faces with RED ARROW, YELLOW ARROW, GREEN ARROW indications. Signal indications for protected-only mode in a shared signal face are required to be Circular RED, YELLOW, GREEN, GREEN ARROW indications. This would be for use where the circular GREEN and GREEN ARROW indications always begin and end together (i.e. Split phasing).
- **Protected-Permissive Mode.** Both protected and permissive modes can occur on an approach during the same cycle. Signal indications for protected-permissive mode in a separate left-turn signal face are required to be RED ARROW, YELLOW ARROW, Flashing YELLOW ARROW, and GREEN ARROW (a flashing RED ARROW is also allowed). Signal indications for protected-permissive mode in a shared signal face are required to be Circular RED, YELLOW, GREEN, YELLOW ARROW and GREEN ARROW. Initially, TxDOT practice for protected-permissive left-turn mode for standard diamond interchanges was to use a shared signal face. This is no longer the case, separate signal faces with flashing yellow arrow displays may be used for standard diamond interchanges.
- **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 or as traffic conditions change. Variable mode operation requires signal indications as defined above for a separate protected-permissive signal face. Variable mode may be implemented by time of day or possibly by rail or emergency preemption.

Signal Head Requirements

Left-turn signal heads are required to have different arrangements as discussed below, depending on the signal face type (shared or separate) and the mode of operation (permissive only, protected only, protected permissive, variable, etc.). These requirements come from the 2011 TMUTCD and are listed below. To see these arrangements detailed graphically, see Table 5-1. It is an unofficial summary of Figures 4D-6 through 4D-12 of the 2011 TMUTCD.

Shared Signal Faces in a Protected-Only Operation:

- A four-section head with Circular RED, Circular YELLOW, Circular GREEN and left-turn GREEN ARROW is required.
- Shared signal faces for protected-only operations shall only be used if the Circular GREEN and GREEN ARROW always terminate together (i.e. Split Phasing).

Separate Signal Faces in a Protected-Only Operation:

- Signal indications for protected-only mode left turns in a separate signal face are required to be a 3 section signal face with RED ARROW, YELLOW ARROW, GREEN ARROW indications.

Shared Signal Faces in a Protected-Permissive Operation:

- A head with Circular RED, YELLOW, GREEN, as well as YELLOW ARROW, GREEN ARROW is required.
- Five-section signal faces mounted overhead must be centered over (or slightly right of) a projection of the lane line dividing the through lane and the turn lane.
- The circular indications must display the same color as the adjacent through indications.

Separate Signal Faces in a Protected-Permissive Operation:

- A four-section head with steady left-turn RED ARROW, steady left-turn YELLOW ARROW, flashing YELLOW ARROW and steady left-turn GREEN ARROW is required. As a practice, TxDOT does not currently use the dual arrow signal section.
- The flashing YELLOW ARROW indication is permitted to be displayed while adjacent through signals display a steady circular RED indication.
- The use of a RED ARROW is required to terminate a steady YELLOW ARROW. Past TxDOT practice to not use RED ARROW indications is now superseded by this new TMUTCD requirement.

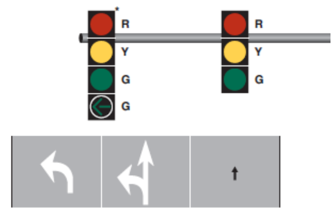
Shared Signal Faces in a Permissive-Only Operation:

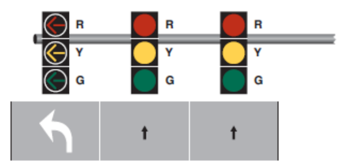
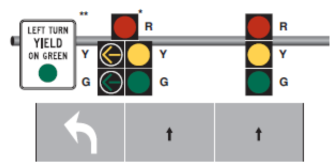
- A three-section head with Circular RED, Circular YELLOW, Circular GREEN is required.

Separate Signal Faces in a Permissive-Only Operation:

- A three-section head with RED ARROW, steady YELLOW ARROW, and flashing YELLOW ARROW is required.

Table 5-1: Left-Turn Signal Head Arrangements

<table>
<tr><th colspan="2">Signal Face Type</th><th colspan="3">Left-Turn Operation</th><th colspan="2" rowspan="2">Example of Minimum Required Signal Heads for Left-Turning Lanes (See TMUTCD Figure Referenced For Details)</th></tr>
<tr><th>Shared</th><th>Separate</th><th>Protected Only</th><th>Protected Permissive</th><th>Permissive Only</th></tr>
<tr><td>X</td><td></td><td>X</td><td></td><td></td><td>

All GREEN heads terminate together.</td><td>TMUTCD Figure 4D-9</td></tr>
<tr><td></td><td>X</td><td>X</td><td></td><td></td><td>
</td><td>TMUTCD Figure 4D-10</td></tr>
<tr><td>X</td><td></td><td></td><td>X</td><td></td><td>

Sign is Optional

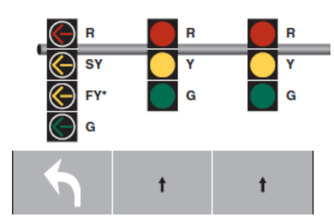
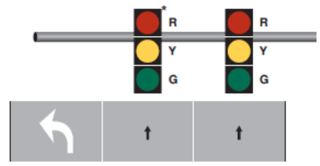
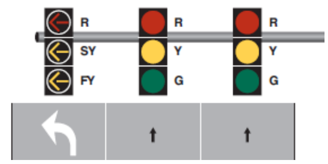

Horizontal Option</td><td>TMUTCD Figure 4D-11</td></tr>
<tr><td></td><td>X</td><td></td><td>X</td><td></td><td>
</td><td>TMUTCD Figure 4D-12</td></tr>
</table>

Table 5-1: Left-Turn Signal Head Arrangements

Signal Face Type		Left-Turn Operation			Example of Minimum Required Signal Heads for Left-Turning Lanes (See TMUTCD Figure Referenced For Details)	
Shared	**Separate**	**Protected Only**	**Protected Permissive**	**Permissive Only**		
X				X		TMUTCD Figure 4D-6
	X			X		TMUTCD Figure 4D-7

Engineering Study

An engineering study should be conducted to determine the appropriate left-turn signal control mode for signalized intersections. The study should consider left-turn volumes, crash history, 85th percentile (posted) speed, sight distance, number of left-turn lanes, number of opposing through lanes, pedestrian volumes, and opposing through volumes. Additionally, intersection geometry can affect the selection of the left-turn signal control mode. Intersections with wide medians, conflicting turning paths, non-standard alignments, etc., are also factors in determining left-turn signal mode.

There are many sources for determining left-turn control mode. Two flow charts obtained from recent research projects that may be used as an aid in determining the appropriate left-turn control mode are shown below.

- Figure 62: "Decision-Making Flowchart for Selecting Left-Turn Signal Control Mode," FHWA/TX-09/0-5840-1, *Development of Left-Turn Operations Guidelines at Signalized Intersections*, Authors: Lei Yu, Yi Qi, Hongxi Yu, Lei Guo and Xin Chen.
- Appendix A, Figure A-6. "Guidelines for Determining Left-Turn Operational Mode," FHWA/TX-11/0-6402-P1, *Traffic Signal Operations Handbook, Second Edition*. Authors: J. Bonneson, S. Sunkari, M. Pratt, and P. Songchitruksa.

Recommended Practice

Flashing Yellow Arrow (FYA) is an option for protected-permissive left-turn phasing. Careful consideration is needed in deciding where to install the FYA.

Some areas have existing FYA installations, while others have no experience with the display. Generally, implementation should consist of an initial pilot or demonstration project consisting of a few isolated intersections or a small section of corridor. The district should obtain local buy-in and approval, and provide press releases and information explaining where the FYA is being installed, what the FYA indications mean, how the motorists should interpret the indications, and why we are changing the existing set-up (the benefits).

Locations to consider for the pilot project installation of FYA protected-permissive left turns are typically sections of corridors with signalized intersections with the following characteristics:

- Low speeds
- 1 left-turn bay per approach
- 3 or less through lanes
- Low number of left-turn related crashes
- Adequate driver sight distance to oncoming vehicles
- Low left-turn volume during peak periods
- Low traffic volume
- Signal coordination plans indicate operational improvement with the FYA protected-permissive operation.

Locations with the following characteristics are discouraged for use in the pilot project installation of FYA protected-permissive left turns:

- Corridors with multiple signalized intersections in view using solid green ball for permissive phase
- High speeds
- Dual left-turn lanes
- 4 or more through lanes
- High left-turn crash history
- Poor sight distance to oncoming vehicles
- High left-turn volumes during peak periods, and/or
- High traffic volumes.

It is better to be consistent in the application of left-turn treatment along a corridor for driver expectation. That said, it may not be practical to install FYA left turns consistently along a corridor. FYA left-turn operation requires a separate left-turn signal face. If a corridor is equipped with shared signal faces it may need new signal poles installed with longer mast-arms to cover the left-turn lane. Thus, it may be cost prohibitive to convert to FYA left-turn operation.

Installing FYA protected-permissive mode at a location that previously operated in protected-only mode should be considered only after careful study of the intersection. One research study of locations that were converted from protected-only mode to FYA protected-permissive mode saw an increase in the crash frequency. Do not remove protected-only left-turn phasing if opposing sight distance is inadequate for permissive left turns, operating speed is too great, roadway geometry is complicated, or there are too many opposing through lanes. If the protected-only left turn was installed for other safety reasons (crash prevention when under less restrictive phasing), care should be used in operating a possible FYA protected-permissive installation.

Emergency Preemption

Installing protected-permissive FYA operation along emergency vehicle preemption routes requires special study and consideration. Work closely with emergency vehicles to provide the preemption operation that best fits their preference. Carefully consider whether to allow or terminate FYA for the opposing left during preemption. If the opposing FYA is to be turned off during preemption, the through phases will need to be terminated (go to all red) prior to dropping FYA for preemption.

For example, consider an intersection that is displaying Circular GREEN (for through) and FYA (left-turn lane) for both approaches of an arterial. Then, preemption activates to provide a protected through and left turn (Circular GREEN and GREEN ARROW dwell phase) to the approach for the emergency vehicle. From here, there are two possible states for the opposing left-turn FYA. It may continue to flash during the preemption dwell phase or it may be terminated. If it is decided to terminate the opposing left-turn FYA, then to go to all-red prior to displaying the dwell phase.

Variable Mode Operation

Variable mode operation is when signal operation changes between protected-only to protected-permissive mode, or between protected-permissive to permissive-only operation based on the time of day. It is possible with the 4-section FYA signal face when a study shows this type of operation to be beneficial. However, you must ensure that the controller is capable of switching between modes such that the flashing yellow arrow indication and the opposing through movement indication terminate together.

In other words, the controller should be capable of transitioning between modes without the flashing yellow arrow terminating while the opposing through movement stays green. Additionally, when switching between protected-permissive to permissive-only mode, ensure that the controller is capable of reassigning the left-turn detectors to call the associated through phases by time of day.

Public Notification

Installation of FYA left-turn operation should be coordinated with the District Public Information Office. Consider press releases with specific details on when the public can expect to see the new indications. Press releases should be prepared and sent out approximately two weeks or more in advance of conversion. Special attention should be given to the first installation in an area. If available, place portable changeable message signs in advance of the affected signals at least five days before the FYA activation date.

Equipment Issues

The majority of current TxDOT traffic signal equipment is compatible with FYA operation. TxDOT signal cabinets, as currently equipped, can be modified to perform FYA. Prior to installing or converting an intersection to FYA left-turn operations, it will be necessary to ensure that there is adequate field wiring, the signal controller cabinet has adequate channels (load switches), and the controller and Malfunction Management Unit (MMU) are capable of FYA operation. Configuration of the traffic signal cabinet may be dependent on several conditions at the intersection such as the controller requirements, the monitor requirements, the cabinet size and available load switches, and whether pedestrian signals are being utilized. Careful planning is required to ensure a successful installation.

Cabinet Modification

Controller manufacturers have standardized FYA operation, however, there may be older equipment that is not FYA compatible. Cabinet modification will depend on controller make and model. An MMU capable of FYA operation is required. If needed, install a new MMU recommended by the controller manufacturer. A modification to the cabinet flash programming is required. Contact the manufacturer representative or the TRF-TM Engineering Support Branch for assistance if needed.

Signing

While the 2011 *TMUTCD* does not require this signing, a "Left-Turn Signal - Yield on Flashing Arrow" (R10-17T) sign should be installed adjacent to the new head for clarification. If the FYA face is to be installed at an existing location with a 5-section face, verify the sign can be installed and ensure any conflicting signs, such as the "Left Turn Yield on Green" sign (R10-12), is removed if in place.

Observations

Signal observations should be performed periodically as discretely as possible, and particularly during the times where the phasing has changed from the previous installation. When converting left-turn signal operations to FYA protected-permissive, be sure to observe driver behavior, especially in cases where the intersection previously operated in a protected-only mode.

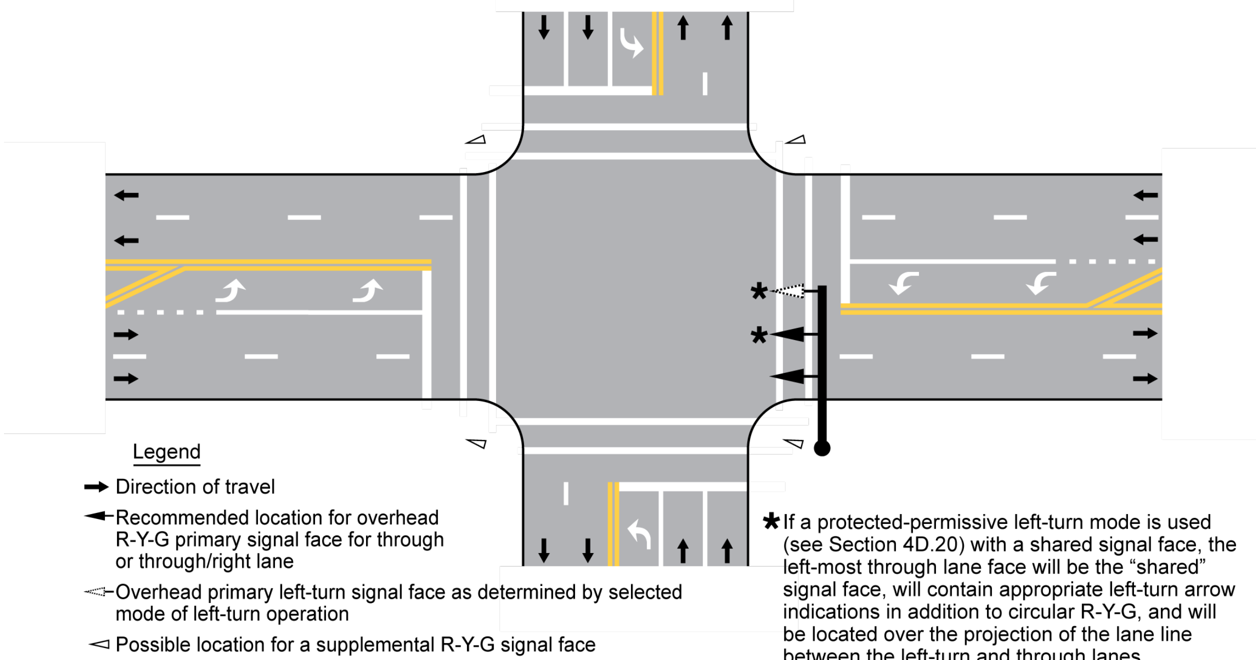
Crash Data

With the initial FYA installations in your area, monitor the crash data for at least one year after installation.

Other Considerations

The 2011 *TMUTCD* provides Figure 4D-3, "Recommended Vehicular Signal Faces for Approaches with Posted, Statutory, or 85th Percentile Speed of 45 mph or Higher," and 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” (Shown in Figures 5-2 and 5-3 below). Requirements from the table are a "should condition," The table should be consulted for minimum number and location of primary signal faces for through traffic.

Figure 4D-3. Recommended Vehicular Signal Faces for Approaches with Posted, Statutory, or 85th-Percentile Speed of 45 mph or Higher



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-2.
2. Any primary left-turn and/or right-turn signal faces, as determined by Sections 4D.17 through 4D.24, should be overhead for each exclusive 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 5-2. TMUTCD Figure 4D-3: “Recommended Vehicular Signal Faces for Approaches with Posted, Statutory, or 85th Percentile Speed of 45 mph or Higher”

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 Approach	Total Number of Primary Through Signal Faces for Approach*	Minimum Number of Overhead-Mounted Primary Through Signal Faces for 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.11). These recommended numbers of through signal faces may be exceeded. Also, see cone of vision requirements otherwise indicated in Section 4D.13.

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

Figure 5-3. TMUTCD 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"

References

- David A. Noyce, Casey R. Bergh, Jeremy R. Chapman, NCHRP Web Only Document, 123, *Evaluation of the Flashing Yellow Arrow Permissive-Only Left-Turn Indication Field Implementation*.
- Yi Qi, Xiaoming Chen, Lei Yu, Yubian Wang, Min Zhang, Peina Yuan and Khali R. Persad, FHWA/TX-09/0-6568-1, *Use of Flashing Yellow Operations to Improve Safety at Signals with Protected-Permissive Left Turn (PPLT) Operations*.
- 2011 *Texas Manual on Uniform Traffic Control Devices* (TMUTCD).

Section 7 — Pedestrian Hybrid Beacons

Introduction

The *2011 Texas Manual on Uniform Traffic Control Devices* (TMUTCD) includes the Pedestrian Hybrid Beacons (PHB) for use at marked crosswalks which are not managed by a traffic control device such as a traffic signal or stop signs.

A PHB is a pedestrian-activated warning device located on the roadside, or on mast arms over midblock pedestrian crossings. The beacon head consists of two red lenses above a single yellow lens. The beacon head is dark until the pedestrian wanting to cross the roadway presses the button and activates the beacons.

This device provides an additional tool for improving the safety of crosswalks when traffic signals do not meet warrants. PHB's should be used in conjunction with signs and pavement markings to warn and control traffic at locations where pedestrians enter or cross a street or highway.

Considerations

All of the following conditions must be met before PHB can be considered on our roadways:

- an engineering study must be performed and meet the guidelines detailed in Chapter 4F of the TMUTCD.
- an established crosswalk with adequate visibility, markings and signs.
- a posted speed limit of 40 mph or less (does not include school speed zones).
- 20 pedestrians or more crossing in one hour.
- location deemed as a high risk area (e.g. schools, shopping centers, etc.).
- crosswalk is more than 300 ft. from an existing, traffic controlled pedestrian crossing.

Districts must receive Traffic Safety Division (TRF) approval for installation of a PHB for each location.

You can reference Appendix A of NCHRP Report 562, “Guidelines for Pedestrian Crossing Treatments” for additional information on PHB.

If the proposed location meets the criteria listed above for a PHB, please submit to the Traffic Safety Division for approval.

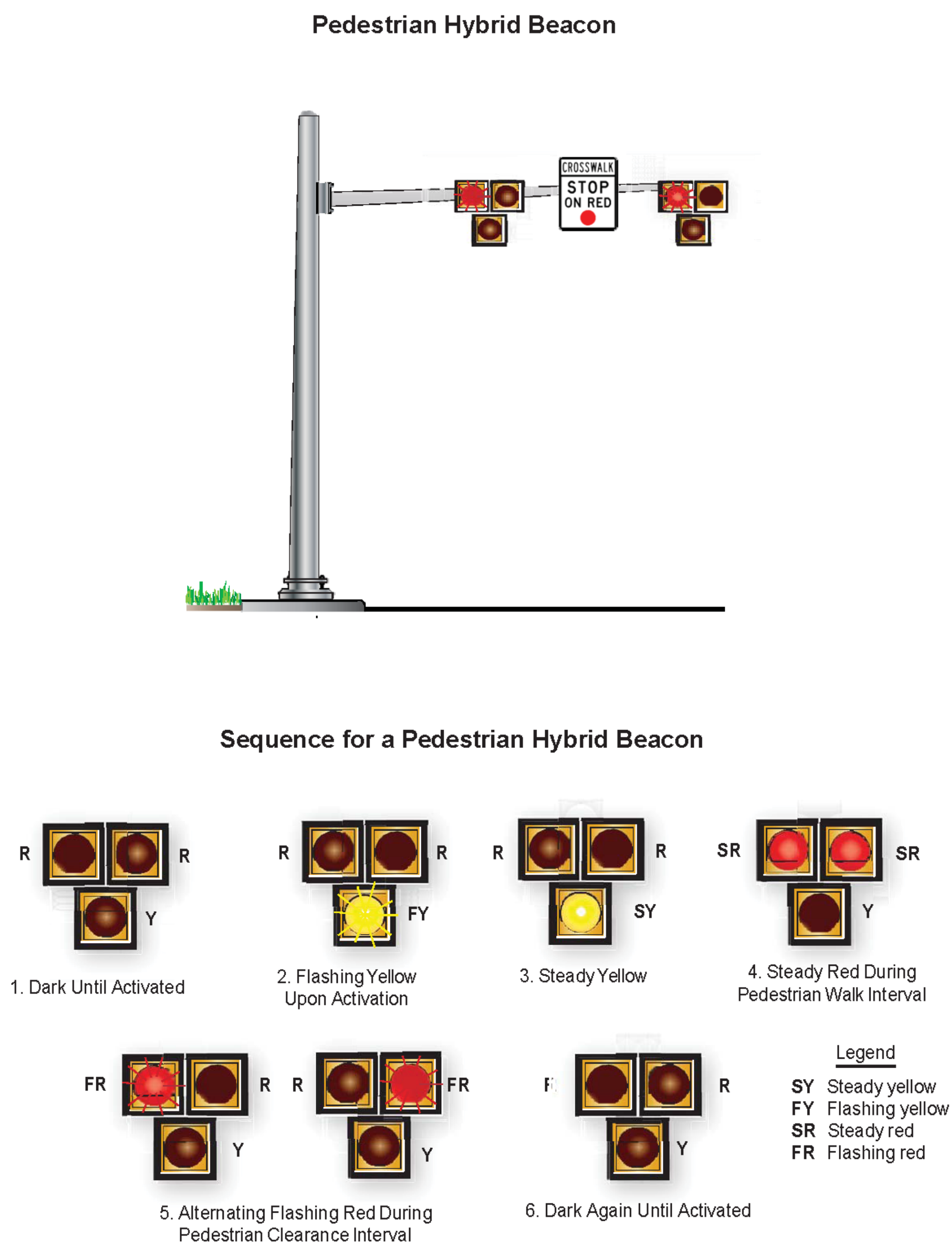


Figure 5-4. Sequence for a Pedestrian Hybrid Beacon

Appendix A — Forms

Introduction

This appendix lists the forms described in this manual. The forms can be found in the TxDOT eForms System accessible through Crossroads or the previous link.

List of Forms

The following table contains forms commonly used by TxDOT for planning and monitoring traffic signal operations.

Forms Pertaining to Traffic Signals

Form Name	eForms Link	# of Pgs.	Described in Chap.
Traffic Signal Authorization Form	TFF-TSAR	1	2, 5
Vehicle Volume Summary Sheet	TFF-VVS	1	3
Vehicle Volume Summary Sheet (for Five-way Intersection)	TFF-VVS5	1	3
Pedestrian Group Size Study/Pedestrian Delay Time Study	TFF-PGD	1	3
Traffic Survey – Count Analysis Form	TFF-TSCA	8	3
Pedestrian Volume Summary Sheet	TFF-PVS	1	3
Pedestrian Volume Summary Sheet (for Five-way Intersection)	TFF-PVS5	1	3
Intersection Delay Study Field Sheet	TFF-IDS	1	3
Guide for Determining Time Requirements for Traffic Signal Preemption at Highway-Rail Grade Crossings	Form 2304	4	4
Instructions for Guide for Determining Time Requirements for Traffic Signal Preemption at Highway-Rail Grade Crossings	Form 2304-I	20	4

Appendix B — Determination of Need for Traffic Control at School Crossings

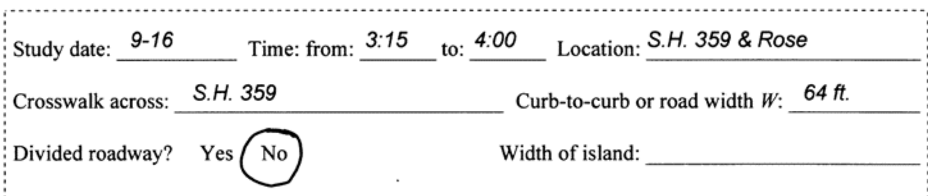
Introduction

The determination of need for traffic control at a school crossing involves a five step process. This appendix explains the five steps and provides example data and calculations for a hypothetical crossing.

The Pedestrian Group Size Study form and the Pedestrian Delay Time Study form provide a means of documenting the process (See Appendix A). Districts may also create their own forms for this purpose.

Be sure that the basic information concerning the time of the study and the location is recorded on the forms.

EXAMPLE:



Study date: 9-16 Time: from: 3:15 to: 4:00 Location: S.H. 359 & Rose

Crosswalk across: S.H. 359 Curb-to-curb or road width *W*: 64 ft.

Divided roadway? Yes (No) Width of island:

Figure B-1. Example basic information concerning time and location of study

Step 1. Pedestrian Count

Pedestrian counts should be made on a normal school day during the heaviest hours of crossing activity in the morning or afternoon — preferably both. A tabulation should be made of the number of children crossing the roadway and the time required for the group to cross. It is assumed that up to five pedestrians will walk abreast when a group crosses the roadway. The number of rows is determined by dividing the group size by five. Note that the number of rows is taken as a whole number, since even one pedestrian in excess of an even five will make an additional row, requiring extra clearance time.

EXAMPLE:

Time	Children Crossing	No. of Rows	Time	Children Crossing	No. of Rows	Time	Children Crossing	No. of Rows
3.15	1	1	3:46	10	2	4:00	1	1
3:17	1	1	3:47	8	2			
3:20	4	1	3:48	15	3			
3:21	5	1	3:49	15	3			
3:24	4	1	3:50	17	4			
3:28	1	1	3:51	7	2			
3:30	2	1	3:53	6	2			
3:34	4	1	3:55	3	1			
3:40	6	2	3:56	3	1			
3:45	4	1	3:58	2	1			

Figure B-2. Example pedestrian count

Step 2. Determination of the Number of Rows N

The total number of groups is found by adding up the number of groups that crossed the roadway. This number is then multiplied by 0.85 to obtain the 85 percentile cumulative number of groups (*C*). *C* is then compared to the CUMULATIVE column, where the cutoff point is chosen. The CUMULATIVE column cutoff point is the first number greater than or equal to *C*, as read from the bottom to the top in the column. At the cutoff point the 85 percentile number of rows *N* can be found in the NUMBER OF ROWS column.

EXAMPLE:

Group Size	No. of Rows	Number of Groups		Cumulative	Computations
		Tally	Total		
46–50	10				*C* = 21 × 0.85 = 17.85, which is the 85 percentile cumulative number of groups.
41–45	9				
36–40	8				
31–35	7				Since 17.85 is between 13 and 18, we choose 18 as the CUMULATIVE column cutoff point.
26–30	6				
21–25	5				
16–20	4	/	1	21	
11–15	3	//	2	20	Reading across the page gives the 85 percentile number of rows.
6–10	2 ◄	/////	5	18 ◄	
1–5	2	///// ///// ///	13	13	
		Total Number of Groups:	21		*N* = 2

Figure B-3. 3. Example determination of the number of rows N

Step 3. Determination of the Adequate Gap Time G

The adequate gap time *G* is determined from the equation:

$$G = \frac{W}{S} + P + 2(N - 1)$$

Where:

W is the curb-to-curb road width in feet.

N is the 85 percentile number of rows.

S is the average walking speed — assumed to be 3.5 ft./sec.

P is the average perception and reaction time — assumed to be 3.0 seconds

$2(N-1)$ is the pedestrian clearance time.

EXAMPLE:

$$G = \frac{W}{3.5} + 3 + 2(N - 1)$$

$$G = \frac{64}{3.5} + 3 + 2(2 - 1)$$

$$G = 18 + 3 + 2 = 23 \text{ seconds}$$

Step 4. Pedestrian Delay Time D

Pedestrian delay time is determined by recording the number of gaps with a gap size greater than or equal to the adequate gap time *G*. (The Pedestrian Delay Time Study form is designed for this purpose.) The number of gaps for a particular gap size is then multiplied by the gap size. Then the total time *t* of all gaps equal to or greater than *G* is found by adding up the product of the number of gaps and the gap size. The actual pedestrian delay time *D* is then found by the equation:

$$D = \frac{T - t}{T}(100)$$

Where *T* is the total survey time in seconds.

EXAMPLE:

Study date: *9-19* Location: *S.H.359 & Rose* Crosswalk across: *S.H.359*

End of survey (to nearest minute): *4:00 P.M.* 85th percentile rows — N: *2*

Start of survey (to nearest minute): *3:15 P.M.* Roadway width — W: *64 ft.*

Total survey time (minutes) — T: *45 min.* Adequate gap time — G: *23.3* secs.

Gap Size (seconds)	Number of Gaps: Field Study Data	Number of Gaps: Total	Multiply by Gap Size
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23	////	4	92
24	///// /	6	144
25	////	4	100
26	///// //	7	182
27	///	3	81
28	////	4	112
29	//	2	58
30	///	3	90
31	//	2	62
32			
33			
34			
35			
36			
37			
38			
39			
40			
41			
42			
43			
t (total time of all gaps equal to or greater than G) =			921 secs.

Computations

T = total survey time × 60

$$T = 45 \times 60$$

$$T = 2700 \text{ sec.}$$

$$D = \frac{T - t}{T}(100)$$

$$D = \frac{2700 - 921}{2700}(100)$$

$$D = 65.8\%$$

Figure B-4. Example determination of pedestrian delay time D

Step 5. Determination of Need for Traffic Control

Curb-to-curb width (*W*), pedestrian delay time (*D*), and the 85 percentile number of rows (*N*) can be plotted on a graph as shown in Figure B-5 to determine if control is needed.

EXAMPLE: The graph shown in Figure B-5 shows that a traffic signal could be justified in the hypothetical example, since point A is above the line N=2.

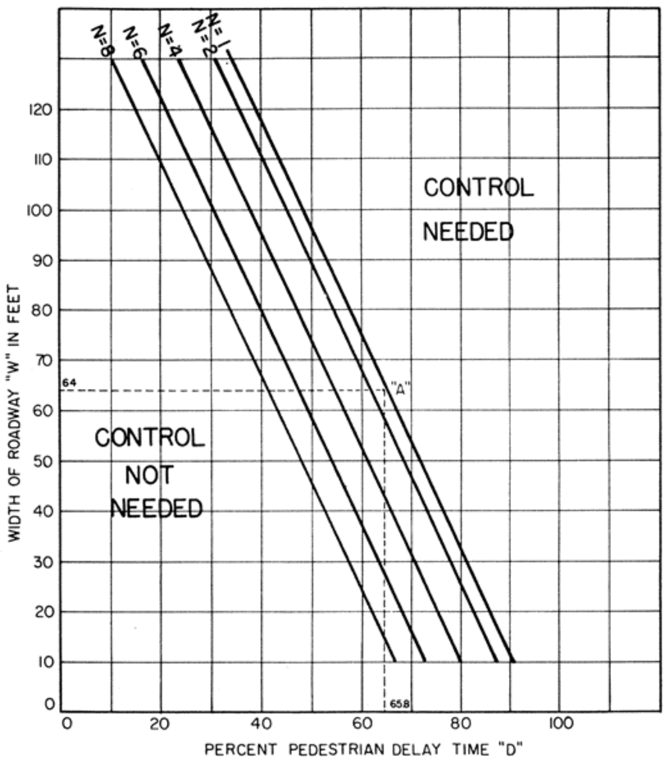


Figure B-5. Determination of need for traffic control at school crossings. Here a traffic signal could be justified, since point A is above the line N=2.

Appendix C — Intersection Prioritization Tool Worksheet

Intersection Prioritization Tool

The intersection prioritization tool provided below was recreated from National Cooperative Highway Research Program (NCHRP) 3-62 research. The worksheets are a product of NCHRP 3-62 and are published in the Transportation Research Record, Journal of the Transportation Research Board, No. 1982, pp.13-20, entitled, "Development of an Intersection Prioritization Tool for Accessible Pedestrian Signal Installation". The intersection prioritization tool consists of two worksheets.

- The **Intersection Worksheet** accounts for intersection characteristics and layout, signalization type, and location related to transit facilities, facilities for the visually impaired, and major pedestrian attractions.
- The **Crossing Worksheet** accounts for the individual crossing characteristics. Each crossing at the intersection is rated based on several factors including:
  - Crossing width
  - Speed limit
  - Geometrics
  - Pedestrian signal control
  - Vehicle signal control
  - Off-peak traffic presence
  - Availability of alternative APS
  - Requests for APS installation.

The prioritization tool provides a method of scoring individual crossings for relative crossing difficulty to visually impaired individuals. This provides a method to compare crossings for priority for installation of APS systems. In general, if one crossing generates a high priority, it would be desirable to provide APS for all crossings at the intersection.

Detailed instructions on the correct method for filling out and completing the worksheets are available on the internet at http://onlinepubs/nchrp/nchrp_w117a_appendix-d.pdf.

A print version of the prioritization tool worksheets is located on the following pages.

Intersection Prioritization Tool for Installation of Accessible Pedestrian Signals, adapted from NCHRP 3-62, 2006			
Intersection Worksheet			
Location:			
Sketch: See instructions for information to include. Label crosswalks as A,B,C,D, etc.	Configuration (select one)	Points	Score
	4-leg	**0**	
	4-leg offset	**3**	
	3-Leg (T or Y)	**3**	
	5 or more legs	**12**	
Indicate North	**Midblock location**	**14**	
	Signalization* (select one)**	Points	Score
	Pre-timed (non-actuated)	**0**	
	Actuated (semi or fully)	**2**	
	Split Phasing	**6**	
	Exclusive ped phase	**8**	
	Transit Facilities within a block (- 1/8 miles) of the intersection - all legs (select one)	Points	Score
	No Transit Facilities	**0**	
	Single bus route	**1**	
	Multiple bus routes	**3**	
	Transit mail/rail station	**5**	
	Distance to Facility for Visually Impaired (select one)	Points	Score
	> 2600 ft (~1/2 mile)	**0**	
	< 2600 ft (~1/2 mile)	**4**	
	< 1300 ft (~1/4 mile)	**6**	
	< 650 ft (~1/8 mile)	**8**	
	< 300 ft	**10**	
Other Intersection Level Issues			
	Distance to Major Pedestrian Attraction (select one)	Points	Score
	> 2600 ft (~1/2 mile)	**0**	
	< 2600 ft (~1/2 mile)	**2**	
	< 1300 ft (~1/4 mile)	**3**	
	< 650 ft (~1/8 mile)	**4**	
	< 300 ft	**5**	
	**** For intersections only. Signalized midblock locations are accounted for under Configuration***		
	***** Select the option with the highest point value that applies to the situation.***		
	Intersection Worksheet Score: (sum of scores on this page)		

Figure C-1. Intersection Priority Tool: Intersection Worksheet

Intersection Prioritization Tool for Installation of Accessible Pedestrian Signals, adapted from NCHRP 3-62, 2006

Crosswalk Worksheet

(Complete one sheet for each crossing)

Location:	Crosswalk Label:

Crossing Width (select one)	Points	Score
< 40 ft	0	
40 - 59 ft	1	
60 - 79 ft	2	
80 - 99 ft	3	
100 - 119 ft	4	
≥ 120 ft	5	

Speed Limit (select one)	Points	Score
< 20 mph	0	
25 mph	1	
30 mph	2	
35 mph	3	
40 mph	4	
≥ 45 mph	5	

Approach/crossing Geometrics (select all that apply)	Points	Score
Skewed crossing	7	
Curb radius > 25 ft (either coorner)	1	
Apex curb ramp (either corner)	2	
Channelized right turn island	2	
Islands or medians (painted, raised or cut-through)	1	
Transverse slope on crosswalk	1	

Pedestrian Signal Control (select all that apply)	Points	Score
Timed for crossing to median crossing island	8	
Push button actuation required for WALK signal	4	
Leading Pedestrian Interval (LPI) with parallel street green	8	
Non-concurrent WALK interval	4	

Vehicle Signal Control (select all that apply)	Points	Score
Protected right turn phase / right turn overlap (on parallel street)	7	
Leading protected left-turn phase (on parallel street)	3	
Right Turn-on-Red permitted (on parallel street)	2	
Channelized right turn lane under signal control	8	

Off peak Traffic Presence - at least 2 vehicles present on parallel street (select one)	Points	Score
Constant (> 90 percent of cycles)	1	
Heavy (70 - 80 percent)	2	
Moderate (50 - 60 percent)	3	
Light (30 - 40 percent)	4	
Occasional (< 30 percent)	5	
None (i.e., no throughlanes present to create surge noise - e.g. stem of T-intersection)	6	

Distance to Alternative APS Crossing (select one)	Points	Score
< 300 ft	0	
< 650 ft (~1/8 mile)	1	
< 1300 ft (~1/4 mile)	2	
< 2600 ft (~1/2 mile)	3	
≥ 2600 ft (~1/2 mile)	4	

Pedestrian Pushbutton Location - either corner (select all that apply)	Points	Score
Located > 10 ft from curb	3	
Located > 5 ft from the CW extd.	3	

Request for APS (select one)	Points	Score
No requests	0	
1 or more requests	6	

Other Crossing Level Issues

Crossing Worksheet Score: (score from this page)	
Intersection Worksheet Score: (score from the intersection form)	
Total Crossing Score: (add the two above scores)	

Figure C-2. Intersection Priority Tool: Crosswalk Worksheet