

Traffic Signals

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Ontario Traffic Manual

Foreword

The purpose of the Ontario Traffic Manual (OTM) is to provide information and guidance for transportation practitioners and to promote uniformity of treatment in the design, application and operation of traffic control devices and systems across Ontario. The objective is safe driving behaviour, achieved by a predictable roadway environment through the consistent, appropriate application of traffic control devices.

Further purposes of the OTM are to provide a set of guidelines consistent with the intent of the *Highway Traffic Act* (HTA) and to provide a basis for road authorities to generate or update their own guidelines and standards.

The OTM is made up of a number of Books, which are being generated over a period of time, and for which a process of continuous updating is planned. Through the updating process, it is proposed that the OTM will become more comprehensive and representative by including many traffic control devices and applications specific to municipal use. Some of the Books of the OTM are new, while others incorporate updated material from the Manual of Uniform Traffic Control Devices for Canada (MUTCDC¹⁶) and the King's Highway Guide Signing Policy Manual (KHGSPM).

The OTM incorporates current best practices in the Province of Ontario, and the Manual's primary users are traffic practitioners. The interpretations, recommendations and guidelines in the OTM are intended to provide an understanding of traffic

operations and they cover a broad range of traffic situations encountered in practice.

The interpretations and guidelines are based on many factors which may determine the specific design and operational effectiveness of traffic control systems. However, no manual can cover all contingencies or all cases encountered in the field. Therefore, field experience and knowledge of application are essential in deciding what to do in the absence of specific direction from the Manual itself and in overriding any recommendations in this Manual.

The traffic practitioner's fundamental responsibility is to exercise engineering judgment and experience on technical matters in the best interests of the public and workers. Guidelines are provided in the OTM to assist in making those judgments, but the guidelines should not be used as a substitute for judgment.

Design, application and operational guidelines and procedures should be used with judicious care and proper consideration of the prevailing circumstances. In some designs, applications, or operational features, the traffic practitioner's judgment is to meet or exceed a guideline while in others, a guideline might not be met for sound reasons, such as space availability, yet still produce a design or operation which may be judged to be safe. Every effort should be made to stay as close to the guidelines as possible in situations like these, and to document reasons for departures from them.

Custodial Office

Inquiries, suggestions or comments regarding the Ontario Traffic Manual may be directed to:

Ministry of Transportation, Traffic Office
301 St. Paul Street, 2nd Floor
St. Catharines, Ontario, Canada
L2R 7R4
Phone: (905) 704-2960
e-mail: otm@ontario.ca

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Consulting Team Members

Andrew Beal, CIMA+
Alireza Hadayeghi, CIMA+
Jared Neto, CIMA+
Hart Solomon, CIMA+

Technical Advisory Committee Members

Vereen Rattigan, Ministry of Transportation,
Kelly Schmid, Ministry of Transportation
Michael Pardo, Ministry of Transportation
Ousama Shebeeb, Ministry of Transportation

Tim Apostolopoulos, Ministry of Transportation
Debbie MacArthur, Ministry of Transportation
William Harrett, Ministry of Transportation
Michael Chan, Ministry of Transportation
Mike Barnet, City of Toronto
Jason Pires, City of Toronto
Chris Brinkmann, City of Ottawa
Jonathan Pach, City of Ottawa
Leslie Green, City of Mississauga
Zvonimir Miller, City of Mississauga
Mushfiquir Rahman, City of Hamilton
Kayla Dixon, City of Thunder Bay
Adam Webber, City of Greater Sudbury
John Soriano, Region of York
Antonino Spoleti, Region of Halton
Rebecca Caughey, Region of Peel
Steven Kemp, Region of Durham
Bob Henderson, Region of Waterloo
Heide Schlegl, Town of Milton / OTC
Shawna Boakes, IMSA Ontario
Mark Rankin, Vision Loss Rehabilitation
Canada
Kat Hamilton, CNIB

Desktop Publishing

Marisa Esther Torres Rodriguez
Gordon Bryant

Editor

Heather Crewe

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1. General Information

1.1 Introduction

In this Ontario Traffic Manual (OTM), Book 12 (Traffic Signals), the use of the terms “Traffic Control Signals” or “Traffic Signals” shall mean a reference to either a vehicular traffic control signal, a bicycle traffic control signal, a pedestrian signal or any combination of the three as required to control all road users at an intersection or a crossing.

Traffic control signals are intended to convey information to the road user. The objective of the information is to advise road users of traffic regulations in order to encourage compliance with the law, to warn of intersecting roadways or road hazards, and to provide the information necessary for the road user to safely navigate through the intersection. Simplification of the driving task through uniformity in the design and application of traffic control signals is necessary to accomplish these objectives.

If traffic control signals are not properly designed, installed and operated, they can interfere and distract from each other, become visually ineffective or lose their effectiveness through excessive use. Therefore, simplicity in design, care in placement and a high standard of maintenance is essential. An effective traffic control signal will attract attention, be legible and comprehensible and be appropriate to all road users’ needs.

A principal goal in the development of the OTMs is the achievement of uniformity throughout the province and compatibility with the rest of Canada and North America. Achievement of this goal requires that the manuals provide the user with the design and dimensions of devices and with

guidance in the preferred usage and methods of application.

OTM Book 12 is intended to provide some elementary instructions to beginners and to provide a reference for experienced persons for the design and operation of traffic control signals. The intent is to provide a recommended best practice guide. This is not to say that the recommended methods are the only methods, or necessarily the best methods for the specific set of traffic control signals under consideration, as many factors are involved.

Users should recognize that the planning, design, application and operation of traffic control signals is complex. No manual can provide all the required information, therefore, extensive knowledge and experience are required to be proficient in the field.

OTM Book 12 was first published in 2001 as a replacement for the Manual of Uniform Traffic Control Devices for Canada (MUTCDC¹⁶), Chapter on Traffic Signals. It was updated in 2007 and in 2012. This latest version of the manual includes updates that reflect recent changes in the industry, changes in legislation, and new material that is of interest to practitioners who design, operate and maintain traffic control signals in the Province of Ontario.

This version has incorporated the contents of OTM Book 12A (Bicycle Signals) as an additional Section instead of OTM Book 12A (Bicycle Signals) being a standalone book. The intent is that when designers are planning for and designing traffic control signals, bicycle considerations are an integrated part of the process as opposed to an afterthought.

Designers should use this Book in combination with OTM Book 18 (Cycling Facilities) to ensure signing, pavement markings and design and operational practice for bicycle signals are based on the most up-to-date information.

In addition to this new information, some of the suggested methodologies have been updated. The content also reflects new standards and guidelines available in the industry and emphasizes human factors criteria, where applicable. Links are provided to related information inside the manual and to outside sources of information available at the time of publication.

1.2 Sections In This Book

This manual is organized into six sections:

- **Section 1, General Information**, documents general information and basic signal concepts.
- **Section 2, Legal Requirements**, documents legal requirements pertaining to the application of the *Highway Traffic Act* (HTA), *The Accessibility for Ontarians with Disabilities Act* (AODA) and the Municipal Act. Acts can be found at (<http://www.e-laws.gov.on.ca>)
- **Section 3, Operational Practice**, documents guidelines and recommended practice for operational features.
- **Section 4, Planning and Justification**, documents guidelines and recommended practice for justifying the need for traffic signals.
- **Section 5, Design Practice**, documents guidelines and recommended practice for design concepts, philosophy and details.
- **Section 6, Bicycle Signals**, documents the following information:
 - Minimum green, amber and red clearance signal timings and how these may be altered to serve cyclists.

This is based on the understanding that cyclists are vehicles, but with different performance characteristics and needs.

- Options available for signal displays specific to cyclists and how to best differentiate these from motor vehicle signal heads, in terms of placement, size, shape and colour.
- Typical types of special phasing which may be used to manage bicycle traffic at a signalized crossing. Included are configurations for intersection and mid-block locations. Operational options include a range from no special bicycle control up to bicycle-exclusive phasing. Special discussions include Intersection Pedestrian Signals and contraflow locations.
- A range of criteria which may suggest when the use of bicycle-specific signals and phasing may be appropriate or beneficial. Criteria include traffic volumes/delay, collisions/ conflicts, planning, geometric, signal timing/ phasing or demographics/geographics.
- Types of detectors that can be employed to specifically detect the presence of bicycles and the required signing and pavement markings to accompany the detection equipment.

This manual refers to various publications produced by the Ministry of Transportation Ontario (MTO) and other agencies such as the Institute of Transportation Engineers (ITE), the International Municipal Signals Association (IMSA), the Transportation Association of Canada (TAC) and the Ontario Traffic Council (OTC). Links to secure and stable sites are provided in the PDF version.

This manual uses acronyms and, of necessity, some industry jargon. A glossary is provided in Appendix B.

Symbols used on layout drawings may be found in Ontario Provincial Standard Drawings¹⁸ Volume 4, Electrical Drawings, Division 2000.

1.3 Use of Terms in This Book

In Ontario, many aspects of traffic control signals are specified in law (for example, the meaning of specific signal indications). Others are based on standards intended to establish consistency throughout the province. Still other signal concepts are founded on recommendations established through experience. In this publication, specific terms are adopted to convey the differences between the sources of traffic control concepts. These terms and the corresponding meanings follow below.

“Legal Requirement(s)”, “Legally Required”, “Legal” and equivalent terms mean that the requirement is the law of Ontario as established under the *Highway Traffic Act*¹² (HTA) and its Regulations. The requirement is typically described by the use of “Shall” or “Must”. “Must” indicates that the requirements of the design or application of the device as described in this manual are mandatory.

“Interpretation” means the interpretations and emphasis of the legal requirements. The interpretations are not necessarily precise wording interpretations of the HTA¹² and Regulations. The interpretations are given in lay language and may include some industry jargon. The requirements are typically described by the use of “Shall”. “Shall” means the same as “Must”.

“Recommended Practice” suggests a consistent manner in which the legal requirements and interpretations are applied using the typical procedures and equipment in use in Ontario.

The recommended practices are not necessarily the only practices available based on the interpretation of the legal requirements or the selection of equipment or methods of operation. The recommendation is typically described by the use of “Should”. “Should” indicates that the action is advised (recommended but not mandatory).

“Guideline” suggests a method of practical application of the legal requirements and interpretations using the typical procedures and equipment and methods of operation in use in Ontario. The guidelines are meant to provide guidance to those in the traffic signal industry who may be unsure of the methods of application. A guideline has no legal connotation and several alternative methods of achieving the same result may be available. A guideline is typically described by the use of “May”. “May” indicates a permissive condition. No requirement for design or application is intended.

1.4 Functions of Traffic Control Signals

The function of a traffic control signal is to alternate the right-of-way between conflicting streams of vehicular traffic, or vehicular traffic and pedestrians crossing a roadway, with maximum safety and efficiency. Safety requires that the traffic control signals operate at the minimum hazard to all road users, including vehicle occupants, bicyclists and pedestrians. Maximum efficiency implies the minimum delay to traffic. Practitioners should consider both safety and efficiency when identifying elements of design or selecting operational practices. In some cases, decisions can result in a benefit to both safety and efficiency (such as properly timed clearance intervals). In other cases, greater efficiency may result in a reduction in safety and vice versa. For example, restricted left turns or a bicycle specific phase may reduce collision frequencies but increase delays.

The practice of installing traffic control signals for reasons other than right-of-way control has led to installations in some instances where justification is weak. In these cases, traffic waiting at a side road STOP sign may have a lower overall delay without a signal than would otherwise occur waiting for a signal change.

Unjustified traffic control signals can lead to excessive delay, increased use of fuel, increased air pollution, increased noise, motorist frustration, greater disobedience of the signals and the increased use of alternative routes in attempting to avoid these types of signals. Unjustified traffic control signals may alter the number and type of collisions. For example, traffic control signals installed at a location previously controlled by a STOP sign may reduce the number of right angle collisions but increase the number of rear-end collisions. Therefore, the installation of traffic control signals does not necessarily guarantee a reduction in collision frequency, though some signals can be justified on a safety basis only.

A traffic control signal is a control device rather than a safety device. Traffic control signals should not be used for traffic calming schemes, for limiting traffic volumes on specific routes, as speed control devices, as demand control devices, or for discouraging motorists, cyclists and pedestrians from using a specific route.

The justification for traffic signals for motorists and pedestrians should be based on studies and needs as outlined in Section 4 and for bicycles in Section 6.

1.5 Driver Needs and Limitations

Traffic control devices are intended to provide vital information to drivers and will be more effective if designed with driver needs and limitations in mind. In particular, consideration must be given to how drivers search the roadway, how driving demands

affect what drivers notice, and drivers' tendency to inattention in familiar or monotonous environments.

The visual field of the human eye is very large but only a small area of it allows accurate vision. This central area covers a cone of about two to four degrees, which is an area about the size of a quarter held at arm's length. In order to identify a target, one must look directly at it. When driving, the driver searches the roadway scene in a series of fixations, looking at successive objects of interest.

Studies of driver eye movements show that, while driving, fixations range from 1/10 second minimum up to two seconds or more. At 100 km/h, a driver moves 3 m during the shortest glance. During more complex tasks, like reading a guide sign, a driver can move up to 60 m or more during a single fixation. Thus, the number of fixations that can be made, and the number of objects that can be identified as a driver moves through a road section, is quite limited.

Where drivers look is mainly determined by the demands of the driving task. On curves, eye movement studies show that the number of glances a driver makes at the road to maintain lane position doubles. Time available for noticing or reading signs is reduced. At intersections, freeway interchanges, or merges, drivers also face increased visual search demands associated with noting other road users and have less time to devote to reading signs or noticing unusual roadway features. For this reason, standardization in location and design of traffic control devices is critical in assisting the driver to know where to direct his attention and when.

As environments continue to increase in complexity, the importance of effectively providing information to drivers continues to increase. The standards selected for the design and operation of traffic control signals need to

continually promote this effective communication to drivers.

1.6 Continuity of Operation

Unless power has been interrupted, or unusual or emergency conditions prevail at the intersection, a set of traffic signals should always operate with some active indications displayed to the road users. If activities are planned that involve the deactivation of the signal indications, control should be provided by a police officer.

When the traffic signal is to be taken out of service for an extended period of time, the signal heads should be removed or the signal indications covered in such a manner that they are no longer visible to motorists and/or pedestrians.

If some or all of the existing traffic signal heads need to be replaced or relocated due to a collision or reconstruction, an interim installation of temporary signal heads should be considered. It is necessary to maintain the proper and safe operation of the intersection. If the final repairs will take a considerable amount of time (e.g., longer than it is practical to keep a police officer on site), the interim installation should be considered as being required. The temporary signal heads must conform to the requirements for traffic control signals.

1.7 Traffic Signal Life Cycle Process Diagram

Many of the remaining sections of this book deal with traffic signals at the various stages of the justification, design, and operation life cycle. The detailed life cycle diagram shown in Figure 1 assists in understanding the interrelationship between the various stages. Broadly speaking, the stages include determining the need for signalization, establishing the necessary

and required operations, undertaking the design, identifying the ongoing operations and maintenance requirements, and even the possible decommissioning of a signal. Specific details of each process follow in the remaining sections of this manual.

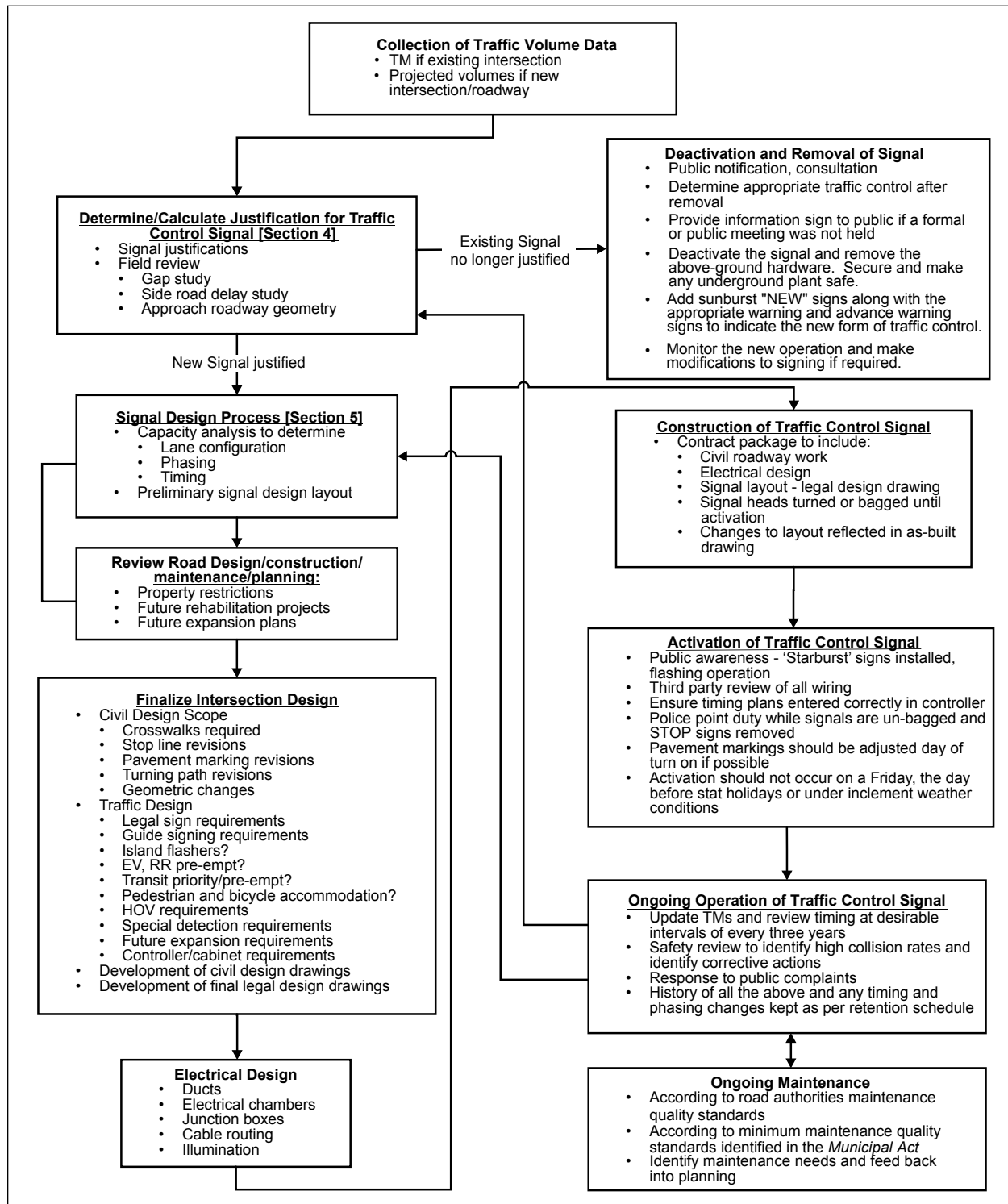


Figure 1 — Life Cycle Diagram

2. Legal Requirements

2.1 General

For the purpose of understanding the Regulations of the HTA, “Traffic Signal Control System” means the entire signalized intersection, which includes all electrical components, signs and pavement markings. The system also includes the “Traffic Control Signals”, which are the actual traffic signal heads.

Though legal counsel should be consulted on the statutes of the HTA, Section 2 provides an interpretation of various Sections and Regulations of [HTA](#)¹² associated with traffic control signal systems and traffic control signals.

These Sections include:

- Section 130 — Careless Driving
- Section 133 — Bicycle, Vehicle, Bicycle Traffic Control Signal, Traffic Control Signal, Traffic Control Signals System
- Section 144 — Yielding to Traffic, Approvals of Signal Designs, Obeying Lane Lights, White Vertical Bar, Riding in Crosswalks Prohibited, Flashing Green, Red Light Camera Offences
- Section 147 — Keeping to the Right
- Regulation 626 — Traffic Control Signal Systems.
- Section 146 — Portable Lane Control Signal Systems and Automated Flagger Assistance Devices
- Regulation 185/22 — Portable Traffic Control Systems

- Regulation 277/99 — Red Light Camera System Evidence
- Regulation 34/06 — Pre-empting Traffic Control Signal Devices
- Section 195 — Effect of By-Laws

Pedestrian facilities must be installed in accordance with the *Accessibility for Ontarians with Disabilities Act*, 2005, S.O., c. 119 (AODA) and associated Regulations¹.

Portions of the *Municipal Act* may be found useful in some circumstances. Those are detailed in this section as well.

2.2. Highway Traffic Act — Section 130

1. Legal Requirements

Section 130 of the HTA states:

Careless Driving

130(1) Every person is guilty of the offence of driving carelessly who drives a vehicle or streetcar on a highway without due care and attention or without reasonable consideration for other persons using the highway. 2017, c. 26, Sched. 4, s. 17.

Penalty

130(2) On conviction under subsection (1), a person is liable to a fine of not less than \$400 and not more than \$2,000 or to imprisonment for a term of not more than six months, or to both, and in addition his or her driver's licence or permit may be suspended for a period of not more than two years. 2017, c. 26, Sched. 4, s. 17.

Careless driving causing bodily harm or death

130(3) Every person is guilty of the offence of driving carelessly who drives a vehicle or streetcar on a highway without due care and attention or without reasonable consideration for other persons using the highway and who thereby causes bodily harm or death to any person. 2017, c. 26, Sched. 4, s. 17.

Penalty

130(4) On conviction under subsection (3), a person is liable to a fine of not less than \$2,000 and not more than \$50,000 or to imprisonment for a term of not more than two years, or to both, and in addition his or her driver's licence or permit may be suspended for a period of not more than five years. 2017, c. 26, Sched. 4, s. 17.

2. Interpretation

- i. Drivers and cyclists within an intersection or on a road section must ensure that they take specific action to ensure the safety of all other road users, including pedestrians.

2.3. Highway Traffic Act — Section 133

1. Legal Requirements

Section 133 of the HTA states:

This document refers to various terms and relies on their definitions as provided in the HTA. Specific terms defined in the HTA and used in this document include:

“Bicycle” includes a tricycle, a unicycle and a power assisted bicycle but does not include a motor-assisted bicycle; (“bicyclette”);

“Vehicle” includes a bicycle (emphasis added) and any vehicle drawn, propelled or driven by any kind of power, including muscular power;

“Bicycle Traffic Control Signal” means a traffic control signal where the coloured lenses each display a prescribed bicycle symbol; “Indication” means a signal lens display that is activated by internal illumination;

“Traffic Control Signal” means that part of a traffic control signal system that consists of one set of no less than three coloured lenses, red, amber and green, mounted on a frame and commonly referred to as a signal head and includes a bicycle traffic control signal;

“Traffic Control Signal System” means all of the signal equipment making up the installation at any location.

2. Interpretation

- i. A bicycle traffic control signal is a traffic signal head that contains as a minimum a red, an amber and a green lens each displaying a prescribed bicycle symbol when illuminated.
- ii. A traffic control signal is a signal head that can be any of the signal heads for vehicular traffic, pedestrian signals or bicycle signals that may be part of a traffic control signal system.
- iii. The minimum requirements specified in the HTA for traffic control signals also apply to bicycle traffic control signals unless a distinction is made specifically for bicycle traffic control signals.

2.4. Highway Traffic Act — Section 144

HTA Statute 144 (8) — Yielding to Traffic

1. Legal Requirements

Section 144 (8) of the HTA states:

Yielding to Traffic

When under this section a driver is permitted to proceed, he or she shall yield the right-of-way to traffic lawfully using an intersection or, where traffic control signals are erected where a private road or driveway meets a highway, lawfully using the area controlled by the traffic control signals. R.S.O. 1990, c. H.8, s. 144 (8); 2006, c. 19, Sched. T, s. 6 (3).

2. Interpretation

- i. Any road users facing a green signal indication must first yield the right-of-way to other users lawfully using an intersection, such as may have entered on a previous signal phase or during a signal clearance interval.
- ii. This implies that right or left turning vehicles must yield to oncoming bicycles and pedestrians travelling straight ahead.
- iii. A motorist must yield the right-of-way to any cyclist or pedestrian that may be within the confines of an intersection during the red signal indication who first legally entered it during the green or amber indications or a walk indication.
- iv. Turning vehicles must yield to straight through bicycles or pedestrians, such as parallel movements with a bike lane/bike track or crosswalks. Straight through motor vehicles must yield to bicycles or pedestrians that have been released earlier, such as from a bike box or a leading bicycle or pedestrian phase.

HTA Statute 144 (31) — Approvals of Signal Designs

1. Legal Requirements

Section 144 (31) of the HTA states:

(31) Subject to subsection (31.1), no traffic control signal system or traffic control signal used in conjunction with a traffic control signal system shall be erected or installed except in accordance with an approval obtained from a person designated to give such approvals by the Municipality or other authority that has jurisdiction over the highway or the intersection.

(31.1) No traffic control signal system or traffic control signal used in conjunction with a traffic control signal system shall be erected or installed on a highway designated as a connecting link under subsection 21(1) of the Public Transportation and Highway Improvement Act except in accordance with an approval obtained from the Minister or an official of the Ministry authorized by the Minister to grant such approval.

2. Interpretation

- i. All Road Authorities in Ontario are responsible for designating a person to approve traffic signal designs and installations on their own roadways.
- ii. The Ministry of Transportation is responsible for approving traffic signal designs and installations on connecting links.
- iii. For highways and ramp terminal intersections under Ministry jurisdiction but where the Ministry has entered into maintenance and operations agreements with Municipalities, the agreement will typically identify the party responsible for preparing any updated legal

drawings (PHM-125), however the Ministry is responsible for the approval.

- iv. If signal heads are relocated, additional signal heads installed, or roadway geometrics/lane configurations modified, the entire installation must be re-approved by the designated approval person(s).

3. Recommended Practice

- i. It is a recommended practice that all road authorities ensure that competent, qualified persons review the design for the traffic control signal system to ensure the design complies with applicable standards and guidelines, thereby optimizing the safety and operation of the signal and assisting in the protection of the road authority should a traffic collision or other mishap occur. In many cases, Municipalities have formally designated the positions responsible for the approval through Council resolutions (although this is not specifically required by law). It is recommended practice that the responsibility for approval should be granted to two people designated to authorize the signal design. It is also recommended that the signal design be represented as a drawing as this is the best way to represent head placements and aiming requirements that are consistent with HTA Regulation 626, this manual and the road authority's internal standards. This approval process is separate and distinct from the approval process for any electrical or civil engineering designs for a traffic signal system.
- ii. Where smaller Municipalities are undertaking traffic signal installations or modifications and do not have a person experienced with the work, it is strongly suggested that the Municipalities engage competent, qualified persons with experience and training who can design and/or certify the design before approval

by the designated persons of the Municipalities. These persons do not have to be an internal staff member.

- iii. As a minimum, it is a recommended practice that the traffic control signal system plans should be produced to a scale of 1:200, 1:250 or 1:500. The plans should show the intersection details on all approaches for the distance from the intersection that directly affects the signal operation (not less than 30m) and should indicate, to scale, the following (minimum) details:

- Edge of roadway (edge of pavement or curb and gutter), sidewalks, islands;
- Legal and lane designation signs;
- Property Access (driveways, curb cuts, ramps);
- Utility poles if signal attachments are required;
- The exact location, orientation and type of traffic signal heads and their mounting height;
- The exact location and orientation of pedestrian signal heads and pushbuttons;
- Geometrics;
- Pavement markings (centreline, lane lines, crosswalks, stop lines, turn arrows);
- Blank-out signs and active or continuous flashing advance warning signs or other types of equipment operated by the signal controller;
- Vehicle detection zones and their location (the type of detection device should be

noted in the legend with a symbol used to show where the detection device is installed at the intersection); and

- Signs relating to signal operation.
- iv. As a guideline, the following items may also be added to the plan at the option of the road authority:
- Location of traffic signal controller cabinet;
 - Property lines, street lines, building outlines, parking meters and parking control;
 - Bus bays and bus stops; or
 - Lane dimensions.
- v. It is recommended practice that approval plans should be prepared for both temporary and permanent signals.

HTA Statute 144 (10) — Obeying Lane Lights

1. Legal Requirements

Section 144 (10) of the HTA states:

Every driver shall obey every traffic control signal that applies to the lane that he or she is in and, for greater certainty, where both a traffic control signal that is not a bicycle traffic control signal and a bicycle traffic control signal apply to the same lane,

- (a) a person riding or operating a bicycle in that lane shall obey the bicycle traffic control signal; and*
- (b) a person driving a vehicle other than a bicycle in that lane shall obey the traffic control signal that is not a bicycle traffic control signal. 2015, c. 14, s. 40 (1).*

2. Interpretation

- i. Traffic signal indications may be configured to be given specific displays for individual or specific lanes. Where there are signals for specific users, the cyclists and general traffic drivers must obey the signals that are specific to their movements.
- ii. Where both a traffic control signal and a bicycle signal apply to the same lane, the driver of a vehicle shall obey the traffic control signal that applies to that lane and the cyclist shall obey the bicycle signal that applies to that lane.
- iii. This section allows for Leading Bicycle Intervals to be used.

3. Recommended Practice

- i. Bicycle-specific traffic signals should be used to give direction to designated bicycle lanes, cycle tracks, bicycle paths or multi-use trails and to specific movements for different types of vehicles.
- ii. For more details on the design and operation of bicycle signals refer to Section 6, Bicycle Signals.

HTA Statute 144 (19.1) — White Vertical Bar Indication

1. Legal Requirements

Section 144 (19.1) of the HTA states:

A driver operating a bus or streetcar on a scheduled transit authority route approaching a traffic control signal showing a white vertical bar indication may, with caution, proceed forward or turn right or left. 1994, c. 27, s. 138 (13).

2. Interpretation

- i. Transit signals apply to the lane(s) occupied by transit vehicles.
- ii. Transit signals must also conform to the standards set out in HTA Regulation 626.
- iii. The definition of a streetcar includes a Light Rail Transit Vehicle.

3. Recommended Practice

- i. It is strongly recommended that all transit operators be educated on the intended meaning of transit signals when the signals are first introduced on a jurisdiction's roadways.
- ii. Where a white vertical bar transit priority section is used, the total number of indications, including the transit section, should not exceed five.

HTA Statute 144 (29) — Riding in Crosswalks Prohibited

1. Legal Requirements

Section 144 (29) of the HTA states:

No person shall ride or operate a bicycle across a roadway within a crosswalk at an intersection or at a location, other than an intersection, which is controlled by a traffic control signal system.

2. Interpretation

- i. Riding a bicycle within the crosswalk at a full traffic signal or an intersection pedestrian signal is prohibited.

3. Recommended Practice

- i. Where a formal bicycle signal facility intersects with a traffic signal, such as at a mid-block

signalized path crossing or where a multi-use trail parallel to a sidewalk ("Boulevard Path") intersects at a full signal; one treatment is to erect "Dismount and Walk" signs and require the cyclist to become a pedestrian when using the crosswalk. The preferred alternative is to separate the pedestrian and the bicycle crossings by providing a crossride adjacent to the crosswalk. In order that this does not leave the bicycles without any form of protected crossing, this suggests the need for a form of traffic control for the bicycles and/or the parallel traffic whenever crossing volumes are significant.

- ii. If no crossride exists, riding on either side of the crosswalk is acceptable.
- iii. For more details on the use of crossrides, refer to Section 6, Bicycle Signals

HTA Statute 144 (13) — Flashing Green

1. Legal Requirements

Section 144 (13) of the HTA states:

A driver approaching a traffic control signal showing a circular flashing green indication or a solid or flashing left turn green arrow indication in conjunction with a circular green indication and facing the indication may, despite subsection 141 (5), proceed forward or turn left or right unless otherwise directed. (R.S.O. 1990, c. H.8, s. 144 (13))

2. Interpretation

- i. The circular flashing green indication has been used to provide a separate advanced left turn phase to represent the protected portion of a protected/permissive phase in a single direction only.

- ii. The protected portion of the protected/ permissive left turn phase may also be provided using a solid or flashing arrow in conjunction with a green ball.

3. Recommended Practice

- i. Ontario is one of only a few users of the circular flashing advanced green in North America and its use may cause some confusion for unfamiliar motorists. In the future, the *Highway Traffic Act* will no longer recognize the flashing green indication as a valid display. At this time, the flashing green ball display is no longer a recommended practice and any jurisdictions still operating flashing green ball indications should have plans to remove them or replace them with left turn arrow indications.
- ii. The flashing green arrow indication is a permissible display in Ontario as long as it is for a single direction of travel and not for back-to-back left turns. However, if the flashing green ball indication was in use at a site, consideration should be given to the use of the solid green arrow to provide a period of time as a transition period. Also, during the phase out period, it is strongly recommended that a flashing green arrow not be used in the proximity of intersections with circular flashing advanced greens since drivers may be confused by the different displays.

HTA Statute 144 (18.6) — Purpose of subsections related to Red Light Camera Offenses

1. Legal Requirements

Section 144 (18.6) of the HTA states:

The purpose of subsections (18.1) to (18.5) is to facilitate the use of computer systems that are maintained by the Government of Ontario for recording and processing information related to

provincial offenses and that depend, in order to make certain distinctions, on different provision numbers being specified in certificates of offenses.

2. Interpretation

- i. Subsections (18.1) to (18.5) allow for a driver or a vehicle owner to be charged with failing to stop at a red light through the use of a red light camera system.
- ii. For offense notices where evidence from a red light camera system is used, the offense notice should identify contravention of subsection 18.1 if the person being issued the offense notice is the owner of the vehicle.
- iii. For offense notices where evidence from a red light camera system is used, the offense notice should identify contravention of subsection 18.2 if the person being issued the offense notice is the driver of the vehicle.

3. Recommended Practice

- i. It is recommended that any road authority that is using red light camera enforcement systems ensure that the correct subsections of the HTA are referenced.

2.5 HTA Statute 79.1 (1) — Pre-empting Traffic Control Signal Devices Prohibited

1. Legal Requirements

Section 79.1 (1) of the HTA states:

No person shall drive on a highway a motor vehicle that is equipped with, carries, contains or has attached to it a pre-empting traffic control signal device.

2. Interpretation

- i Only vehicles that are specially identified in Regulation 34/06 of the *Highway Traffic Act* may use or have a traffic signal pre-empting device mounted on or located in them.

2.6 HTA Statute 147 — Keeping to the Right

1. Legal Requirements

Section 147 of the HTA states:

Slow vehicles to travel on right side

147(1) Any vehicle travelling upon a roadway at less than the normal speed of traffic at that time and place shall, where practicable, be driven in the right-hand lane then available for traffic or as close as practicable to the right hand curb or edge of the roadway. R.S.O. 1990, c. H.8, s. 147 (1).

Exception

147(2) Subsection (1) does not apply to a driver of a,

- (a) vehicle while overtaking and passing another vehicle proceeding in the same direction;
- (b) vehicle while preparing for a left turn at an intersection or into a private road or driveway;
- (c) road service vehicle; or
- (d) bicycle in a lane designated under subsection 153 (2) for travel in the opposite direction of traffic. R.S.O. 1990, c. H.8, s. 147 (2); 2015, c. 14, s. 41.

2. Interpretation

- i. Contraflow bicycle lanes are specifically recognized and enabled in the HTA.
- ii. Single or bi-directional contraflow bicycle lanes are one option for maintaining good continuity in a bicycle network.

2.7 Regulation 626

HTA Regulation 626 Sub-section 1. (1) — Minimum Signal Head Requirements

1. Legal Requirements

Sub-section 1. (1) states:

Every traffic control signal shall consist of one circular amber and one circular red indication in combination with,

- (a) a circular green indication;
- (b) a circular green indication and one or more green arrow indications;
- (c) a circular green indication, one or more green arrow indications and one or more amber arrow indications; or
- (d) one or more green arrow indications.

2. Interpretation

- i. Every traffic control signal must have a mandatory circular red and circular amber indication.
- ii. Every traffic control signal head must have a mandatory green indication.
- iii. The green indication may be composed of a single circular green or a maximum of three

green arrows, indicating only right, left and through traffic movements.

- iv. Every circular green indication must have a circular amber indication to indicate that the green interval has ended.
- v. Where the green indication consists of either left, right or through arrows, or any proper combination thereof, shown concurrently with a circular green (for example, with type 10 or 10A heads as per Figure 2), then the arrows indicate single protected movements that are active at the same time as the circular green (and not independently active), and one circular amber indication only shall be used.

3. Recommended Practice

- i. For reasons of simplicity and physical constraints and to increase their effectiveness, it is a recommended practice that no more than five indications should be combined in one signal head.
- ii. Where a circular green indication is displayed (indicating that all traffic movements are allowed, i.e., a “permissive” display), only one additional green arrow indication may be displayed in the same signal head at the same time to indicate that either left or right turns, specifically in one direction only, are “protected” from interference from a conflicting traffic movement. When such an operation is used, care should be taken that the protected green arrows do not conflict with concurrent pedestrian movements.
- iii. Where both a circular green and a left green arrow indication are used to allow protected/permissive movements during a single direction left turn, the circular amber indication operates in conjunction with the circular green indication. An amber arrow is recommended to act in conjunction with the green arrow to indicate

that the protected portion of the left turn phase is terminating and to be consistent with the requirements for simultaneous protected/permissive left turns as given under HTA Subsection 1.¹² Where provided, the left turn amber arrow may consist of either a single arrow that changes from green to amber (type 9 and 9A heads) or a separate amber arrow mounted above the green arrow (type 8 and 8A heads).

- iv. The standard indications shown in Figure 2 are the only configurations that should be allowed to be installed in the majority of circumstances so that the burden of interpretation is not on the motorist. In unusual conditions, it may sometimes be required to use a non-standard signal head that is not shown in Figure 2. This should be done only under the supervision and approval of a very senior and fully experienced traffic engineer/analyst and with the approval of the road authority.
- v. Lens sizes may be either 200 mm or 300 mm for solid green and amber circular displays in any of the signal heads given in Figure 2. All arrow lenses and all circular red lenses, except the red lens for the “standard” signal head, should be 300 mm diameter.

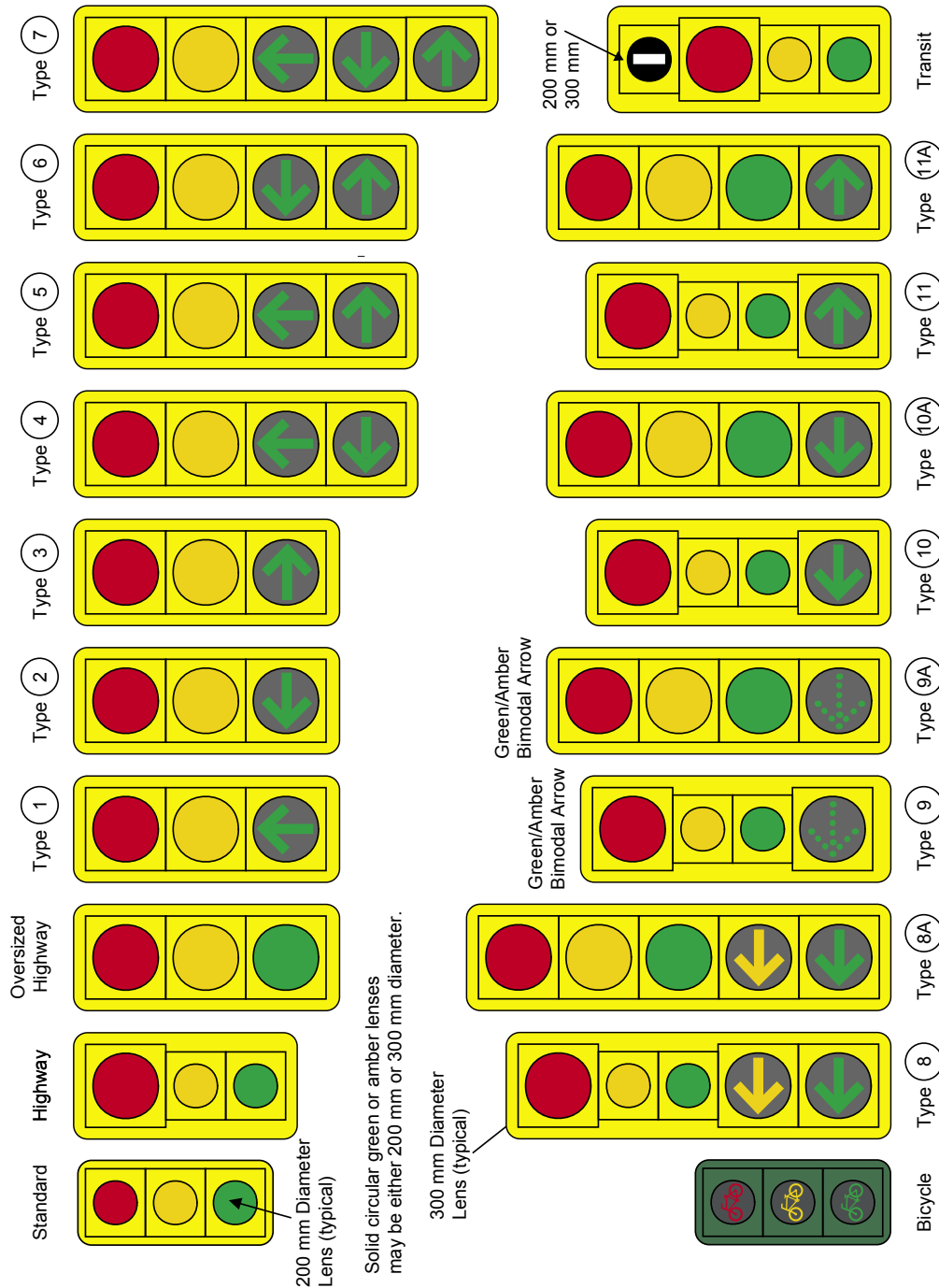
HTA Regulation 626 Sub-section 1. (2) – Vertical Order of Signal Indications

1. Legal Requirements

Sub-section 1. (2) states:

Green arrow, amber arrow, circular green, circular amber, circular red and white vertical bar indications may be used for traffic control signals and where they are used, they shall be arranged vertically from the bottom as follows: right turn green arrow, right turn amber arrow, left turn green arrow, left turn amber arrow, straight through green

Figure 2 — Traffic Control Signal Heads



Note 1: All signal heads displayed in this figure are shown with backboards, as backboards are recommended to improve signal head conspicuity. However, special conditions may exist where backboards are not installed, such as for bicycle signals or transit signals mounted close together where there is a need to distinguish them from vehicular heads.

Note 2: The signal heads shown in this figure are the most commonly used in Ontario. Some signal operations such as Leading Pedestrian Intervals (LPI's) or transit operations may require a variation of the signal heads shown. When using signal heads not shown in this figure, care should be taken to ensure they comply with the signal head requirements described in HTA Regulation 626.

arrow, circular green, circular amber, circular red and white vertical bar. O. Reg. 65/96, s. 1.

2. Interpretation

- i. Whether combined in one unit or mounted as connected sections, the relative vertical locations, from top to bottom, of the various indications must be as specified in Table 1.

3. Recommended Practice

- i. For reasons of simplicity and physical constraints and to increase their effectiveness, it is a recommended practice that no more than five indications be combined in one signal head.
- ii. Figure 2 shows the only types of traffic signal head configurations that should be used to maintain uniformity in Ontario (with the exception of lens size which may be either 200

mm or 300 mm for circular lenses). Exceptions to the types of heads shown should only be used where authorized by a senior and experienced traffic engineer/analyst and with the approval of the road authority.

- iii. Where a white vertical bar transit priority section is used, the total number of indications, including the transit section, should not exceed five.

HTA Regulation 626 Sub-section 1. (3) — Use of Circular Signal Indications

1. Legal Requirements

Sub-section 1. (3) states:

No traffic control signal system shall be operated so as to show more than one circular indication simultaneously on the same traffic control signal.

Table 1 — Relative Vertical Positions of Signal Indications

Signal Indication	Comment
White Vertical Bar	Transit Priority Only
Red	Mandatory
Amber	Mandatory
Green	Notes 1 and 3 below
Amber Arrow	Note 2 below
Straight Through Green Arrow	Note 3 below
Left Turn Green Arrow	Note 3 below
Right Turn Green Arrow	Note 3 below

Notes:

1. The circular green indication may be replaced by a straight through, left turn, or right turn green arrow where indicated.
2. The amber arrow direction must be the same as that of the green arrow that precedes it.
3. A green indication, either a circular green or a green arrow, is mandatory on a signal head.

2. Interpretation

- i. One circular indication only (green or amber or red) must be shown if no green or amber arrows are active.
- ii. A red indication must not be displayed at the same time as a circular amber or circular green indication but may be displayed at the same time as any arrow indication(s) on heads which also have a circular green.

3. Recommended Practice

- i. In practice, a circular amber indication is displayed immediately after the time of de-energization of a circular green indication (or green arrow indication where a circular green does not exist as in Figure 2, signal head types 1 to 7) such that both the amber and green are not illuminated at the same time.
- ii. Similarly, a circular red indication is always displayed immediately after a circular amber indication, but a circular red or green may be displayed after an amber arrow (Figure 2, signal head types 8, 8A, 9, 9A).

HTA Regulation 626 Sub-section 1. (4) — Two Signal Heads Required

1. Legal Requirements

Sub-section 1. (4) states:

Every traffic control signal system that is installed shall have at least two traffic control signals located on the far side of the intersection from which vehicles are approaching, at least one of which shall be located on the far-right side. O. Reg. 65/96, s. 2.

2. Interpretation

- i. Every traffic approach to an intersection requires that two signal heads must face

oncoming traffic from the far side of the intersection. The “Far Side” of the intersection is the half or side of the intersection that is across the intersecting roadway from the traffic approaching the signals.

- i. At least one signal head must be mounted at the far-right hand side of the intersection quadrant or in an equivalent location on the far-right side if there is no intersecting roadway on that side of the intersection.
- iii. Partial signalization or signalization of less than all of the traffic approaches of an intersection shall not be permitted except for Intersection Pedestrian Signals.

3. Recommended Practice

- i. The signal head on the far-right side is designated as the “Primary” signal head. The signal head on the left of the primary head is designated as the “Secondary” signal head. A signal head installed in addition to the primary and secondary signal heads is for the purposes of aiding in signal visibility and is termed an “Auxiliary” signal head.
- ii. Auxiliary signal heads shall display the same indications at the same times as the primary and secondary heads. If signal head indications are timed differently, they must be on a separate phase from the primary and secondary heads.
- iii. Two separate signal heads shall be provided for any fully protected phase, such as a left turn operation facing type 2 signal heads, a bicycle phase, or a phase that represents the only opportunity for traffic to be served during a cycle (i.e., a fully protected right turn movement facing type 3 signal heads). In the case of the fully protected left turn operation, the type 2 head on the traffic island is the primary signal and the type 2 signal head on the far-left side

of the intersection fulfills the need for the secondary signal head.

- iv. It is recommended that primary and secondary signal heads be installed on separate poles so as not to lose all signal heads controlling an approach in the case of a pole knockdown. Having a primary signal head on the far-right and a secondary signal head on the far-left side of the intersection is also a good practice from a human factors perspective to help guide drivers in poor visibility conditions.
- v. At “T” intersections of publicly owned roadways, any public-use driveway opposite the terminating roadway should be treated as a highway for the purposes of traffic control signals. This indicates that driveways to commercial establishments open to the public that front onto an intersection, such as schools, churches, and community centres, should be signalized normally.
- vi. Private driveways that front onto an intersection may be provided with traffic control signals. In most instances, it is not necessary to provide traffic signal indications for single-family dwellings or where there is no general public access.
- vii. A protected/permissive left turn operation facing type 8, 8A, 9, 9A, 10 or 10A signal heads mounted in the median traffic island must not utilize four signal heads on the same side of the intersection to ensure the orientation of the heads is distinct from a fully protected type of left operation. A maximum of three heads are permitted, and a minimum of one or a maximum of two of the three heads must display the left turn arrow. The protected/permissive type of operation is intended to protect left turning traffic by operation of a green left arrow when opposing traffic is stopped followed by a circular green indication that permits traffic to proceed through the intersection, turn left when

the opposing traffic allows for a suitable gap or turn right when the intersecting roadway is clear of pedestrian traffic.

HTA Regulation 626 Sub-section 1. (4.1) — Intersection Pedestrian Signals

1. Legal Requirements

Sub-section 1. (4.1) states:

Despite subsection (4), a traffic control signal system installed at a crosswalk at an intersection for the purpose of assisting pedestrians to cross the roadway shall have

- (a) at least two traffic control signals facing the directions from which vehicles on the roadway approach the crossing; and*
- (b) at least one STOP sign facing vehicles approaching the intersection from the other intersecting roadway. O. Reg. 65/96, s. 2.*

2. Interpretation

- i. This subsection allows the use of Intersection Pedestrian Signals (IPS) in Ontario.
- ii. For the roadway being signalized, two signal heads must face approaching traffic in each direction. The signal heads shall be conventional “Standard” or “Highway” signal heads as no turns are to be signalized, although a Transit Priority signal head may be used for turning buses.
- iii. The other roadway is always controlled with STOP sign(s).

3. Recommended Practice

- i. IPS are intended for use as an alternative to Pedestrian Crossovers (PXOs). The decision to choose a PXO or an IPS should be based on factors such as pedestrian volumes, pedestrian

types (young and seniors), consistency with other traffic control devices in the area, the road authority's policy, and/or roadway/intersection geometry.

- ii. Conventional pedestrian heads are required to cross the main roadway as there are no other signal indications facing either direction along the crosswalk.
- iii. In Ontario it is recommended that the IPS should be restricted to a single crosswalk at any intersection. The opposite side of the intersection requires a pedestrian crossing prohibition sign. (The MUTCDC¹⁶ indicates the use of two crosswalks crossing the main road and this type of IPS is used in some parts of Canada.)

HTA Regulation 626 Sub-section 1. (5) — Height of Signal Heads

1. Legal Requirements

Sub-section 1. (5) states:

Traffic control signals, where installed, shall not be less than 2.75 meters above the level of the roadway when adjacent to the travelled portion of the roadway and not less than 4.5 meters above the level of the roadway when suspended over the travelled portion of the roadway.

2. Interpretation

- i. Signal heads shall not be mounted at a height of less than 2.75 m from finished grade to the bottom of the signal head or backboard (clearance point).
- ii. All signal heads mounted over the lanes of a roadway, the flare areas of intersections, ramps or any other area normally travelled by vehicles must be mounted at not less than 4.5 m from finished grade to the bottom of the signal head or backboard (clearance point).

- iii. It is permissible to mount signal heads higher than the minimum heights given, as long as the height is practical for viewing by motorists.

3. Recommended Practice

- i. The recommended practice for mounting of any signal heads over traffic lanes is 5.0 m height, with 5.8 m recommended for span-wire mounted signal heads. It has been found by experience that signal heads mounted at the 4.5 m minimum height sometimes interfere with over-height trucks, loose truck tarpaulins or similar objects and are then damaged. Further, span-wire mounted signals with 8-pole rather than 4-pole configurations may be considered so that the entire assembly is not damaged in the event of a vehicle colliding with a pole.
- ii. Primary heads should be mounted at a minimum height of 4.5 m or higher and desirably at a height of 5.0 m regardless of roadway posted speed.
- iii. Secondary heads, where mounted on the far-left and not over traffic lanes, may be mounted at a minimum height of 2.75 m or higher, and desirably at a height of 5.0 m so that they may be seen from a distance over the tops of vehicles. Intermediate mounting heights between 2.75 m and 5.0 m are useful for improving visibility in congested urban areas where it may be difficult to otherwise keep the secondary heads from being masked by the opposing primary heads. For roads with a posted speed of 80 km/h and over, all secondary heads should be mounted at least at the 5.0 m clearance height.
- iv. Auxiliary heads may be mounted at a height of 2.75 m or as high as necessary to obtain good visibility. The desirable height in most cases is still 5.0 m. Auxiliary heads mounted at the far-left of the intersection at various heights are normally used to provide better visibility where

the left turn lane is often blocked by large vehicles.

HTA Regulation 626 Sub-section 1. (6) — Ramp Metering Signals

1. Legal Requirements

Sub-section 1. (6) states:

Notwithstanding subsection (5), where a traffic control signal system is installed at a freeway entrance ramp as a part of a traffic management system,

- (a) one traffic control signal shall be located to the left side of the roadway not less than one meter above the level of the roadway; and*
- (b) one traffic control signal shall be located to the right side of the roadway, not less than 2.75 meters above the level of the roadway.*

2. Interpretation

- i. The low-mounted signal head referred to in (a) is required because the stop line is very near to the signal head, and it is necessary that drivers can readily see the head as the metering is accomplished by allowing only one vehicle per lane per green indication through the location.
- ii. The primary or right-hand signal head is to be mounted at not less than 2.75 m to give continuity with normal traffic control signals and to allow for reasonable visibility on approach.

3. Recommended Practice

- i. This subsection refers to special “Ramp Metering” signals used on some freeways to control the number of vehicles per hour entering the main freeway traffic. The recommended practices and guidelines for

normal traffic control signals do not apply to these special signals because the approach speed is very low, and because the signals are predominantly used in “Rush Hour” to meter or gate the volumes of traffic, not to allow right-of-way to other vehicles at an intersection.

HTA Regulation 626 Sub-section 1. (7) — Don’t Walk Signals

1. Legal Requirements

Sub-section 1. (7) states:

A symbol ‘don’t walk’ pedestrian control indication shall:

- (a) be rectangular in shape and shall not be less than 30 centimeters in height or width; and*
- (b) consist of an orange silhouette of a hand on an opaque background as illustrated in Figure 3.*

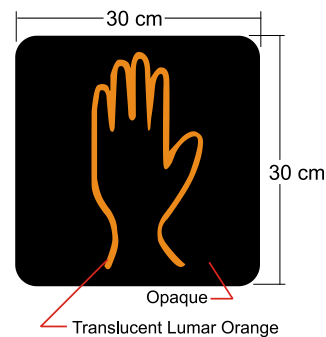


Figure 3 — Don’t Walk Signal

2. Interpretation

- i. Previous iterations of the pedestrian control signal displaying the words “DONT WALK” must not be used.
- ii. The colour of the “Hand” shall be orange (not red as per international practice) and the hand shall present an outline figure.
- iii. “Opaque” shall mean black or non-light-emitting.

3. Recommended Practice

- i. Minimum 300 x 300 mm pedestrian control heads should be used.
- ii. Light sources for pedestrian control indications must meet the colour requirements of ITE Publication ST—055-E.
- iii. The shape of the orange hand shall conform to the figures provided in the HTA Regulation 626 Sub-section 1 to the satisfaction of the road authority.
- iv. The pedestrian control signal shall be mounted at a minimum height of 2.75 m or higher from finished grade to the bottom of the housing (clearance distance) if in a single housing, or at a minimum height of 2.75 m from finished grade to the bottom of the “Walk” section of the head where used independently or as part of a two-section “Pedestrian Head”.
- v. Pedestrian control indications shall be mounted so as to be visible along the crosswalk from the opposite side of the roadway at an intersection and shall not be mounted over the travelled portions of roads.
- vi. The orange hand (“Don’t Walk”) or flashing orange hand (Pedestrian Clearance Interval)

must not be displayed at any time during which the walking man (“Walk”) signal is displayed.

HTA Regulation 626 Sub-section 1. (8) — Walk Signals

1. Legal Requirements

Sub-section 1. (8) states:

A symbol ‘Walk’ pedestrian control indication shall be rectangular in shape and shall not be less than thirty centimeters in height or width and shall consist of,

(a) in the case of a lens that cannot provide a solid symbol, an outlined symbol of a walking pedestrian in lunar white on an opaque background as illustrated in Figure 4; or

(b) in the case of a lens that can provide a solid symbol, a solid symbol of a walking pedestrian in lunar white on an opaque background as illustrated in Figure 4. O. Reg. 213/92, s. 1(1).

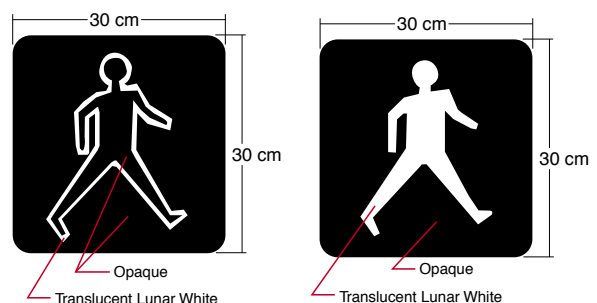


Figure 4 — Walk Signals

2. Interpretation

- i. Standard minimum 300 x 300 mm pedestrian control heads shall be used.
- ii. Previous iterations of the pedestrian control signal displaying the word “WALK” must not be used.
- iii. The colour of the walking man must be a bright (“lunar”) white (not green as per European and some other international practices) and may be illustrated either as a solid figure or as an outline.
- iv. “Opaque” is taken to mean black or non-light-emitting.

3. Recommended Practice

- i. The walking pedestrian symbol must not be displayed at any time during which the orange hand (“Don’t Walk”) or flashing orange hand (Pedestrian Clearance Interval) is displayed.
- ii. Pedestrian control signals shall be mounted at a minimum height of 2.75 m from finished grade to the bottom of the housing (clearance distance).
- iii. Pedestrian control indications shall not be mounted over the portions of roads travelled by vehicles and shall be mounted so as to be visible along the crosswalk from the opposite side of the roadway at an intersection.
- iv. Light sources for pedestrian control indications must meet the colour requirements of ITE Publication ST-055-E.
- v. The shape of the walking pedestrian symbol shall conform to the figures provided in the HTA Regulation 626 Sub-section 1 to the satisfaction of the road authority.

HTA Regulation 626 Sub-section 1. (9) — Mounting of Pedestrian Signals

1. Legal Requirements

Sub-section 1. (9) states:

The positions of the symbol pedestrian control indications referred to in subsections (7) and (8) shall be as provided in any one of the following paragraphs:

1. *The symbols are mounted vertically with the hand outline on top.*
2. *The symbols are within the same lens and are superimposed over each other.*
3. *The symbols are side by side within the same lens with the hand outline to the left. O. Reg. 213/92, s. 1 (2).*

2. Interpretation

- i. There are three ways that the standard 300 x 300 mm (minimum) pedestrian control heads shall be used:
 - Both displays may be integrated into a single lens with the “Hand” symbol superimposed on the “Walking Pedestrian” symbol.
 - Both displays may be integrated in a single lens with the “Hand” symbol to the left of the “Walking Pedestrian” symbol.
 - The “Walking Pedestrian” symbol may also be in a separate section mounted below the hand.

3. Recommended Practice

- i. Single head pedestrian heads or two-section pedestrian heads with incandescent lamps may be used.

- ii. The walking pedestrian (“Walk”) symbol shall not be displayed at any time during which the orange hand (“Don’t Walk”) symbol or flashing orange hand (“Pedestrian Clearance Interval”) is displayed.
- iii. Pedestrian symbols shall be located at the intersection so as to be visible from the opposite side of the intersection where pedestrians are expected to stand to wait to cross the roadway.

HTA Regulation 626 Sub-section 1. (10) — Signals Not At Intersections

1. Legal Requirements

Sub-section 1. (10) states:

A traffic control signal system may be erected and maintained at a place other than an intersection, in which event the arrangement of the traffic control signals shall comply as nearly as possible with the provisions of subsections (4) and (5).

2. Interpretation

- i. This sub-section allows for the installation of:
 - “Mid-block Signals” where traffic control signals are installed solely to allow crossing of the roadway by pedestrians.
 - “Traffic Signals” at the intersection of a roadway with a private driveway.
 - “Special Traffic Control Signals” where it is considered necessary to install signals for the protection of the public. These situations may occur at moveable bridge spans, at rail or transit crossings, at special factory equipment or material moving crossings of a roadway, and at other locations where it is necessary to interrupt the right-of-way of the roadway for good reasons.

- “Ramp Metering Signals” for control of traffic volumes on ramps entering a roadway (see Subsection for HTA Regulation 626, 1. (6)).

- ii. The appearance of traffic signals installed at the foregoing locations shall be consistent for approaching motorists with the appearance of a normally signalized intersection. All primary, secondary and auxiliary signal heads should obey the legal requirements as if an intersection were present in front of the activity that is taking place.

3. Recommended Practice

- i. The appearance of the special traffic signals should match the appearance of a normally signalized intersection in the area as closely as practical.

HTA Regulation 626 Sub-section 1. (11) — Amber Left Turn Arrows

1. Legal Requirements

Sub-section 1. (11) states:

A traffic control signal system that operates as a simultaneous protected and permissive left turn system shall display a left turn amber arrow indication immediately after the display of a left turn green arrow indication.

2. Interpretation

- i. A simultaneous protected and permissive left turn operation includes opposing left turn movements that overlap but do not necessarily terminate at the same time.
- ii. Where both a circular green and a left green arrow indication are used to allow simultaneous protected/permissive movements during a left turn, an amber arrow must follow the green arrow to conclude the protected left turn portion

of the phase. The left turn amber arrow may be included with the green arrow in a single unit which changes from green to amber, or a separate amber arrow section may be mounted directly above the left green arrow section.

- iii. Refer to Section 3 for explanation of the terms “Permissive” and “Protected”.

3. Recommended Practice

- i. Signal head types 8, 8A, 9 or 9A of Figure 2 should be used for the protected/permissive indications;
- ii. Flashing green and amber arrows are not allowed for simultaneous left turns.

HTA Regulation 626 Sub-Section 2 — Bicycle Signals

1. Legal Requirements

Sub-section 1. (2.1) states:

Despite subsection (1), a bicycle traffic control signal shall consist of three opaque circular indications, each with a coloured translucent bicycle symbol, arranged vertically from the bottom as follows: green, amber, red.

Sub-section 1. (2.2) states:

A green arrow indication on an opaque circular indication may be used for bicycle traffic control signals and, where it is used, it shall be arranged vertically below the three opaque circular indications described in subsection 1. (2.1)

Sub-section 1. (2.3) states:

An amber arrow indication, on the same opaque circular indication that is used for the green arrow indication described in subsection (2.2) or on a separate opaque circular indication, may be

used for bicycle traffic control signals and, where a separate opaque circular indication is used, it shall be arranged vertically above the green arrow indication.

Sub-section 1. (2.4) states:

For the purpose of subsection (2.1), the bicycle symbol shall be as illustrated in the following Figure 5.

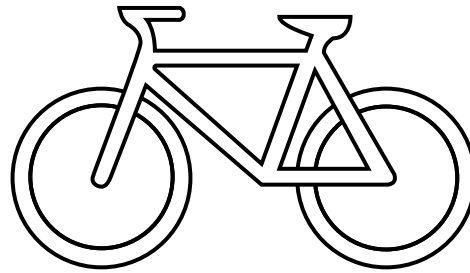


Figure 5 — Bicycle Symbol

Sub-section 1. (4.2) states:

A bicycle traffic control signal installed at an intersection shall be located on the far side of the intersection from which vehicles are approaching and an additional bicycle traffic control signal may be located on the near side of the intersection from which vehicles are approaching.

Sub-section 1. (4.2) states:

A bicycle traffic control signal installed at an intersection shall be located on the far side of the intersection from which vehicles are approaching and an additional bicycle traffic control signal may be located on the near side of the intersection from which vehicles are approaching.

Sub-section 1. (5.1) states:

Despite subsection (5), a bicycle traffic control signal, where installed, shall be not less than 2.5 meters above the level of the roadway when adjacent to the travelled portion of the roadway and not less than 4.5 meters above the level of the roadway when suspended over the travelled portion of the roadway.

2. Interpretation

- i. The bicycle outline symbol may be used in a specific signal head to direct cyclists.
- ii. The exact symbol as shown in the Regulation must be used.
- iii. Green and amber arrows may be used in conjunction with the bicycle signal head to define the bicycle signal head as applying to a specific direction of travel.
- iv. A minimum of one bicycle signal is required for each direction.
- v. At least one bicycle signal shall be far side, but an additional near side signal is allowed.
- vi. Bicycle signals shall be installed a minimum of 4.5 meters from the finished grade to the bottom of the signal head. If mounted adjacent to the roadway a bicycle signal head must be mounted at least 2.5 meters above the grade of the roadway.

3. Recommended Practice

- i. Recommended practice for installing and using bicycle signals is discussed in Section 6 of this manual.

2.8 HTA Section 146 — Portable Lane Control Signal Systems and Automated Flagger Assistance Devices

1. Legal Requirements

Section 146 of the HTA states:

1. HTA Statute 146 discusses the use of, and driver actions at Portable Lane Control Signal Systems.
2. HTA 146(1) discusses the use of and driver actions at Automated Flagger Assistance Devices as an alternative to traffic control persons use of traffic control stop and slow signs.
3. Legal requirements for both of these devices can be found in Regulation 185/22 Portable Traffic Control Systems.

2.9 HTA Regulation 185/22 — Portable Traffic Control Systems

1.0 Portable Lane Control Signal Systems

1. Legal Requirements

Regulation 185/22 of the HTA states:

1. (1) Every portable lane control signal system shall consist of at least one portable lane control signal for each direction from which traffic to be controlled by the system approaches.
- (2) A portable lane control signal shall have a set of lenses that meet the following criteria:
 - i. The set must contain no lens other than one red lens, one amber lens and one green lens
 - ii. The lenses in the set must be arranged

vertically in the following order, commencing at the bottom: green, amber, red.

iii. Each lens in the set must be at least 20 centimeters in diameter.

2. (1) A portable lane control signal shall be mounted on a yellow backboard that,
 - (a) is not less than 100 centimeters in height and not less than 50 centimeters in width; and,
 - (b) is placed so that the bottom edge of the backboard is at least 2.75 meters above the level of the roadway.

(2) If a backboard has dimensions greater than 100 centimeters in height and 50 centimeters in width, the increased dimensions must be proportional relative to each other.

(3) Figure 6 is an illustration of a portable lane control signal that meets the requirements set out in this section and section 1.

3. (1) A portable lane control signal system shall not be operated in such a manner as to show green and amber lenses illuminated simultaneously.
- (2) Each lamp and each lens in a portable lane control signal shall be maintained so that, when the lamp is illuminated, the lens is clearly visible to approaching traffic at a distance of at least 100 meters.
4. (1) A portable lane control signal system shall be placed on a highway such that one portable lane control signal is to the right of, facing and clearly visible to approaching traffic.
- (2) A portable lane control signal system shall not be located at an intersection or pedestrian crossover.

(3) A portable lane control signal system shall not be located in any place or manner so as to conflict with any traffic control signal system.

5. Signs shall be erected in accordance with the following rules:

1. The following signs shall be erected in front of each portable lane control signal in a portable lane control signal system:

- i. A DO NOT PASS sign, as prescribed in Regulation 615 of the Revised Regulations of Ontario, 1990 made under the Act.
- ii. A sign with an orange background indicating that a portable lane control signal is ahead.

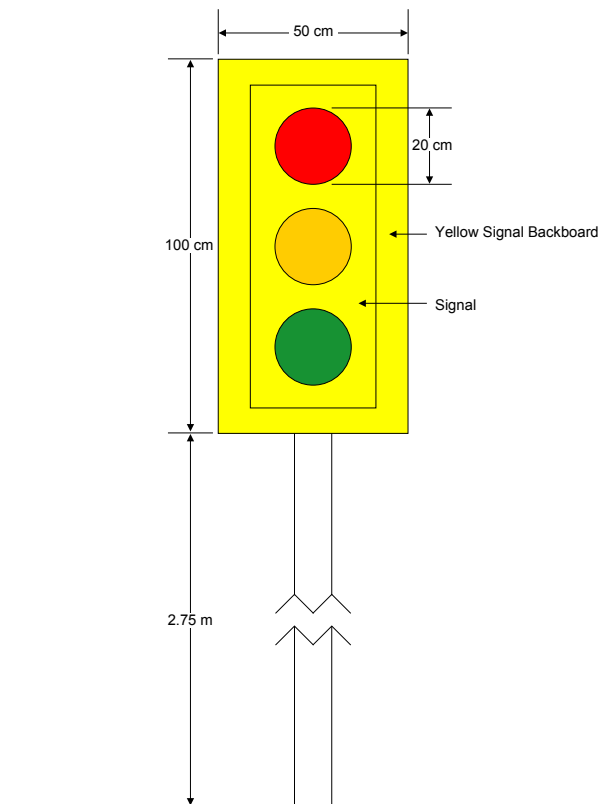


Figure 6 — Portable Lane Control Signal

- iii. A sign indicating the location at which a driver approaching a portable lane control signal system is to bring their vehicle to a stop.
2. The signs shall be erected in the order set out in paragraph 1 commencing farthest from the portable lane control signal.
3. The signs shall be located to the right of, facing and clearly visible to approaching traffic.
4. The signs shall bear the markings as illustrated in Figure 7 unless the signs are erected in an area designated by the French Language Services Act, in which case the signs shall bear the markings as illustrated in Figure 8.
5. Despite paragraph 4, if a municipality that is in a designated area has not passed a by-law under subsection 14 (1) of the French Language Services Act, the signs erected in that area shall bear the markings illustrated in either Figure 7 or Figure 8.
6. Each sign shall be ground-mounted or mounted on a portable stand.
7. If a sign is ground-mounted, the bottom edge of the sign shall be at least 1.5 meters but not more than 2.5 meters above the level of the roadway.

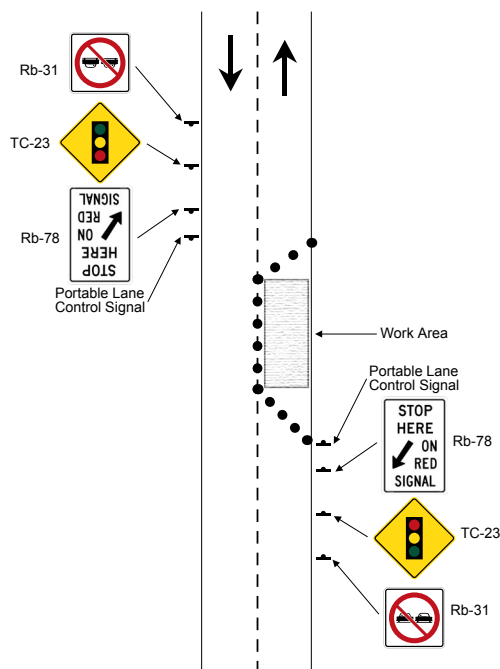


Figure 7 — Sign Layout Required for Portable Lane Control Signal System

(Refer to OTM Book 7 for Typical Layout)

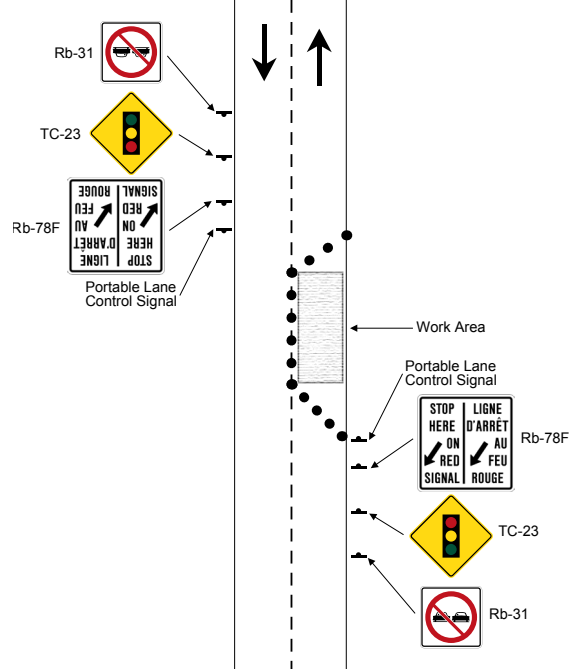


Figure 8 — Sign Layout Required for Bilingual Portable Lane Control Signal System

(Refer to OTM Book 7 for Typical Layout)

8. *If a sign is mounted on a portable stand, the bottom edge of the sign shall be at least 1.0 meters but not more than 2.5 meters above the level of the roadway.*
9. *Each sign shall have a retro-reflective background.*

2. Interpretation

- i. Portable Lane Control Signals must conform to the standards set out in HTA Section 146.
- ii. Portable Lane Control Signals must conform to the detailed requirements for design, signal head mounting, operation, placement and signing as detailed in HTA Regulation 185/22
- iii. A legal approval process is not required for a portable lane control signal.

3. Recommended Practice

- i. Portable Lane Control signals are intended for use on work sites for Mobile Operations, Very Short Duration or Short Duration Work as Defined in OTM Book 7 (Temporary Conditions).²⁰
- ii. Portable Lane Control signals should be operated only during daylight hours and should be attended during use.

It is recommended that two signal heads, where practical, per approach be used in a portable lane control situation and that the second signal head be located in the standard secondary head location.

- iii. In the event that a portable lane control signal has to be left unattended or operated for Long Duration work as defined in OTM Book 7, (Temporary Conditions)²⁰, the signals should meet the requirements for temporary signals, and a legal drawing should be prepared

and approved indicating conformance with Regulation 626, including the use of at least two signal heads for each approach.

2.0 Automated Flagger Assistance Devices

1. Legal Requirements

1. *An automated flagger assistance device shall be operated in accordance with this Regulation.*
2. (1) *Every automated flagger assistance device shall consist of a gate arm and a signal.*

(2) *The signal on an automated flagger assistance device shall have a set of lenses that meets the following criteria:*
 1. *The set must contain no lens other than one red lens and one amber lens.*
 2. *The lenses in the set must be arranged vertically in the following order, commencing at the bottom: amber and red.*
 3. *Each lens in the set must be at least 30 centimeters in diameter.*
3. (1) *The signal on an automated flagger assistance device shall be mounted on a black backboard that,*
 - (a) *is not less than 85 centimeters in height and not less than 50 centimeters in width;*
 - (b) *has an orange retro-reflective border that is at least 2.5 centimeters in width; and*
 - (c) *is placed so that the bottom edge of the backboard is at least two meters above the level of the roadway.*
4. (1) *The gate arm of an automated flagger assistance device shall meet the following criteria:*

1. The gate arm must be at least two meters long and at least 10 centimeters wide.
2. The gate arm must be covered on both sides with alternating vertical contrasting stripes. At least one set of stripes must be made of retro-reflective sheeting. *NOTE: on July 1, 2027, paragraph 2 of sub section 9(1) of this Regulation is revoked and the following substituted: the gate arm must be covered on both sides with alternating vertical stripes of orange and black. The orange stripes must be made of retro-reflective sheeting.*
3. When lowered, the bottom edge of the gate arm must be not less than 110 centimeters but not more than 140 centimeters above the level of the roadway.

(2) Figure 9 is an illustration of an automated flagger assistance device that meets the requirements set out in this section.

5. (1) The gate arm of an automated flagger assistance device shall be horizontal when a red lens is illuminated.

(2) The gate arm of an automated flagger assistance device shall be raised when an amber lens is illuminated.

(3) An automated flagger assistance device shall not be operated in such a manner as to show amber and red lenses illuminated simultaneously to approaching traffic.

(4) To indicate to approaching traffic that the signal is about to change from amber to red, the lenses in the signal of an automated flagger assistance device shall be illuminated in the following sequence:

1. Flashing amber.

2. Solid amber.

3. Solid red.

(5) Each lamp and each lens in the signal of an automated flagger assistance device shall be maintained so that, when the lamp is illuminated, the lens is clearly visible to approaching traffic at a distance of at least 165 meters.

(6) An automated flagger assistance device shall not be operated unless a traffic control person is positioned close enough to the device to enable the person to immediately display a traffic control STOP/SLOW sign to approaching traffic if the device malfunctions.

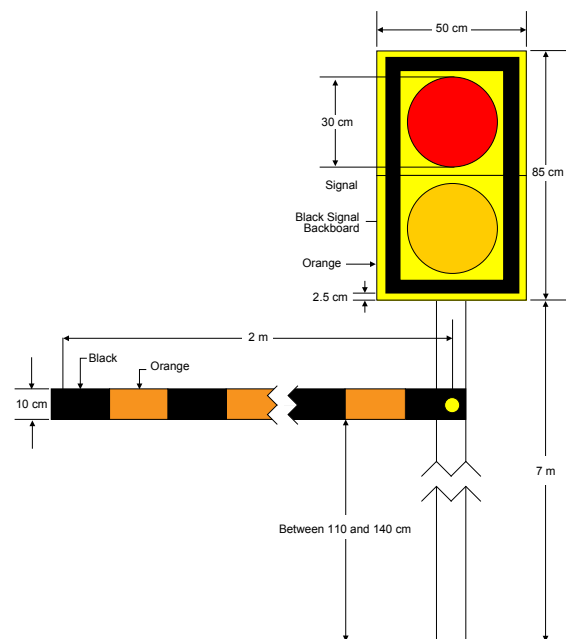


Figure 9 — Automated Flagger Assistance Device

6. (1) *An automated flagger assistance device shall be placed on a highway such that the signal of the device is to the right of, facing and clearly visible to approaching traffic.*

(2) An automated flagger assistance device shall not be located at an intersection or pedestrian crossover.

(3) An automated flagger assistance device shall not be located in any place or manner so as to conflict with any traffic control signal system.

7. (1) *Signs shall be erected in accordance with the following rules:*

The following signs shall be erected in front of each automated flagger assistance device:

- i. A DO NOT PASS sign, as prescribed in Regulation 615 of the Revised Regulations of Ontario, 1990 made under the Act.*
- ii. A sign with an orange background indicating that an automated flagger assistance device is ahead.*
- iii. A sign indicating the location at which a driver approaching an automated flagger assistance device is to bring their vehicle to a stop.*

(2) The signs shall be erected in the order set out in paragraph 1 commencing farthest from the automated flagger assistance device.

(3) The signs shall be located to the right of, facing and clearly visible to approaching traffic.

(4) The signs shall bear the markings as illustrated in Figure 10 unless the signs are erected in an area designated by the French Language Services Act, in which case the signs shall bear the markings as illustrated in Figure 11.

(5) Despite paragraph 4, if a municipality that is in a designated area has not passed a by-law under subsection 14 (1) of the French Language Services Act, the signs erected in that area shall bear the markings illustrated in either Figure 10 or Figure 11.

(6) Each sign shall be ground-mounted or mounted on a portable stand.

(7) If a sign is ground-mounted, the bottom edge of the sign shall be at least 1.5 meters but not more than 2.5 meters above the level of the roadway.

(8) If a sign is mounted on a portable stand, the bottom edge of the sign shall be at least 1.0 meters but not more than 2.5 meters above the level of the roadway.

(9) Each sign shall have a retro-reflective background.

2. Interpretation

- i. Automated Flagger Assistance Devices must conform to the standards set out in HTA Section 146.*
- ii. Automated Flagger Assistance Devices must conform to the detailed requirements for design, signal head mounting, operation, placement and signing as detailed in HTA Regulation 185/22.*
- iii. TCPs must be close enough to control traffic with a stop/slow paddle should the Automated Flagger Assistance Device malfunction.*
- iv. A legal approval process is not required for an Automated Flagger Assistance Device.*
- v. If the contractor leaves the site, the AFADs must be removed and two-way flow of traffic resumed.*

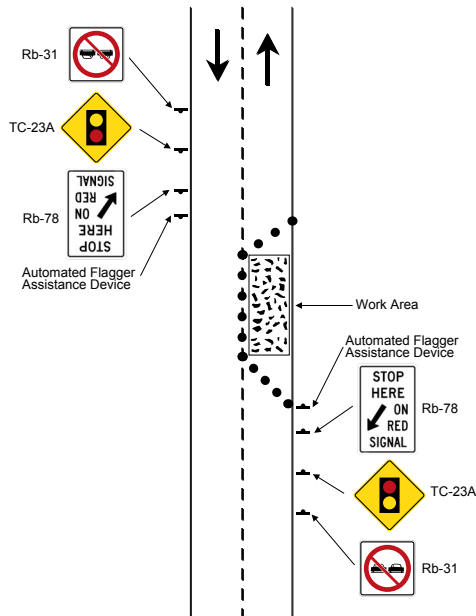


Figure 10 — Sign Layout Required for Automated Flagger Assistance Device

(Refer to OTM Book 7 for Typical Layout)

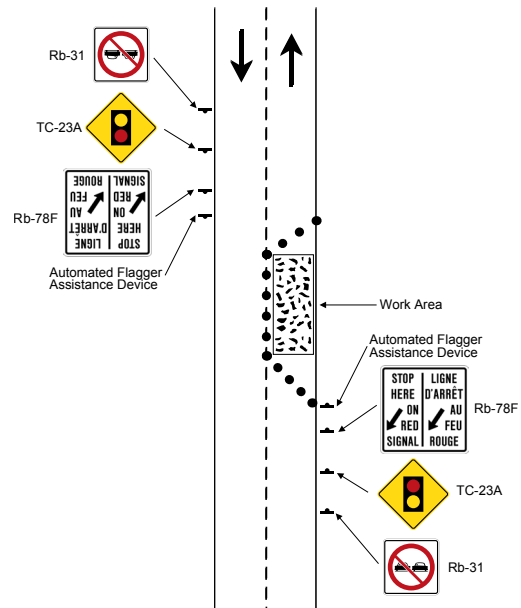


Figure 11 — Sign Layout Required for Bilingual Automated Flagger Assistance Device

(Refer to OTM Book 7 for Typical Layout)

3. Recommended Practice

- i. Automated Flagger Assistance Devices are intended as a supplement to Traffic Control Persons and not a replacement.
- ii. Automated Flagger Assistance Devices should only be used on work sites for Intermittent Duration, Very Short Duration or Short Duration Work as Defined in OTM Book 7 (Temporary Conditions).²⁰
- iii. Two TCPs are always required to use an Automated Flagger Assistance Device where one TCP operates and AFAD at either end of a work zone or where a TCP operates an AFAD at one end of the work zone and a TCP controls traffic at the other end of the work zone.

2.10 Regulation 277/99 — Red Light Camera System Evidence

This regulation contains 4 major sections that detail the use of red light cameras:

- i. Definitions and Application
- ii. Information required on the photographs which also includes the municipalities that are able to use red light cameras and the unique codes on the photographs that indicate which municipality the offense was captured.
- iii. How an offense notice must be served.
- iv. The form to be used if striking out an offense.

1. Interpretation

- i. A photograph can be any form of electronically recorded image, a reproduction of all or part of a photograph or an enlargement of all or part of a photograph.
- ii. A red light camera system must be either the TraffiStar SR 520-ONT or the TraffiStar SR 590-ONT and no other red light camera systems are presently allowed for use in Ontario.
- iii. The red light camera system must take a series of photographs with the first photograph showing the vehicle approaching the intersection at or above a set speed when a red indication is displayed and one or more additional photographs that display the vehicle in the intersection.
- iv. Date, time, location, length of time the signal was displaying a red indication before the photograph was taken, length of time that the amber indication was displayed before the photograph was taken, and the speed the vehicle was travelling at when the first photograph was taken is all information that can be included in the photograph or superimposed on it.
- v. The license plate of the vehicle must be clearly seen in the photograph or the enlargement of the photograph.
- vi. Municipalities that use a red light camera system must specifically be identified in the Regulation.

2.11 Regulation 34/06 — Pre-empting Traffic Control Signal Devices

1. Legal Requirements

Definitions

1. In this Regulation,

“emergency vehicle” means an ambulance, a fire department vehicle or a police department vehicle

“public transit vehicle” means,

(a) a vehicle operated by or on behalf of a municipality, or

(b) a bus operated by the Greater Toronto Transit Authority, also known as GO Transit

“traffic signal maintenance vehicle” means a vehicle that is used by or on behalf of a road authority to maintain traffic control signal systems.

Exemptions from prohibition

2. The following vehicles are exempt from the prohibition in subsection 79.1 (1) of the Act against pre-empting traffic control signal devices:

1. Public transit vehicles.
2. Emergency vehicles.
3. Traffic signal maintenance vehicles, so long as the pre-empting traffic control signal device is being used only to test traffic control signal systems or to test the pre-empting traffic control signal device.

2. Interpretation

- i. Public Transit Vehicles operated by or on behalf of a municipality including GO buses, ambulances, police vehicles or fire response vehicle can have attached to them, contain and may use a traffic signal pre-empting device despite Section 79.1 (1) of the HTA that prohibits their use.
- ii. Traffic signal maintenance vehicles, either owned by a road authority or contracted to perform traffic signal maintenance or inspection work for a road authority may also use a traffic signal pre-empting device despite Section 79.1 (1) of the HTA that prohibits their use,
- ii. The Accessibility standard for pedestrian crossings within a public right-of-way is defined as part of the Design of Public Spaces Standards (Accessibility Standard for Built Environment) prescribed by Ontario Regulation 191/11.
- iii. Pedestrian crossings shall provide a continuous, and clear path across the vehicular route. An accessible path must be barrier-free and designed to address a range of capabilities as exhibited by the individuals that might use them. Consideration shall be given to the expected number and type of users in determining the design parameters that will enable independent, safe, and efficient use of the crossings by individuals of all ages and capabilities.

2.12 Accessibility for Ontarians with Disabilities Act, 2005 (AODA)

2.0 Pedestrian Signals

1. Legal Requirements

This Section of the Act states:

Pedestrian facilities are installed in accordance with the Accessibility for Ontarians with Disabilities Act, 2005, S.O. 2005, c. 11 and associated Regulations. The goal of the AODA¹ is to: achieve accessibility for Ontarians with disabilities with respect to goods, services, facilities, accommodation, employment, buildings, structures and premises by January 1, 2025.

2. Interpretation

- i. The requirements of the AODA include the Legal authority, framework, and processes for the Ontario Government to develop, implement and enforce the accessibility standards, under which the public and private sectors must comply.
- iv. A barrier-free environment means the elimination of physical or information barriers. Physical barriers such as curbs, steep slopes or obstacles may restrict movements of pedestrians with mobility impairments; while information barriers such as the lack of tactile or audible cues will limit pedestrians with visual or hearing impairments in their ability to recognize the conditions of the environment.
- v. According to the Accessibility Standards for Built Environment Ontario Regulation 191/11, treatments to enhance accessibility applicable to pedestrian signal crossing treatments within the scope of this manual include the following:
 - Curb Ramps (Sub-section 80.26)
 - Depressed Curb (Sub-section 80.27)
 - Accessible Pedestrian Signals (Sub section 80.28)

2.13 AODA Regulation 191/11

AODA Regulation 191/11 Sub-Section 80.26

Curb Ramps

1. Legal Requirements

Sub-section (1) states:

Where a curb ramp is provided on an exterior path of travel, the curb ramp must align with the direction of travel and meet the following requirements:

1. *The curb ramp must have a minimum clear width of 1,200 mm, exclusive of any flared sides*
2. *The running slope of the curb must,*
 - i. *be a maximum of 1:8, where elevation is less than 75 mm, and*
 - ii. *be a maximum of 1:10, where elevation is 75 mm or greater and 200 mm or less*
3. *The maximum cross slope of the curb ramp must be no more than 1:50*
4. *The maximum slope on the flared side of the curb ramp must be no more than 1:10.*
5. *Where the curb ramp is provided at a pedestrian crossing, it must have tactile walking surface indicators that,*
 - i. *have raised tactile profiles,*
 - ii. *have a high tonal contrast with the adjacent surface,*
 - iii. *are located at the bottom of the curb ramp,*
 - iv. *are set back between 150 mm and 200 mm from the curb edge,*

v. *extend the full width of the curb ramp, and*

vi. *are a minimum of 610 mm in depth.*

Sub Section (2) states:

Curb ramp means a ramp that is cut through a curb or that is built up to a curb. Ontario Regulation 413/12 Sub-Section 6.

2. Interpretation

- i. Curb ramps provide access for people in wheelchairs or on scooters at crossings where there is an elevation change between the sidewalk and the street level crossing.
- ii. Curb ramps are to be included as a component of any new signalized intersection where pedestrian signal heads are to be used or at any new Mid-Block Pedestrian Signals (MPS) or Intersection Pedestrian Signals (IPS) to address the needs of pedestrians with mobility impairments and pedestrians with visual impairments.
- iii. Curb ramps are to be included as a component when retrofitting or rebuilding any existing signalized intersection where pedestrian signal heads will be added, replaced or upgraded, or where audible pedestrian signals are added.
- iv. Curb ramps as a minimum shall meet the design standards as identified in AODA Regulation 191/11 Sub Section 80.26.

3. Recommended Practice

- i. Curb Ramps should be installed at any existing signalized intersection, MPS or IPS that is being retrofitted or rehabilitated where pedestrian signal heads are to be used and at least 25% of the installation is to be upgraded or rebuilt.

- ii. Curb ramps are the preferred design over depressed curbs for accessibility at signalized intersections and there should be two distinct curb ramps on each corner providing guidance to individuals with partial sight as to the direction of travel.
- iii. Depending on the geometric design of the intersection, it may be necessary to combine two curb ramps into a single one (Depressed Curb), however separate tactile pads should always be installed to provide guidance to individuals with partial sight on the direction of travel.

AODA Regulation 191/11 Sub-Section 80.27

Depressed Curbs

1. Legal Requirements

Regulation 191/11 Sub-Section 80.27 states:

The design of depressed curbs, if used, must consider the standards as described in AODA Regulation 191/11 Sub-Section 80.27.

Sub-section (1) states:

(1) Where a depressed curb is provided on an exterior path of travel, the depressed curb must meet the following requirements:

- *The depressed curb must have a maximum running slope of 1:20.*
- *The depressed curb must be aligned with the direction of travel.*
- *Where the depressed curb is provided at a pedestrian crossing, it must have tactile walking surface indicators that,*

- i. have raised tactile profiles,*
- ii. have high tonal contrast with the adjacent surface,*
- iii. are located at the bottom portion of the depressed curb that is flush with the roadway,*
- iv. are set back between 150 mm and 200 mm from the curb edge, and*
- v. are a minimum of 610 mm in depth.*

(2) Depressed curb means a seamless gradual slope at transitions between sidewalks and highways and is usually found at intersections. Ontario Regulation 413/12 Sub Section 6

2. Interpretation

- i. If depressed curbs are to be used instead of curb ramps they must meet the requirements as set out in AODA Regulation as described above.
- ii. Depressed curbs provide the same transition from the curb level to the roadway level surface as a curb ramp, however depressed curbs are much wider than a curb ramp, typically running the complete length of an element such as a wide pedestrian walkway.

3. Recommended Practice

- i. If depressed curbs are used at the corners of an intersection, separate tactile surfaces should be installed to provide guidance to individuals with partial sight on the direction of travel.

AODA Regulation 191/11 Sub-Section 80.28**Accessible Pedestrian Signals (APS)****1. Legal Requirements**

Regulation 191/11 Sub-Section 80.28 states:

The legal requirements for APS in Ontario as prescribed in the Accessibility Standards for Built Environment Standard, Ontario Regulation 413/12 Sub-Section 80.28 (1)4 are as follows:

Where a new traffic control signal system with pedestrian control signal heads is being installed at an intersection or an existing traffic control signal system with pedestrian control signal heads is being replaced at an intersection, the pedestrian signals must be accessible.

The 'intersection' includes any portion of a highway indicated by markings on the surface of the roadway as a crossing place for pedestrians.

The APS must meet the following requirements:

- *They must have a locator tone that is distinct from a walk indicator tone*
- *They must be installed within 1,500 mm of the edge of the curb*
- *They must be mounted at a maximum of 1,100 mm above ground level*
- *They must have tactile arrows that align with the direction of crossing*
- *They must include both manual and automatic activation features*
- *They must include both audible and vibro-tactile walk indicators.*

Where two APS assemblies are installed on the same corner, they must be a minimum of 3,000 mm apart.

Where the above requirement of 3,000 mm apart cannot be met because of site constraints or existing infrastructure, two APS assemblies can be installed on a single post, and when this occurs, a verbal announcement must clearly state which crossing is active.

2. Interpretation

- i. Accessible Pedestrian Signals (APS) are auxiliary devices that supplement traffic control signals to aid pedestrians with visual or visual and hearing impairments to cross the road. APS devices communicate information in a non-visual format to provide cues at both ends of a crossing, such as audible tones, verbal messages, and/or vibrotactile indications.
- ii. APS devices that have speakers mounted in, on, or near pedestrian pushbuttons emit a sound such as a Canadian melody and birdcall (typically cuckoo and chirp) during the WALK interval. Additional equipment may produce tones to locate the pushbuttons, tones to acknowledge the button has been pushed, and tones to indicate the direction to start crossing. The sound of APS signals must be capable of being heard above ambient traffic noise.
- iii. Infrared transmitters located at the pedestrian head can transmit a speech message to hand-held receivers. Messages may identify the location and direction of travel of the pedestrian, give the name of the street to be crossed, and provide real time information about WALK and DON'T WALK intervals. APS devices may have vibrating features that operate in parallel with the audible sounds.

- iv. APS are to be included as a component of any new signalized intersection where pedestrian signal heads are to be used or at any new Mid-Block Pedestrian Signals (MPS) or Intersection Pedestrian Signals (IPS) to address the needs of pedestrians with mobility impairments and pedestrians with visual impairments.
- v. APS are to be included as a component when retrofitting or rebuilding any existing signalized intersection where pedestrian signal heads will be added, replaced or upgraded, or where audible pedestrian signals are added.
- vi. APS as a minimum shall meet the design standards as identified in AODA Regulation 191/11 Sub Section 80.28.

3. Recommended Practice

- i. For comprehensive understanding on APS applications, practitioners may refer to TAC's Guidelines for Understanding Use and Implementation of Accessible Pedestrian Signals, May 2008.⁹ The guideline provides details on all stages of an APS installation.

2.14 Municipal Act — Respecting the Municipal Act of Ontario

The *Municipal Act* defines the powers municipalities possess with regard to setting rules and by-laws. These may include by laws pertaining to signs, markings, or bicycle movements.

1. Legal Requirements

Scope of powers

- 8 (1) *The powers of a municipality under this or any other Act shall be interpreted broadly so as to confer broad authority on the municipality to enable the municipality to govern its affairs as it considers appropriate and to enhance the municipality's ability to*

respond to municipal issues. 2006, c. 32, Sched. A, s. 8.

Ambiguity

- 8 (2) *In the event of ambiguity in whether or not a municipality has the authority under this or any other Act to pass a by-law or to take any other action, the ambiguity shall be resolved so as to include, rather than exclude, powers the municipality had on the day before this Act came into force. 2006, c. 32, Sched. A, s. 8.*

Scope of by-law making power

- 8 (3) *Without limiting the generality of subsections (1) and (2), a by-law under sections 10 and 11 respecting a matter may,*
 - (a) *regulate or prohibit respecting the matter;*
 - (b) *require persons to do things respecting the matter;*
 - (c) *provide for a system of licences respecting the matter. 2006, c. 32, Sched. A, s. 8.*

Scope of by-laws generally

- 8 (4) *Without limiting the generality of subsections (1), (2) and (3) and except as otherwise provided, a by-law under this Act may be general or specific in its application and may differentiate in any way and on any basis a municipality considers appropriate. 2006, c. 32, Sched. A, s. 8.*

2. Interpretation

- i. If an action or intent is not expressly discussed in the *Municipal Act*, 2001, or the *Highway Traffic Act*, a municipality is free to make decisions and pass by-laws as it deems appropriate.

- ii. However, it should be noted that Section 195 of the HTA specifically speaks to conflicts between municipal by-laws and the HTA, stating that the HTA always takes precedence by saying:

195(1) If a provision of a municipal by-law passed by council of a municipality or police services board for, (a) regulating traffic on highways is inconsistent with this act or the regulations, the provision of the by-law shall be deemed to be repealed upon the inconsistency arising. R.S.O. 1990 H.8, s. 195(1); 1996, c.33, s.15(1); 2002, c.17, Sched F, Table.

3. Recommended Practice

- i. Some aspects of bicycle traffic signals and cyclist actions when directed by bicycle traffic signals are not addressed in the HTA. Location information is specific to the individual sites. Therefore, it appears that municipalities may make decisions, take actions and implement by-laws to:
 - (a) Implement bicycle-specific signal phasing using bicycle signals or standard traffic signals, with appropriate signing;
 - (b) Pass by-laws regulating the movement and behaviour of cyclists under bicycle-specific phasing (providing those regulations do not conflict with Section 144 of the HTA).
- ii. For the above actions, it would be appropriate to have municipal by-laws in place, defining the signs, cyclist responsibilities and penalties for failure to obey the by-laws.

3. Operational Practice

3.1 Introduction

General

Operational analysis requires an understanding of the theories of traffic flow and experience in the application of those theories to traffic control signals. References may be found in ITE's "Canadian Capacity Guide for Signalized Intersections" (CCG)² and the "Transportation Research Board (TRB) Highway Capacity Manual" (HCM).¹³

It is necessary to use industry jargon to describe hardware and signal operations terms.

The reader is referred to the Glossary to obtain an understanding of any unfamiliar terms that are not explained here. One specific term that is widely used by the industry is "Traffic Control Signals". In this section of the manual, the term traffic control signals refers to the system of equipment (e.g., poles, heads, controllers, detectors, etc.) that controls traffic at an intersection. An individual signal head is referred to as a "Traffic Signal Head" and a "Traffic Signal Indication" refers to the lens within a signal head. These terms differ slightly from the legal definitions presented in Section 2.

Standardization

Standardization of the many aspects of traffic control signal operation throughout Ontario is important from the viewpoint of motorists' expectations and safety. Standardization is achieved through the application of:

- Consistent decision-making on the need for and type of traffic control signals;
- Consistent signal head use and placement;

- Consistent traffic systems engineering/analysis practices in relation to selection of the mode of control; and
- Consistent decision-making on the need and type of phasing.

Items requiring standardization provincially and locally are:

- Operational design of phasing requirements and phase and interval timing;
- Timing of clearance intervals; and
- Determination of phase omissions or additions by time-of-day.

Signal Operations Report

A Traffic Signal Operations Study may be undertaken at intersections with operational concerns and at new intersections being considered for signals. The Traffic Signals Operations Study should consider the following elements:

- Collision history at the intersection;
- Pedestrian and cyclist volumes at various times of day;
- Turning movements, including truck and bus volumes;
- Approach speeds;
- Geometric requirements;
- Sight distance requirements;
- Requirement for phase adjustments (adding or removing) or changes to mode of operation (fixed or semi-actuated to fully actuated);

- Modifications to timing (clearances, minimums, splits);
 - Requirements for preemption or priority operations;
 - Requirements for pedestrian signal indications;
 - Requirements for bicycle signal indications;
 - Requirements for auxiliary traffic control device such as advanced warning beacons, auxiliary signal heads, programmable signal heads or signing;
 - Proximity to other intersections. The need to operate independently or in a system; and
 - Proximity to railway track crossings.
- (CPU) (or Remote Processing Unit (RPU) if the controller is in a system) is programmed using appropriate software to set all timed and actuated intervals and variables, and to allow the required phases for the intersection.
 - The computer board sends commands via a 24 volt line to an electronic load switch that allows 120 volts to pass through or be cut off from the incoming line to the signal head indications.
 - Various peripherals monitor the controller circuits: “Watchdog” circuits monitor voltages and currents and alert the “Conflict Monitor/ Malfunction Management Unit (MMU)” to shut down the signals and revert to “All Flash” mode in the event of a conflict, the absence of red signal indications, or low power supply voltage.

Section 4 provides a methodology for estimating the safety impacts of signalization and may be used in conjunction with the standard signal justifications to determine whether an intersection should be signalized or not.

3.2 Controller Operation

This section addresses some of the physical attributes of traffic signal controllers. This section concentrates on solid state controllers, including the Type 170 controller, the NEMA Standard controller and the Advanced Transportation Controller (ATC). Although other types of solid state and electro-mechanical controllers are still used by municipalities, they are not discussed in this manual.

Modern signal controllers consist of printed circuit boards with various peripheral devices to control different operations. A simplified description of their operation follows:

- The controller’s Central Processing Unit

Modern traffic signal controllers can communicate with central systems and other ITS equipment through the use of the National Transportation Communications for Intelligent Transportation System (ITS) Protocol (NTCIP). This protocol provides both the rules for communicating (protocols) and the vocabulary (called objects) that allow devices to be used in a mix and match approach. It should be recognized that a certain number of objects are specified that all manufacturers must follow, however manufacturers will typically add objects for special features that are usable only within their own family of products.

It is at the discretion of the roadway authority to select the type and brand of traffic signal controllers.

Many municipalities currently use the NEMA specification controllers and cabinets, either TS1 or TS2 (Type 1 or Type 2). NEMA is a functional standard that specifies functions that all controllers must follow. The NEMA controller is supplied complete with manufacturers’ software designed to meet or exceed the functional specifications. The TS-1 standard is the older standard and specifies

three large multi-pin connectors (A, B and C) for inputs and outputs where communication between the controller and equipment within the cabinet is through point to point wiring.

The TS-2 controllers and cabinets standardized detection and communications and introduced serial datalink communications (SDLC) between the controller and equipment within the cabinet. The TS-2 specification is split into two Types.

TS-2 Type 1, which requires all equipment within the cabinet to communicate through SDLC, results in the elimination of the large A, B and C connectors on the controller, although there is still an A connector for power to the controller. The point-to-point wiring within the cabinet was eliminated.

The TS-2, Type 2 controller and cabinet is a hybrid of the TS-1 and the TS-2 Type 1 specifications as it retains the A, B and C connectors for the input and output to the back panel of the cabinet, however conflict monitoring and detection are on a serial data bus for simplified wiring and easier troubleshooting.

The Ministry and several large municipalities use the Type 170 signal controller which was developed as a hardware based modular controller. The Type 170 controller is based on a common set of input/output specifications and hardware for any manufacturers to follow. Operational software must be purchased separately and is usually function dependent. The Type 170 controller is typically specified along with a 33X cabinet assembly that is wired for all inputs and outputs to/from the controller through a single C1 connector. The Type 170 controller is no longer being manufactured and jurisdictions that had previously used these controllers are phasing them out, switching to the Model 2070 Advanced Transportation Controller (ATC) and upgraded intersection control software. Many NEMA manufacturers can also supply

controllers that are rack mountable and backward compatible to the 33X cabinets.

As jurisdictions install new traffic signals or retrofit existing ones, there is a desire for a platform that can perform more than just signalized intersection control. The Advanced Transportation Controller standards were developed to provide an open architecture hardware and software platform to support a variety of Intelligent Transportation Systems (ITS) applications such as dynamic message sign control, security cameras, ramp metering, and data collection to name a few. There is therefore a movement toward ATC controllers and cabinets that meet either the ATC 5201 standard or the ATC 5202 Model 2070 Controller Standard.

All modern controllers and cabinets can be configured for multiple phase operation. Typically, between 2 and 8 phases are all that is required for vehicular traffic. However, as signalized intersections become more complex and transit priority phases, separate pedestrian phases or separate bicycle phases are required, the jurisdictions may need to consider a signal controller and cabinet that can be configured for more than 8 phases (modern controllers are available that can be configured for up to 16 phases).

All modern controllers provide connections for conflict monitors/malfunction management units. These devices detect the interruption of electronic circuits; signal conflicts on green, amber and walk signals; the absence of sufficient voltage; and the absence of all-red signal indications for a given approach. Industry specifications require 170, ATC 2070 and NEMA controllers to be operated only with conflict monitor/malfunction management units.

When deciding on the type of signal controller and cabinet assembly to use a road jurisdiction will often consider:

- Consistency with existing equipment resulting in the jurisdiction only having to maintain expertise and spare equipment for one type of controller and cabinet and potential ease of communication with a central or local control and monitoring system.
- Functionality required, considering the number of phases, operations that may include emergency preemption, rail preemption, transit priority or preemption, and the use of bicycle signals and pedestrian indications.
- Additional functionality above and beyond intersection control, such as ramp metering, control of variable message signs and other ITS technologies such as queue end warning.
- Consideration of future functionality for connected vehicles that can provide additional safety and operational features at the signalized intersection.
- Central control and monitoring or adaptive control systems compatibility.

Detailed information on controllers may be found in the publications of the major controller manufacturers and in the NEMA^{27 28} and Ministry¹⁹ specifications.

3.3 Traffic Signals and Connected Vehicles

The sharing of data between vehicles near or approaching a signalized intersection and the traffic signal controller, either through Dedicated Short-Range Communication (DSRC) or cellular communications channels can provide a range of both safety and operational benefits. For this reason, it is important for designers to consider the integration of complementary technologies when sourcing signal controller equipment.

Modern Advanced Transportation Controllers (NEMA and 2070) can communicate with approaching and nearby vehicles to provide Signal Phase and Timing (SPaT) data and map information through either built in technology and software or through Roadside Units (RSUs) installed at the intersection.

Nearby and approaching vehicles can provide speed, acceleration/deceleration rates and other vehicle data to the signal controller using either an aftermarket On Board Unit (OBU) for communications, or through technology being built into newer vehicles.

An ATC controller with the necessary connected vehicle applications can act as a data hub, recording the traffic data for later use, or using it for real time adaptive signal operations. The vehicular data can also be used for preemption for emergency vehicles, for priority operations for transit vehicles, or for holding a green interval for a vehicle whose data indicates it will be unable to stop if the light were to change.

With the data received from the signal controller an approaching vehicle can be provided additional warning of a signal change of the time-to-green and even be provided with an alert that a conflicting pedestrian, bicycle or vehicle is currently in the intersection.

Connected vehicle technology is advancing quickly, and jurisdictions should check with signal controller and cabinet manufacturers and suppliers to confirm the capabilities of their modern equipment and how it may fit within the road authority's long-term vision of leveraging connected vehicle technologies for safer and more effective traffic signal operations.

3.4 Determination of Intersection Operation

The mode of control used (see Subsection 3.5) can have a profound effect on the operational efficiency and safety of any signal. The selection of the best type of control for any location can be made only with full knowledge of local conditions but, in general, can be based on:

- The variation in traffic volumes on all approaches throughout the day;
- The volume of pedestrians crossing each crosswalk;
- The percentage of large vehicles;
- The volume of specialized vehicles such as bicycles, transit vehicles and emergency vehicles;
- The volume of turning vehicles;
- The seasonal variations in traffic volumes and characteristics;
- The length of time that the signal will be in operation (if temporary);
- The volume of pedestrians with special needs; and
- Proximity to adjacent existing signals.

For any intersection, it is desirable to maximize efficiency of the traffic flow through the intersection and provide a measure of quality of service to pedestrians, motorists, passengers, cyclists, and the movement of goods. Although maximum efficiency is important, safety of the road users is even more important and should take precedence. To achieve these objectives, the ITE's "Canadian Capacity Guide for Signalized Intersections"

(CCG)² recommends a four-step iterative process which is paraphrased as follows:

1. Definition of Objectives at an Intersection

Objectives should be clearly stated and measurable. They may include minimization of average overall vehicle delay, equitable allocation of vehicle or person delay to individual intersection approaches or lanes, maximization of vehicle capacity, control of queues, minimization of gridlock risk, minimization of vehicle stops, etc.

2. Analysis

Analysis includes investigation of intersection conditions and the determination of relevant evaluation, design or planning variables and parameters.

Intersection variables, in particular vehicle flows and saturation flows, which act as the cornerstone of the CCG methodology can be determined via field survey. Appropriate methods are defined in the CCG.

Analysis includes consideration of preliminary signal timing, any constraints on parameters that may be altered, and the level of detailed traffic input required. These parameters establish a balance between efficiency and optimal safety and are only derived from traffic control signals when the lengths of the various intervals are set in accordance with traffic demands with primary consideration given to the safety of both vehicular and pedestrian traffic.

3. Planning and Design

The planning and design step considers alterations to the intersection such that the evaluated operational performance meets the stated objectives as part of step 1.

This step may include alterations to the detailed geometry (approach lane width, pedestrian refuge, storage length, etc.) or operational parameters (cycle structure, cycle time, signal intervals, etc.) as limited by the analysis parameters defined in step 2. Typically, operational parameters are attempted to be changed first, and if found to not satisfy the objectives, the iterative process then considers a geometric change, as geometric changes are typically more costly and onerous.

The planning and design step considers future geometric features and the iterative design of the operational parameters. The step may include field surveys for arrival flow, saturation flow, overload factor, average overall delay, average stopped delay and queue length.

4. Evaluation

The evaluation step includes the evaluation of any changes made to the traffic control signals. Because the introduction of a new or altered traffic signal control signal impacts the traffic flow on all intersection approaches, it is necessary to determine:

- Measured or predicted traffic flow;
- Existing or planned intersection geometry
- Cycle composition of traffic movements, phases, phase sequence, change and clearance intervals;
- Timing design for cycle times that include times for green intervals, walk intervals, separate bicycle intervals, change and clearance intervals; and
- Intersection capacity, queuing, arrival traffic flow, peaking characteristics, and mode splits.

These parameters can be determined based on calculated traffic analysis, or field surveys of

the new conditions. The parameters are then compared against the defined objectives as part of step 1 to determine if the new design is satisfactory. Otherwise, the process can return to step 3, and alterations to the planning and design of the intersection can be made before another round of evaluation.

Appropriate methods for field surveys are defined in the CCG.

These four steps and associated analyses are discussed in detail in ITE's "Canadian Capacity Guide for Signalized Intersections" (CCG).²

Alternatively, the practitioner may choose to use a software program to evaluate many of the factors, both local and system. The practitioner should choose the appropriate software based on the particular problem and need. The key to the successful use of any automated approach is a thorough understanding of the assumptions and constants built into the program.

PTV Vistro is a commonly used program that replicates the CCG procedures as well as HCM methodology, however there are other software packages that allow for the evaluation of signal timing parameters such as, Highway Capacity Software and Synchro/Sim Traffic which are also based on HCM methodology.

The key to the successful use of any automated approach is a thorough understanding of the assumptions and default values built into the software.

3.5 Selection of Mode of Control

General

The selection of the mode of control at any signalized intersection will depend on several factors:

- Proximity to other signalized intersections;
 - Operation within an existing area of interconnection;
 - Operation within an arterial or area wide system;
 - Variations in traffic flows for each approach by time of day, day of week, and season;
 - Side street to main street volume relationships;
 - Volumes of pedestrians and cyclists crossing the main road; and
 - Percentage of buses and heavy trucks.
- The following modes of control may be used for isolated intersections (operating independently), within an interconnected system, or for a central system:
- Pretimed controllers do not depend on the movement of approaching vehicles past detectors. Thus, the operation of the controller is not adversely affected by such conditions as a stopped vehicle or construction work within the area.
 - Pretimed control may be more appropriate than traffic-actuated control in areas where large and fairly consistent pedestrian volumes are present, or where there is a desire to prioritize pedestrian or cyclist traffic without requiring them to request service.
 - Generally, pretimed equipment costs less to purchase and install, and it is simpler and more easily maintained than traffic-actuated equipment.

Pretimed (or Fixed Time) Mode

A pretimed controller is one that operates within a fixed cycle length using preset intervals and no detection. A pretimed signal is a traffic control signal that directs traffic to stop and permits traffic to proceed in accordance with a single predetermined time schedule or a series of such schedules. Operational features of pretimed signals, such as cycle length, split, sequence, offset, etc., can be changed according to a predetermined program or plan.

Pretimed control is best suited to locations where traffic patterns and volumes are predictable. The equipment can usually accommodate several plans with differing cycle lengths, splits and offsets. Potential advantages include:

- The consistent starting time and interval duration facilitates coordination with adjacent traffic signals. It also provides more precise

Actuated Mode

An actuated signal is a traffic control signal that makes use of detection to respond to vehicle and/or pedestrian demand. Depending on the number and placement of detectors, the operation may be fully actuated or semi-actuated. Potential advantages include:

- Traffic-actuated control may provide maximum efficiency at intersections where fluctuations in traffic cannot be anticipated and programmed using pretimed control.
- Traffic-actuated control may provide maximum efficiency at complex intersections where one or more movements are sporadic or subject to variation in volume.
- Traffic-actuated control may provide maximum

efficiency at intersections that are poorly located within progressive pretimed systems. In these locations, interruptions of main road traffic are undesirable and must be held to a minimum frequency and duration.

- Traffic-actuated control may minimize delay during periods of light traffic because no green time is provided to phases where no traffic demand exists.
- Traffic-actuated control may reduce the number of collisions associated with the arbitrary stopping of vehicles that may be within the dilemma zone.

Semi-actuated Mode

In semi-actuated control, detectors are located on the side road approaches and in the left turn lanes of the main road. Semi-actuated control is suitable for use at intersections with heavy traffic volumes on the arterial and relatively light volumes on the side road. The signal rests in green on the main road, changing to the side road only as a result of a vehicle or pedestrian actuation.

In the more flexible types of controllers, the duration of the side road green interval varies according to the traffic demand, with provision for a maximum limit. When the minor-street phase expires, the green indication reverts to the major street where it must remain for at least a predetermined minimum interval. When this minimum interval expires, the control is again free to respond to minor street actuation.

As the semi-actuated controller receives no actuation from traffic on the main road through lanes, the controller may assign the right-of-way to the side road at inopportune times (i.e., just before the arrival of a main road platoon of vehicles). The effective use of semi-actuated control is therefore limited to intersections with very lightly travelled side roads, or intersections in coordinated systems

where main road progression can be assured. This impact can be minimized with proper setup of offsets and the yield interval.

In a coordinated system, side road actuation for each cycle can be limited to a “Window” of time that best accommodates a break in the main street progression.

In a semi-actuated controller, side street signal indications are not usually of fixed length but determined by the side road’s changing traffic flow at the intersection. The side street signal indication can occur within a fixed cycle length, or within specified minimum and maximum limits of main and side road green indications. In some cases, certain phases or intervals may be omitted when there is no actuation or demand from waiting vehicles or pedestrians.

Many jurisdictions run the semi-actuated operation using the “Main Road Ped Recall” feature. In this mode, the controller will cycle back to the main road green/walk interval and rest in this state (called the non-actuated phase) until demands are detected on the actuated phases.

Fully Actuated Mode

Fully actuated control requires detection on all approaches of both the main road and the side road. Fully actuated operation is suitable for use at:

- Intersections where the traffic volumes of the main road and the side road are more or less equal but where the traffic distribution may be sporadic and varying.
- Locations where turning volumes are high at times and low at other times.
- High speed locations where there is a need to avoid “Dilemma Zone” problems.

In rural situations where traffic volumes on both the main road and side road are similar, presence/extension detection loops may be installed at the stop lines on both roads. The signal phase rests in the green display of the traffic direction last served. Alternatively, a recall for the main road may be programmed so the signal rests on the main road green in the absence of any other demands.

An option exists on most controllers to have the intersection rest in red when there are no actuations.

Many fully actuated intersections use set back detectors, which are in each lane upstream from the intersection. The detectors can be operated in a variety of ways. For example, set back detectors can count the number of vehicle actuations during a red phase and provide a green time that is based on the number of actuations. Another example is a setback detector in a left turn lane so that a protected/permissive left turn is not called for unless there are more than 2-3 vehicles in queue.

A variation of fully actuated operation is commonly used on roadways posted at 60 km/h or greater where the side road is actuated but the main road rests in green. Set back detectors are used in the through lanes to extend the green. This form of control is referred to as “Long Distance Detection” and is described in detail in Section 5.

Under fully actuated control, or even semi-actuated control it is possible for a phase to go from green to amber and then if a call from an actuated phase drops, the signal could return to green again without ever displaying a red indication. The use of a red revert interval prevents this sequence by forcing the controller to display a red indication after the yellow for at least a short period of time before reverting to green for the same phase. The red revert time is generally defaulted to two seconds and is used as a safety feature to ensure the intersection is cleared prior to returning to green for the same phase it just left.

System Operation

General

A system can vary from two or more interconnected controllers to large, centralized computers controlling thousands of intersection controllers. System intersections may be controlled as follows:

- Local controllers at each intersection are controlled by a field master controller.
- Local controllers at each intersection are controlled by a central computer (normally a PC for small systems). Each controller can have its own dedicated connection to the central computer or a group of controllers can be connected to the central computer via a master controller.

With the exception of signal systems using traffic adaptive software, systems use a common cycle length and have a definite offset relationship for all system intersections. Any system that accommodates traffic progression offers the following advantages over isolated/independent operation:

- Traffic is processed into tightly spaced groups, or platoons, with gaps between platoons. The gaps may be used for vehicle or pedestrian crossing times on sideroads, at unsignalized intersections, or at entrances between signalized intersections.
- Although delay may be increased on sideroads, stops for main road traffic are reduced and overall delay is generally decreased.
- Increased intersection capacity is achieved by decreasing the number of queued vehicles and thereby decreasing startup delays.

- The number of collisions is reduced by reducing the speed differential between individual vehicles.
- Fewer rear-end collisions occur due to fewer stops.
- Fuel consumption, noise and air pollution are all reduced due to fewer stops and lower delay times.
- Maintenance benefits are achieved by reducing field visits required to update timing plans, and by providing quicker response to problems through earlier notification of equipment malfunctions.

Coordination

Coordination may be considered advantageous where intersections are spaced less than 1.0 km apart with posted speeds less than 80 km/h, or where intersections are spaced less than 1.5 km apart for posted speeds of 80 km/h and over.

In a simple coordinated system, different timing plans may be selected on a time-of-day basis or on a traffic responsive basis. In traffic responsive systems, vehicular volume and density (occupancy) are measured by detection devices in the roadway, and appropriate cycle lengths and offsets are chosen for programming into the master controller or central computer.

In a more complex traffic adaptive system, the traffic is continually travelling over loops placed downstream of all intersections and the central computer calculates and applies new cycle lengths, splits and offsets to better accommodate the traffic flows.

Where good progression is possible, pretimed operation can promote the formation of tight platoons of traffic. This is because vehicles

entering the coordinated route will usually be released from the first intersection with a high probability of staying within a green band (successive greens).

Actuated control may allocate unused phase time from the actuated phases (side streets or main street left turns) back onto the main street further increasing progression opportunities, but decreasing the certainty of the progression pattern. Actuated control simulates pretimed control when vehicle volumes on the side street are high enough to lead to continuous vehicle actuation and cause the side road to go to the full phase time allowed.

Design and analysis software is available for coordination and network analysis. The coordination calculation is designed to progress vehicular traffic through a particular set of traffic signals along an arterial by using an offset time at each intersection. When determining offsets, preference is normally given to the direction with the higher traffic demands.

The effectiveness of two-way progression is a function of intersection spacing, cycle lengths, and the number of signals in the control area. When controlling a grid network, the balancing of directional preferences is more difficult than for single arterials, but similar principles are used.

Modes for Isolated Operation

When a traffic signal is running isolated from other surrounding signals, it does not necessarily need to operate in a coordinated manner and therefore does not require a constant cycle length. Actuation of vehicle phases is generally the most efficient means of operating isolated signals if traffic volumes vary. Similarly, pedestrian actuation is generally the most efficient means of operating the signals if pedestrians are not present for the majority of signal cycles.

Night-Time Flash (Scheduled Flash)

Traffic signals can be scheduled to operate in flash mode by time of day. This is also known as night-time flash as it was typically used in the late-night hours when traffic volumes were low. In this mode the intersection typically flashes amber on the main road and red on the side street. This operation was used in the past when most traffic signals operated fixed time and was used to reduce vehicular delay and energy consumption late at night. With most signals now operating efficiently in semi or fully actuated mode, night-time flash is rarely used. In addition, there have been a number of studies since the 1980's that indicated removing night-time flash operations resulted in a reduction in angle collisions.

3.6 Phase Determination

General

The number of phases required for efficient operation depends on the physical characteristics of the intersection, collision trends and patterns, and the through and turning movements taking place. The smallest practical number of phases should always be used to reduce the "Lost Time" due to change and clearance intervals between phases.

Guidelines for calculating lost time values and typical lost time values are available in ITE's "Canadian Capacity Guide for Signalized Intersections" (CCG)².

Where the volume of vehicular or pedestrian traffic entering or crossing one or more approaches is sufficient to impact the operation of the intersection, but not sufficient to justify a completely separate phase, one or more of the normal phases may be split or programmed as a "Subordinate" phase to provide an interval within

the associated or parent phase. An advanced green combined with a through movement is an example of a subordinate phase.

The number and type of phases required will largely depend on the volumes and intersection geometrics. The number of required phases and their sequence constitute the cycle structure.

Standard Movements

General

It is recommended that the standard traffic movements be identified by number according to the type of controller. The type 170 controller and the NEMA type controller use similar numerical methods to identify phases. However, by convention, the side street phase numbers used by 170/2070 and NEMA controllers are reversed. The NEMA convention for traffic movements is shown in Figure 12. "F" designates a "Faze" (movement) number, and "P" designates a pedestrian movement number. The following convention is used:

- The through fazes are even numbers starting with faze 2 (typically on the main road) in either the northbound or eastbound location and progressing counter-clockwise around the intersection (clockwise for 170/2070 controllers).
- Unless separate signal indications are provided, the right turn movements are usually represented by the faze number designated to the adjacent through movement.
- The left turn fazes are odd numbers, starting with faze 1 (always on the main road) in the southbound to eastbound or the westbound to southbound direction and progressing counter-clockwise around the intersection (clockwise for 170/2070 controllers).

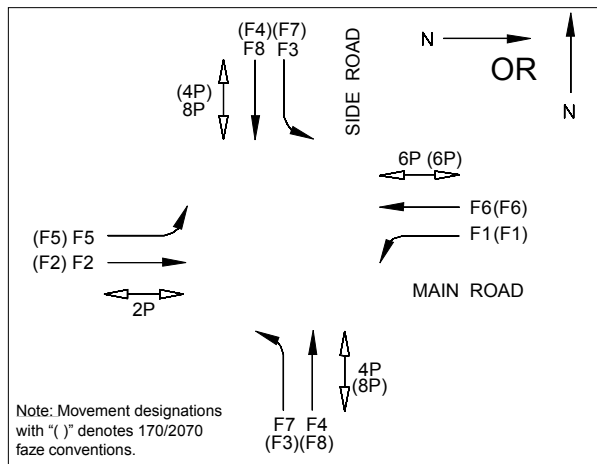


Figure 12 — NEMA and 170/2070 Movements

- Faze 1 always opposes faze 2. Odd number fazes are always left turn movements and even numbered fazes are always through movements.

When separate bicycle phasing is used the bicycle phases would be assigned a standard phase number. More information on bicycle phasing can be found in Section 6 of this manual.

Interval Sequence

A phase can be broken down into a sequence of intervals. An interval may be defined as a period of time during which the signal indications do not change. An interval may include, for example, a green ball and green arrow, or a solid amber ball indication. The traditional normal sequence of indications is indicated in a “Phase Diagram”.

Phase Diagrams

It is recommended that phase sequence diagrams be on or attached to the approved signal timings to ensure the phasing matches the signal layout shown.

The phase sequence diagram should include the following information:

- Each lane should be shown.
- The signalized movements should be shown in solid lines with the appropriate movement numbers.
- The movements within each circle should represent only those taking place within the phase.
- The connecting lines between the phase circles should be solid with arrows indicating the permitted direction of phase change.

All phase sequence diagrams are specific to the intersection and must be individually determined.

The examples in Figures 14 and 15 show three phase and multi-phase diagrams for “Permissive” and “Protected” left-turn movements for the 170 and NEMA controllers.

In a *permissive* mode, the left-turning motorist is permitted to turn during the normal circular green display and can complete the turn if adequate gaps occur in opposing traffic. The motorist must yield to opposing traffic and pedestrians crossing the roadway. The left-turning vehicle can clear the intersection on the normal amber indication after yielding to any opposing through vehicles and pedestrians clearing the intersection.

In a *protected* mode the left-turning motorist is given a signal display that provides right-of-way over conflicting traffic. Both pedestrians and opposing traffic are prohibited from crossing the path of the left-turning vehicle during the protected left-turn movement. The protected left turn is indicated by a left arrow display.

In a *fully protected* mode, left turning traffic is prohibited from moving other than when provided a protected left turn indication.

Combinations of different modes of left turns are possible and can be varied by time of day. For example, a permissive movement may be applied to one approach and a protected movement may be applied to another within the same intersection.

In some cases, simultaneous left turns are used where left turning vehicles from opposing directions are allowed to make their turn at the same time during protected left-turn movements. The simultaneous left turns are indicated by left arrow displays facing each opposing lane of turning vehicles. For true simultaneous operation, both opposing left-turn phases start and stop at the same time. However, because it is common to apply detection to both opposing lefts, the term “simultaneous” is also used where the two left-turn indications may start and end at different times.

Two Phase Operation

In a two phase operation, the controller simply alternates between main road and side road greens and can run under any mode of operation. Figure 13 shows the phase diagram.

Three Phase Operation

A three phase operation adds a left-turn signal on one approach. An example of this operation is shown in Figure 14 in which movement 5 is the advance green. Note that this operation would be classed as “Protected Permissive” as the left-turn green signal display shows a left-turn arrow type 8, 8A, 9 or 9A, or a flashing green arrow for the protected left-turn movement. Permissive left turns are permitted after the left-turn display has cleared.

Note that in Figure 14, the phase sequencing arrows show that the signal cannot sequence from Phase B directly to Phase A, but must first pass through Phase C. (This operation ensures that a call for an advance green within Phase B does not create a trap situation.) The arrows also ensure that after serving an advance green phase,

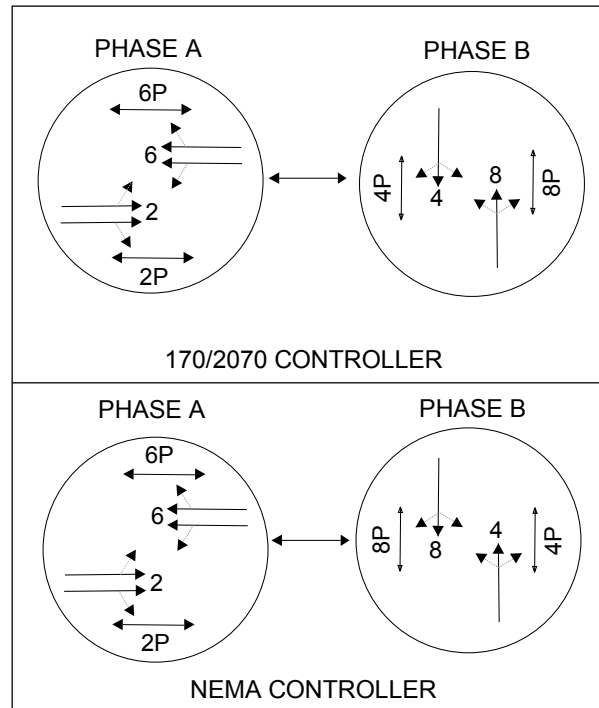


Figure 13 — Two Phase Diagram

the signal must sequence to Phase B so as not to violate driver expectancy: drivers expect the parent through phases to come up after an advance green.

Multiple Phase Operation

The number of phases may be increased where analysis indicates that additional phases are required to serve the traffic demands effectively and, or to improve safety.

For more complete discussions of phase diagrams and allowable phases and interval sequencing within the dual/multi-ring configurations, the engineer/analyst should consult the printed materials of the major controller manufacturers and the Ministry’s Electrical Design Manual.⁴

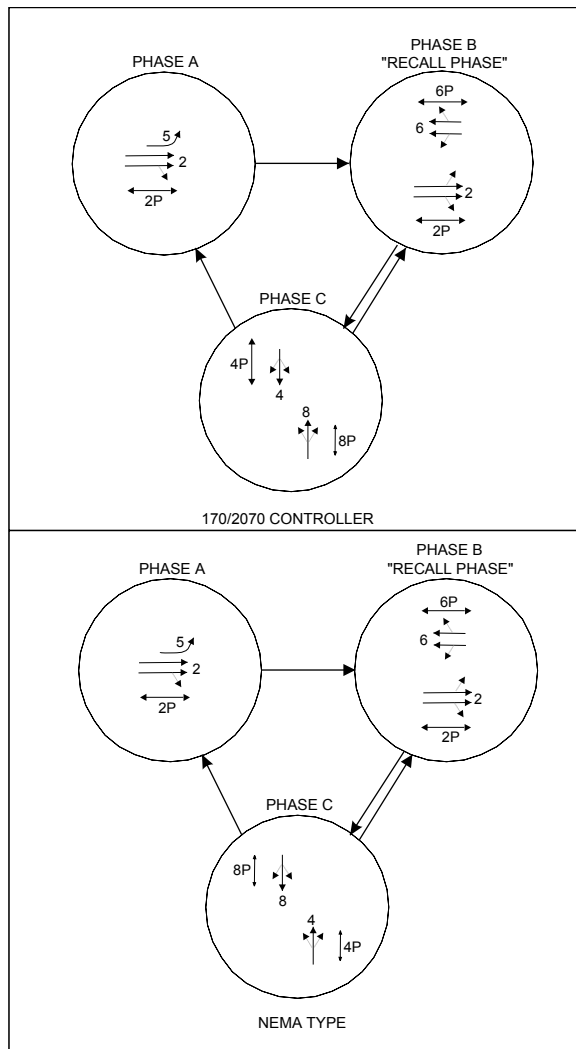


Figure 14 — Three Phase Diagram

For demonstration purposes, diagrams showing eight phase operations with protected/permissive simultaneous left turns on the side road approaches and fully protected simultaneous left turns on the main road are shown in Figure 15. The following should be noted:

- Stopped traffic is not shown.
- The operation shown will operate with a maximum of six phases per cycle since only

phase 'B' or 'C' on the main road and phase 'F' or 'G' on the side road may occur in any one cycle.

Pedestrian Phases

General

Where new pedestrian signals are installed, or existing ones replaced or rehabilitated they must meet the *Accessibility for Ontarians with Disabilities Act (AODA)* O. Regulation 191/11 requirements, meaning accessible pedestrian signals (APS) with the appropriate civil requirements are to be installed.

Additional information on APS operational guidelines can be found in the MUTCDC¹⁶ and the TAC "Guidelines for Understanding Use and Implementation of Accessible Pedestrian Signals"¹⁰ document that can be found at <http://www.tac-atc.ca/>

Pedestrian signal indications should follow the following sequence:

- Walking Pedestrian ("Walk") shall be displayed only when the corresponding through movement green indications are displayed, or when an all-red period is displayed if special pedestrian phasing is used (such as leading pedestrian intervals or exclusive pedestrian phases). The Walking Pedestrian indication does not necessarily need to be displayed with the green at actuated intersections (where a pushbutton actuation is used) as this approach allows for the use of less vehicular green time during cycles when no pedestrians are waiting to cross.
- Flashing Hand ("Flashing Don't Walk" (FDW)) must be displayed after every Walking Pedestrian indication as this is a clearance interval required to warn pedestrians of an upcoming steady Hand Outline indication. Most agencies terminate the flashing hand at the beginning of the amber, but it is permissible

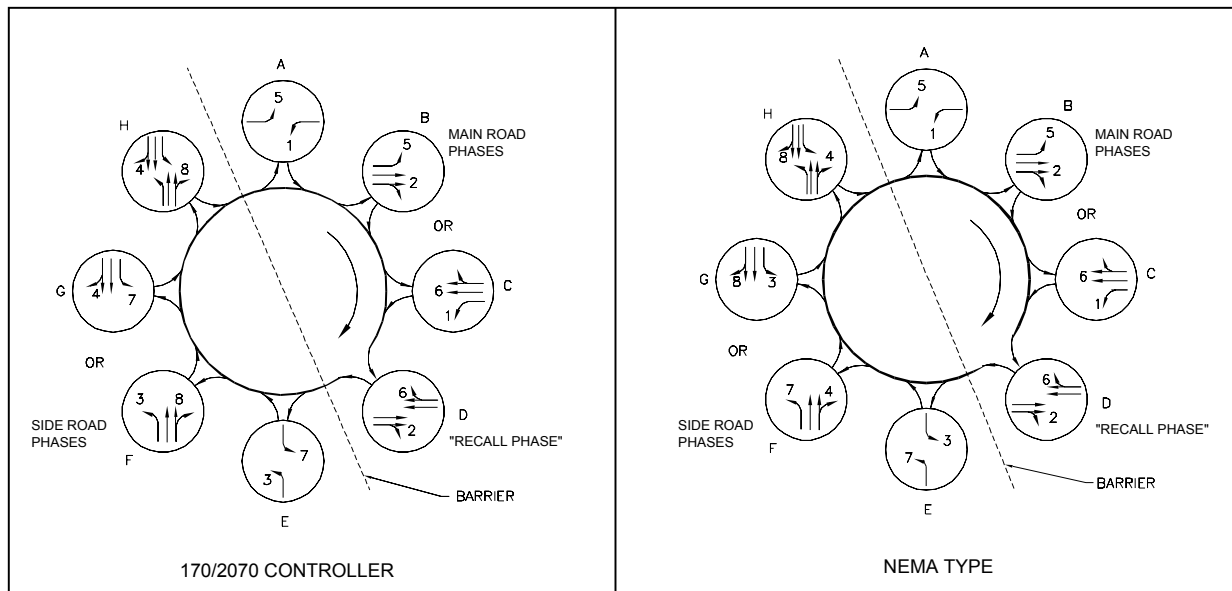


Figure 15 – Multi Phase Diagrams with Fully Protected Operation on the Main Road and Protected/Permissive Operation on the Side Road

to continue the FDW through the amber or all-red clearance intervals as this may provide additional information or reassurance to crossing pedestrians.

- The Steady Hand Outline (“Don’t Walk”) shall be displayed with any conflicting phases. This indication may also be displayed during the amber and all-red displays.

Exclusive Pedestrian Phases

Despite the pedestrian indications discussed above, an exclusive pedestrian phase typically shows the walk indications for one or more pedestrian movements while displaying red on all traffic signal indications. A unique form of this operation is called the “Barnes Dance” where pedestrians are able to cross in any direction including diagonally. Exclusive pedestrian phases are normally required only where the volumes of crossing pedestrians are extremely high and safety is impaired by the use of normal pedestrian display

intervals parallel to the vehicle signal head. Driver confusion and undesirable delays must be carefully considered before implementing an exclusive pedestrian phase. “No Right Turn On Red” regulations implemented with this phasing may be considered to minimize conflicts and maximize pedestrian throughput.

Leading Pedestrian Phases

Another form of priority pedestrian phasing is the advance pedestrian interval also known as the Leading Pedestrian Interval (LPI). The LPI provides a head start for pedestrians by providing a walk indication prior to the release of vehicular traffic in the same direction of travel. The LPI is intended to increase the visibility of pedestrians in the intersection and reinforce their right-of-way over turning vehicles. The LPI is used to encourage motorists to yield to pedestrians already in the crosswalk and is particularly helpful for older pedestrians who may take longer to enter the crosswalk at the start of the walk interval.

LPIs should be considered where heavy turning traffic conflicts with crossing pedestrians during the permissive vehicular phase as identified either through an existing collision trend or through a conflict study, and where pedestrian volumes and vehicular turning volumes are high enough to justify a dedicated interval for pedestrians. LPIs should provide a minimum head start for pedestrians generally between 4 and 6 seconds depending on the overall roadway crossing distance. The following formula can be used to calculate the length of an LPI:

$$\text{LPI} = \text{greater of 5 seconds, or } (TL/2 + PL) / W$$

Where:

- LPI = the number of seconds from the start of the WALK signal for pedestrians to the start of the green indication for vehicles.
- TL = the distance on the crosswalk to clear the total width of all moving lanes between the curb and the centreline of the roadway, not including the parking lane.
- PL = the distance on the crosswalk to clear the parking/merging lane if they exist.
- W = walking speed (recommended speed of 1.0 m/s).

LPIs can be implemented on most modern signal controllers through a “Delayed Vehicle Green” function where all vehicular traffic is shown either an all-red display or just all conflicting movements are provided a red indication. If a separate right turn lane is provided, a straight through green arrow can be displayed for through vehicular traffic while the LPI is on, which is then followed by a circular green display once the LPI had timed out. Figure 22 illustrates how an LPI would operate.

A “NO RIGHT TURN ON RED” regulation and sign may be required if conflicts between right turning vehicles and pedestrians are identified.

Care should be taken to ensure that any conflicting protected/permissive left turn movements are held on a red indication so they do not conflict with a LPI and that when any left turn movement terminates, clearance intervals are sufficient that no left turning vehicles are caught trying to complete their left turns as the LPI interval is starting up.

If LPI is being used at the intersection, it should be fully equipped with APS to ensure pedestrians with impaired vision are able to start into the crosswalk using the audible indications and do not get confused by the lack of sound from the parallel traffic surge.

Pedestrian Signal Operation

Pedestrians facing the Walking Pedestrian indication may enter the crosswalk and proceed in the direction of the Walk display. For the pedestrian interval clearance, the Hand Outline shall be a flashing indication. The clearance interval may terminate (and change to the steady Hand display) at the onset of the accompanying vehicular amber, but in practice the clearance interval is also allowed to continue until the beginning of the all-red.

Pedestrians facing the flashing Hand Outline must not start to cross the roadway in the direction of the pedestrian signal indication. Pedestrians who have started the crossing while facing the Walking Pedestrian indication may complete their crossing

The flashing Hand Outline should be flashed at a rate of not more than 60 nor less than 50 ON and OFF flashes per minute, with the length of each ON period approximately equal to the length of each OFF period.

Left-Turn Phase Justification

General

Left-turning movements are affected by turning volume, lane configurations, pedestrian and bicycle movements, opposing traffic flow, the width of the intersection, and the phasing of the traffic control signals.

Except for the case of a protected left-turn phase, left-turning vehicles will take more time to clear the intersection than the straight through vehicles because of the slower cornering speeds and opposing traffic. The left-turning vehicles may also block through vehicles unless a separate left-turn lane with adequate storage is provided.

The contents of this subsection assume that an adequate left-turn lane can be provided. If this is not the case, consideration should be given to restricting left-turning movements to one direction only or to providing a separate phase. Where shared left-through lanes are considered, and through traffic is blocked by a left turn vehicle, lane changes by through traffic must be taken into account.

Approximation

A simplified method using traffic volumes to estimate delays may be used initially to analyze the need for left-turn phases at planned or existing signalized intersections. The method is as follows:

A left-turn phase may be justified:

1. If the left-turning vehicles are not finding suitable turning gaps, volume exceeds at least two vehicles per cycle, and the Level of Service at the intersection will not be jeopardized;
2. If the left-turning volume plus the opposing volume > 720 vehicles per hour;
3. If a field check shows that vehicles consistently require more than two cycles in the queue in order to turn left;
4. If an over-representation of left turning collisions is identified at the intersection. It should be noted that if there is a collision history, fully protected left turn phasing is much more likely to reduce collisions than protected permissive left turn phasing; or
5. If the number of lanes a left turn vehicle must cross can also suggests the need for a protected left turn phase—as drivers have more difficulty assessing speed and available gaps over multiple lanes.

Analytical Method

Several analytical methods for determining the justification for separate left-turn phases are used in Ontario.

Ontario Capacity Analysis Method

The capacity analysis method is particularly useful for the planning of new signals.

The threshold capacity of a left-turn lane can be stated as $[1400 G/C - V_o]$ taking into account V_o , the opposing volume of traffic. This method checks to determine whether the left-turn volumes are greater than the threshold capacity required for a left-turn phase. V_o includes right-turning traffic if there is no right-turn channelization. G is the green time for the opposing flow in seconds, and C is the cycle length in seconds. If there is more than one opposing lane (not counting opposing left-turning vehicles), the left-turn lane capacity of $[1400 G/C - V_o]$ must be modified by a factor “(f)” to take into account the effect of multiple opposing lanes, as given in Table 2.

Table 2 — Capacity Factor for Opposing Lanes

Number of Opposing Flow Lanes	1	2	3	4
(f) value	1.0	0.625	0.5	0.44

The left-turning volumes normally include an allowance of two vehicles clearing the intersection per cycle by turning on the amber/all-red interval, (assuming a reasonably large intersection). The capacity of the left-turn lane during the permissive stage (no separate left-turn phase) is given by:

$$c_{Lt} = 1400 G/C - (f) V_o + Lt_a$$

Where:

c_{Lt} = the capacity of the separate left-turn lane during the permissive stage of the phase in vehicles per hour

(f) = the volume adjustment for the opposing number of lanes (Table 2)

V_o = total opposing traffic flow (vph), including through lanes, shared lanes and right-turn lanes where right-turn channelization does not exist

G/C = green time interval for the opposing flow/cycle length (seconds)

Lt_a = $7200/C$ vph and is the number of vehicles turning left on amber assuming two vehicles per cycle

If the calculated value of c_{Lt} is less than the actual number of left-turning vehicles, then a separate left-turn phase may be justified.

If the opposing and the left-turning traffic is mixed with transit buses and trucks, the volumes in the formula should be adjusted to represent passenger car equivalent volume.

Canadian Capacity Guide

The Canadian Capacity Guide² provides capacity evaluation techniques for left turns which consider many variables such as lane geometry, city environment, pedestrians, and multiple turn lanes. It is particularly applicable if saturation flow rates have been measured because CCG procedures are heavily reliant on flow parameters to generate their results. Assumed flows are subject to adjustment factors in order to more closely replicate real world conditions. However, measured saturation flow rates calibrate the calculations to a higher degree by accounting for all adjustment factors, while requiring only one measurement.

CCG analysis is particularly useful for understanding the effect of various factors in complex situations. The relative capacities, queueing impact and environmental impact of various options can be compared to find the phasing which best suits the left-turn demand.

There may also be locations where protected left turn phases are not justified based on traffic flow analysis, but instead may be considered due to inadequate sight distance visibility that may result due to approach geometry or the need to cross multiple lanes of high speed traffic. Network screening may be used to identify locations where safety can be improved through the use of fully protected left turn phasing.

Bicycle Phasing

Requirements for separate bicycle phasing can be found in Section 6 and OTM Book 18 (Bicycle Facilities).

Determination of the Type of Left-Turn Phase

General

Once it has been determined that a left-turn phase is required, it is necessary to assess the type of operational characteristics required. These range from the relatively simple and common protected/permissive advanced green on one approach only (using type 8, 8A, 9 or 9A signal heads) to the complex multiple phase operation with left-turn phases in all directions. The designer must choose the type of operation based on the following considerations:

1. If there is a geometric or visibility problem at the intersection, or if there is a historical collision pattern involving left turn vehicles, a fully protected left-turn phase should be considered.
2. Where the capacity analysis of equivalent turning volumes or queue end requirements indicates that dual left-turn lanes are required, due to equivalent left-turning volumes or because of queue length requirements, fully protected operation should be considered. If using double left turn lanes, consideration should be given to prohibiting right turns on red for the opposing right turning vehicles. Protective/permissive operation may be considered for use with dual left-turn lane operation only when:
 - The geometry of the intersection and approaches allows proper turning treatment.
 - The opposing through volumes are very low and it is considered that motorists will not have problems judging gaps in opposing traffic from the most right-hand left-turn lane.
3. Simultaneous left-turn operations should be considered wherever both opposing left-turn lanes require separate phases and the

geometry of the intersection allows. The left-turn phases may be operated in the protected/permissive mode or the fully protected mode.

Recommended practice for simultaneous protected/permissive left-turn operation with single left-turn lanes uses type 8, 8A, 9 or 9A signal heads. Fully protected left-turn operation must use separate left-turn signal heads (Type 2 heads). A sign showing LEFT TURN SIGNAL is also required for fully protected left-turn operation. The sign should be located to the left of the median pole between the left-turn signal head and the pole, or as close to the signal head as practical and as specified in OTM Book 5 (Regulatory Signs).

4. Delayed green or permissive/protected operation should be considered only where there is no opposing left-turn movement that could create an unsafe trap situation. The MUTCDC (B4.5.3) defines the trap as entrapment and uses the following example, *“An entrapment could be created if Approach 1 rests in green and Approach 2 goes to amber. Left-turn drivers on Approach 2 would expect that vehicles on Approach 1 also have the amber indication and, therefore, would be preparing to stop. Left-turn drivers on Approach 2 may try to use the clearance interval to cross opposing traffic which would still have a green indication on Approach 1.”*

Types of Left-Turn Phasing

The figures shown in this section are intended only to show only the left-turn parameters. They have been adopted from the TAC MUTCDC.¹⁶ Additional amber, clearance and other traffic movement phases beyond those shown may be required to accommodate the local conditions of a specific intersection.

1. Protected/Permissive Single Direction Left Turn Phasing

Protected/permissive single direction left turn signal phasing (also known as “Advance Green” phasing) gives a protected/permissive left-turn movement in one direction. The left-turning vehicles are first given a protected interval on which to turn with the opposing traffic (including conflicting pedestrians) stopped. The associated through and right-turning vehicles are also allowed to proceed during the protected left-turn phase. After the protected left turn movement terminates with a clearance interval, the opposing traffic is released with a normal circular green ball display, allowing the left-turning vehicles to turn only after yielding to any opposing traffic.

Signal heads 8, 8A, 9, 9A, 10 or 10A may be used for protected/permissive single direction operations. The use of the amber arrow after a green left turn arrow is mandated by Regulation 626 of the HTA for simultaneous left turn operation. For single direction left turns, the use of the amber arrow is optional but should be used for consistency and to conform with TAC’s requirements.

Protected/permissive, single direction, left turn phasing is shown in Figure 16.

2. Right Turn Overlap Phase

Right turn phasing may be controlled in a permissive or protected manner depending on demand, lane configuration, the presence of pedestrians, the presence of a separate cycling facility, and the operation of other phases at the intersection.

Right turns may be operated in a protected mode on an overlap phase to increase efficiency at an intersection. The most typical overlap is the right turn operating at the same time as a perpendicular left turn protected phase.

Right turn overlap phasing is shown in Figure 17. The overlap right turn phase is controlled by a four section signal head, (Type 11 or 11A) in the primary position. The clearance from protected to permissive right turn is typically achieved through a short period between the end of the right turn arrow display and the beginning of the Walk display and green ball display. This would be a hidden clearance interval; however, it is recommended that an amber arrow be used and would use the same clearance time as the perpendicular left turn protected phase it overlaps.

Right turn overlap phasing is generally only required where there is high right turn demand during some parts of the day. An exclusive right turn lane is strongly recommended for the operation of right turn overlap phasing.

Right turn overlap phasing can also be implemented with back-to-back simultaneous left turn protected permissive phasing.

3. Protected/Permissive Simultaneous Left Turn Phasing

Protected/permissive simultaneous left turn phasing gives left-turning vehicles from opposing directions a protected left-turn phase at the same time. No other conflicting vehicles or pedestrians are allowed to enter the intersection during the simultaneous protected left-turn phase. After the simultaneous protected left-turn phase has been terminated, the left-turning vehicles are permitted to turn through opposing traffic, but they must yield right-of-way.

When the left-turn lanes are separately actuated, the protected left-turn phase from one direction may terminate before the other left-turn phase. When this occurs, the associated through and right-turn vehicles, and non-conflicting pedestrians, are allowed to proceed with the one remaining protected left-turn movement. If there are no opposing left-turning vehicles during a cycle, the

opposing protected left-turn phase can be skipped. In this case, the operation during that cycle will be similar to a single direction protected/permmissive operation. Figure 18 shows the basic intervals.

4. Fully Protected Simultaneous Left Turn Phasing

In fully protected simultaneous left turn phasing, left turns move only in a fully protected mode. This phasing requires left-turning vehicles to be provided with their own traffic control signal heads. Left-turning vehicles from opposing directions are given a left-turn indication at the same time. No other conflicting vehicles or pedestrians are allowed to enter the intersection during the left-turn phase. In normal Ontario practice, the turn movements are usually programmed to give overlapping simultaneous lefts. The left-turn intervals are terminated with their own clearance displays and left-turning vehicles are not permitted to proceed when the opposing through traffic is given a green indication. The opposing left turns may terminate at different times.

To help the motorist to recognize the Type 2 left-turn signal heads, a LEFT TURN SIGNAL sign must be placed adjacent to the Type 2 heads. The fully protected simultaneous left turn operation is used where the visibility of vehicles making left turns to the opposing traffic (or vice versa) is limited. The operation may also be used where the opposing traffic approach has high volumes resulting in poor availability of gaps in the opposing traffic for permissive left turns. Fully protected simultaneous left turn phasing should also be used on high speed roads with potential visibility problems due to geometry, or where collision problems exist. Double left-turn lanes should also require fully protected simultaneous left turn phasing. Figure 19 shows the basic intervals.

5. Permissive/Protected Lagging Left Turn Phasing – Single Direction

For permissive/protected lagging left-turn phasing, left-turning vehicles are first permitted to turn after yielding to opposing vehicles during a normal green ball display. They are then provided with a protected left-turn phase in one direction after the opposing approach has been terminated with a circular amber and circular red display. The associated through and right-turn movements are allowed to proceed during the protected left-turn phase. This type of phasing should only be used at locations where there is no opposing left-turn movement, for example, at “T” intersections and at 4-Leg intersections where the opposing left-turn movement is prohibited. If used in other situations, an opposing left-turn vehicle may choose an inappropriate time to proceed while waiting for a gap as motorists generally expect the opposing traffic to receive the same signal indications (i.e., an amber display) at the same time. It is also suggested that signs be installed indicating the operation of the extended left turn. Figure 20 shows the basic intervals.

6. Separate Protected Left Turn Operation (Separate Phasing)

Separate protected left turn phasing allows one traffic approach to the intersection to proceed while the traffic on all other approaches is stopped. This is also referred to as Split Phasing.

All movements on the separate phase approach including left turns are permitted to proceed through the intersection.

Separated protected left turn phasing is typically used to improve capacity where intersection geometrics prevent simultaneous left turns, or where there are shared lanes. This phasing may also be chosen as an effective countermeasure

where a left turn with opposing through collision pattern cannot be resolved through other, less restrictive methods. Separate phasing is generally less efficient than other types of left turn phases or the standard two phase operation, but it offers a very effective way to eliminate this specific collision type.

Figure 21 illustrates the basic intervals for separated protected left turn phasing.

7. Lagging Fully Protected Simultaneous Left Turn

The lagging fully protected simultaneous left turn is similar to the Fully Protected Simultaneous Left Turn Operation described previously except that left-turn movements are given a protected phase after the through traffic phase.

Lagging fully protected simultaneous left turn phasing is seldom used because left-turning displays are normally displayed before the through traffic indications. The exception occurs at intersections that are running fully actuated operation. At these locations, the fully protected left turn phase may lead or lag the through movement for any specific cycle depending on vehicle actuation.

Consideration could be given to using lagging fully protected left turn movements when using an LPI or LBI as it removes any potential conflict between the pedestrians or cyclists entering the intersection as left turning vehicles are trying to clear the intersection during the clearance interval.

PROTECTED/PERMISSIVE SINGLE DIRECTION LEADING LEFT-TURN PHASING

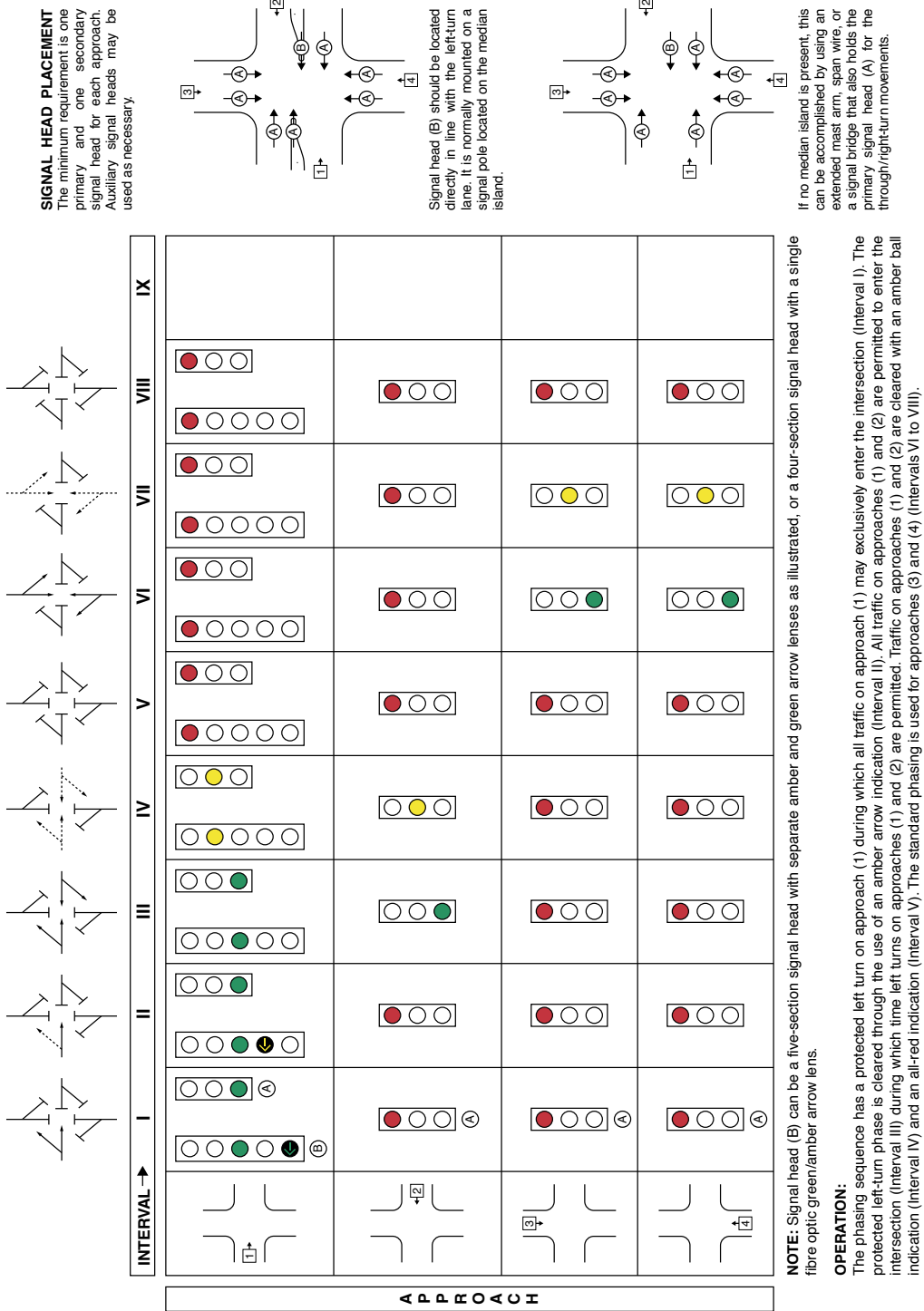


Figure 16 — Protected / Permissive Single Direction Leading Left-Turn Phasing (Source: TAC MUTCDC Figure B4-5)

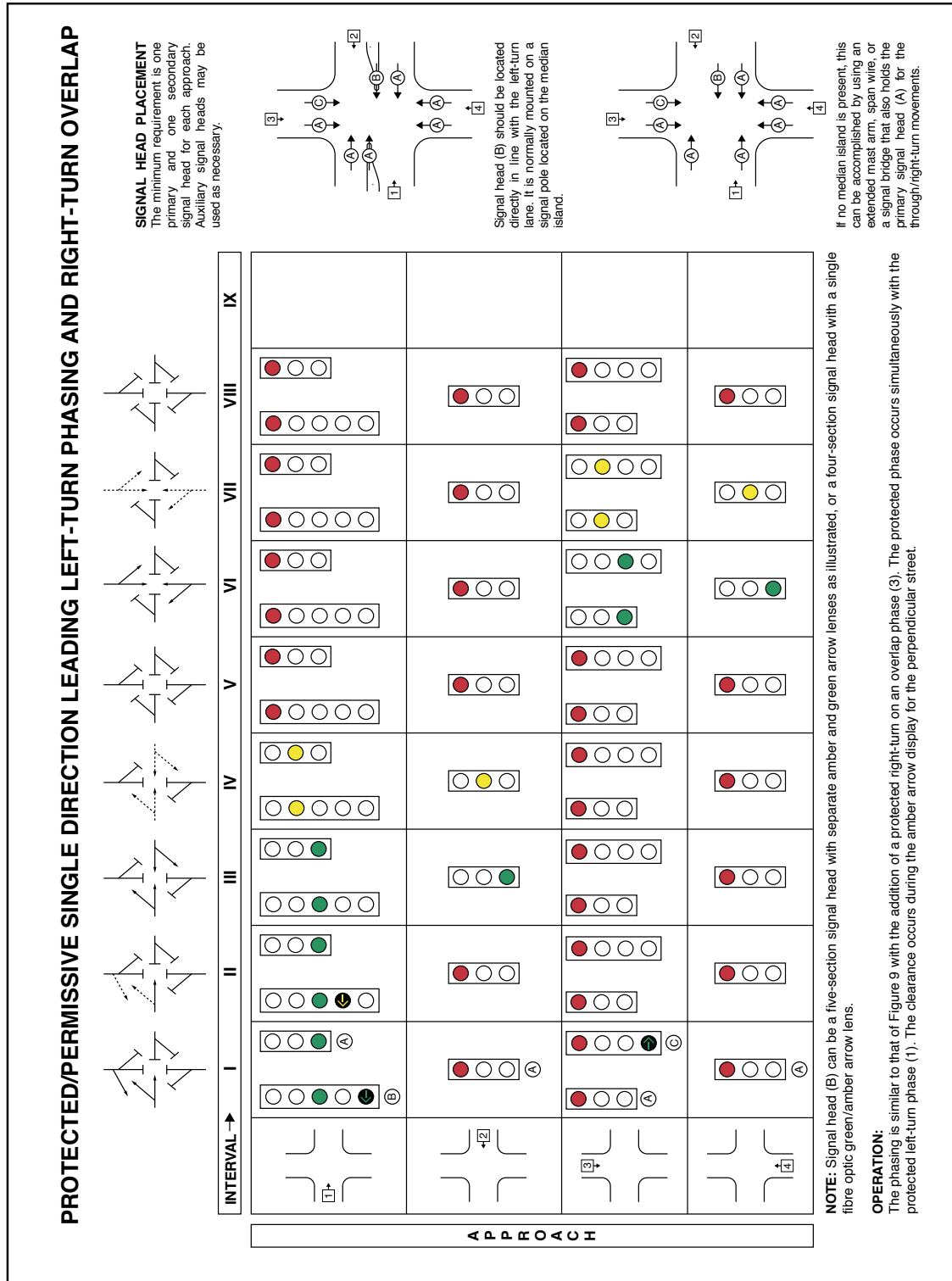


Figure 17 — Protected / Permissive Single Direction Leading Left-Turn Phasing and Right-Turn Overlap

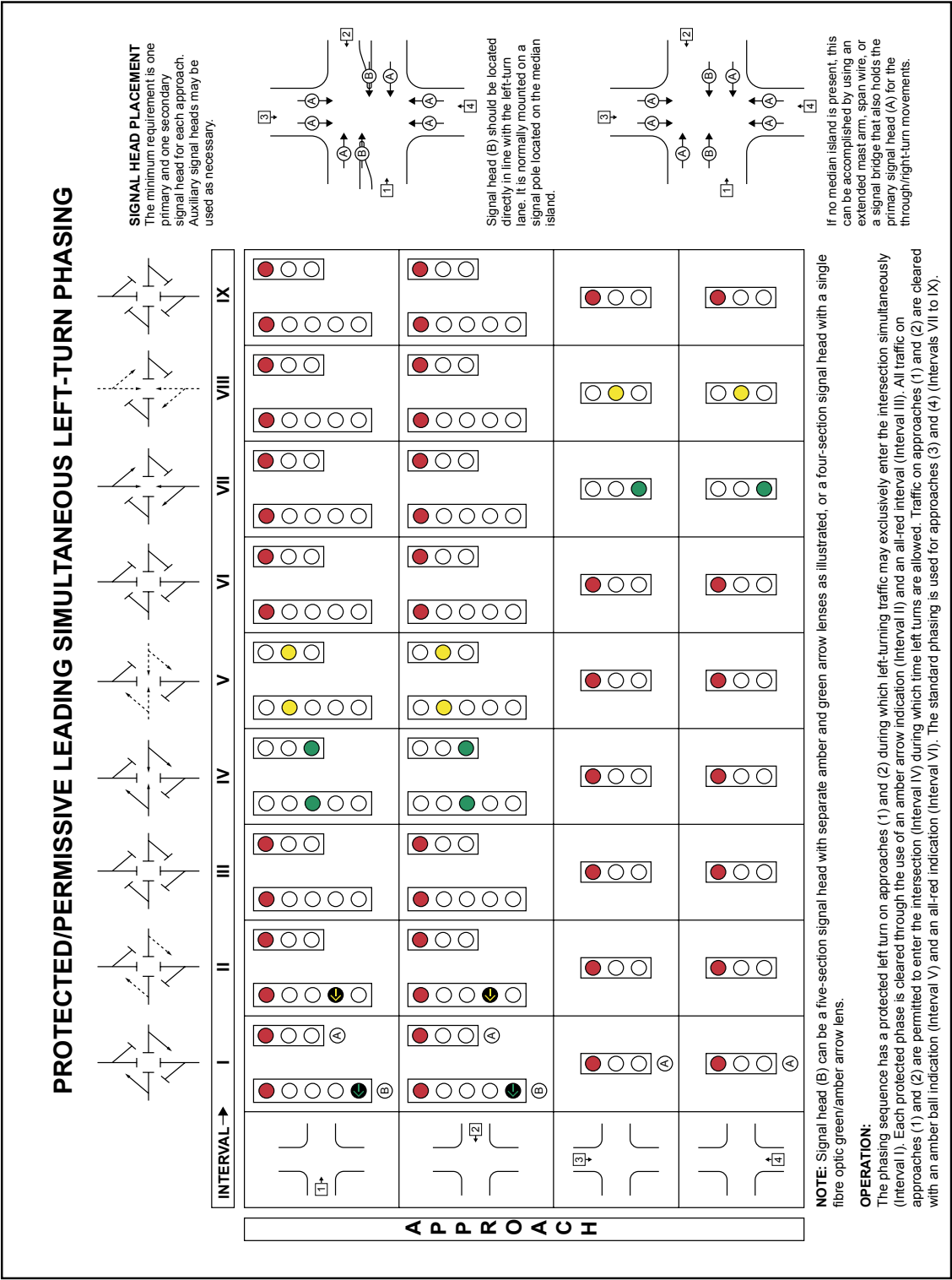
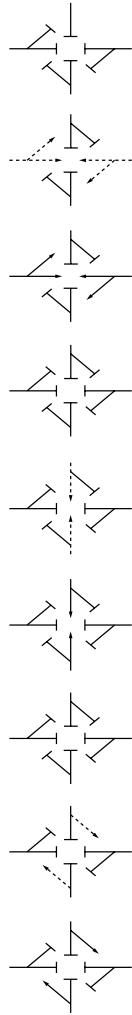
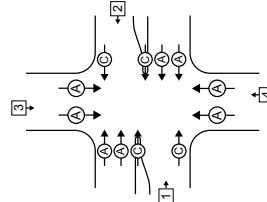


Figure 18 — Protected / Permissive Leading Simultaneous Left-Turn Phasing (Source: TAC MUTCDC Figure B4-6)

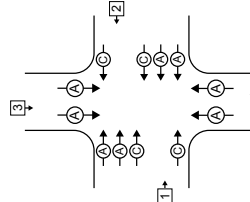
FULLY PROTECTED LEADING SIMULTANEOUS LEFT-TURN PHASING



SIGNAL HEAD PLACEMENT
The minimum requirement is one primary and one secondary signal head for each approach. Auxiliary signal heads may be used as necessary.



The primary left-turn signal head (C) should be located directly in line with the left-turn lane. It is normally mounted on a signal pole located on the median island.



If no median island is present, this can be accomplished by using an extended mast arm, span wire, or a signal bridge that also holds the primary and secondary through/right-turn signal heads (A).

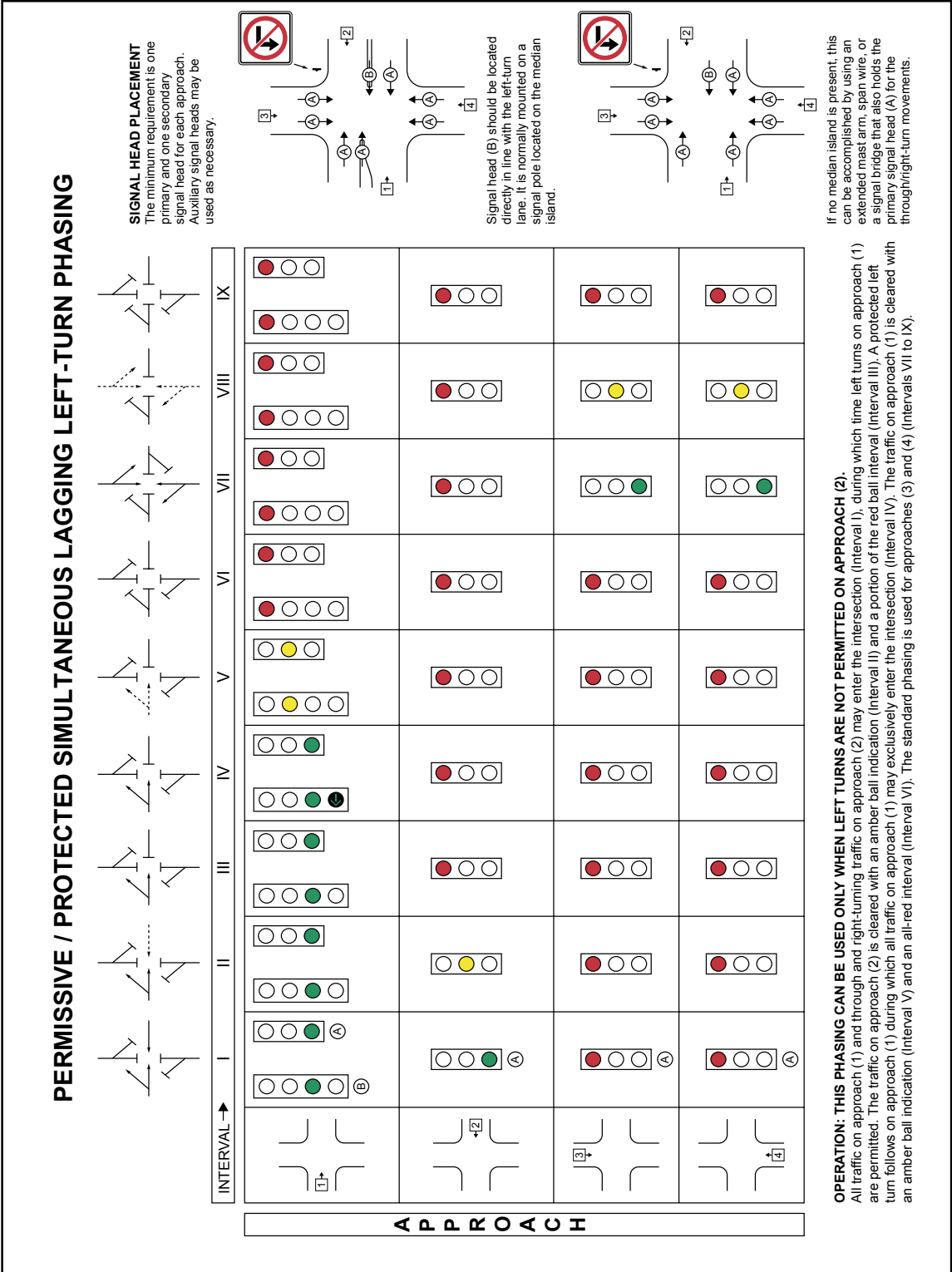
INTERVAL →	I	II	III	IV	V	VI	VII	VIII	IX
APPROACH									
Signal Head 1	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 2	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 3	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 4	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 5	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 6	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 7	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 8	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 9	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 10	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 11	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 12	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 13	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 14	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 15	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 16	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 17	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 18	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 19	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 20	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 21	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 22	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 23	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 24	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 25	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 26	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 27	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 28	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 29	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 30	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 31	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 32	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 33	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 34	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 35	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 36	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 37	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 38	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 39	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 40	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 41	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 42	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 43	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 44	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 45	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 46	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 47	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 48	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 49	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 50	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 51	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 52	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 53	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 54	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 55	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 56	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 57	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 58	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 59	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 60	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 61	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 62	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 63	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 64	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 65	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 66	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 67	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 68	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 69	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 70	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 71	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 72	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 73	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 74	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 75	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 76	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 77	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 78	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 79	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 80	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 81	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 82	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 83	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 84	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 85	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 86	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 87	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 88	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 89	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 90	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 91	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 92	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 93	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 94	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 95	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 96	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 97	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 98	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 99	Red	Red	Red	Red	Red	Red	Red	Red	Red
Signal Head 100	Red	Red	Red	Red	Red	Red	Red	Red	Red

NOTE: At an actuated intersection when the left turn is called on one approach and not on the opposing approach, the controller may be programmed to display the Fully Protected Leading Left-Turn Phasing (Figure B4-7) for that approach.

OPERATION:

The phasing sequence has a protected left turn during which only left-turn traffic on approaches (1) and (2) may enter the intersection (Interval I). The protected left-turn phase is cleared with an amber ball indication (Interval II) and an all-red interval (Interval III). Only through and right-turn traffic on approaches (1) and (2) may enter the intersection (Interval IV). The through and right-turn traffic is cleared with an amber ball indication (Interval V) and an all-red interval (Interval VI). The standard phasing is used for approaches (3) and (4) (Intervals VII to IX).

Figure 19 — Fully Protected Simultaneous Left-Turn Phasing (Source: TAC MUTCDC Figure B4-9)



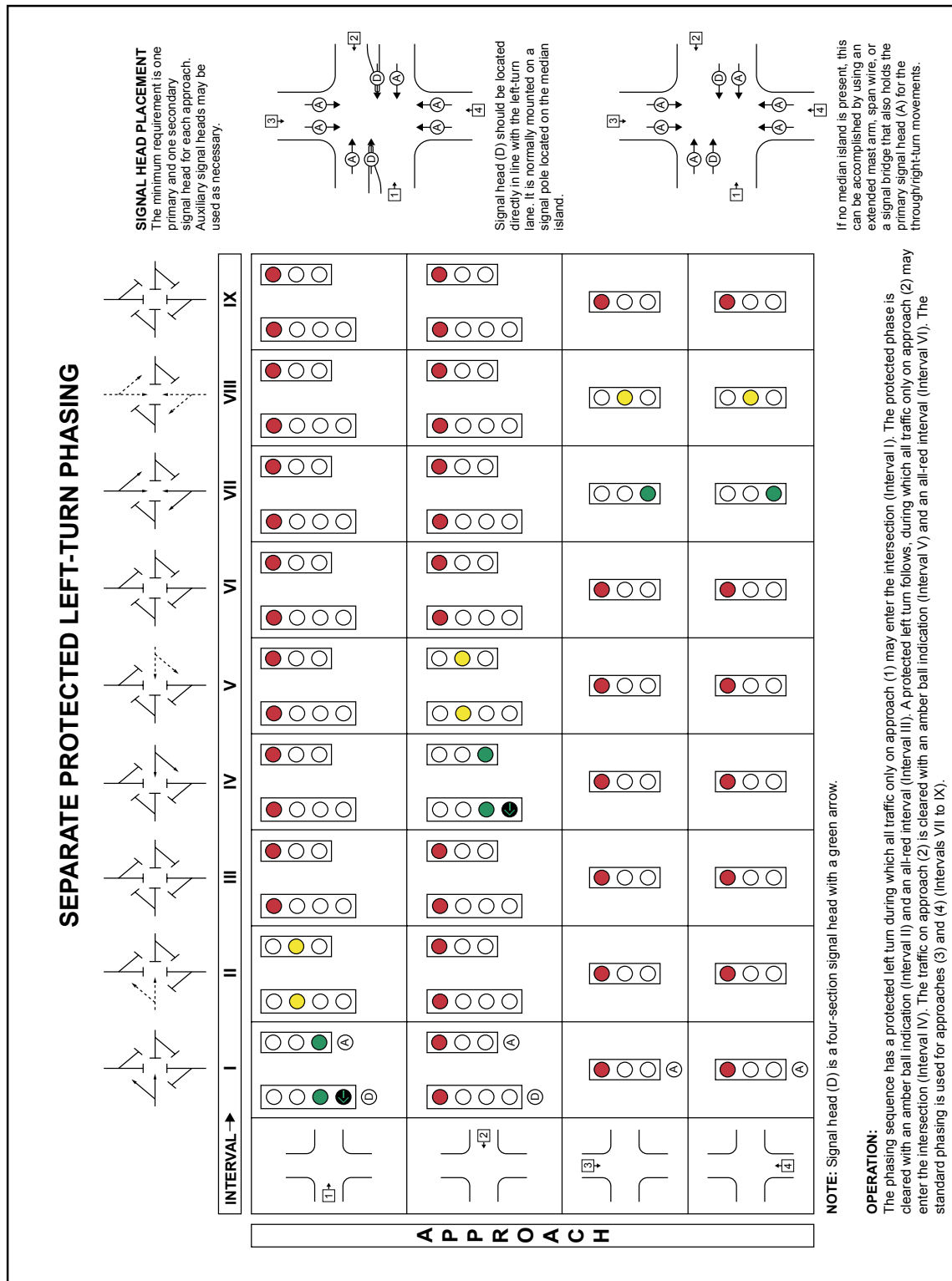


Figure 21 — Separate Protected Left-Turn Phasing (Source: TAC MUTCDC Figure B4-13)

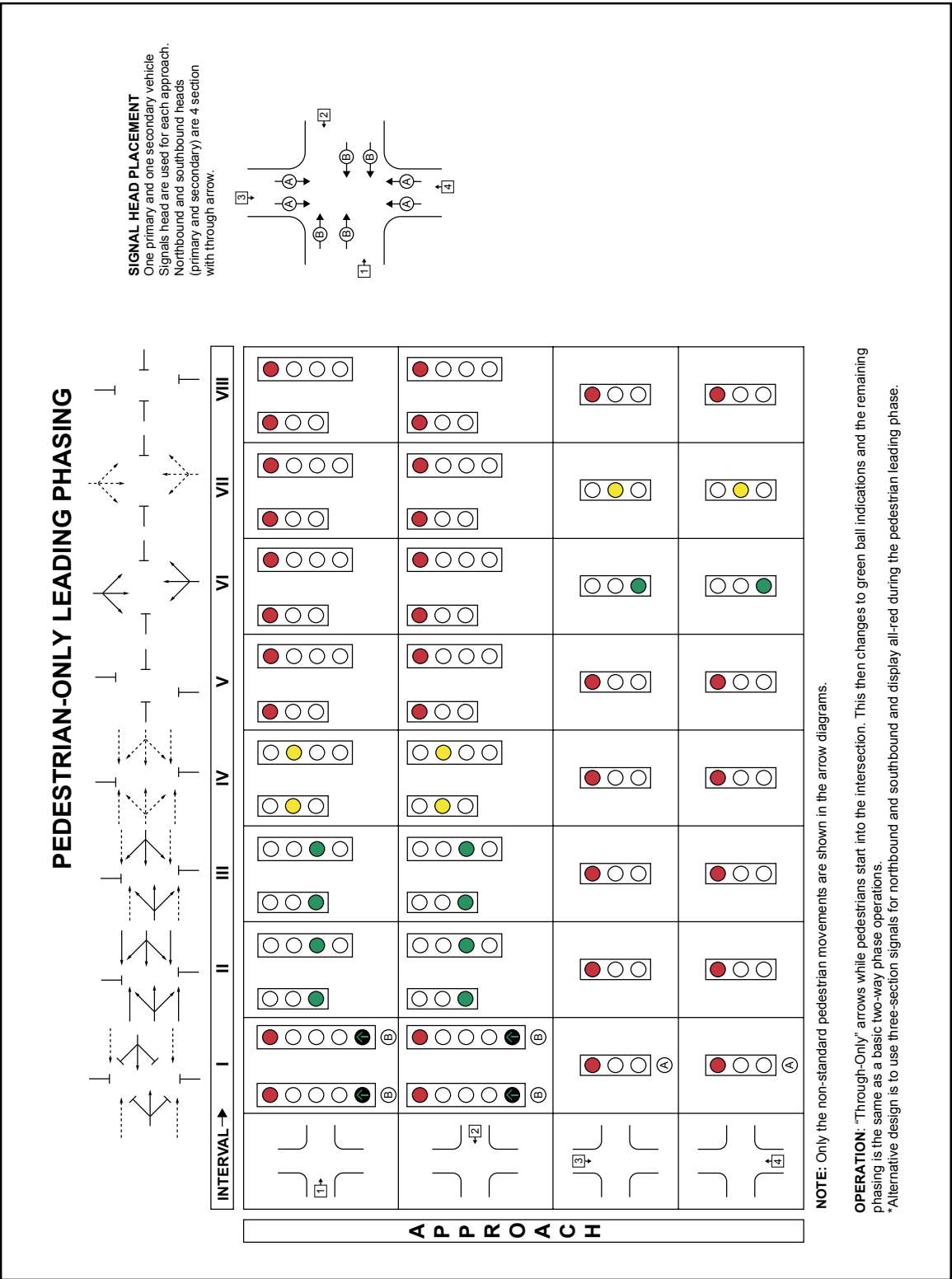


Figure 22 – Pedestrian Only Leading Phase (Source: TAC MUTCDC Figure B4-4)

3.7 Timing

General

To estimate the interval and phase timing required reasonably up-to-date or predicted traffic volumes per movement are needed. Before deriving the traffic control signal timing, vehicle and pedestrian traffic flow and equivalent volumes must be analyzed. Traffic demand analysis will determine the optimum interval timing to best balance safety and traffic flow efficiency.

Guidelines are available in ITE's "Canadian Capacity Guide for Signalized Intersections" (CCG).²

When determining equivalent traffic volumes (in accordance with the principles of the CCG²), care should be taken to apply appropriate factors for turning vehicles, heavy vehicles (trucks and buses), and approach lanes. In urban conditions, the number of usable lanes may also vary at different times of the day as on-street parking, bus stops, HOV lanes, etc., may be present. The CCG uses the theory of intersection and lane flow ratios to determine minimum and optimum cycle times, capacity, delay and lost time per cycle.

However, consideration of minimum interval timing is required before the analysis of the cycle timings.

Minimum Interval Timing

Motorists do not expect a signal display that has just started to be terminated immediately. Minimum interval times are used to avoid this situation. Table 3 shows guidelines for minimum interval timing values. Minimum bicycle signal green times are discussed in Section 6 of this manual.

Table 3 — Minimum Interval Times

Interval	Preferred (seconds)	Minimum (seconds)
Circular Green for roads posted at less than 80 km/h	10.0	7.0
Circular Green for roads posted at 80 km/h or more	20.0 (Main Road) 10.0 (Side Road)	15.0 (Main Road) 7.0 (Side Road)
Circular Amber	3.0	3.0
Protected Green Arrow portion of protected / permissive	7.0	5.0
Amber Arrow Clearance for protected portion of protected / permissive	3.0	2.0*
Green Arrow for Fully protected left or right	7.0	5.0
Amber Arrow Clearance for Fully protected	3.0	3.0
All-Red	1.0	1.0
Transit Priority	5.0	3.0
Pedestrian Walk	7.0	5.0
Pedestrian Clearance	5.0	3.0

Source: ref. 2 (in part)

* NEMA controllers are limited to 2.7 seconds minimum.

General

The required clearance time for any through movement phase is related to the approach operating speed, motorists' perception and reaction times, the crossing width of the intersection, and the average deceleration rate of the vehicles.

Amber times are set so that motorists can reach the intersection if they are unable to stop when at the decision point for stopping or proceeding. The all-red times are set so that vehicles just crossing the stop line have sufficient time to clear the intersection. It is generally accepted that the posted speed is used to ensure safe clearance times.

Amber and All-Red Clearance Intervals

The total clearance period is separated into the amber interval clearance and the all-red interval clearance. The clearance period may be expressed as:^{2 22}

$$\text{Clearance} = y + r = \text{amber} + \text{all-red} \\ = [t + V / (2a \pm 70.6g)] + [3.6(W + l) / V]$$

Where:

y = amber interval clearance(s)

r = all-red interval clearance (s)

t = perception and reaction time (1 second minimum)

V = approach posted speed (km/h)

70.6 = factor of 2x acceleration of gravity in km/h/s

g = % grade/100: positive for uphill, negative for downgrade

a = average deceleration rate (11 km/h/s is used)

l = length of the average passenger vehicle (6.0 m is used)

W = width of the intersecting road (m) to be crossed from the near side stop line to the far side curb line or the far outside edge of the crosswalk where used

3.6 = factor to convert km/h to m/s

The amber interval $[y = t + V / (2a \pm 70.6g)]$ informs the driver that the right-of-way is about to change and must therefore provide sufficient time for the approaching motorist to travel the stopping sight distance. The amber clearance interval in Table 4 assumes 1.0 seconds as the minimum perception-reaction time and assumes a level approach grade. The road authority may, at its discretion and under specific conditions (typically isolated rural or high speed locations) choose to employ a longer perception-reaction time. If this is the case, and/or if the approach grade to the intersection is significant, the amber time must be calculated directly from the formula above.

The all-red interval $[r = 3.6 (W + l) / V]$ represents the time required to provide a safe passage across the intersection for vehicles entering the intersection at or near the end of the amber interval. In the interests of standardization, an all-red interval should be used at all signalized intersections.

Modern traffic signal controllers can program amber and all-red intervals to one decimal place (tenth of a second) so it is recommended all calculations be rounded to 1/10th of a second.

If a Red Light Camera (RLC) is being installed, the clearance interval data saved and displayed by the RLC should be checked to ensure it exactly corresponds with the clearance intervals programmed into the signal controller as an RLC may truncate the clearance interval times.

Table 4 — Amber Clearance Interval Times

Posted Speed (km/h)	40	50	60	70	80	90	100
Amber clearance for 1.0 seconds perception + reaction time (seconds)	3.0	3.3	3.7	4.2	4.6	5.1	5.5

Table 5 — All-Red Clearance Interval Times

Clearing Distance (W + L) (m)	Posted Speed (km/h)						
	40	50	60	70	80	90	100
12.0	1.1	1.0	1.0	1.0	1.0	1.0	1.0
13.5	1.2	1.0	1.0	1.0	1.0	1.0	1.0
15.0	1.4	1.1	1.0	1.0	1.0	1.0	1.0
16.5	1.5	1.2	1.0	1.0	1.0	1.0	1.0
18.0	1.6	1.3	1.1	1.0	1.0	1.0	1.0
19.5	1.8	1.4	1.2	1.0	1.0	1.0	1.0
21.0	1.9	1.5	1.3	1.1	1.0	1.0	1.0
22.5	2.0	1.6	1.4	1.2	1.0	1.0	1.0
24.0	2.2	1.7	1.4	1.2	1.1	1.0	1.0
25.5	2.3	1.8	1.5	1.3	1.1	1.0	1.0
27.0	2.4	1.9	1.6	1.4	1.2	1.1	1.0
28.5	2.6	2.1	1.7	1.5	1.3	1.1	1.0
30.0	2.7	2.2	1.8	1.5	1.4	1.2	1.1
31.5	2.8	2.3	1.9	1.6	1.4	1.3	1.1
33.0	3.0	2.4	2.0	1.7	1.5	1.4	1.2
34.5	3.1	2.5	2.1	1.8	1.6	1.4	1.2
36.0	3.2	2.6	2.2	1.9	1.6	1.5	1.3
37.5	3.4	2.7	2.3	1.9	1.7	1.6	1.4
39.0	3.5	2.8	2.3	2.0	1.8	1.6	1.4
40.5	3.6	2.9	2.4	2.1	1.8	1.6	1.5
42.0	3.8	3.0	2.5	2.2	1.9	1.7	1.5
43.5	3.9	3.1	2.6	2.2	2.0	1.7	1.6
45.0	4.1	3.2	2.7	2.3	2.0	1.8	1.6

Notes:

1. Values do not apply to left turn clearances.
2. Where the approach to the intersection is on a significant grade, the formula used should be: $y = [t + v / (2a \pm 70.6g)]$ where $g = \% \text{ grade} / 100$ and $70.6 = \text{factor } 2 \times \text{acceleration of gravity } (2 \times 3.6 \times 9.81) \text{ in km/h/s}$.
3. Three seconds is the recommended minimum for the amber clearance time. One second is the recommended minimum for the all-red.
4. If posted speeds are less than 40 km/h, 3.0 seconds for the amber and 1.0 second for the all-red are recommended.
5. W is the width of the intersection and L is the length of the typical vehicle, both in meters.

Clearance for Left-Turn Signals

A minimum amber clearance time of 2.0 to 3.0 seconds must follow a protected permissive left turn green arrow before the opposing traffic is released. An all-red of 1.0 to 1.5 seconds should be used after the amber arrow if additional clearance is required.

Where the fully protected mode of operation is used in a left-turn lane, a nominal amber clearance time of 3.0 seconds should be used, followed by a 1.5 second to 2.0 second all-red to complete the clearance of any left turning vehicles left trapped in the intersection.

For protected permissive left turn movements in one direction, an amber arrow may be followed by what is called a hidden clearance. With a hidden clearance, after the amber arrow the controller will time an all-red interval programmed into the signal controller, however that red interval is not displayed on street. Once the hidden clearance times out, the signal will cycle to the next phase. This hidden clearance may also be used for a protected permissive left turn in one direction where a Type 10 signal head is used (no amber arrow display). In this case the signal controller has an amber clearance entered and it times that amber clearance but it is not displayed on street.

This additional all-red clearance is particularly important if the interval following the left turn clearance is an LBI or LPI.

Level of Service

General

Various methods may be used to define the level of service (LOS) at an intersection (see Tables 6 and 7). While LOS A is ideal, it may not be realistic to design for this condition. LOS B or C is normally the design condition for isolated rural intersections (posted speed of 80 km/h or greater), and LOS

C or D is normally the design condition for urban intersections (posted at less than 80 km/h), but it is not unusual to have LOS E or F in congested downtown areas or under certain specific circumstances.

The most common methods used to determine LOS are LOS Based on Delay, and LOS Based on Probability of Clearing the Arrivals.

LOS Based on Delay

The level of service for signalized intersections may be defined in terms of delay. Delay is a measure of driver discomfort and frustration, fuel consumption, and lost travel time as given in the HCM.¹³ Table 6 gives LOS for signalized intersections.

Table 6 — LOS Based on Delay

Level of service	Control Delay (s/veh)
A	≤ 10
B	> 10 - 20
C	> 20 - 35
D	> 35 - 55
E	> 55 - 80
F	> 80

Note: This table assumes Volume/Capacity Ratio of 1.0 or less. LOS is always F if Volume/Capacity Ratio is greater than 1.0.

LOS Based on Probability of Clearing the Arrivals

In the LOS Based on Probability of Clearing the Arrivals, LOS is based on a probability that all vehicles arriving in the critical lane will clear the intersection in one cycle (one green interval).

This method is based on average lane arrivals per cycle per critical lane. (Note that the actual arrival patterns could be different.) The probability of arrival vehicles clearing the intersection in one cycle defines the LOS and is given in Table 7.

Table 7 — LOS Based on Clearing Arrivals

Level of service	Probability of arrival vehicles clearing
A	95%
B	90%
C	75%
D	60%
E	50%

Determination of Green Interval Timing

General

The highest rate of traffic flow begins after approximately two to three vehicles in the same lane have started through the green signal. This is because the headway of the initial vehicles is significantly longer than the headway of vehicles further back in the queue (due to start-up lost times).

The analysis of traffic flow to determine green interval times may be accomplished by several methods. For most methodologies, there now exist software packages to assist the practitioner. The software may even include animation tools to view the operation of the simulated intersection or roadway signal group. Nonetheless, use of automated tools requires a thorough understanding of the background concepts, principles and default constant values which support the software, before the results should be depended on. Three of the common methodologies used in Ontario are:

Canadian Capacity Guide Methodology

ITE's "Canadian Capacity Guide for Signalized Intersections" (CCG)² gives a theoretical method for determining capacity based on saturation flow. In this method, Saturation Flow is defined as the rate at which vehicles that have been waiting in a queue during the red interval cross the stop line of a signalized intersection approach lane per hour of green. This method generally employs the use of arrival flows to represent travel demand for the analysis, design or evaluation of the intersection.

The guide uses lane by lane analytical techniques. The procedure requires all arrival flows and saturation flows to be expressed separately for each lane group. The critical lane group is identified by the highest flow ratio for a given phase and is computed as the ratio of arrival flow and saturation flow. The sum of the flow ratios for the critical lanes is called the intersection flow ratio and provides an indication of the quality of service at the intersection.

The allocation of green intervals, i.e., the duration of individual phases, normally employs the proportioning of the total available green time based on the relative values of the critical lane ratios for each phase.

Degree of saturation, capacity, probability of discharge overload, queuing and delay are measures of effectiveness used to evaluate how the intersection operates using the CCG methodology.

Software for this method is available from private sources.

Highway Capacity Manual Methodology

The principles employed in the HCM¹³ and CCG² have identical theoretical foundations. The documents differ in the applications of these basic principles, in the measured values, and in

the calibrated relationships that reflect specific conditions in Canada and the USA. The CCG establishes a link between the average overall delay used in the CCG and the average delay applied in the HCM for the determination of the level of service.

The Highway Capacity Manual (HCM¹³) method uses volume to capacity ratios and average delays to measure intersection performance. Volume to capacity ratios provide a measure of sufficiency of capacity, and average delays provide a measure of the quality of service.

Capacities are determined by multiplying “Saturation Flows” by the proportion of time the movements have green during the design hour. In the HCM method, saturation flow is the number of vehicles per hour that can pass through an intersection via a lane group under prevailing traffic and roadway conditions, assuming green 100% of the time. Delay is estimated from Webster’s delay formula.

The HCM method takes operational objectives into account. These objectives can be used to determine green interval timing for preferred approaches using balanced delays, volume to capacity ratios, or by maximizing either measure.

The Highway Capacity Manual is available from the Transportation Research Board. Software (HCS) is available privately.

Ministry of Transportation Methodology

The Ministry of Transportation, Ontario (MTO) methodology for calculating required green times employs the Poisson random probability function.

The Poisson random probability function is based on the concept that vehicles arriving at a signalized intersection will, to a certain degree of probability, be able to clear the intersection during the first green interval encountered upon their arrival. The

Poisson distribution is used because it has been found to give a reasonably good simulation of actual traffic conditions at signalized intersections.

The level of service is used to describe the quality of traffic flow under various operating and geometric conditions. The degree of probability of the vehicles clearing the intersection determines the level of service. Five levels of service are used in this method, each with a different degree of probability of clearing the intersection during the first green interval. To determine the length of a green interval for a through phase, it is necessary to identify the critical movement for the phase. The critical movement is the movement with the highest average equivalent volume per lane, VLe , or average arrival rate per lane, m . Using the average arrival rate (m) for the critical movement at a specified LOS, the green plus amber time for the phase is obtained.

The average arrival rate (m) is determined as the total number of vehicles per hour arriving at the intersection divided by the number of signal cycles per hour. Lookup tables (Tables 8 and 9) have been developed for both rural and urban commuter environments. The tables show the relationship between average arrivals for each clearance probability (level of service) and the time required for successive vehicles to enter the intersection upon the start of the green interval. For a desired level of service and calculated average arrival rate, the corresponding green plus amber time can be found in the lookup table.

Calculation of Initial Green and Green Extension Time for Actuated Control

Where actuation of an individual intersection is used, the green interval timing may be set to a fixed initial portion plus a variable extendible portion. The extendible portion consists of a series of green extensions. The number of extensions called depends on the traffic demands on that phase. The green interval time may be extended up to

a set maximum value. The minimum time for the green interval is the fixed initial portion plus one unit of extension. However, for some controllers the minimum time for green is just the fixed initial portion. The initial portion green interval should be calculated to clear all vehicles which could queue between the stop line and the detector closest to the intersection. The actual timing setting would be the calculated minimum green minus one vehicle extension time unit. A unit extension is typically the time allowed for vehicles moving at average speed to travel from the detectors to within one second of the stop line and may also be referred to as “Gap” or “Passage” time. In some systems, the unit extension time should be based on holding the phase green to service an approaching vehicle while demand for the conflicting flow is present. Longer extension times should be considered for approaches with high volumes of heavy vehicles.

Vehicle actuations during the initial portion have no effect on interval timing, but each succeeding vehicle actuation during the extendible portion cancels the previous unit extension and starts a new extension timer. The green interval is extended as long as vehicle actuations are spaced closer than the extension times, unless terminated by a “Maxout”.

Table 8 — Rural Intersections: Arrival Rates for Various Levels of Service

Level of Service					"X" VEHICLES	GREEN plus AMBER (SEC)
A (95%)	B (90%)	C (75%)	D (60%)	E (50%)		
0.0 - 0.3	0.2 - 0.5	0.3 - 0.9	0.5 - 1.3	0.7 - 1.6	1	3.8
0.4 - 0.8	0.6 - 1.1	1.0 - 1.7	1.4 - 2.2	1.7 - 2.6	2	7.0
0.9 - 1.3	1.2 - 1.7	1.8 - 2.5	2.3 - 3.1	2.7 - 3.6	3	9.7
1.4 - 1.9	1.8 - 2.4	2.6 - 3.3	3.2 - 4.0	3.7 - 4.6	4	12.0
2.0 - 2.8	2.5 - 3.1	3.4 - 4.2	4.1 - 5.0	4.7 - 5.6	5	14.2
2.9 - 3.2	3.2 - 3.8	4.3 - 5.0	5.1 - 6.0	5.7 - 6.6	6	16.4
3.3 - 3.9	3.9 - 4.6	5.1 - 5.9	6.1 - 6.9	6.7 - 7.6	7	18.6
4.0 - 4.6	4.7 - 5.4	6.0 - 6.8	7.0 - 7.9	7.7 - 8.6	8	20.8
4.7 - 5.4	5.5 - 6.2	6.9 - 7.7	8.0 - 8.8	8.7 - 9.6	9	23.0
5.5 - 6.1	6.3 - 7.0	7.8 - 8.6	8.9 - 9.8	9.7 - 10.6	10	25.1
6.2 - 6.9	7.1 - 7.8	8.7 - 9.5	9.9 - 10.8	10.7 - 11.6	11	27.2
7.0 - 7.7	7.9 - 8.6	9.6 - 10.4	10.9 - 11.7	11.7 - 12.6	12	29.3
7.8 - 8.4	8.7 - 9.4	10.5 - 11.3	11.8 - 12.7	12.7 - 13.6	13	31.4
8.5 - 9.2	9.5 - 10.3	11.4 - 12.2	12.8 - 13.7	13.7 - 14.6	14	33.5
9.3 - 10.0	10.4 - 11.1	12.3 - 13.1	13.8 - 14.6	14.7 - 15.6	15	35.6
10.1 - 10.8	11.2 - 11.9	13.2 - 14.0	14.7 - 15.6	15.7 - 16.6	16	37.7
10.9 - 11.6	12.0 - 12.8	14.1 - 14.9	15.7 - 16.6	16.7 - 17.6	17	39.8
11.7 - 12.4	12.9 - 13.6	15.0 - 15.9	16.7 - 17.6	17.7 - 18.6	18	41.9
12.5 - 13.2	13.7 - 14.5	16.0 - 16.9	17.7 - 18.5	18.7 - 19.6	19	44.0
13.3 - 14.0	14.6 - 15.3	17.0 - 17.8	18.6 - 19.5	19.7 - 20.6	20	46.0
14.1 - 14.9	15.4 - 16.2	17.9 - 18.7	19.6 - 20.5	20.7 - 21.6	21	48.0
15.0 - 15.7	16.3 - 17.0	18.8 - 19.6	20.6 - 21.5	21.7 - 22.6	22	50.0
15.8 - 16.5	17.1 - 17.9	19.7 - 20.5	21.6 - 22.4	22.7 - 23.6	23	52.0
16.6 - 17.4	18.0 - 18.8	20.6 - 21.4	22.5 - 23.4	23.7 - 24.6	24	54.0
17.5 - 18.2	18.9 - 19.7	21.5 - 22.4	23.5 - 24.4	24.7 - 25.6	25	56.0
18.3 - 19.0	19.8 - 20.6	22.5 - 23.3	24.5 - 25.4	25.7 - 26.6	26	58.0
19.1 - 19.9	20.7 - 21.5	23.4 - 24.3	25.5 - 26.3	26.7 - 27.6	27	60.0
20.0 - 20.7	21.6 - 22.3	24.4 - 25.2	26.4 - 27.3	27.7 - 28.6	28	62.0
20.8 - 21.6	22.4 - 23.2	25.3 - 26.2	27.4 - 28.3	28.7 - 29.6	29	64.0
21.7 - 22.4	23.3 - 24.1	26.3 - 27.1	28.4 - 29.3	29.7 - 30.6	30	66.0
22.5 - 23.3	24.2 - 25.0	27.2 - 28.0	29.4 - 30.3	30.7 - 31.6	31	68.0
23.4 - 24.2	25.1 - 25.9	28.1 - 29.0	30.4 - 31.2	31.7 - 32.6	32	70.0
24.3 - 25.1	26.0 - 26.8	29.1 - 29.9	31.3 - 32.2	32.7 - 33.6	33	72.0
25.2 - 25.9	26.9 - 27.6	30.0 - 30.9	32.3 - 33.2	33.7 - 34.6	34	74.0
26.0 - 26.7	27.7 - 28.5	31.0 - 31.8	33.3 - 34.2	34.7 - 35.6	35	76.0

Notes:

1. The relationship between the average and maximum arrival rates is based on the Poisson Distribution.
2. The relationship between arrival rates and phase times is based on Greenshields Chart of Headways for passenger (car) vehicles.
3. Each truck or bus is equivalent to 2.0 passenger cars.
4. The percentages for each column are the probabilities of a vehicle clearing the intersection on the first green.
5. "X" vehicles are the average flow at LOS E for the associated green plus amber time.
6. The shaded area falls below the minimum through movement timing requirements.

Table 9 — Urban Intersections: Arrival Rates for Various Levels of Service

Level of Service					"X" VEHICLES	GREEN plus AMBER (SEC)
A (95%)	B (90%)	C (75%)	D (60%)	E (50%)		
0.0 - 0.3	0.2 - 0.5	0.3 - 0.9	0.5 - 1.3	0.7 - 1.6	1	2.6
0.4 - 0.8	0.6 - 1.1	1.0 - 1.7	1.4 - 2.2	1.7 - 2.6	2	4.9
0.9 - 1.3	1.2 - 1.7	1.8 - 2.5	2.3 - 3.1	2.7 - 3.6	3	7.0
1.4 - 1.9	1.8 - 2.4	2.6 - 3.3	3.2 - 4.0	3.7 - 4.6	4	8.9
2.0 - 2.8	2.5 - 3.1	3.4 - 4.2	4.1 - 5.0	4.7 - 5.6	5	10.8
2.9 - 3.2	3.2 - 3.8	4.3 - 5.0	5.1 - 6.0	5.7 - 6.6	6	12.7
3.3 - 3.9	3.9 - 4.6	5.1 - 5.9	6.1 - 6.9	6.7 - 7.6	7	14.6
4.0 - 4.6	4.7 - 5.4	6.0 - 6.8	7.0 - 7.9	7.7 - 8.6	8	16.5
4.7 - 5.4	5.5 - 6.2	6.9 - 7.7	8.0 - 8.8	8.7 - 9.6	9	18.4
5.5 - 6.1	6.3 - 7.0	7.8 - 8.6	8.9 - 9.8	9.7 - 10.6	10	20.2
6.2 - 6.9	7.1 - 7.8	8.7 - 9.5	9.9 - 10.8	10.7 - 11.6	11	22.0
7.0 - 7.7	7.9 - 8.6	9.6 - 10.4	10.9 - 11.7	11.7 - 12.6	12	23.8
7.8 - 8.4	8.7 - 9.4	10.5 - 11.3	11.8 - 12.7	12.7 - 13.6	13	25.6
8.5 - 9.2	9.5 - 10.3	11.4 - 12.2	12.8 - 13.7	13.7 - 14.6	14	27.4
9.3 - 10.0	10.4 - 11.1	12.3 - 13.1	13.8 - 14.6	14.7 - 15.6	15	29.2
10.1 - 10.8	11.2 - 11.9	13.2 - 14.0	14.7 - 15.6	15.7 - 16.6	16	31.0
10.9 - 11.6	12.0 - 12.8	14.1 - 14.9	15.7 - 16.6	16.7 - 17.6	17	32.8
11.7 - 12.4	12.9 - 13.6	15.0 - 15.9	16.7 - 17.6	17.7 - 18.6	18	34.6
12.5 - 13.2	13.7 - 14.5	16.0 - 16.9	17.7 - 18.5	18.7 - 19.6	19	36.4
13.3 - 14.0	14.6 - 15.3	17.0 - 17.8	18.6 - 19.5	19.7 - 20.6	20	38.2
14.1 - 14.9	15.4 - 16.2	17.9 - 18.7	19.6 - 20.5	20.7 - 21.6	21	40.0
15.0 - 15.7	16.3 - 17.0	18.8 - 19.6	20.6 - 21.5	21.7 - 22.6	22	41.8
15.8 - 16.5	17.1 - 17.9	19.7 - 20.5	21.6 - 22.4	22.7 - 23.6	23	43.7
16.6 - 17.4	18.0 - 18.8	20.6 - 21.4	22.5 - 23.4	23.7 - 24.6	24	45.6
17.5 - 18.2	18.9 - 19.7	21.5 - 22.4	23.5 - 24.4	24.7 - 25.6	25	47.5
18.3 - 19.0	19.8 - 20.6	22.5 - 23.3	24.5 - 25.4	25.7 - 26.6	26	49.4
19.1 - 19.9	20.7 - 21.5	23.4 - 24.3	25.5 - 26.3	26.7 - 27.6	27	51.3
20.0 - 20.7	21.6 - 22.3	24.4 - 25.2	26.4 - 27.3	27.7 - 28.6	28	53.2
20.8 - 21.6	22.4 - 23.2	25.3 - 26.2	27.4 - 28.3	28.7 - 29.6	29	55.1
21.7 - 22.4	23.3 - 24.1	26.3 - 27.1	28.4 - 29.3	29.7 - 30.6	30	57.0
22.5 - 23.3	24.2 - 25.0	27.2 - 28.0	29.4 - 30.3	30.7 - 31.6	31	58.9
23.4 - 24.2	25.1 - 25.9	28.1 - 29.0	30.4 - 31.2	31.7 - 32.6	32	60.8
24.3 - 25.1	26.0 - 26.8	29.1 - 29.9	31.3 - 32.2	32.7 - 33.6	33	62.7
25.2 - 25.9	26.9 - 27.6	30.0 - 30.9	32.3 - 33.2	33.7 - 34.6	34	64.6
26.0 - 26.7	27.7 - 28.5	31.0 - 31.8	33.3 - 34.2	34.7 - 35.6	35	66.5

Notes:

1. The relationship between the average and maximum arrival rates is based on the Poisson Distribution.
2. The relationship between arrival rates and phase times is based on Ministry of Transportation of Ontario Time to Enter Studies (1986 to 1988).
3. Each truck or bus is equivalent to 2.0 passenger cars.
4. The percentages for each column are the probabilities of a vehicle clearing the intersection on the first green.
5. "X" vehicles are the average flow at LOS E for the associated green plus amber time.
6. The shaded area falls below the minimum through movement timing requirements.

Determination of Delays on Actuation

Where actuation of an approach or phase is used, a delay in the registration of a vehicular actuation at the controller may be set for the detectors. This delay is commonly used for vehicles that stop at the detection device but are turning when a gap is available in conflicting traffic. Delays may be set for either right turns or left turns.

The right turn delay time is typically based on allowing a reasonable opportunity for a right turn on red and is normally set between 5 and 12 seconds. If the waiting vehicle does not clear the detection device within this period, a call will be placed in the controller to service the phase.

Left turn detector delays are more typically based on the possibility that a perpendicularly travelling vehicle will cut the corner and will momentarily travel over the edge of the left turn detector, sending a false call for service. The left turn detector delay is typically 1 to 3 seconds and may need to be determined through site observation after the intersection is installed.

Calculation of Pedestrian Timing

General

Where pedestrians are present at signalized intersections, the minimum safe crossing needs should be accommodated in the times provided for the pedestrian interval (“Walk”) and the pedestrian clearance interval (“Flashing Don’t Walk” and “Solid Don’t Walk” through the amber and/or all-red intervals). Pedestrian timings must be generous enough to ensure that pedestrians are given enough time to cross safely and comfortably, but not so generous that service to vehicular traffic is unduly compromised.

The pedestrian clearance interval, or “Flashing Don’t Walk” (FDW), is generally calculated to include the amber and all-red intervals. However,

the FDW may be displayed up to the amber, through the amber, or through the amber/all-red intervals. The advantage of displaying the FDW during the amber or amber/all-red clearance interval times is that it gives pedestrians reassurance that they still have the right to be in the intersection during the vehicle clearance. A disadvantage of this approach is the potential conflicts between pedestrians still in the crosswalk and turning vehicles trying to clear the intersection.

The FDW should not be less than 5.0 seconds duration except in exceptional circumstances such as a crossing on a very narrow (two lane) roadway with low posted speeds. Here, the pedestrian clearance interval may be reduced to a minimum of 3.0 seconds provided that the pedestrian clearance interval terminates upon activation of the vehicular amber interval.

When the sum of the vehicle green and amber (and optionally all-red) clearance times is in total greater than the minimum total pedestrian Walk and pedestrian clearance intervals, the difference should be added to the Walk time. When the pedestrian Walk plus clearance interval times are greater than the required vehicle phase time, the pedestrian values shall overrule the required vehicular values, and the vehicle phase shall be extended to at least match the minimum required pedestrian total interval times.

Walking speed is affected by factors such as age, and disabilities and these factors should be considered when calculating pedestrian timing. A walking speed of 1.0 m/s can be used for initial calculations; however, the walking speed may be adjusted as follows:

- At locations where at least 20 percent of pedestrians crossing the signalized intersection use assistive devices for mobility (e.g., walkers, canes and manual wheelchairs) a walking speed of 0.8 m/s should be used regardless of whether the crossing is equipped with

accessible pedestrian signals or not.

- At locations where at least 20 percent of pedestrians crossing the signalized intersection are older persons (65 years of age or older) a walking speed of 0.9 m/s should be used.

On wide arterial roadways, the total pedestrian times normally govern the time available for non-coordinated phases and may impact the minimum cycle time.

The pedestrian crossing distance, W_c , may be taken as the longest distance within the crosswalk measured from the point of stepping onto the pavement to the point of non-conflict with any traffic or as the distance from curb to curb along the centreline of the crosswalk.

The minimum Walk time (as per Table 3) should be observed. The pedestrian clearance interval should be equal to W_c / W_s .

As a result of prevailing local conditions, pedestrian timing methods may vary from the above approach, and may vary among road authorities (as implemented by experienced and knowledgeable designers). The key point is the need to maintain consistency ensuring adequate time for pedestrians to cross and not violate pedestrian expectancy.

Pedestrian Actuation

When the minimum vehicle green interval is less than the sum of the minimum pedestrian crossing time and the pedestrian clearance time (for vehicles at intersections with traffic actuated controls), and a pedestrian actuation is detected, the green vehicle time must be extended.

In most operations, the pedestrian pushbutton actuation is accepted as a call during all times except when the Walking Pedestrian indication is already underway.

Determination of Cycle Length

Guidelines

The calculation and selection of cycle lengths requires an estimation of the “Lost Capacity” per phase due to start-up headways and the effects of cycle length on vehicle delay. The calculation and selection of cycle lengths also requires good judgment on the part of the designer.

Guidelines for cycle length selection are as follows²²:

- The most efficient range for cycle lengths is between 50 and 120 seconds for 2- or 3-phase operation.
- Where roadways are wide (over 15 m), with long pedestrian walk times (over 20 seconds), or where heavy traffic is present, or turning interference is significant, a cycle length of 60 to 90 seconds is required to serve minimum timing requirements.
- Where three or four phases are present, a cycle length of 90 to 120 seconds is generally preferred.
- For capacity calculations, a cycle length of 90 seconds is usually considered optimum since lost time is approaching a minimum, capacity is approaching a maximum, and delay is not too great.
- Intersection capacity drops substantially when cycle lengths fall below 60 seconds (a greater percentage of available time is used by the clearance intervals).
- The impact of cycle length on pedestrian and side road delays and on side road and left-turn queue lengths should be considered in the selection of cycle length.

- There are only minimal increases in capacity when cycle lengths rise above 100 seconds. As any through green interval approaches 45 seconds duration, there is a decrease in saturated flow so that fewer vehicles per lane per second traverse the intersection.
- In many situations, the pedestrian timing required (walk interval plus pedestrian clearance interval) will be greater than the green interval time required for traffic. This is particularly true for side road timing as the pedestrians must cross the wider main road, and at intersections where it is necessary to adjust walk time for the accommodation of seniors, young children, and/or persons with mobility impairments. In such cases, the pedestrian timing will overrule the green interval timing, and the green indication will be on, but not efficiently serving vehicular traffic.
- Analysis and evaluation should consider optimization of the cycle length (to the nearest second) to obtain minimal delays to vehicles, cyclists and pedestrians, and to promote the most efficient operation possible. Starting the analysis with a 90 second cycle length is suggested. If the traffic signal is to be part of a coordinated system, consideration should be given to using even number cycle lengths to allow for half cycle lengths to be used if they promote better performance.
- Where interconnected or central systems are operating, it is preferable to use a cycle length that fits in with other surrounding intersections and allows for coordinated operations.
- Hourly, daily and weekly traffic variations should be examined to determine when different timing plans are required. It is not uncommon to use different phase timing and different cycle lengths to accommodate the variations in flows and directions at different times of day, week or season.
- Protected left-turn phases should be considered where demand and safety dictates. However, the use of left-turn phases should be considered against a decline in progression, a degradation in the opposing level of service and the possibility of not being able to fit the turn phase timing into the existing cycle length at a signal operating in a coordinated system on a predetermined background cycle.

Many worked examples may be found in ITE's "Canadian Capacity Guide for Signalized Intersections" (CCG).²

Cycle Composition

Cycle length calculations require consideration of the following points:

- Amber and all-red clearance times are fixed by the speed of the traffic and the width of the intersection and they should be added together to determine the "Intergreen"² time or the "Lost Time". Longer clearances are associated with more "Lost Time".

3.8 Signal Spacing

New Signalized Intersections

Closely spaced traffic signals result in frequent stops, unnecessary delay, increased fuel consumption, excessive vehicular emissions, and higher crash rates. According to the Transportation Research Board (TRB) Access Management Manual, increasing signal spacing from 400 meters to 800 meters could reduce vehicle hours of delay by up to 60% and several studies have found that the number of collisions and collision rates increase as the frequency of traffic signals increase along a corridor.

The functional area of any signalized intersection includes the length of roadway upstream of the upcoming intersection needed by motorists for travel during a perception-reaction time, maneuvering and deceleration, plus any required queue storage.

Where a new intersection is planned, the distance between adjacent signalized intersections should be reviewed taking into account the following:

- When signals are too closely spaced, drivers may be focusing on the signal displays for the signalized intersection downstream of the one they are approaching. It is a common practice to attain a minimum distance of 215 m between signalized intersections as this distance is will usually be sufficient to allow motorists to recognize and focus on the nearest signal indications related to their movement.
- Given that left turn storage lanes do not usually exceed 85 m in length for low LOS, the minimum distance between intersections is approximately 215 m for roads posted at 60 km/h or less and up to 350 m for roads posted at 80 km/h. These minimum distances are designed to allow “Back-to-back” left turn lanes and proper tapers (but do not consider optimal coordination).
- A coordinated system should be considered for local or central system operation where intersections are less than 1.0 km apart for posted speeds less than 80 km/h and less than 1.5 km apart for posted speeds of 80 km/h and over.
- Intersection spacing that is less than 415 m or greater than 625 m may affect progression efficiency at a posted speed of 50 km/h.

Any new intersection will produce delays to overall traffic flow. When a new signalized intersection is being considered within 1 km of an existing signalized intersection, analysis of the traffic

impacts using a recognized simulation tool should be considered to determine the upstream and downstream operational impacts as well as the overall network impacts on any signals in close proximity on the cross streets. Traffic analysis should consider the pattern that routinely occurs at traffic signals: deceleration, decreasing headways, stopping, accelerating, and increasing headways. Repeating this pattern at the new intersection may produce unacceptable delays and poorer levels of service.

Signal spacing should include a progression analysis to ensure that proper coordination of the signals is possible for a range of traffic demands while also meeting the needs of pedestrians and cyclists.

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Signal spacing should include a progression analysis to ensure that proper coordination of the signals is possible for a range of traffic demands while also meeting the needs of pedestrians and cyclists.

3.9 Flashing Operation

Flashing Arrow Operation

The national standards, as given in the TAC MUTCDC¹⁶, recognize flashing arrow signal displays only, and do not recognize steady arrow or flashing circular displays. The use of the flashing advanced green arrow is at the discretion of the road authority. If the flashing green arrow is used, it should be used consistently throughout a jurisdiction and consideration should be given to being consistent with adjacent jurisdictions.

The ON time should be approximately equal to the OFF time with a minimum flash rate of 100 flashes per minute and a maximum flash rate of 120 flashes per minute. It is recommended that it be used only in an area which does not have any circular flashing advance greens.

Standardized Flashing Amber and Red Operation

Traffic control signals may be switched from their normal cycling operation to flashing operation. Three modes of flashing operation are normally used:

- Start-up flash – the signals are commonly started with flashing ambers on the main road and flashing reds on the side roads.
- Emergency flash – when a conflict is detected, the signals are commonly flashed in an all-red or “red-red” mode if the controller flashers have that capability. The red-red mode has a safety advantage over the red-amber mode (reds on side road; ambers on main roads). as it forces all vehicles to stop and provides an opportunity for pedestrians and cyclists to be observed. However, the red-amber mode is an acceptable alternative and is considered preferable on roads with posted speeds of 80 km/h and above with light side road traffic as fewer stops are required.

- Timed flash – the signals may be programmed to operate in the red-red or red-amber mode during various periods of the night, week, or season, for special events, or during a police over-ride mode of operation. This is a practice that is not widely used now with the semi or fully actuated signals operations providing a more efficient and potentially safer operation. This operation is more fully described under Modes of Isolated Operation earlier in this section.

Flashing operations within a traffic control signal cabinet are generally wired as either red-red or amber-red and the flash circuit cannot be changed from one mode to another without re-wiring the necessary circuits. Protected left turn movements are flashed red.

Planned flashing operation for signalized intersections may be advantageous to traffic flow under some specific and limited conditions. Flashing operation may help to reduce vehicle delay and stops in pretimed networks at locations with poor signal spacing. Planned flashing is only applicable under conditions of very light minor street traffic such as during the overnight period, or in locations that have extended periods of low volume such as accesses to an industrial area.

Caution should be used in the application of planned flashing signal operation. It should only be used if:

- Side street traffic is very light (less than 200 vph combined for both directions);
- The traffic signals operate fixed time (i.e., no side street vehicular or pedestrian actuation);
- The planned flash mode is amber flash for the main street and red flash for the side street;
- There is no emergency vehicle preemption capability;

- Pedestrian volumes crossing the main street during planned flashing period are very light; or
- The major roadway is not channelized and has no more than four lanes (including turn lanes).
- An approaching emergency fire vehicle or ambulance is detected on the approach. This causes the signal to return to green for that approach or roadway as soon as possible, and/or to hold the green on the vehicle's approach or roadway

If planned signal flash is implemented, regular safety reviews should be conducted to compare the occurrence of collisions during the flash hours at intersections with planned flash to similar locations without planned flash.

The standard flashing red or flashing amber traffic control signal indication shall be at a rate of not more than 60 and not less than 50 ON and OFF flashes per minute, with the length of each ON period approximately equal to the length of each OFF period.

3.10 Preemption and Priority

General

All modern controllers offer both preemption and priority operations in addition to signal plans. Preemption involves an interruption in the timing or phasing operations of the traffic signal. Priority operations allow for phasing and timing changes (generally within the active cycle time) that do not require the controller to interrupt the operations of the timing plan.

Most modern controllers have two preemption modes of operation: one for railway plans (two plans) and one for emergency vehicle plans (two to four plans). The preemption mode allows a limited operation where one or more phases remain on red and one or more phases remain on green until the preemption event is terminated. The preemption may be activated by one of the following events:

- An approaching train is detected on a level crossing that crosses one or two roadways near or within an intersection.

Transit signal priority is the most common and widely used form of traffic signal priority operations in Ontario. Upon detection of an approaching transit vehicle, a traffic signal controller may respond in the following ways: it may invoke timing changes such as an early green or green extension, or it may invoke phasing changes such as servicing an actuated priority phase, inserting a phase into the cycle, or rotating the phases within the cycle.

Different manufacturers of traffic control equipment execute preemption and priority in slightly different ways. Many modern controllers are capable of providing these functions directly, while in other situations, the functions are provided from a master controller or a central system.

Preemption For Railway Crossings

Where a proposed traffic control signal installation is close to a railway crossing, the traffic control signal installation should be discussed with the appropriate railway authority. The installation must operate in a way that reflects Transport Canada guidelines.

Where the railway crossing actually lies within the intersection itself, special treatment of railway and highway signals is required to provide greater protection for vehicles. Examples of this are given in the MUTCDC.¹⁶

A railway preemption sequence must be compatible with the railway crossing signals to provide for safe vehicle, pedestrian and train movements. Because trains cannot stop in time to accommodate traffic at the level crossing, separate

intersection and railway signal devices should complement rather than conflict with each other.²³

The following situations may require railway preemption phases and the interconnection of railway and vehicle signals:

1. Where a railway crossing is in proximity to an intersection such that vehicles queue toward the tracks, and inadvertent vehicular stoppage may occur on the level crossing, it is necessary to provide a preemption phase to clear the approach before the train arrival. This situation requires analysis of the time required to clear the tracks during the preemption phase (plus a suitable factor of safety).
2. Similarly, a railway crossing may be close to the intersection, and the activation of the railway crossing control gates may cause vehicles to queue back into the intersection, essentially plugging up the distance between the intersection and the railway tracks. In these cases, railway preemption can help to prevent the intersection from becoming blocked.
3. Where a railway crossing may be close to the intersection, it is also necessary to disallow turns into the roadway with the railway crossing while the preemption is active. This may be accomplished by eliminating a phase, by activating arrow signal heads, by activating blank-out signs, or some combination of these options.

The ITE's "Preemption of Traffic Signals At or Near Railroad Grade Crossings with Active Warning Devices"²³ provides recommendations on when to include preemption operations, and some recommended design considerations.

The MUTCDC¹⁶ provides operational considerations for railroad preemption operations.

Signals that require railway interconnection should not be constructed until the approval of the appropriate railway authority has been received. In some instances, this process can take many months to complete.

Preemption For Emergency Vehicles

Preemption for emergency vehicles can be activated through systems that use dedicated short-range communications (DSRC). They may be radio, hardwired, optical, GPS or cellular. Preemption for a small number of intersections close to a station can similarly be activated by simple devices such as a pushbutton inside the station. Preemption can be used locally to allow traffic control signals at or near the station entrance to remain on green until the emergency vehicles have left allowing easier passage through nearby intersections. The activation is similar to the action of a detector sensor amplifier and puts in a call for the preemption phase to begin after suitable minimum interval times and clearance times have been met. In the case of centralized systems, once the initial call is made, a moving window form of preemption can be implemented.

Either type of preemption system normally requires an investigation of the intersections or arterials to be managed and of the vehicles to be fitted. Other factors include a review of the impacts of coordination and the capabilities of the existing equipment, and an agreement on cost sharing for the involved parties.

3.11 Miscellaneous Signals

Pedestrian Signals

Traffic control signal systems intended to serve only pedestrian traffic may be installed at appropriate pedestrian crossing locations. The locations may be at intersections (Intersection Pedestrian Signals (IPS)) or between intersections

(Midblock Pedestrian Signals (MPS)). Both types require the main road traffic to be fully signalized.

Where new MPS or IPS are installed, or existing ones replaced or rehabilitated they must meet the *Accessibility for Ontarians with Disabilities Act*, 2005, S.O. 2005, c. 11 and associated regulations, meaning accessible pedestrian signals (APS) with the appropriate civil requirements are to be installed.

Additional information on APS operational guidelines can be found in the MUTCDC¹⁶ and the TAC “Guidelines for Understanding Use and Implementation of Accessible Pedestrian Signals” document that can be found at <http://www.tac-atc.ca/>.

At IPS locations, the side road must be controlled with STOP signs. The control of the pedestrian signals is by pedestrian actuated two phase operation with pedestrian signal indications used for crossing the main street and regular traffic control signals used on the main roadway approaches. No pedestrian signals are used on the main road to cross the side street.

Pedestrian timing should be set as for normal intersections and should consider the factors discussed in Subsection 3.6. The controller should rest in main road green until a pedestrian actuation is received. The controller may operate in conjunction with the background cycle imposed by a system (half cycling would be an option), but system control may often be at odds with the purpose of the pedestrian signal, which is installed to provide a high level of service and quick response to waiting pedestrians. The controller timings should have a minimum green interval programmed for the main road so that an acceptable level of service for main street vehicular traffic can be maintained in the event of continual pedestrian actuations.

Transit Priority Signals (TPS)

Transit Priority Signals (TPS) may be used to assign the right-of-way to public transit vehicles over other vehicles and pedestrian traffic movements within a signalized intersection.

Transit Vehicles, whether they be buses (Bus Rapid Transit (BRT)), streetcars or Light Rail Transit (LRT) vehicles may operate within their own exclusive corridor or dedicated transit lanes and when those corridors or lanes intersect with a general traffic signal these vehicles should be controlled by their own exclusive phase with their own distinct and separate transit signal heads. For this type of operation there must be two separate transit signal heads that may or may not utilize a white vertical bar lens mounted on top of the circular red signal lens as shown in Figure 23). Additional details of the design and layout requirements can be found in Section 5.

Transit vehicles, specifically buses, also operate in mixed traffic in shared lanes and may be provided local bus only lanes at signalized intersections to allow them to take advantage of transit priority signals that can provide them with priority movement at the intersection. A common form of this operation is known as a *queue jump* where buses in localized bus only lanes are allowed to move through the intersection ahead of other types of traffic. Transit priority signals used for this type of operation employ a white vertical bar lens mounted above the circular red lens on the general traffic signal heads. The white vertical bar lens may be mounted on the primary traffic signal head or on the secondary traffic signal head or on both, depending on the transit movement, the location of transit lane, and the operation of the intersection. Transit vehicles facing a normal red indication and an illuminated white transit vehicle indication may proceed with caution through the intersection.

The transit vehicles can request a preemption operation where the regular phase sequencing

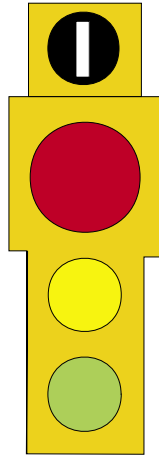


Figure 23 — Transit Priority Signal

of the intersection is interrupted, and the transit vehicle is provided its own phase while all other traffic is held on a red signal indication. This type of operation, while providing ideal service for the transit vehicle, tends to be very disruptive to the general traffic and makes maintaining any kind of coordination with adjacent signals very difficult, especially for frequently scheduled routes.

A preferred and more common approach is to use a transit priority request where a transit phase is fit within the regular cycle at the signalized intersection. This operation reduces the delay transit vehicles experience by either extending or reducing the green indications on specified phases, altering phase sequencing and including special phases that fit within the cycle length without interrupting coordination with adjacent signalized intersections.

Transit priority signals, regardless of whether being used to control dedicated corridors or lanes (i.e. BRT, LRT, streetcars) or for localized bus only lanes, may be operated exclusively during a protected transit movement or concurrently with other non-conflicting vehicular movements.

Upon termination of the transit phase, a normal red clearance interval is required before the signals revert to normal phasing. The transit priority signal may also be operated concurrently with other non-conflicting vehicular and pedestrian movements, as directed by the traffic control signal indications. When the vertical white bar is not displayed, transit vehicles must obey the normal traffic signals. The transit signals may be required only at certain times of the day, on certain days or for special events. The additional transit phase(s) can generally be programmed into the appropriate signal plan.

Reference documents on operating transit signal priority include the planning and implementation handbook by the U.S. Department of Transportation. The Transportation Association of Canada has just published a guide¹¹ dedicated to transit signal priority and associated phasing and signalization. The TAC guide provides additional information, but some concepts, such as transit signals oriented at 45 degrees, are not supported by the HTA. More information on transit priority signal timing is also provided in Section 3.9 – Preemption and Priority.

Movable Span Bridge Traffic Control Signals

When a roadway crosses a drawbridge, swing bridge or lift bridge, normal traffic signal heads should be considered in conjunction with control gates or other forms of physical protection. The traffic signals and protection system are to be interconnected with the bridge mechanism in such a way that the signal indications will change to amber at least 15 seconds before the gates are closed and will not show green at any time the bridge is not traversable. The all-red interval should allow sufficient time for all traffic to clear the bridge deck before activation of the protection devices. In cases where areas of traffic congestion are present, traffic presence detection on the bridge may be required to detect any vehicles stranded on the bridge.

Where railway crossings are present, another set of advance signals may be required to ensure that vehicles are not trapped and forced to stop between the bridge barrier and the railway tracks. Where signalized intersections are within 150 m of the bridge signals, they are to be interconnected with the bridge signals and upon activation of the bridge signals, they are to enter preemption mode, resting in red in the direction approaching the bridge. Where the bridge has pedestrian walkways, it may be necessary to supply pedestrian signals and calculate the all-red time to be sufficient to allow pedestrians to clear the bridge before the span moves.

A great deal of care should be taken with the design of bridge signals as it is not possible to stop large water vessels in a short distance and, once activated, the bridge mechanism must continue to open the bridge. It is good practice to allow a distance of at least 15 m between the end of the movable part of the bridge and any barrier protection. This space provides storage for one or two vehicles in an emergency.

Lane Direction Signals

Lane direction signals (see Figure 24) are used to indicate the direction of traffic flow on reversible direction lanes. The downward green arrow indicates right-of-way in the lane for through traffic approaching the display. A red “X” indicates that approaching traffic must not travel in the lane. A separate display must be used over each reversible lane, and the heads are normally mounted back-to-back provided visibility from both directions permits. It should be noted that there is no reference to Lane Direction Signals in the HTA therefore a city by-law would be required to enforce them.

Lane direction signals may be used in conjunction with control gates to physically indicate closure of lanes or roads.

Amber “X” indications are not used for clearance intervals in Ontario. A flashing red “X” can, however, be used as a clearance interval. Where hardware does not allow for a flashing red “X” clearance, it will be necessary to allow enough phase time to allow a vehicle travelling at posted speed plus a buffer time to completely clear the full length of the lane (by use of a long all-red clearance interval) before switching to the reverse direction. Alternatives to this method involve vehicle detection and axle counting and controller software modifications that allow reversal on lane clearance. TAC has published national guidelines on the use of reversible lanes systems. Entitled “Guidelines for the Planning, Design, Implementation and Evaluation of Reversible Lane Systems (2010)”,⁹ the guide is described by TAC as “*offering roadway design practices and suggested warrant guidelines / thresholds, as well as an evaluation of multiple configurations, addressing left turn issues and safety considerations. Systems capacity and evaluation / assessment methods are also included.*”

Automated Flagger Assistance Devices (AFADs)

An Automated Flagger Assistance Device (AFAD) is defined in Section 146.1 (7) of the *Highway Traffic Act* as a self-contained, portable traffic control system that is operated remotely by a Traffic Control Person to control traffic movement and features a circular red lens and a circular



Figure 24 — Lane Direction Signals

amber lens and a gate arm. This device should not be confused with a Portable Lane Control Signal (PLCS).

It is intended to be used as a supplement for a Traffic Control Person (TCP) to control two-way traffic on two lane roadways that have been reduced to one lane during Intermittent Duration, Very Short Duration or Short Duration work as defined in Ontario Traffic Manual, Book 7 (Temporary Conditions).

AFADs should only be operated by a TCP who has been trained on their use and operation and the TCPs shall not leave the AFAD(s) unattended at any time while they are operational.

For road users to proceed through the one-lane section, the AFAD shall display a flashing amber indication with the gate arm in the up position. To stop vehicles, the AFAD must first sequence to a solid amber indication with the gate arm remaining in the up position, which would then be followed by a solid red indication with the gate arm in the down position. (HTA Section 146(3.1) and (4.1)).

The solid amber display is a change interval used to warn road users they are about to lose their right-of-way and will be required to stop. This solid amber change interval should be between 4 and 6 seconds in duration.

An AFAD shall not be operated unless a TCP is positioned close enough to the device to enable the TCP to immediately display a traffic control stop/slow paddle to approaching traffic if the device malfunctions. Based on this legal requirement, two TCPs are always required and could operate the AFADs as follows:

1. One TCP operates an AFAD at either end of the work zone, or
2. One TCP operates an AFAD at one end of the work zone and the second TCP controls traffic

with a TC-22 STOP/SLOW paddle at the other end of the work zone.

These devices should be removed, or the signal heads covered when not in use.

An AFAD shall not be located at an intersection or pedestrian crossover and shall not be located in any place or manner so as to conflict with any traffic control signal.

An automated flagger assistance device is not considered a traffic control signal according to the HTA so a legal design drawing is not required for its use. However, the basic design, placement, operational requirements, and the additional signing requirements for its use are stipulated under Regulation 185/22 of the HTA.

Additional details on the setup and operation of AFADs can be found in Ontario Traffic Manual, Book 7 (Temporary Conditions)²⁰ and Section 5 of this manual.

Portable Lane Control Signals (PLCS)

Portable Lane Control Signals (PLCS) consist of at least one “Standard” vehicle traffic signal head, normally mounted on a movable pole/trailer, with programmable timing. PLCS with two signal heads are recommended, where practicable, with the second signal head located in the typical secondary signal head location.

A PLCS is not considered a traffic control signal according to the HTA so a legal design drawing is not required for its use. The basic design, placement, operational requirements, and the signing requirements for its use are stipulated under Regulation 185/22 of the HTA.

The use of PLCS is an alternative to continuous flagging by a Traffic Control Person (TCP) and is not to be confused with a Portable Temporary Traffic Signal (PTTS).

PLCS may only be used to control one lane, two-way traffic for Intermittent Duration, Very Short Duration or Short Duration work as defined on Ontario Traffic Manual, Book 7 (Temporary Conditions).²⁰

These devices must only be operated while the contractor is on site. PLCS must be removed, and two-way flow of traffic resumed whenever the contractor leaves the site.

A PLCS shall not be located at an intersection or pedestrian crossover and shall not be located in any place or manner so as to conflict with any traffic control signal.

Additional details on the operation of PLCS can be found in Ontario Traffic Manual, Book 7 (Temporary Conditions).

Details on the setup and conditions of use of these devices are provided in Section 5 of this manual.

Portable Temporary Traffic Signals (PTTS)

Portable Temporary Traffic Signals consist of two standard traffic signal heads mounted on movable trailers.

PTTS can be used as lane control signals to alternate the right-of-way on two lane highways that have been reduced to a single lane as an alternative to a Traffic Control Person, an AFAD or a PLCS. If being used for this function, they must be installed using the required signing as prescribed in Regulation 185/22 for PLCS and can be installed for Intermittent, Very Short and Short Duration work as defined in OTM Book 7 (Temporary Conditions).²⁰ The benefits to using a PTTS under the above circumstances are:

- The signal heads are more visible to approaching drivers;
- A legal design drawing is not required;

- The contractor is able to temporarily leave the work site; and
- The PTTS can be used on highways with an NPRS greater than 60 km/h.

Note that if the PTTS is to be used as a lane control signal for Long Duration work as defined in OTM Book 7 (Temporary Conditions), it must be installed to meet the requirements of Section 144 and Regulation 626 of the HTA and as such must also have a signed legal design drawing. The duration of the work should not be longer than 8 months (April to November) due to maintenance and reliability concerns. During the winter months and outside this time frame the operation should return to normal two way traffic flow, or a Temporary Traffic Signal system on span wire should be used.

PTTS can also be used as a temporary traffic signal system at intersections, however, approval for this application should first be obtained by the road authority. On MTO contracts, PTTS trailers shall not be used at intersections to emulate traffic control signals.

Additional details on the operation of PTTS can be found in Ontario Traffic Manual, Book 7 (Temporary Conditions), as well as in Section 5 of this manual.

Temporary Traffic Signals

Temporary traffic signals typically consist of traffic signal heads positioned on span wires or temporary poles. Temporary signals are intended to be used as an alternative to permanent traffic signals for limited periods before or during the re-construction of roadways. More details are provided in Section 5 of this manual.

Accessible Pedestrian Signals

Accessible Pedestrian Signals (APS) are auxiliary audible and tactile indications that supplement

traditional traffic control signal technology to assist pedestrians with impaired vision to cross at signalized roadway crossings.

According to the *Accessibility Standards for Built Environment* (Ontario Regulation 413/12 or Ontario Regulation 191/11 with amendment Regulation 413/12) treatments to enhance accessibility applicable to pedestrian crossing treatments within the scope of this manual include the following:

- Curb Ramps (Sub-section 80.26);
- Depressed Curb (Sub-section 80.27); and
- Accessible Pedestrian Signals (Sub-section 80.28).

Where pedestrian signals are being installed or existing pedestrian signals are being replaced or rehabilitated at a traffic signal installation, the road authority must ensure accessible pedestrian signals, with the appropriate civil requirements, are installed.

A recognized organization knowledgeable in the needs of the visually challenged such as the Canadian National Institute for the Blind (CNIB) can help jurisdictions prioritize the need for, and choice of locations/crosswalks and can help to train users at specific locations where accessible pedestrian signals are installed.

The “Walk” indication must be audible and tactile and is only used as an indication of the start of the “Walk” and not generally as a guide across the intersection. A “Cuckoo” sound is used for north-south direction and the “Canadian Melody” sound is used for the east-west direction. The “Walk” indicator tone may be emitted from the pushbutton or from supplemental overhead speakers (beacons) directed toward the crosswalk. When overhead APS beacons are used, the beacons shall be mounted as per the TAC guidelines.

In addition to the audible and tactile “Walk” indications, accessible equipment must include tones that locate the pedestrian pushbuttons. The tones must be distinct from the walk indicator tones. The pushbuttons themselves must have tactile arrows that align with the direction of the crossing and should provide an acknowledgement that the pushbutton has been pressed either through the use of an acknowledgement tone or vibrating feature that operates in parallel to the tone.

These traffic signal features operate in conjunction with typical accessibility features in the sidewalk and crosswalk that are identified in Section 5, Design Considerations for APS.

The activation of these devices at traffic control signals should include a training program for users provided by an agency recognized as dealing with the needs of the visually challenged

Additional information on APS operational guidelines can be found in the MUTCDC and the TAC *Guidelines for Understanding Use and Implementation of Accessible Pedestrian Signals* document that can be found at <http://www.tac-atc.ca/>.

Pedestrian Countdown Signals

Pedestrian countdown displays supplement the regular Walk and Flashing Don’t Walk symbols with a numeric countdown of the number of seconds left in the interval(s). Early generations of countdown pedestrian heads determined the display time using the duration of pedestrian intervals from previous cycle(s). As a result, phases more consistent in duration are more appropriate for countdown pedestrian heads because of the associated accuracy in the countdown display time.

Any new pedestrian countdown timer displays installed should start to display the number of seconds remaining at the beginning of the Flashing Hand interval. After the countdown timer has terminated, the display must remain dark until the beginning of the next Flashing Hand interval. Countdown displays during the Walk interval should no longer be installed.

Additional details on the operation of pedestrian countdown times can be found in the MUTCDC.

Tunnel Signals

“Tunnel Signals” may consist of signals at the ends of a tunnel used to prohibit the entrance of traffic, lane control signals within the tunnel, and signals on the tunnel approaches. Signals are also used for reversible lanes or for the closure of lanes for maintenance.

Signals located near the ends of a tunnel should be constructed at crossing roads so that traffic may be diverted should it be necessary to close the tunnel. The tunnel may be closed by a manually activated or automatic preemption signal sent to the controller. The preempt signal may come from the tunnel alarm systems for, for example, fire, collision, noxious gases or water leakage.

The signals operate similarly to those for railway preemption.

The principles of the use of symbols, visibility distances and operational strategies as outlined under “Lane Direction Signals” also apply to tunnel signals.

Ramp Metering Signals

Ramp metering signals are used on freeway or expressway entrance ramps to control the rate of traffic flow onto the highway. Metering signals normally operate only during rush hours and in a preferred direction (normally toward the Central

Business District (CBD) in morning and outbound from the CBD in the evening).

Ramp metering signals are normally controlled by traffic management computer software at the Traffic Operations Centre. The signals have a controlled cycle length that depends on the volume/density of the highway lanes. When the highway is operating at LOS E, the ramp metering cycle length will be relatively long (e.g., 15 seconds) so that the number of vehicles per hour is restricted in order to alleviate the highway congestion. When the highway speeds and volumes increase and volumes of throughput increase, the central computer commands a relaxation in the ramp metering cycle (e.g., 5 seconds), thus allowing more vehicles per hour from the ramp to enter the highway.

The ramp metering station (RMS) itself requires a controller with modified software/firmware to access values of minimum green and amber which are normally disallowed for intersection controllers. The green time is normally set to a very short interval, in the order of 1.0 seconds (one vehicle only per green signal), with the amber interval even shorter (in the order of 0.5 seconds). The signals rest in red for the remainder of the cycle and must be activated by a detector when the system is running. The ramp metering signals typically rest in green during the off-peak hours of the day.

Ramp metering signals are always used in conjunction with an advance flasher to indicate that RMS is in operation.

Optically Programmable Traffic Signals

Optically Programmable Signal indications can be used to limit the visibility of signal indications to specific areas. These types of indications are generally used to avoid conflicting or confusing indications to drivers approaching in adjacent lanes or approaching signals that are very closely spaced or at severely skewed intersections.

Example applications include left turn indications on high speed roadways with centre medians, and unusual geometric intersection configurations. The optically programmed heads are also used where signalized intersections on the same roadway are so closely spaced that drivers may look past the closest signal to the one farther away, resulting in violations and collisions.

Many programmable signal indications are designed to veil the areas where the signal indication is to be restricted by applying opaquing material to portions of the signal lens (which actually consists of an optical window located within the signal head). The veiling process is generally done by opening the back door of the head, looking through the window at the approach, and “taping off” areas where the indication is to be restricted. This process is almost always done after the signal is placed and aligned at the intersection. Typically, these signal heads are rigidly mounted so that the programming will remain consistent in relation to the area of the roadway for which the signal indication should be visible or veiled. These signal heads are not intended for use on span wire installations.

Road authorities should routinely confirm that the programmable indication is visible within the intended boundaries, and that the signal head has not shifted or moved. This routine check could be made a standard part of the maintenance practices and should apply for all traffic signal locations with optically programmable traffic signals.

Further specifications are available through the ITE at <http://www.ite.org/standards>.

Bicycle Signal Indications, Timing and Phasing

Bicycles are defined as vehicles in the *Highway Traffic Act* and are therefore governed by the rules of the road as defined in the Act. In most circumstances, standard vehicle displays, standard signal phasing, and standard signal timing and

clearance intervals should be adequate to control bicycle movements through intersections, but where bicycles make up the majority of vehicle flow, it may be necessary to have a slightly longer minimum green time. The use of bicycle specific signals and/or bicycle phasing should be considered where safety or efficiency can be improved for cyclists or other users, and not randomly or universally applied to all signalized intersections. The use of boulevard facilities with cycle tracks or MUTs where cross rides are used will typically require the use of bicycle signals.

Details on the justification, design and operation of bicycle signals can be found in Section 6 – Bicycle Signals in this manual.

An additional reference document is the TAC *Traffic Signal Guidelines for Bicycles* document. Please refer to the TAC Transportation Information Service for added information. The contact e-mail is: TIS@tac-atc.ca.

3.12 Flashing Beacons

General

Flashing beacons may be used at locations where full traffic control signals are not justified, but lack of visibility or other hazards mean that regulatory or cautionary signs alone are not sufficient. Flashing red or flashing amber indications may be shown. The red indicates that all approaching traffic must stop before proceeding, and the amber indicates that traffic may proceed with caution provided that the way is clear. The red flashing beacon is always used in conjunction with stop control for the same direction.

Beacons must be clearly visible to approaching motorists for the distances shown in Section 5.

Beacons must be flashed at a rate of not more than 60 or less than 50 ON and OFF flashes

per minute, with the length of each ON period approximately equal to the length of each OFF period.

Beacons should be used with considerable discretion because over-use of these devices may lead to them being disregarded by motorists. The decision to install flashing beacons should be based, at least in part, on a higher than expected collision risk, and the presence of a pattern of collisions of a type which should be prevented or reduced by the installation of the flashing beacon.

Hazard Identification Beacons

Hazard beacons include those used for reinforcement of signs or signing systems. Examples of the use of hazard beacons include their use for obstructions in or immediately adjacent to the roadway, and as a supplement to advance warning and regulatory signs such as KEEP RIGHT, STOP or SIGNALS AHEAD. Hazard beacons are also used as visual warning on pedestrian crossovers.

Beacons with flashing amber indications may be used to emphasize the need for caution. Studies that determine the justification for hazard beacons investigate problems identified at the intersection, the location's collision experience, and the presence of any of the following conditions:

- A physical obstruction in the roadway.
- A sharp curve in the roadway.
- A major intersection that is hidden by a sharp curve or severe grade.
- The beginning of a divided highway (median).

Beacons in Advance of a Signalized Intersection

An amber flasher on a KEEP RIGHT sign on a median island shall be used only if it does not visually distract from nearby vehicular traffic signals. This type of flasher is therefore seldom used for traffic signal islands. These beacons are usually considered only in locations that are a minimum of 300 m away from signals.

Intersection Control Beacons

General

Intersection control beacons consist of 200 mm or 300 mm diameter lenses with continuously flashing red or amber indications. Applications include overhead beacons mounted on suspension wire at the centre of an intersection; and the provision of visual assistance where STOP signs are not conspicuous, where sightlines to the major road are poor or in situations where the driver has not needed to stop for some distance and may not be expecting to need to do so.

Intersection control beacons may be considered when any of the following criteria are satisfied:

- Two major high-speed roads intersect in a rural area.
- There is a stop condition on a major roadway that has not required traffic to stop for 15 km or more.
- An intersection experiences four or more collisions of types susceptible to correction (reducible) per year over a continuous three year analysis period (80% or more warrant of Signal Justification 5 as described in Section 4.7).
- Reducible collisions are those involving vehicles and/ or pedestrians which, under

signalized conditions, would move on separate phases. Reducible collisions are described in detail in Section 4.14.

The specific type of intersection control beacon to be implemented depends on the intersection, as discussed later in this section.

1-Way or 2-Way Overhead Red Flashing Beacons

1-way or 2-way overhead red flashing beacons are used where the visibility of intersections or STOP signs is poor due to abrupt vertical curves or other visibility restrictions that result in poor STOP sign compliance and/or collisions. The beacons provide additional visual assistance for normal STOP signs.

These types of overhead beacons should use 300 mm red lenses and should be positioned to be clearly visible along each approach of the side road. STOP signs must also be located at the intersection.

3-Way and 4-Way Overhead Red Flashing Beacons

3-way or 4-way overhead red flashing beacons are used where “all-way” stop conditions are in place, but traffic control signals are not justified. The beacons are used where geometric conditions, visibility conditions or the collision history suggest that the STOP signs require reinforcement.

These types of overhead beacons should be positioned to be clearly visible along each approach. STOP signs must also be used on each approach.

3-Way and 4-Way Overhead Red/Amber Flashing Beacons

3-way or 4-way overhead red/amber flashing beacons are used where the side road traffic is required to exercise caution and stop, but traffic control signals are not justified. The

beacons are used where geometric conditions, visibility conditions or collision history requires reinforcement of the normal STOP signs, and where side road traffic may have difficulty turning due to limited sight distance.

These types of overhead beacons should be positioned to be clearly visible along each approach of the intersection with the red beacons facing the side road(s) and the amber beacons facing the main road. STOP signs must be located on the side road approaches.

Red Beacon for STOP Sign Reinforcement

A red beacon for STOP sign reinforcement is typically used above an oversized STOP sign. The beacons should be 200 mm diameter to prevent excessive glare caused by the low mounting height. The beacons must operate 24 hours a day.

Warning Beacons in Advance of Signalized Intersections

In general, warning beacons in advance of signalized intersections should be implemented if one or more of the following criteria are met:

- The view of the signals is obstructed due to vertical or horizontal alignment (due to buildings, rock cuts or large signs along the inside of curves) such that the traffic signal indications are not visible for the minimum sight distances, as described in Section 5.
- Freeway conditions come to an end at a signalized intersection.
- The grade approaching the intersection is sufficient to require more than normal braking effort.

- Where the beacons can provide a supplement to double long distance detection on downhill approaches (except for true active advance warning).

In addition, jurisdictions may consider the use of warning beacons in advance of a signalized intersection if drivers are exposed to a long distance of travel without encountering a traffic control signal.

Warning beacons can be in the form of full-time flashing operation, or one of two types of operation interconnected with the traffic controller, as described in the next sections.

Continuous Advance Warning Beacons for Traffic Signals

Continuous advance warning beacons for traffic signals are single 200 mm diameter beacons. They are used as reinforcement for the TRAFFIC SIGNALS AHEAD warning signs where the visibility of intersections with traffic control signals is restricted, where signal observance is found to be substandard, or where signals may not be expected by motorists such as on remote highways. A typical configuration is shown in Figure 25.

Continuous advance warning beacons may be used in advance of signalized intersections where there may be limited sight distances (due to buildings, rock cuts or large signs along the inside of curves) or on abrupt vertical curves in locations where the traffic signal indications are not visible for the minimum sight distances, as described in Section 5. In these situations, continuously operating single flashing beacons with the oversized TRAFFIC SIGNALS AHEAD sign (Wb-102) may be required. The location of the signs shall be in conformance with the requirements shown in OTM Book 6 (Warning Signs).

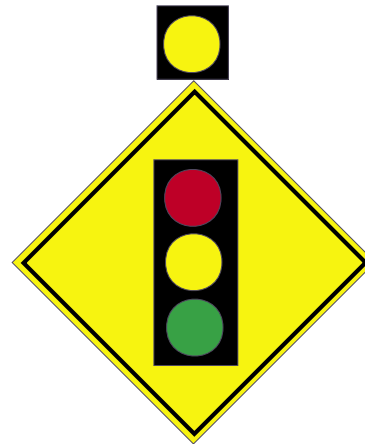


Figure 25 — Signalized Intersection Warning Beacon

Active Advance Warning Beacons for Traffic Signals

Active advance warning beacons consist of a special oversized PREPARE TO STOP AT TRAFFIC SIGNALS AHEAD warning sign (Wb-102A), two alternating flashing amber beacons (200 mm) (one mounted on each side of the sign) and a word tab (Wb-102At), that reads PREPARE TO STOP WHEN FLASHING mounted below the sign. Figure 26 shows a typical arrangement. The word tab must be bilingual in designated areas. The beacons are interconnected to the traffic control signal and are activated at the beginning of the corresponding amber signal display. The beacons continue to flash until the approach receives the next green signal indication. The beacons should also flash when the traffic control signal goes into flash operation.

Successful operation of active advance warning beacons is directly related to accurate placement of the sign. If located too close to the intersection, the sign may not provide sufficient advanced warning. If the sign is located too far from the intersection, a motorist passing the sign may have insufficient time to clear the intersection.



Figure 26 — Active Advance Warning Beacon

To ensure efficient and safe intersection operation, the following equation should be used:

$$D_A = Vt_y - D_p$$

Where:

- D_A = distance of the active advance warning sign from the stop bar (m)
- V = operating speed (85th percentile speed or 10 km/h above the posted speed limit (m/sec)
- t_y = amber time (seconds)
- D_p = minimum distance at which the flashers can be perceived (21.3 m)

True Active Advance Warning Beacons for Traffic Signals

True active advance warning signs are interconnected with the traffic signal controller. They are similar to active advance warning

beacons, but instead of commencing flashing at the start of amber, they are programmed to start flashing a pre-determined time before the amber. They continue to flash until the approach receives the next green indication. The operation of this device is intended to provide motorists with additional information, compared to other types of advance beacons, about the operation of the traffic signals to assist the driver in making decisions. These devices consist of a PREPARE TO STOP AT TRAFFIC SIGNALS AHEAD warning sign (Wb-102A), two alternating flashing amber beacons (20 cm) (one mounted on each side of the sign), and a tab sign (Wb-102At) that reads PREPARE TO STOP WHEN FLASHING. This tab must be bilingual in designated areas. The beacons should also flash if the signal goes into flashing operation. The sign must be accurately located to be effective.

True Active Advance Warning Beacons provide the motorist with valuable information related to the existing or impending state of the traffic control signal at an approaching intersection. Motorists viewing the sign as it is activated are provided with a true warning that they are about to lose the right-of-way at the intersection and should adjust their speed accordingly. Motorists who are just past the sign as it is activated are provided with sufficient time to travel through the pre-defined dilemma zone before the amber is displayed.

True Active Advance Warning Beacons should only be implemented when the intersection operates in fixed time mode or is semi-actuated (with no advance detection on the approach where the sign is being considered).

Since the safety advantages of signal “Gap-out” are diminished by adding a pre-amber flash time, True Active Advance Warning Beacons are not recommended for use in combination with Long Distance Detection. True Active Advance Warning Signs should never be used in combination with Double Long Distance Detection.

The key elements to the successful operation of True Active Advance Warning Beacons are related to the accurate placement of the sign and to the calculation of the advance flash time provided before the onset of amber. The sign should be placed before the stop line, at a distance equal to that required to bring the vehicle to a comfortable stop.

Recommended sign placement is shown in Figure 27 and is summarized in Table 10. The distance is calculated using the following equation:

$$D_{TA} = VT_{pr} + \frac{V^2}{2a}$$

Where:

D_{TA} = distance of the True Active Advance Warning Sign from the stop bar (dry stopping distance (m))

V = operating speed (85th percentile speed or 10 km/h above the posted speed limit (m/sec))

T_{pr} = perception reaction time (1.8 seconds recommended)

a = average deceleration rate (3.06 m/sec/sec or 11 km/hr/sec recommended)

The advance warning flasher should be timed to begin a pre-determined number of seconds before the signals change to amber. This time is calculated so that a driver who passes the advance flashers just a fraction of a second before they are activated is afforded time to clear the dilemma zone safely. The length of time the signs flash before the signals change to amber is summarized in Table 10, as calculated using the following equation:

$$TBA = \frac{D_{TA} + D_P}{V} - t_D$$

Where:

TBA = time before amber (pre-amber flash time, seconds)

D_{TA} = distance of the True Active Advance Warning Sign from the stop bar

D_P = minimum distance at which the flashers can be perceived (21.3 m)

V = operating speed (m/s)

t_D = 1 second

3.13 Systems

Need for a System

Traffic signal control systems can be used to operate, monitor and control traffic signal controllers located at each intersection. Traffic signal control systems can be very cost effective if frequent adjustments to the timing are required, if more dynamic forms of control are indicated, or if frequent retrieval of the traffic data is necessary.

Traffic signal control systems can also be integrated with other systems such as freeway traffic management systems, transit control centres, or fleet management systems. More information on system integration can be found in the ITS Architecture for Canada (see <http://wwwapps.tc.gc.ca/innovation/its/eng/architecture/menu.htm>).

A feasibility study should be undertaken to assess the need and justification for a traffic signal control system and, if justified, the most appropriate type of system for the present and projected requirements of the road authority.

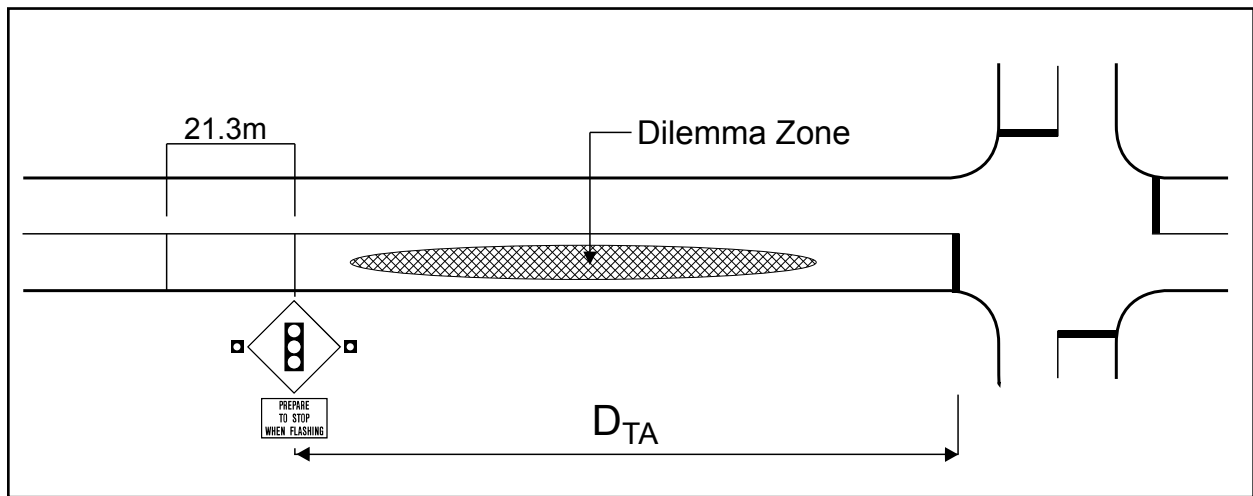


Figure 27 — True Active Advance Warning Beacon - Recommended Installation

Table 10 — True Active Advance Warning Beacon Placement

OPERATING SPEED (km/h)	PRE-AMBER FLASH TIME (TBA) (seconds)	SIGN PLACEMENT (D_{TA})* (meters)
60	4.8	75
70	5.1	97
80	5.4	121
90	5.7	147
100	6.1	176
110	6.5	208
120	6.9	242

* Distance is measured from the stop bar.

3.14 Maintenance Considerations

Traffic control signals require regular maintenance to ensure that they function properly, to maximize safety to the public, and to proactively avoid potential operational problems. The legislated component of required maintenance for traffic control signals is set out in the *Municipal Act*, Regulation 239/02 as amended. This Regulation is entitled *Minimum Maintenance Standards for Municipal Highways*. More information is available at www.e-laws.gov.on.ca.

Suggested traffic signal maintenance standards for consideration (including those listed in the *Municipal Act*) include the following:

Every 6 months

Traffic Control Subsystem

- Check conflict monitor.
- Ensure any programmable heads are still properly programmed as they are subject to alignment changes due to wind and vibration.
- Check UPS.
- Jointly conduct railway crossing interconnected signal inspection and rail preemption testing.

Every 12 months

Traffic Control Subsystem

- Vacuum cabinet.
- Change filter.
- Check cover plates.
- Check heater/fan.
- Check for pests.

- Check/service cabinet joints and sealants.
- Verify maintenance logs are being used.
- Check that supporting documents/ drawings are in cabinet or readily available for reference while in the field.
- Verify operation of system connection and communications.

Display Subsystem

- Re-lamp signals (incandescent).
- Visually inspect and clean lenses if necessary.
- Verify head alignments.
- Check/service condition of hangers, backboards.
- Check/service cabling for temporary signals.
- Verify integrity of mast arms, brackets, poles, base bolts, back guys.
- Verify integrity of pedestrian heads, pole and bases.
- Ensure any ancillary devices such as active advance warning signs/beacons or blank out turn restrictions signs are operating properly.
- Ensure APS subsystem is fully operational.

External Detection Subsystem

- Clean/service pedestrian push buttons.
- Check and verify operation of vehicle detectors.
- Check and verify operation of emergency vehicle and railway preemption.

- Check and verify transit priority requests and servicing.
- If using off road vehicle detection systems such as video detection, ensure mounting mechanisms are still secure and ensure detection zones are properly programmed.

Road authorities are encouraged to establish maintenance practices and schedules that reflect the needs of their own local circumstances provided they are compliant with the requirements listed in the *Municipal Act*.

Maintenance staff should stock standard equipment used for replacement purposes. The choice of hardware should consider ease of replacement and minimization of stock requirements. The Ministry uses Ontario Provincial Standards Drawings (OPSD) for traffic signal standardization purposes.

3.15 Other Considerations

Electrical Considerations

Traffic control signal design has traditionally been managed or approved by traffic engineers because the signals are a tool of traffic management and regulation. Traffic signal installations in Ontario are subject to inspections from the Electrical Safety Authority (ESA). Information on agency responsibilities and inspection details can be found in the latest amended ESA Bulletin (2-12) available through the ESA website (<http://www.esasafe.com>).

Other recommended practices with regard to the electrical design of traffic control signals include:

- Where in-house design capability does not exist, a consulting engineering firm with electrical design expertise in traffic signals may be selected.

- Municipalities may adopt methods and practices that best address the specific design requirements for their local signals.
- All electrical equipment items should be ESA approved as a safety measure and as part of a pro-active risk management process.
- Where contracts for the traffic signal installation work are let, the contractors should use qualified licensed electricians for the wiring, and qualified IMSA technicians for the controller setup. The contractor should obtain inspection and certification of a qualified staff electrical technician, qualified electrician, or qualified electrical engineer.

Aesthetic and Practical General Design Considerations

Although aesthetics play a minor part in the functionality of a traffic signal system, it should be kept in mind that local citizens see the equipment on an everyday basis. Since standard equipment is used in most installations, consideration of aesthetic values consists mainly of avoiding of signal elements that are not considered pleasing. The same choices that will satisfy aesthetic considerations will often lead to more efficient design and lower capital cost or maintenance requirements and may serve to comply with disability requirements.

Examples of aesthetic considerations include:

- The number of poles should be kept to a minimum.
- The signal head displays and traffic signals are the only items that should be noticed. Poles and all other equipment should be as inconspicuous as practical.
- The length of single member arms should be kept to the minimum required to satisfy the criteria.

- The locations of corner poles with pushbuttons may lead to complaints if the poles are not installed in a way that is compatible with sidewalks, if they are behind barriers, if the pushbuttons are on the wrong side, or the poles are sited where a pedestrian needs to take a few steps in mud to reach the pushbutton.
- Where buildings are adjacent to the sidewalk, the poles should be sited so that no interference occurs with doors, windows or commercial signs. Spaces between poles and buildings should be a minimum of 1.5 m to allow space for sidewalk snowplows. In some locations, the space between poles and buildings should be closed to allow no more than a 450 mm space. (This may reduce the sidewalk width in tight spaces and will require agreement by the owners of the buildings.)
- Signal arms should project beyond overhanging tree branches so that future tree trimming can be controlled without excessive trimming of large branches.
- Controller cabinets should be oriented parallel to the roadway, particularly in urban areas. Where practical, the controller pad can be directly adjacent to and flush with the sidewalk, provided that offset rules are observed. In congested urban areas, care should be taken to place the controller free of store doors, windows, etc. and as clear of sidewalks as practical to provide a minimum 1.5 m sidewalk space.
- Excessive equipment on poles (particularly on utility poles with external conduits, straps, etc.) can be unsightly.
- Long signal arms on utility poles tend to tilt these poles towards the roadway. Guy anchors with sidewalk struts behind the mast arm attachment brackets can neaten these installations. The need for guy anchors should be discussed with the power supply authority as needed to decide who should do the work.

4. Planning and Justification

4.1 General

Purpose

This section discusses the planning and justification for a traffic signal installation. Traffic signals are not the only option available to provide right-of-way control. There is a range of other choices including STOP signs, YIELD signs (Refer to OTM Book 5 (Regulatory Signs)), and roundabouts. Traffic signals, even if justified, should be selected only if consideration of alternative options suggests that traffic signals are the best choice. A comprehensive study of the traffic conditions and the physical characteristics of the site should be undertaken to determine whether the installation of a traffic control signal would benefit the intersection operation.

The designer should be aware of the advantages and disadvantages of traffic signals. Traffic signals can move traffic efficiently by distributing time and alternating the right-of-way judiciously. Traffic signals can also help to reduce the number of certain types of collisions. A poorly timed signal, however, is likely to serve traffic inefficiently. Designers should also be aware that the installation of a traffic signal does not guarantee the elimination of collisions, and the number of some types of collisions may increase following the installation of traffic signals.

Background/Context

The initiative for considering the installation of a traffic signal at an existing intersection or mid-block location often arises from public complaints or from operational analysis, or concerns related to delay, congestion, safety, or pedestrian crossing. However, the final decision to install a traffic signal should be based on sound engineering judgment.

This section provides guidance on several justification procedures that should be used to assist in determining the need for traffic signals.

The fulfillment of a traffic signal justification does not in itself require the installation of a traffic signal. Justifications must be used in combination with traffic engineering experience, professional judgment, and economic analysis. Satisfying signal installation justifications is only one criterion for determining the suitability of traffic signals for any location.

Even if the evaluation of a location meets a justification, the installation of a signal may be reconsidered if the signal will result in operational problems that create a potential for collisions and/or significantly increase delays to all users. Section 4.15 provides guidance for a procedure that can be used to assess the potential impact of signalization on collisions. Other potential problems should also be assessed including the extension of vehicle queues through upstream intersections, and possible impacts on existing signal progression. These broader network considerations must be considered and necessitate the application of engineering judgment over and above strict reliance on justification criteria:

This section identifies seven distinct justifications for traffic signal installation. Other considerations that support justification for a signal installation may also arise. A few examples are:

- Road user safety considerations related to sight distance visibility that geometric or operational improvements cannot resolve.
- The number of lanes of high-speed traffic making it difficult for road users to judge for safe gaps in traffic.
- Pedestrian, cyclist or vehicular traffic that is using other crossing locations further away due to concerns about being able to cross, or

enter the roadway safely where the designer is considering signalization. This latent demand may not show up on a typical traffic count.

- Adjacent land use considerations such as a nearby development with limited parking availability generating higher numbers of pedestrians and cyclists that may not be accounted for in any traffic impact studies.
- There may also be a benefit to signalizing to assist transit operations.

Regardless of whether the justifications outlined in this section are met, or are not met, it is important that professional judgment be exercised to consider both the safety and operational benefits, and drawbacks, for all road users when making a final decision as to whether to signalize.

4.2 Principles of Justification

The needs investigation conducted using justifications begins with the collection of vehicular, pedestrian, collision, and geometric data (as described in Section 4.3). Using this data, an assessment of whether a signal is technically justified is made using the following criteria:

Justification 1 – Minimum Eight-Hour Vehicle Volume (Section 4.4)

Justification 2 – Delay to Cross Traffic (Section 4.5)

Justification 3 – Combination Warrant (Section 4.6)

Justification 4 – Minimum Four-Hour Vehicle Volume (Section 4.7)

Justification 5 – Collision Experience (Section 4.8) OR Justification 5A – Collision Experience

Alternate / Safety Change Estimation (Section 4.12)

Justification 6 – Pedestrian Volume (Section 4.9)

Justification 7 – Projected Volumes (Section 4.11)

For a traffic signal installation to be technically justified, at least one of the above justifications must be fulfilled. Unless one or more of the signal justifications are met, the installation of signals would not normally proceed as it would likely result in an increase in overall intersection delay and/or a negative impact on intersection safety.

Justifications 1, 2, 3, 4 and 7 are primarily based on a typical driver's ability to find suitable gaps (6 to 9 seconds). If an insufficient number of gaps is available, delay or congestion arise, and signalization may be required to provide additional gaps to remedy the issue. Justification 5 and 5A are based on safety requirements used to determine if correctable collisions are common enough for signalization to provide a safety benefit. Justification 6 is based on the availability of sufficient gaps in vehicular traffic to facilitate pedestrian movements.

4.3 Information Requirements

Basic Input Data

Various basic data and location attributes are required for the analysis of signal justification. Table 11 lists and describes the basic data required for the volume, collision and pedestrian components of Justifications 1 through 6. Justification 7 is used when adequate volume data is unavailable, or the signal is proposed under future roadway geometric conditions, therefore projected volumes are used. Comments providing additional guidance about the collection and application of the data are also included in the Table.

Table 11 — Traffic Control Signal Justification: Data Input Requirements

Justification 1 - Minimum 8-Hour Vehicle Volume Justification 2 - Delay to Cross Traffic Justification 3 - Combination Warrant Justification 4 - Minimum 4-Hour Volume		
Information Required	Description	Notes/Comments
Intersection Configuration	Number of approaches. Number of lanes on each approach.	Three or four leg intersection. Divided into left, through, right, and channelized right turn lanes. If evaluating a roadway with proposed future geometric changes, consider the use of Justification 7.
Traffic Volumes	Number of vehicles entering the intersection during the eight highest hours of an average day categorized by those passing left, through and right.	Vehicles should be categorized into passenger cars, trucks/buses, and bicycles. If eight hours of data is unavailable, consider the use of Justification 7.
Pedestrian Volumes	Number of pedestrians crossing each leg of the intersection during each of the eight highest hours of an average day.	Eight-hour pedestrian volume should coincide with the eight highest traffic volume hours but may not. If eight hours of data unavailable, consider the use of Justification 7.
Roadway Speed	Design, operating, or posted speed on the main roadway during the signal justification analysis period.	For future roadways, the design speed on the main roadway should be used. For existing facilities, the operating or posted speed should be applied. If either figure exceeds 70 km/h, the intersection is assumed to function under free flow conditions.
Area Population	Approximate population of built-up or urban area.	Quantitative measure that assists in determining whether the intersection is operating under free flow (rural) or restricted flow (urban) conditions.

Justification 5 - Collision Experience Warrant Justification 5A - Collision Experience Warrant Alternate / Safety Change Estimation		
Information Required	Description	Notes/Comments
Intersection Configuration	Number of approaches.	Three or four leg intersection.
Traffic Volumes	Traffic volume. Entering AADT volumes for major and minor streets.	At least three years of historical AADT volumes should be provided. The years should correspond to collision data years.
	Expected volume after signalization (if available).	If known, expected traffic volume following the installation of the signal.
Collision Data	Most recent three or more year history of reported collisions.	Collision history should be as current as possible. A shorter time period may be used if major changes to the intersection have taken place.
	Initial impact type detail.	Collision data must be sufficiently detailed to allow the determination of initial impact type so that the collision can be categorized as susceptible to reduction (Reducible) or not susceptible to reduction (Non-Reducible) following signalization. Reducible collisions include Angle and Turning Movement. Non-Reducible collisions include Rear End, Approaching, Sideswipe, Single Motor Vehicle and Other.

Justification 6 - Pedestrian Volume and Delay Warrant		
Information Required	Description	Notes/Comments
Roadway Configuration	Number of lanes on the main road.	Divided into left, through, right and channelized right turn lanes.
	Presence of median island.	Width of median, if any, on main street.
Traffic Volumes	Total number of vehicles in both directions during the eight highest hours of an average day.	Vehicles should be categorized into passenger cars, trucks/buses and bicycles.
Pedestrian Volumes	Number of pedestrians crossing main roadway during the same eight highest hours of an average day.	Total pedestrian volume categorized as “assisted” (children under the age of 12, seniors, and those with mobility challenges/ impairments) or “unassisted,” and segregated by zones.
Pedestrian Delay	Delay time experienced by each pedestrian for the same eight highest hours of an average day.	Eight-hour monitoring of delay is desirable, but delay counts for brief periods can be factored up to create eight-hour totals. A minimum of two one-hour peak periods should be surveyed.
Pedestrian Crossing Opportunities	Percentage of pedestrians from each zone.	A qualitative assessment of the percentage of each zone’s pedestrians who would choose to use the proposed crossing control.

Flow Conditions

The justification for traffic signals has been developed for two types of flow conditions: restricted flow and free flow. The two types are necessary to reflect different operating characteristics. Engineering judgment should be used in determining which condition best describes the study location under existing operating conditions or for a predetermined future analysis scenario:

- Restricted Flow Conditions represent roads with operating or posted speeds of less than 70 km/h and are normally encountered in urban areas where side friction on the roadway (due to parking, numerous entrances, etc.) reduces the operating speed.
- Free Flow Conditions represent roads with operating or posted speeds equal to or greater than 70 km/h and are normally encountered in rural areas or on controlled access roads in urban areas. As driving characteristics in small urban communities can be different from those in larger urban areas, free flow conditions are also used for isolated communities with a population of less than 10,000 and located outside the community influence of a large urban centre, even if the operating speed is less than 70 km/h.

Intersection / Roadway Configuration

Roadway Type

The minimum justification values in Justifications 1 and 2 (minimum 8-Hour vehicle volume and delay to cross traffic) for main road volume are given for a two-lane, two-way roadway and for a multi-lane roadway with four or more through lanes. Vehicle volume justification values for multi-lane roadways having four or more through lanes on the main road are 25% higher than the values for two-lane,

two-way roadways. Two-lane, two-way roadways with exclusive left-turn lanes are generally not classified as multi-lane roadways, but engineering judgment should be used to determine whether the inclusion of left and right auxiliary turn lanes in the main street approach configuration is appropriate. If vehicles encounter conflicts or delays in turning from a right turn lane, it could be included. The main street approach should be considered a multi-lane approach if approximately half of the traffic on the approach turns left and the auxiliary lane is of sufficient length to accommodate all left-turn vehicles.

Median Islands

For the application of Justifications 1 through 4 (traffic volume-based warrants), an intersection with a wide median, even a wide median greater than 9 m, should be considered as one intersection. For the application of Justification 6, each direction on a divided roadway with a raised median island of at least 1.2 m may be considered individually in the justification process.

Traffic Volume Data

Main Road

The main road should be the road that carries the greater hourly vehicular traffic volume over the period of study. As this “Main Road” may not, however, carry the greater volume during each of the hours studied, it is possible to refine the definition of main road to incorporate analysis on an hour-by-hour basis. Where the intersecting volumes are approximately equal, the road having the less restrictive form of existing control is generally selected as the main road.

Determination of an Average Day

The traffic and pedestrian volumes used in the analysis should be representative of traffic and pedestrian volumes likely to be experienced on an

average day, i.e., the typical operating conditions that the signal is intended to address. When signal justifications are met on days other than weekdays, signals may be justified based on recurring congestion, but their design and operation should reflect the variations in their use. Example of these conditions may include roadways in:

- Retail oriented areas that are congested on Saturdays and Sundays rather than during weekdays;
- Recreational areas that experience peak traffic conditions only during summer weekends;
- Employment areas where major shift changes or other operational attributes result in peak travel during periods outside typical morning and afternoon weekday peak periods; or
- Special event areas such as stadiums, arenas, exhibition grounds, theme parks and community centres where there is recurring congestion on a relatively frequent basis.

In each of the above cases, the signal should be operated to avoid causing undue delay during periods when demand is lower.

The hours counted should reflect the eight highest hours of the day. Traffic volumes normally vary hourly, daily, monthly, seasonally, and annually. If the counts available are for the periods other than the one(s) of interest, the counts may be factored appropriately with reference to local or provincial experience. Guidance relating to temporal variations and appropriate adjustment factors is provided in the Traffic Characteristics section of the *Geometric Design Standards for Ontario Highways* (MTO 1999)⁶. Alternative references include Section 4 of the Institute of Transportation Engineers *Traffic Engineering Handbook*,²⁹ and Chapter 8 of the *Highway Capacity Manual* 2000.¹³

Vehicle Counts

Only vehicles entering the intersection should be considered. The vehicles may turn right, go straight through, or turn left. If the right turns are free-flowing, channelized and effectively segregated from the through traffic by means of a physical island, vehicles turning right are not considered to enter the intersection, and therefore should not be included in any justification calculations.

Vehicles entering the intersection from laneways, driveways and offset intersection approaches should be counted.

Bicycles

For the purposes of traffic signal justification analysis, bicycles must be treated as vehicles when on the road. Bicycles should be treated as pedestrians at the intersection of roads and park paths where cyclists dismount to cross the road.

For more details on justification for bicycle signal phasing and timing refer to Section 6.4.

Heavy Vehicle Movements

At locations in or near heavy industrial, manufacturing, agricultural, or natural resource extraction areas, heavy vehicle travel may affect signalized intersection flow or capacity. In these cases, engineering judgment and visual observations of delay, roadway grades, and conflict potential will be required to determine whether a heavy vehicle adjustment factor should be applied to reflect site-specific operational characteristics. Heavy vehicle adjustment factors ranging from 1.5 to 3.5 passenger car unit equivalents (PCUs) have been applied in many operational analysis methodologies. ITE's "Canadian Capacity Guide for Signalized Intersections" (CCG)² provides some guidance to the application of passenger car unit equivalents.

Pedestrian Volume Data

For the purpose of Justification 6: Pedestrian Volume and Delay, an adjusted pedestrian volume is applied to reflect a factored volume based on “Equivalent Adults” and the following definitions:

- Unassisted – Adults and adolescents at or above the age of 12 are considered “Unassisted” pedestrians.
- Assisted – Children under the age of 12, senior citizens, pedestrians with visible disabilities negatively impacting their mobility, and other pedestrians requiring special consideration are termed “Assisted” pedestrians. In cases where an adult is accompanying a pedestrian included in the “Assisted” category, both individuals should be counted as “Assisted” pedestrians to reflect their higher vulnerability. It should be recognized that the exact age of the pedestrian is not critical, but the observer will need to use judgment to place each pedestrian into one of the two categories.

The factored pedestrian volume is calculated as follows:

$$\text{Adjusted volume} = \text{Unassisted Pedestrian Volume} + 2 \times \text{Assisted Pedestrian Volume}$$

Collision Data

Reportable collisions are collisions involving personal injury or property damage that are serious enough to be reported by the police.

Supplementary Input Data

The following supplementary data may provide a more precise understanding of the operation of the intersection and may assist the analyst to apply additional engineering judgment to the results of the signal justification analysis. Supplementary

data that may be obtained for time periods for which the relevant Justification applies include:

- Vehicle Delay – Vehicle-seconds delay determined separately for each approach.
- Gaps – The number, length, and distribution of gaps in vehicular traffic on the main road when side road traffic experiences significant delays.
- Site Conditions – A condition diagram showing the intersection geometrics, lane arrangements, channelization, pavement markings, pedestrian paths, sight distance restrictions, and distance to nearest traffic signals. The condition diagram may also include approach grades, bus stops and routing, on-street parking conditions, driveways, street lighting, utility poles and fixtures, and adjacent land use/plans.

4.4 Justification 1 – Minimum Vehicle Volume

Purpose

The Minimum Vehicle Volume Justification is intended for applications where the principal reason for installing a traffic signal is the cumulative delay produced by a large volume of intersecting traffic at an unsignalized intersection.

Justification 1A reflects the lowest total traffic on all approaches, and Justification 1B reflects the lowest volume on the minor road for which the average delay is similar for both signalized and unsignalized conditions. Therefore, this justification is intended to address the minimum volume conditions for which signalization can be used to minimize total average vehicle delay at the intersection.

As volumes increase beyond threshold criteria, delay to traffic on the minor road will increase, and the overall delay for the intersection will be

greater than would be the case if minor delays were distributed between both main and minor roadways.

Standard

The need for a traffic signal should be considered if both Justification 1A and Justification 1B are 100% fulfilled.

If Justifications 1A and 1B do not reach or exceed 100%, but are at least 80% fulfilled, the lesser fulfilled of the Justifications 1A or 1B can be used in the assessment of Justification 3, the Combination Justification.

In applying Justification 1B (Minimum Vehicle Volume) for “T” intersections, the justification values for the minor street are increased by 50%. This approach reflects the reduction in traffic volumes due to the lack of one of the approaches.

Table 12 may be used for Justification 1: Minimum Vehicle Volume. Restricted Flow is applicable to Urban Conditions, while Free Flow is applicable to Rural conditions (see Section 4.3 for definitions).

Guidelines

Justification 1 evaluates total intersection volume and total minor road volume. The hours selected should represent the eight highest hours of the 24-hour traffic volume, and they do not have to be consecutive hours. Each one of the highest eight hours of the entering volumes is compared to the justification value. The justification should be met for each of the eight hours. “Lowest % Fulfilled” is calculated in Table 12 for reference purposes only and may indicate how close an intersection is to achieving full justification. “Total Across” is calculated by adding all 8-Hour compliance percentages and is for reference purposes only. The Compliance % values used in Table 12 must not exceed 100%.

Table 12 — Justification 1 – Minimum Vehicle Volume

100% SATISFIED – YES ☐ NO ☐

80% SATISFIED – YES ☐ NO ☐

APPROACH LANES	MINIMUM REQUIREMENTS (80% SHOWN IN BRACKETS)				PERCENTAGE WARRANT								TOTAL ACROSS
	1		2 or MORE		HOUR ENDING								
FLOW CONDITION	FREE FLOW 	RESTR. FLOW 	FREE FLOW 	RESTR. FLOW 									
A. ALL APPROACH LANES	480 (385)	720 (575)	600 (480)	900 (720)									
	100% FULFILLED												
	80% FULFILLED												
	ACTUAL % IF BELOW 80% VALUE												
TOTAL DOWN / 8 =													
B. MINOR STREET BOTH APPROACHES	120* (95)*	170* (135)*	120* (95)*	170* (135)*									TOTAL ACROSS
	100% FULFILLED												
	80% FULFILLED												
	ACTUAL % IF BELOW 80% VALUE												
TOTAL DOWN / 8 =													

* For “T” intersections, these values should be increased by 50%.

4.5 Justification 2 – Delay to Cross Traffic

Purpose

The Delay to Cross Traffic Justification is intended for applications where the traffic volume on the main road is so heavy that traffic on the minor road suffers excessive delay or hazard in entering or crossing the main road.

Standard

The need for a traffic signal should be considered if both Justification 2A and Justification 2B are 100% fulfilled. If Justifications 2A or 2B do not meet or exceed 100%, but both are at least 80% fulfilled, the lesser fulfilled of the justifications 2A or 2B can be used in the assessment of Justification 3, the Combination Justification.

Table 13 may be used for Justification 2: Delay to Cross Traffic. Restricted Flow is applicable to Urban Conditions, while Free Flow is applicable to Rural Conditions (see Section 4.3 for Flow Condition definitions).

Guidelines

Justification 2 evaluates major road volume and minor road movements that cross the intersection. The hours selected should represent the eight highest hours of the 24-hour traffic volume, and they do not have to be consecutive hours. The entering volumes of each of the highest eight hours are compared to the justification value. The justification is met if the justification value is 100% and fulfilled by each of the eight hours.

“Lowest % Fulfilled” is calculated in Table 13 for reference purposes only and may indicate how close an intersection is to achieving full justification. “Total Across” is calculated by adding all 8-Hour compliance percentages and is for

reference purposes only. The Compliance % values used in Table 13 must not exceed 100%.

As right turns are not considered as traffic crossing a road, they should be deleted from the combined pedestrian and vehicle volume in the Delay to Cross Traffic Justification. In one-way street systems, left turns from a one-way street into another one-way street should be treated in a similar manner to right turns and be deleted from the justification.

When applying Justification 2B, the crossing volume consists of the sum of:

1. The number of pedestrians crossing the main road.
2. Total left turns from both the side road approaches.
3. The highest through volume from one of the side road approaches.
4. Fifty percent of the heavier left-turn traffic movement from the main road when both of the following criteria are met:
 - a) The left-turn volume is greater than 120 vehicles per hour.
 - b) The total of the heavier left-turn volume plus its opposing volume is greater than 720 vehicles per hour.

Table 13 — Justification 2 – Delay to Cross Traffic

100% SATISFIED – YES ☐ NO ☐
 80% SATISFIED – YES ☐ NO ☐

MINIMUM REQUIREMENTS (80% SHOWN IN BRACKETS)					PERCENTAGE WARRANT									
APPROACH LANES	1		2 or MORE		HOUR ENDING								TOTAL ACROSS	
FLOW CONDITION	FREE FLOW ☐	RESTR. FLOW ☐	FREE FLOW ☐	RESTR. FLOW ☐										
A. MAJOR STREET BOTH APPROACHES	480 (385)	720 (575)	600 (480)	900 (720)										
	100% FULFILLED													
	80% FULFILLED													
	ACTUAL % IF BELOW 80% VALUE													
TOTAL DOWN / 8 =														
B. TRAFFIC CROSSING MAJOR STREET	50 (40)	75 (60)	50 (40)	75 (60)										
	100% FULFILLED													
	80% FULFILLED													
	ACTUAL % IF BELOW 80% VALUE													
TOTAL DOWN / 8 =														

4.6 Justification 3 – Volume/Delay Combination

Purpose

Signals may occasionally be justified where neither Justification 1 nor Justification 2 is 100% satisfied, but both justifications are at least 80% satisfied.

Standard

The requirements for the Volume/Delay Combination Justification are given in Table 14.

Guidelines

Justification 3 should only be applied after an adequate trial of other remedial measures designed to reduce delay and inconvenience to traffic have failed to solve the operational issues at the intersection. Explicit consideration should be given to the safety benefits and disadvantages of installing traffic signal control. Section 4.13 sets out an alternate recommended practice for undertaking and assessing the relative safety effects.

Table 14 — Justification 3 – Volume/Delay Combination

Justification Satisfied 80% or More				Two Justifications Satisfied 80% or More	
Justification 1	Minimum Vehicular Volume	YES ☐	NO ☐	YES ☐	NO ☐
Justification 2	Delay to Cross Traffic	YES ☐	NO ☐	YES ☐	NO ☐

4.7 Justification 4 – Minimum Four-Hour Vehicle Volume

Purpose

The Minimum Four-Hour Vehicle Volume Justification is intended for applications where the intersection experiences excessive delays for four or more peak hours of the day but does not have the prolonged demands throughout the day to meet an eight-hour warrant. The Ministry of Transportation, Ontario does not use the Minimum Four-Hour Vehicle Justification, but some jurisdictions may consider the Justification applicable for limited specific situations. The application of the four-hour justification is focused on locations such as:

- Commuter-dominated roadways – with heavy demands for two or more hours in each of the AM and PM peaks, but considerably reduced demand for the remainder of the day.
- Commercial areas – with limited demand in the morning, but a substantial four-to-six-hour peak in the afternoon and early evening.
- Manufacturing, office, school or industrial areas/accesses – where minor street traffic experiences considerable delays when entering the major street during the mid-day and PM peak periods, but the AM arrival peak creates only low side street demands.

Standard

The need for a traffic signal should be considered if an engineering study indicates that for each of the four highest hours of an average day, the plotted point representing the vehicles per hour on both major street approaches and the corresponding vehicles per hour on the highest minor street approach falls above the applicable curve outlined in Figure 28 (Rural - Unrestricted Flow Conditions) or Figure 29 (Urban - Restricted Flow Conditions).

No adjustments are made for “T” intersections as the methodology is based on the highest minor street approach volume and is applicable irrespective of the configuration.

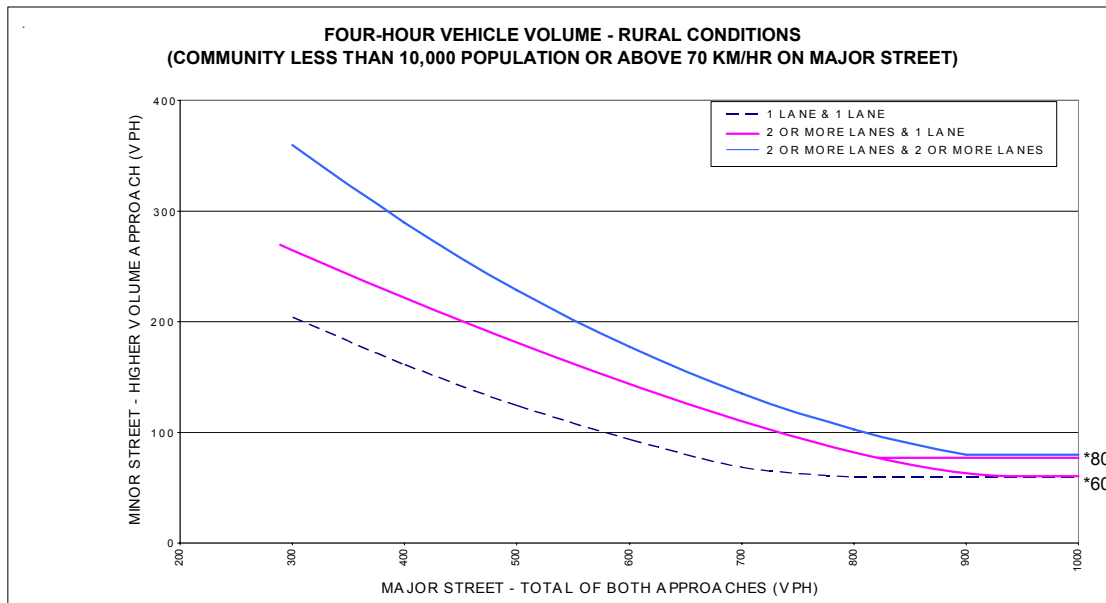
Guidelines

Where the highest volume minor street approach accommodates a heavy right turn volume, engineering judgment is required to determine whether a portion of the right turn volume should be excluded from the approach volume. The decision will depend on site specific operational conditions. The degree of conflict and delay the minor street right turn traffic experiences while entering the main street is the primary consideration. Additional considerations include: the presence of a dedicated right turn lane; the presence of a wide minor street approach that allows right turns independent from left/through movements; or a high percentage of right turns in the minor street volumes. In general, the right turn volume should not be included in the minor street volume if the movement enters the intersection with minimal delay or conflict.

On the minor street, the ‘highest volume approach’ need not be specified as the same approach during each of the four highest hours of the day.

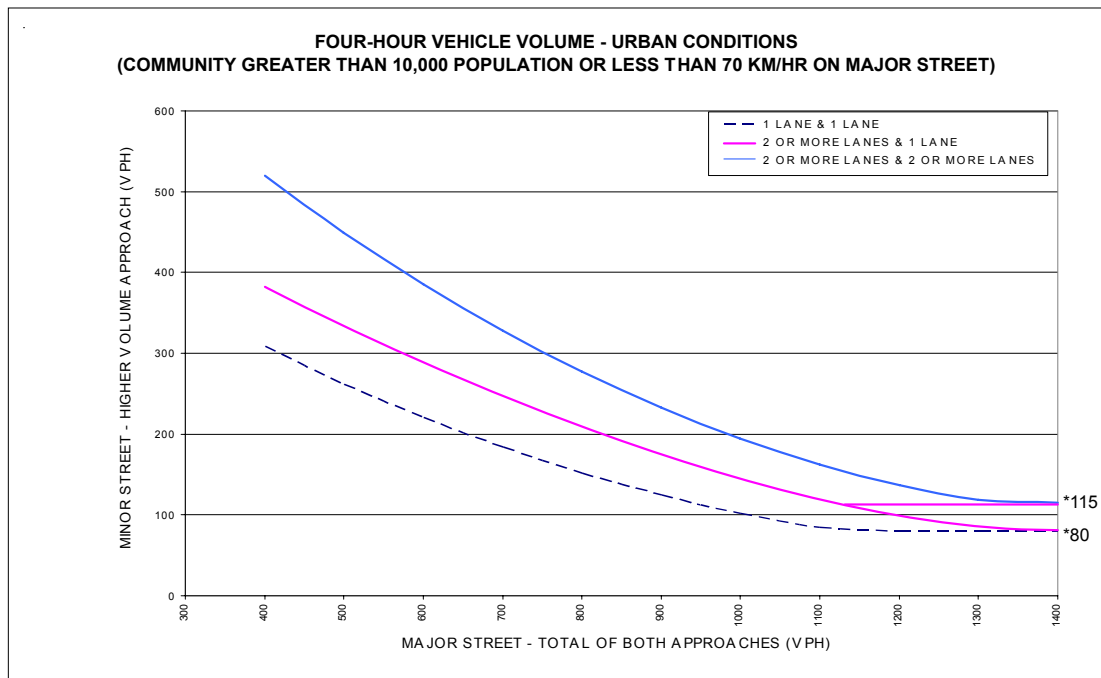
Justification 4 is not to be applied in combination with the other traffic signal control justifications.

Requirements: The four highest hour volumes are plotted on the applicable figure, 28 or 29. If the plot shows that all four points lie above the applicable curve, the justification is satisfied.



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

Figure 28 — Justification 4 – Minimum Four-Hour Justification, Unrestricted Flow



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

Figure 29 — Justification 4 – Minimum Four-Hour Justification, Restricted Flow

4.8 Justification 5 – Collision Experience

Purpose

Traffic signals may be considered one means of improving intersection safety where an unsignalized intersection has an unusually high collision history.

Standard

The approach taken in this section is a practical and straightforward methodology. If the basic frequency method finds that a signal installation is justified, or nearly justified, the agency may wish to consider the alternative methodology (Justification 5A) presented in Section 4.12 to gain more insight into the decision, particularly the expected collision performance of a location following proposed signalization. The alternate method provides details on whether safety will improve based on the installation of a traffic signal.

The installation of traffic signals may be justified when the conditions presented in Table 15 Justification 5 – Collision Experience are satisfied:

1. Five or more reportable collisions of types susceptible to correction per year over a continuous three-year analysis period. Collisions susceptible to reduction are those involving vehicles and/or pedestrians which,

under signalized conditions, would move on separate phases. Reducible collisions are described in detail in Table 11.

If the warrant is 80% or more justified, consideration should be given to the installation of intersection control beacons at the intersection. See Section 3.12 for details on intersection control beacon installation suitability.

2. Adequate trial or consideration of less restrictive remedies with satisfactory observance and enforcement has failed to reduce collision frequency.

Guidelines

Less restrictive measures that could be tried before signals are installed include the improvement of control or warning signs, installation of flashing beacons, the provision of safety or channelizing islands, the improvement of street lighting, geometric or visibility improvements, shifting of bus stops, and/or the prohibition of parking and/or turns.

When applying Justification 5, consideration should be given to whether self-reported or police reported collisions are most prevalent. If self-reported collisions are prevalent, the accuracy of the collision history may be reduced.

Table 15 – Justification 5 – Collision Experience

Reportable Collisions over 36 consecutive months susceptible to correction by a traffic signal			
WARRANT VALUE	TOTAL NUMBER OF CRASHES	OVERALL % COMPLIANCE	
15		%	
Adequate trial of less restrictive remedies has failed to reduce accident frequency		Yes ☐	No ☐
Justification 5	100% Fulfilled	Yes ☐	No ☐
	80% Fulfilled	Yes ☐	No ☐

The justification is intentionally designed to ensure that traffic signals will seldom be justified on the collision justification alone. Engineering judgment should be applied to assess whether signal use may even increase the intersection collision rate due to rear-end collisions, etc., caused directly or indirectly by the signal operation.

An alternate collision experience justification (Justification 5A) that can assess the expected collision performance of a location following signalization is available and can be used to assist with the determination of the net safety change that can be expected to occur after a signal installation. Details of this procedure are included in Section 4.14.

4.9 Justification 6 – Pedestrian Volume and Delay

Purpose

The minimum pedestrian volume conditions are intended for applications where the traffic volume on a main road is so heavy that pedestrians experience excessive delay or hazard in crossing the main road, or where high pedestrian crossing volumes produce the likelihood of such delays.

The justification is applicable to an unsignalized intersection or a mid-block location.

Once justification has been established, determination of the appropriate crossing protection device should be subject to site-specific engineering judgment (see Guideline 3 for options).

Standard

The need for a traffic control device at an intersection or mid-block location should be considered if both the following minimum pedestrian volume and delay criteria are met:

1. The 8-Hour Net Pedestrian Volume Crossing Main Road (V_p) fulfils Justification 6A requirement identified in Table 18 or Figure 30. Methodology for the calculation of V_p is provided as part of Guideline 1 or in Table 16.
2. 8-Hour Net Pedestrian Volume Crossing Main Road Delayed > 10 Seconds (V_d) fulfils the Justification 6B requirement identified in Figure 31 or Table 19.

Guidelines

1. 8-Hour Net Pedestrian Volume Crossing Main Road (V_p) requires the following inputs:
 - a) 8-Hour Pedestrian Volume Crossing Main Road: determined based on a review of the highest eight hours of traffic and does not need to be consecutive. Volume is sorted into unassisted and assisted. Assisted pedestrian volume defined as: senior citizens, pedestrians with a visible disability and children under 12 assisted in crossing the road (Refer to Section 4.3).
 - b) 8-Hour Factored Pedestrian Volume Crossing Main Road: Unassisted pedestrian volume plus 2 times assisted pedestrian volume.
 - c) Percentage assigned to crossing used if a roadway is crossed by pedestrians at several locations, and the introduction of a signal-protected crossing is likely to consolidate the crossings at a single point, the road segment may be divided into zones, with an appropriate percentage of crossings in each zone reassigned to the signal-protected crossing zone included in Tables 16 and 17.
 - d) V_p equals 8-Hour Factored Pedestrian Volume Crossing Main Road multiplied by the percentage assigned to crossing.

Table 16 — Pedestrian Volume Data Summary (Justification 6A Input)

	ZONE 1		ZONE 2 (if needed)		ZONE 3 (if needed)		ZONE 4 (if needed)		TOTAL
	Assisted*	Unassisted	Assisted*	Unassisted	Assisted*	Unassisted	Assisted*	Unassisted	
8-Hour Pedestrian Volume Crossing Main Road									
8-Hour Factored Pedestrian Volume Crossing Main Road **									
% ASSIGNED TO CROSSING RATE***									
8-Hour Net Pedestrian Volume Crossing Main Road (V_p)									
8-Hour Vehicle Volume Crossing Main Road (V_g)									

* Assisted = senior citizens, pedestrians with visible disabilities and children under 12 assisted in crossing road (Refer to Section 4.2)

** Factored volume = unassisted + (2 x assisted)

*** See guideline 1c) of Justification 6

Table 17 — Pedestrian Delay Data Summary (Justification 6B Input)

	ZONE 1		ZONE 2 (if needed)		ZONE 3 (if needed)		ZONE 4 (if needed)		TOTAL
	Assisted*	Unassisted	Assisted*	Unassisted	Assisted*	Unassisted	Assisted*	Unassisted	
8-Hour Pedestrian Volume Crossing Main Road									
8-Hour Pedestrian Volume Crossing Main Road Delayed > 10 Seconds									
8-Hour Factored Pedestrian Volume Crossing Main Road **									
8-Hour Factored Pedestrian Volume Crossing Main Road Delayed > 10 Seconds **									
% ASSIGNED TO CROSSING RATE***									
8-Hour Net Pedestrian Volume Crossing Main Road (V_p)									
8-Hour Net Pedestrian Volume Crossing Main Road Delayed > 10 Seconds (V_d)									

* Assisted = senior citizens, pedestrians with visible disabilities and children under 12 assisted in crossing road (Refer to Section 4.2)

** Factored volume = unassisted + (2 x assisted) volume

*** See guideline 1c) of Justification 6

Signal Justification:

Both Justification 6A (volume) and Justification 6B (delay) met?

___ YES = Traffic Control Justified

___ NO = Traffic Control Not Justified

Table 18 — Pedestrian Volume Justification 6A

8-Hour Vehicle Volume Crossing Main Road (V_8)	8-Hour Net Pedestrian Volume Crossing Main Road (V_p)				
	<200	200 - 275	276 - 475	476 - 1000	>1000
<1440	NOT JUSTIFIED	NOT JUSTIFIED	NOT JUSTIFIED	NOT JUSTIFIED	NOT JUSTIFIED
1440 - 2600	NOT JUSTIFIED	NOT JUSTIFIED	NOT JUSTIFIED	SEE EQUATION 1	JUSTIFIED
2601 - 7000	NOT JUSTIFIED	NOT JUSTIFIED	SEE EQUATION 2	JUSTIFIED	JUSTIFIED
>7000	NOT JUSTIFIED	SEE EQUATION 3	JUSTIFIED	JUSTIFIED	JUSTIFIED

EQUATION 1: Justified if $V_p > (1650 - (0.45V_8))$

EQUATION 2: Justified if $V_p > (0.00001 V_8^2 - 0.146V_8 + 800)$

EQUATION 3: Justified if $V_p > (340 - (0.0094V_8))$

% Justification = (Equation 1, 2 or 3 as appropriate) x 100%

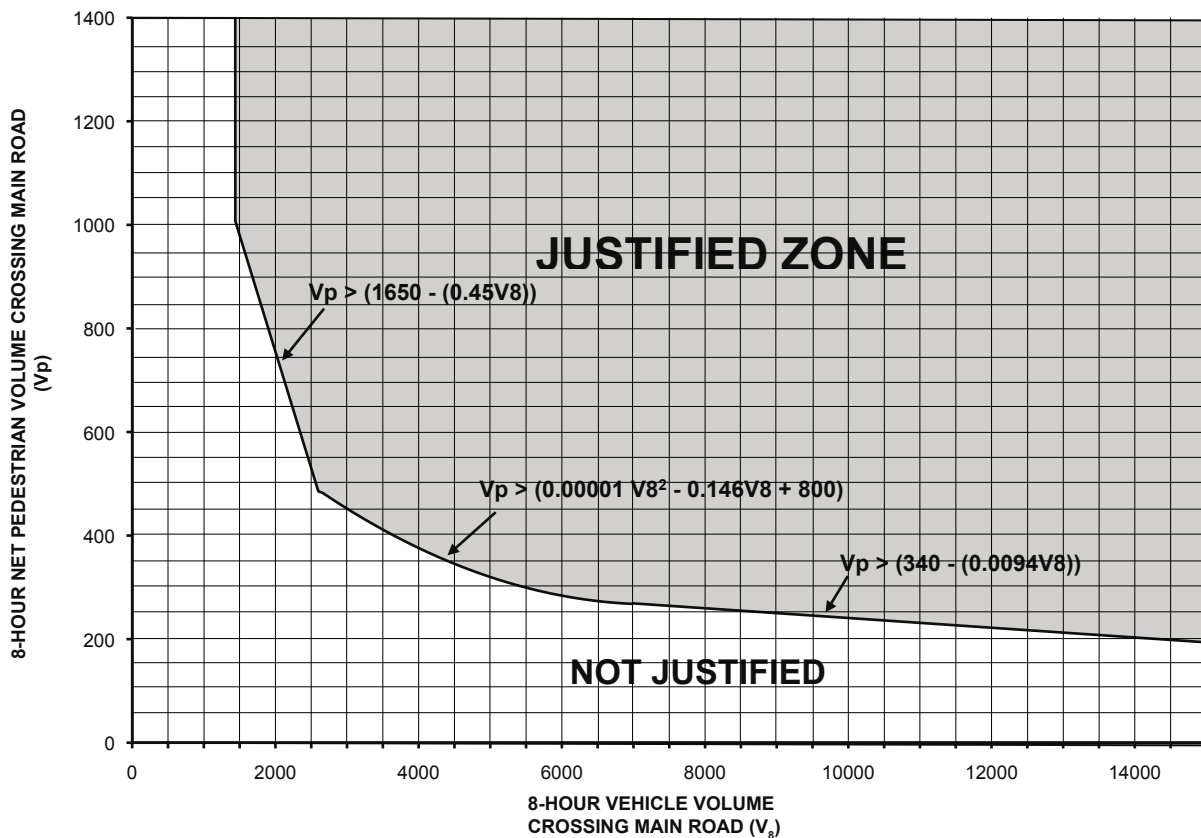
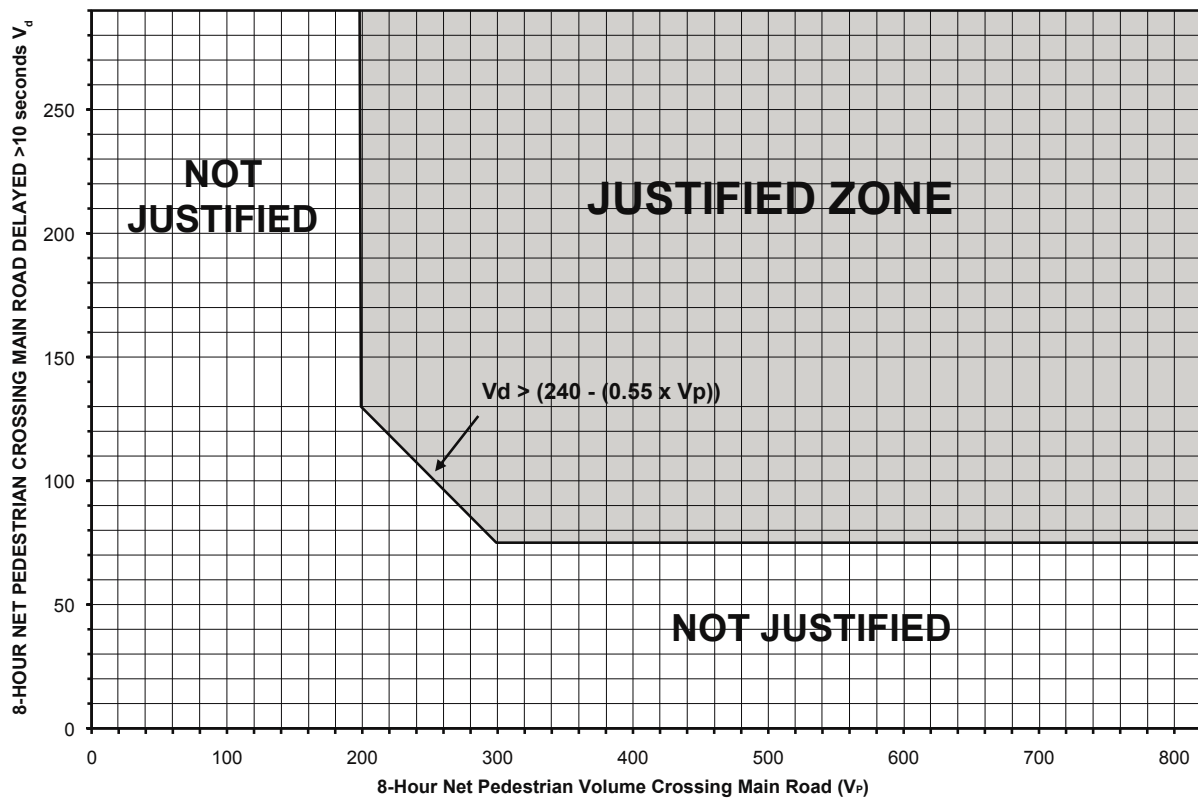


Figure 30 – Pedestrian Volume Justification 6A

Table 19 — Pedestrian Delay Justification 6B

8-Hour Net Pedestrian Volume Crossing Main Road (V_p)	8-Hour Net Pedestrian Volume Crossing Main Road Delayed > 10 Seconds (V_d)		
	<75	75 - 130	>130
<200	NOT JUSTIFIED	NOT JUSTIFIED	NOT JUSTIFIED
200 - 300	NOT JUSTIFIED	JUSTIFIED IF $V_d > (240 - (0.55 \times V_p))$	JUSTIFIED
>300	NOT JUSTIFIED	JUSTIFIED	JUSTIFIED

% Justification = $(V_d / (\text{threshold volume for justification})) \times 100\%$

**Figure 31 – Pedestrian Delay Justification 6B**

2. In the case of a divided roadway with a raised median at least 1.2 m wide, the justification may be calculated separately for each side. The “Worst Case” will govern the outcome: such that if a protected crossing is justified for one side, the entire crossing will be justified.
3. If both Justification 6 and a traffic engineering study determine that protection of pedestrian traffic crossing a roadway is appropriate, consideration may be given to the variety of options. Consistent practice is desirable for pedestrian crossing types, application thresholds, and crossing design. Accordingly, it is recommended that installed crossing treatments be implemented as per the guidelines included in OTM Book 15 (Pedestrian Crossing Treatments). Consistency promotes motorist familiarity with the pedestrian crossing and helps to prevent motorists from running the signal or making other unsafe maneuvers. Unique or limited application of pedestrian crossing types not typically used in a jurisdiction should be avoided.
4. The priority placed on implementing a new pedestrian crossing device should reflect the proximity and convenience of existing crossings; a higher priority should be placed on crossings where no reasonable alternatives exist within walking distance or where pedestrian desire to cross cannot be shifted to another location due to adjacent land uses such as transit stations/stops or front doors of commercial centres.

Pedestrian Crossing Devices

Pedestrian crossing protection devices include:

- a) *Intersection Pedestrian Signals (IPS)*. If the pedestrian crossing is at an intersection, the decision should be based on fulfilment of Justification 6, but the crossing vehicular traffic should be so light that it does not meet one of

the other justifications (1 through 4). If selected for implementation, the practitioner should consult OTM Book 15 (Pedestrian Crossing Treatments) Sections 5 and 6 for additional details on crossing selection and design.

- b) *Pedestrian Crossovers (PXOs)*. Pedestrian Crossovers are intended for low to moderate volume, low speed roadways (60 km/h or less posted speed) and must not be used where the road volume exceeds 35,000 AADT. PXOs should not be installed at sites where there are heavy volumes of turning traffic, or where there are more than four lanes of two-way traffic. PXOs should not be within 200 m of other signal-protected pedestrian crossings. Parking and other sight obstructions should be prohibited within at least 30 m of the crossings. Regulation 615 of the HTA covers most aspects of required PXO traffic control devices and their placement.

Justification for PXOs should be based on the above factors as well as the pedestrian crossover selection matrix included in OTM Book 15 (Pedestrian Crossing Treatments), republished as Table 18 for convenience. If a PXO appears to be appropriate for implementation, the practitioner should consult OTM Book 15 (Pedestrian Crossing Treatments) Sections 5 and 6 for additional details on crossing selection and design.

- c) *Midblock Pedestrian Signals*. Midblock pedestrian signals should be restricted to roadways posted at less than 80 km/h. Justification for midblock pedestrian signals should be based on a percent justification, as given in Figures 22 and 23, which is set by the authority as the required threshold. If selected for implementation, the practitioner should consult OTM Book 15 (Pedestrian Crossing Treatments) Sections 5 and 6 for additional details on crossing selection and design.

d) *Full Intersection Signals.* Consideration should be given to implementing a full traffic signal at an intersection in the case where pedestrian crossing protection is justified but either:

- A PXO, IPS or midblock device is inappropriate because of the roadway physical or operating conditions as noted in (a) or (c) above.
- An IPS is justified but is preferred traffic control device within the municipality.

e) *Pedestrian Grade Separations*

In cases of very heavy pedestrian and traffic volumes, it may be economically viable to construct grade separate pedestrian crossings (bridges or tunnels) although this option would need to be considered along with pedestrian accessibility.

Table 20 – Pedestrian Crossover Selection Matrix

Two-Way Vehicular Volume			Posted Speed Limit (km/h)	Total Number of Lanes for the Roadway Cross Section			
Time period	Lower Bound	Upper Bound		1 or 2 Lanes	3 Lanes	4 lanes w/raised refuge	4 lanes w/o raised refuge
8 Hour	750	2,250	≤50	Level 2 Type D	Level 2 Type C ³	Level 2 Type D ²	Level 2 Type B
4 Hour	395	1,185					
8 Hour	750	2,250	60	Level 2 Type C	Level 2 Type B	Level 2 Type C ²	Level 2 Type B
4 Hour	395	1,185					
8 Hour	2,250	4,500	≤50	Level 2 Type D	Level 2 Type B	Level 2 Type D ²	Level 2 Type B
4 Hour	1,185	2,370					
8 Hour	2,250	4,500	60	Level 2 Type C	Level 2 Type B	Level 2 Type C ²	Level 2 Type B
4 Hour	1,185	2,370					
8 Hour	4,500	6,000	≤50	Level 2 Type C	Level 2 Type B	Level 2 Type C ²	Level 2 Type B
4 Hour	2,370	3,155					
8 Hour	4,500	6,000	60	Level 2 Type B	Level 2 Type B	Level 2 Type C ²	Level 2 Type B
4 Hour	2,370	3,155					
8 Hour	6,000	7,500	≤50	Level 2 Type B	Level 2 Type B	Level 2 Type C ²	Level 1 Type A
4 Hour	3,155	3,950					
8 Hour	6,000	7,500	60	Level 2 Type B	Level 2 Type B		
4 Hour	3,155	3,950					
8 Hour	7,500	17,500	≤50	Level 2 Type B	Level 2 Type B		
4 Hour	3,950	9,215					
8 Hour	7,500	17,500	60	Level 2 Type B			
4 Hour	3,950	9,215					

Approaches to roundabouts should be considered a separate roadways.

1. The total number of lanes is representative of crossing distance. The width of these lanes is assumed to be between 3.0 m and 3.75 m according to MTO Geometric Design Standards for Ontario Highways (Chapter D.2). A cross sectional feature (e.g. bike lane or on-street parking) may extend the average crossing distance beyond this range of lane widths.

2. Use of two sets of side mounted signs for each direction (one on the right side and one on the median)

3. Use Level 2 Type B PXO up to 3 lanes total, cross section one-way.

The hatched cells in this table show that a PXO is not recommended for sites with these traffic and geometric conditions. Generally a traffic signal is warranted for such conditions.

4.10 Summary of Justification 1 to 6

Table 21 presents minimum requirements for installation of traffic signals for Justification 1 to Justification 6.

Table 21 — Summary Table of Traffic Signal Justification

JUSTIFICATION	DESCRIPTION	MINIMUM REQUIREMENT FOR TWO-LANE ROADWAYS		COMPLIANCE	
		FREE FLOW	RESTRICTED FLOW	LOWEST %FULFILLED	ENTIRE %**
		OPERATING SPEED GREATER THAN OR EQUAL TO 70 km/h	OPERATING SPEED LESS THAN 70 km/h		
1. MINIMUM VEHICULAR VOLUME	A*. Vehicle Volume, All Approaches for Each of the Heaviest 8 Hours of an Average Day, and	480	720		
	B***. Vehicle Volume, Along Minor Streets for Each of the Same 8 Hours	120	170		
2. DELAY TO CROSS TRAFFIC	A*. Vehicle Volume, Major Street for Each of the Heaviest 8 Hours of an Average Day, and	480	720		
	B. Combined Vehicle and Pedestrian Volume Crossing the Major Street for Each of the Same 8 Hours	50	75		
3. VOLUME/DELAY COMBINATIONS	The Above Justifications (1 and 2) Both Satisfied to the Extent of 80% or more	YES ☐	NO ☐		
4. MINIMUM FOUR HOUR VEHICLE VOLUME	At Plotted Point Representing Hourly Volume for Minor Approach vs. Major Approach for Four Highest Hours of an Average Day Fall above the Applicable Curve	YES ☐	NO ☐		
5. COLLISION EXPERIENCE	A. Total Reported Accidents of Types Susceptible to Correction by a Traffic Signal, per 12 Month Period Averaged Over a 36 Month Period, and	5			
	B. Adequate Trial of Less Restrictive Remedies, Where Satisfactory Observance and Enforcement Have Failed to Reduce the Number of Collisions	YES ☐	NO ☐		
6. PEDESTRIAN VOLUME AND DELAY	A. Plotted Point Representing 8 Hour 8-Hour Net Pedestrian Volume Crossing Main Road vs. 8-Hour Vehicle Volume Crossing Main Road Falls in Justified Zone, and	YES ☐	NO ☐		
	B. Plotted Point Representing 8-Hour Net Pedestrian Volume Crossing Main Road Delayed > 10 Seconds vs. 8-Hour Net Pedestrian Volume Crossing Main Road Falls in Justified Zone	YES ☐	NO ☐		

Notes:

* Vehicle Volume Warrants (1A) and (2A) for Roadways Having Two or More Moving Lanes in One Direction should be 25% Higher than Values Given Above.

** The Lowest % Fulfilled Governs the Entire Warrant.

*** For "T" Intersections, the Values for Warrant (1B) should be increased by 50%.

4.11 Justification 7 – Projected Volumes

In some cases, it is desirable to determine the future need for traffic signals at an existing or planned intersection. There are two basic scenarios.

1. The intersection may exist and all that is changing is the addition of one or more developments which will add traffic to the intersection.
2. A development which will require, or be associated with, the construction of one or more new legs at an existing intersection or a completely new intersection or roadway.

The prediction of future traffic demands is based on knowledge of growth in roadway usage, growth of local traffic generators and predicted traffic volumes, obtained from a traffic impact study, transportation planning study, environmental assessment, or other similar evaluation. It is incumbent upon the road authority to ensure that the calculation methodology is sound and is based on good data, so that there is a high level of confidence in the predicted traffic volumes.

The preferred approach is that 8-Hour volume projections are estimated as part of the engineering study and evaluated against Justifications 1, 2 or 3.

Analysis Using 8-Hour Volumes

If eight-hour projections are available, Justifications 1, 2 or 3 should be used. For the situation of an existing intersection with new development, Justifications 1 or 2 need to be met to 100%, or Justification 3 both needs to be met to 80%.

Often for future development, especially where the intersection or road may not exist, eight-hour volumes may be difficult to obtain or predict with the necessary accuracy. If eight-hour volumes are unavailable or not considered to be of sufficient

accuracy, Justification 7 can be applied by using Peak Hour Volumes (PHV) estimated as part of the transportation study and reduced to Average Hourly Volumes (AHV) as input to Justification 7.

Analysis Using Average Hour Volume

The Average Hourly Volume for a typical day can be estimated from the Peak Hour Volumes using the following relationships:

$$AHV = \frac{PHV}{2} \text{ or } AHV = \frac{amPHV + pmPHV}{4}$$

Alternately, the Average Hourly Volume for the eight highest hours of an average day can be estimated from Annual Average Daily Traffic (AADT) volume using the following relationship:

$$AHV = \frac{AADT}{16}$$

Where:

AHV = Average hourly volume

AADT = Annual average daily traffic

PHV = Peak Hour Volume (represents 1 hour of time)

A number of factors affect the accuracy of traffic volume projections. It is also clear that each of these factors can insert significant variability into the prediction calculation, and it is extremely difficult to remove or minimize this variability. Some of the elements that create uncertainty are as follows:

- The use of an average hour in the Justification 7 signal warrants, rather than requiring all eight hours to meet the standard, introduces an error factor.

- If the projections are taken from the ITE Trip Generation Manual, some of these studies are outdated and are primarily U.S. based so they are not totally reflective of Canadian conditions. The studies may not have been made at a location or during a time period when Sunday shopping was allowed, and the variability of the results for some of the studies is very large and not confidence inspiring.
- Background traffic, which has its own separate projection, may be affected by unexpected factors.
- Developments do not always evolve exactly as planned, in terms of timing, store or residence type and customer response.
- The methods of projection themselves could have built in errors. An example of these methods is the proxy sites method that is hard to generalize its projection factors as there are always differences in the site conditions.

As a result, the variability in outcomes, relative to predictions, is potentially very high and it is not appropriate to try to assign a single factor or factors to reflect these sources of variability. A revised approach is recommended for responding to requests for future traffic signals, based on development and growth.

The intent of this justification is to determine the likelihood that a traffic signal would be warranted in the future.

The first step is to calculate the AHV based on either:

- 1) projected future volumes for the AM and PM peak periods, or
- 2) projected AADT, depending on availability of peak hourly volumes. If only one time period of projected data is available, this should be used,

but only after attempting to obtain or calculate both AM and PM peak data.

The next step is to apply the following criteria to determine which of the following cases are met:

- Case 1: The traffic signal is certainly warranted – the suggested threshold for this condition is meeting 200 % or more of Justifications 1 or 2.
- Case 2: The traffic signal might be warranted – falls between cases 1 and 3, somewhere between 100% and 199% of Justifications 1 or 2.
- Case 3: Signal warrant is unlikely – meets less than 100% of Justifications 1 or 2.

For Case 1, the traffic signal can be installed at the time of development, at the cost (or shared cost) of the developer. The understanding would be that the activation (actual turn-on) of the signals would still be delayed until the minimum flow levels in the Justification are met.

For Case 2, the need for the traffic signal cannot be known for certain. Jurisdictions could request and hold securities from the developer and operate the intersection under two-way or all-way stop control until such time as one of the Justifications is met as evidenced by actual 8-hours counts on a representative day. In the event that the Justification is not met after five years, the securities are returned. An alternative would be for the jurisdiction to require the developer install the initial underground traffic plant or roadway reconfiguration in advance of the signal, whereas this would not occur under Case 3.

For Case 3, where the signal warrant is unlikely, it is not recommended to hold any securities or install any underground traffic signal plant and the intersection should continue to operate under two-way or all-way stop control. Once the development

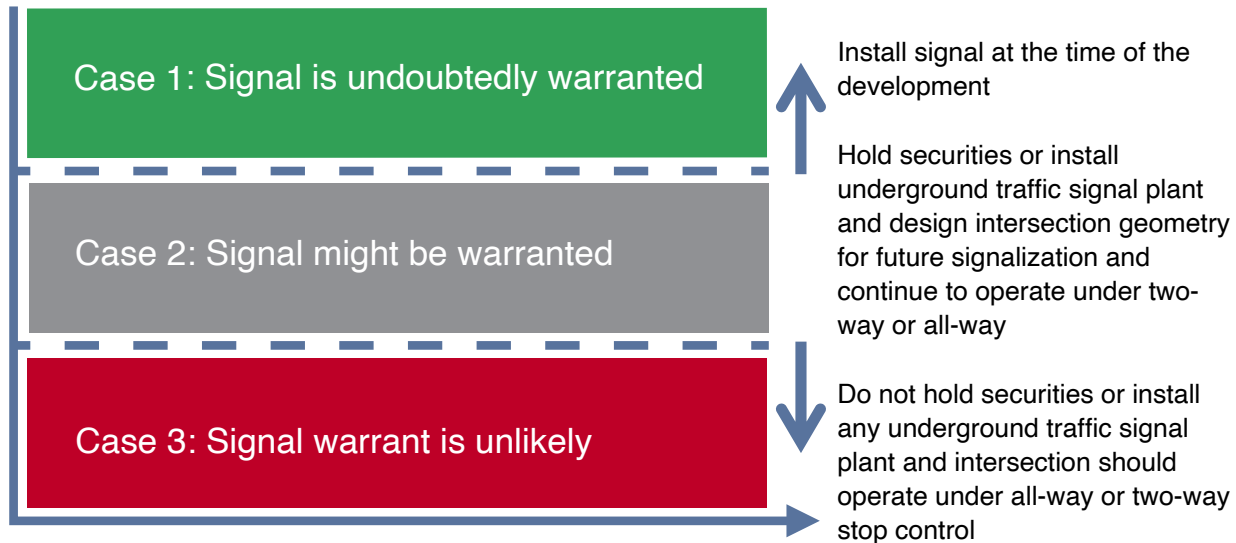


Figure 32 — Likelihood of Traffic Signal Being Justified Using Projected Volumes

is complete the jurisdiction can perform a full 8-Hour Turning Movement Count (TM) and determine if traffic signals are now justified or place the intersection into an appropriate monitoring sequence depending on how close to being warranted the intersection is.

4.12 Signal Installation Prioritization

Due to funding limitations or other constraints, it may not be possible to implement all signals that meet the minimum technical justification criteria network-wide. It is therefore important to understand the relative value of each candidate set of traffic signals so that effort may be directed first to the site that would provide the greatest overall benefits. The benefits are normally expressed in terms of benefit/cost ratios with safety and the movement of people and goods the prime considerations.

One approach is to examine the justification analysis for each potential location and rank the sites by the degree to which they meet each justification. This approach should ensure that the collision history is integrated into the prioritization process. A weighting may be placed on each of the justification components to assign priority. Determination of a weighting scheme is the responsibility of the road authority.

4.13 Removal of Existing Signals

If the conditions under which a signal was installed change significantly and concerns arise that the signal is no longer justified, the need may be analyzed using Justifications 1 to 6 as if the signal was a “new” installation. If, under current conditions, the signal fails to meet any of Justifications 1 to 6, then the signal should be considered a candidate for removal.

If only Justification 6, Pedestrian Volume and Delay, is met, then the installation should be reviewed to ensure that the most appropriate type of pedestrian crossing protection is used. Removal of a signal should not take place without consultation with the affected community.

Key steps that should be followed for traffic signal removal after it is determined that none of the justifications are met, and are not likely to be met for a considerable period of time, are:

- A. Determine the appropriate traffic control to be used after removal of the signal.
- B. Remove any sight-distance restrictions as necessary.
- C. If the public has not been informed through a public consultative process or formal public meeting, notify the public of the pending removal by installing an informational sign (or signs) with the legend **TRAFFIC SIGNAL UNDER CONSIDERATION FOR REMOVAL** or similar) at the signalized location in a position where the sign is visible to all road users (installed at least 3 weeks in advance of removal).
- D. Deactivate the signal and remove the above-ground hardware. Secure and make any underground plant safe. Add sunburst **NEW** signs along with the appropriate warning signs to indicate the new form of traffic

control. Monitor the new operation and make modifications to signing if required.

4.14 Justification 5A – Collision Experience / Safety Change Estimation

Improving traffic safety is a major goal for traffic engineers, the public and elected officials. Traffic collisions cause fatalities, injuries, property damage and highway congestion. In order to improve traffic safety, the identification of highly hazardous locations or collision-prone spots and evaluation of the effectiveness of safety improvements are essential.

In a transportation network, intersections are relatively collision-prone locations due to the complicated conflicts between road users occurring within the intersection. A number of treatments may improve the safety and efficiency of the intersection operation. Signalizing intersections is a common treatment used by road authorities to address the safety and operation issues.

The current signal collision justification (Justification 5 – Section 4.7) for determining traffic signal installation at existing stop-controlled intersections is that an intersection has had five correctable collisions per year for three consecutive years. There are, however, limitations to this approach as it does not take into consideration the effect of traffic volume variations in collisions. As shown in Figure 33, the number of correctable collisions that justifies signal installation remains the same regardless of the traffic volume (AADT).

Justification 5 focuses only on correctable or reducible collisions (those anticipated to be prevented following signal installation) and does not account for the non-correctable, non-reducible collisions that might increase following the installation of traffic signals. In summary, the current collision warrant may not provide a way

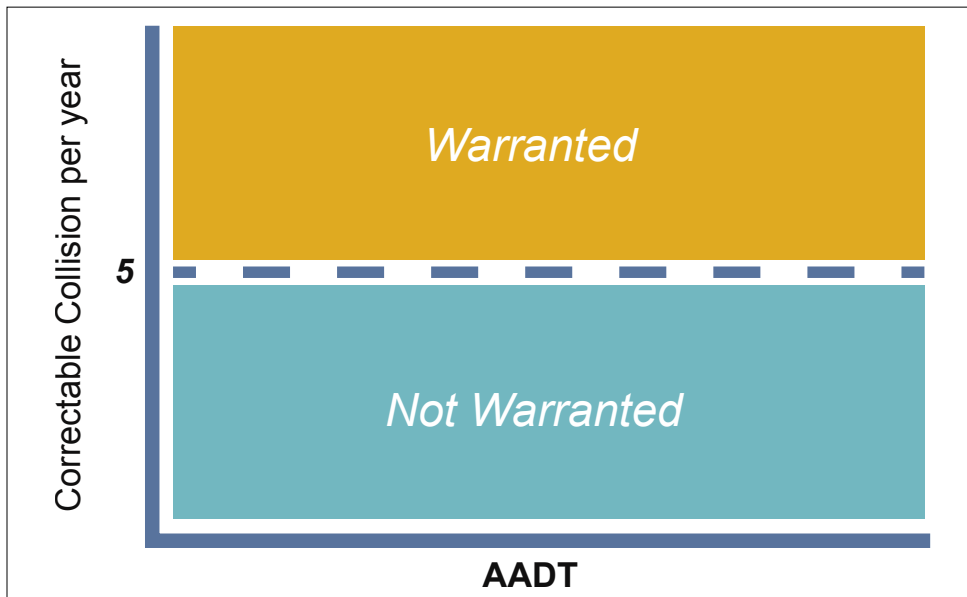


Figure 33 – Current Signal Collision Justification (Justification 5 –Section 4.8)

to measure changes in safety at an intersection after installation of traffic signals. An alternative collision justification procedure has therefore been developed to address these potential shortcomings.

To address the issue of overall intersection safety, new collision justification procedures should examine both the safety benefits and drawbacks that can result from the installation of a signal. Conceptually, the intent is to understand the safety change that will result as the traffic control at a location changes from stop control to signal control, shown graphically in Figure 34.

This section describes a detailed approach for estimating the safety impacts of signal installations. The approach can be used as an alternative method for examining the justification of signalization using collision experience.

Justification 5A has the same data requirements as Justification 5, as described in Table 11.

Purpose

The objective of this section is to demonstrate the use of a safety analysis and evaluation tool for estimating the expected safety of installing traffic signals. The demonstration is intended to help the traffic engineer to use the analysis and evaluation tool to determine the likely safety impact of installing a traffic signal.

The proposed approach considers both the potential increase in some types of collisions and the potential decrease in others. Using the Empirical Bayes (EB) statistical analysis method, which combines the predicted collision performance as indicated by Safety Performance Functions (SPFs) with the collision counts obtained from a safety database, to an estimate of the safety effects (expected impact) of changing a “target” intersection from unsignalized to signalized control.

It is critical that the expected collision performance of signalization takes into account both the recent collision history at the target location and the



Figure 34 – General Consideration of Safety Changes

long-term expected collision performance of traffic signals at similar locations (in terms of traffic volume, intersection type).

Standard

The collision experience justification is based on concepts first introduced to Ontario in the Science of Highway Safety Manual.²⁵ The approach uses Safety Performance Functions (SPFs) to understand how collisions at similar types of locations change with traffic volume. The approach also uses Empirical Bayes (EB) statistical methods to consider the effect of the target location's recent collision history on future outcomes. With this approach, it is possible to assess the potential change in safety that may result from installing a signal.

The Empirical Bayes method is a statistical approach for determining the appropriate weighting for each relevant factor that affects the estimate of expected collision outcomes for the location. The EB method determines a “smoothed” value for the number of predicted collisions (obtained from the SPFs) and eliminates the randomness element in the number of observed collisions. If the random element is ignored, regression to the mean bias may result.

SPFs detail the relationship between collisions and traffic volume. The first step is to consider what the collision behaviour will be if a signal is not installed. The predicted number of collisions for the general type of intersection being investigated is obtained from SPFs and combined with the historical collision counts for the particular intersection to determine the expected number of collisions for that particular intersection if it remains unsignalized. The next step is to examine what the collision behaviour will be if signals are installed.

For traffic signals, it is important to examine two distinct groups of intersection collisions:

Reducible collisions and Non-Reducible collisions.

Reducible collisions are the types of collisions deemed susceptible to reduction following a signal installation. Angle and Turning Movement collisions are considered reducible collisions. These categories include both vehicle-vehicle and vehicle-pedestrian collisions. Non-reducible collisions are the types of collisions that are likely to be increased by a signal installation. They include side-swipe, rear-end and approaching collisions. The reducible and non-reducible collisions are shown in Table 22.

Table 22 — Collision Groups for Calibration of OPF

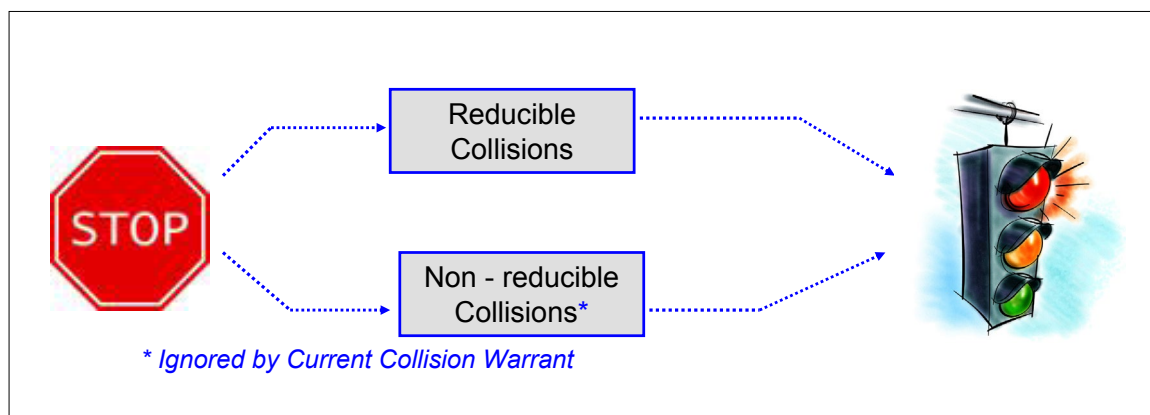
Reducible Collisions (RC)	Non-reducible Collisions (NRC)
Angle	Side-swipe
	Rear-end
Turning-Movement	Approaching
	Other

To examine the effect of installing a signal, it is necessary to look at reducible collisions and non-reducible collisions separately, assessing what will happen to each group as a result of installing the signal. This is because the change in outcome following signalization is different for each group. The net change in safety, looking at both potential benefits and drawbacks can be measured, and a decision to signalize, as it relates to safety, can then be determined. Figure 35 displays this concept graphically.

To develop the collision experience justification for each collision type, SPFs for unsignalized

intersections (representing the before periods) and SPFs for signalized intersections (representing the after periods) were developed for both reducible and non-reducible collisions. The database used for the development of the SPFs was obtained from Ontario's Ministry of Transportation (MTO). The database integrates the crash, intersection configurations, and traffic volume data from all intersections in the MTO's Central and Southwest regions for the six-year period from 2014 to 2019.

To complete the collision experience justification, the unsignalized SPFs for reducible collisions associated with intersections to the characteristics

**Figure 35 – Detailed Consideration of Safety Changes**

of the target intersection are used to predict the expected numbers of collisions for the target intersection. Then the predicted number of collisions (the point on the SPF for unsignalized intersections in Figure 36) and the observed number of collisions are used to determine the expected collisions for the target intersection by using the EB method.

In the next step, the signalized SPFs for reducible collisions applicable to intersections with similar characteristics are used to predict the numbers of collisions for an intersection with similar characteristics if the intersection was to be signalized.

Then the proportion of expected and predicted number of collisions for the unsignalized intersection is applied to the predicted number of collisions for the signalized intersection to determine the expected number of collisions at the target intersection if the intersection was to be signalized. This estimate is shown as “Expected Collisions, Target Intersection (Signalized)” in Figure 36.

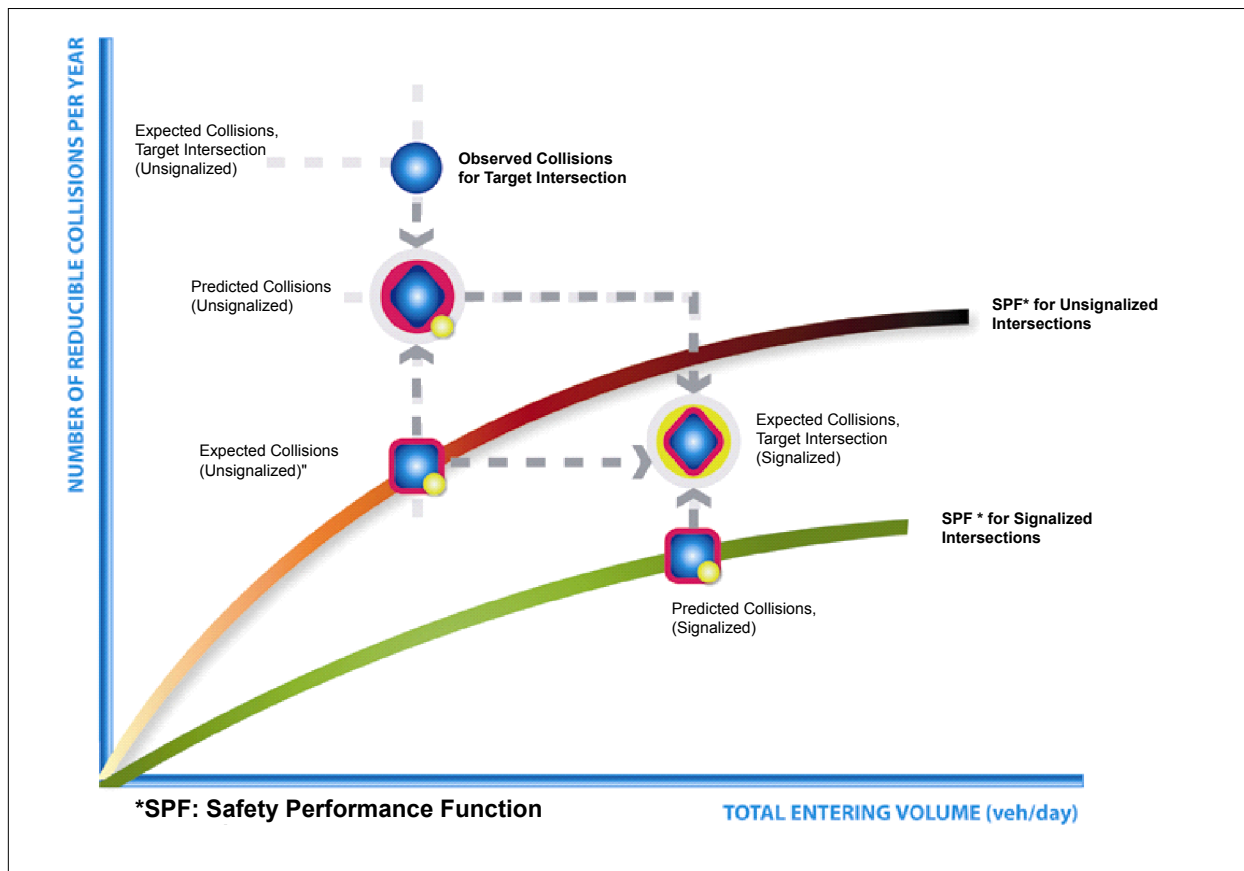


Figure 36 – Justification 5 (Alternative) – Use of Regression Relationship in the Empirical Bayes Approach for Reducible Collisions

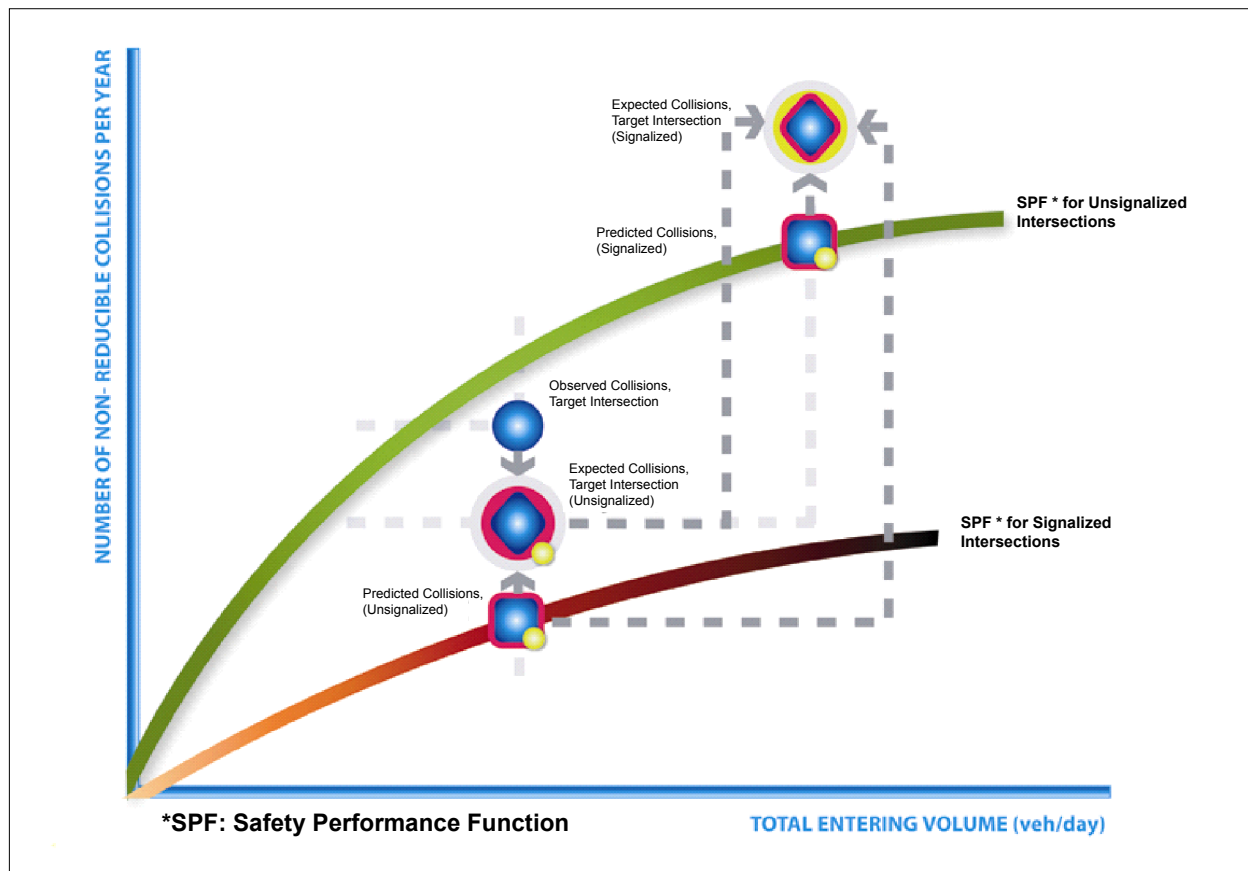


Figure 37 – Justification 5 (Alternative) – Use of Regression Relationship in the Empirical Bayes Approach for Non-Reducible Collisions

The net change between the expected collisions in the unsignalized conditions and the estimated collisions in the signalized condition represents the safety change estimated to occur. Generally, the expected outcome for reducible collisions is a decrease in their occurrence, as shown in Figure 36. This approach is repeated for the non-reducible collisions. The result is shown in Figure 37.

Detailed descriptions and explanations of the procedure described are available in a research paper³ published by the Transportation Research Board. Users of this approach are encouraged to review the paper as it provides detailed information

about the approach and the research carried out in development and application of the approach in Ontario.

Generally, the expected outcomes of Figures 37 and 38 are a decrease in the number of reducible collisions and an increase in the number of non-reducible collisions as shown graphically in Figure 39. It must, however, be stressed that the outcome will vary because the outcome depends directly on the recent collision history and characteristics of the target intersection (or location).

The net safety change at the target intersection cannot be calculated simply as the difference

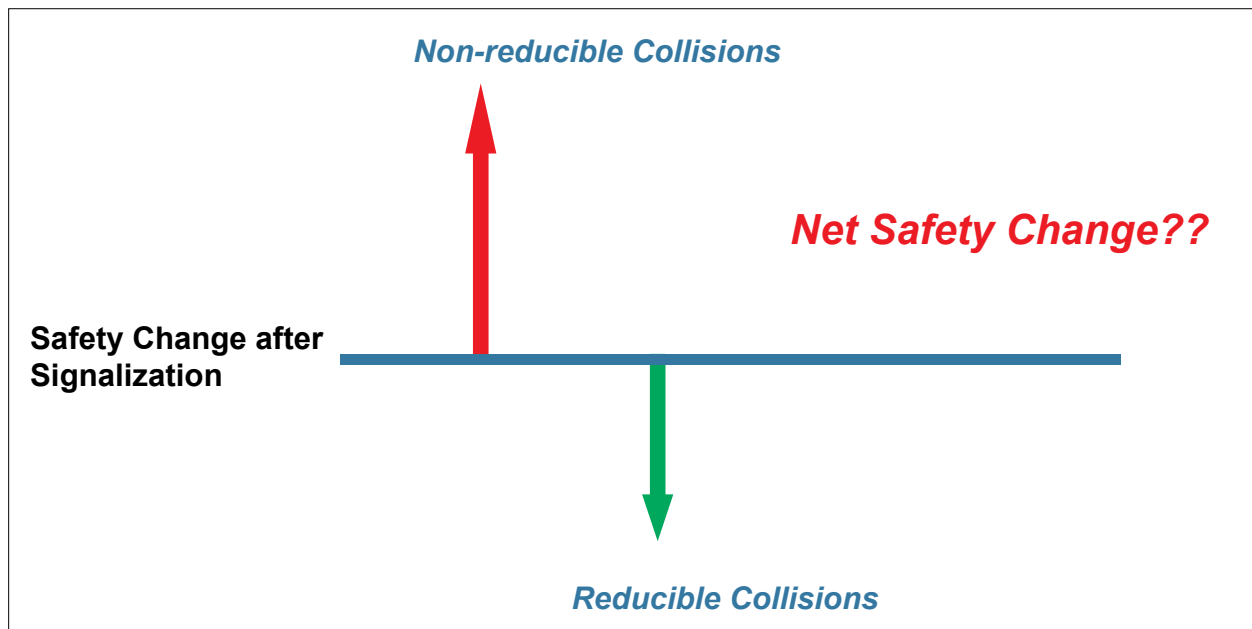


Figure 38 – Safety Changes for Reducible and Non-reducible Collisions for a Typical Case

between the two outcomes shown in Figure 38. It is important to consider the different consequences of reducible and non-reducible collision groups. Reducible collisions are generally more severe than non-reducible collisions, and this difference should be taken into account in the assessment of the net change.

Collision Severity Indexes were used to evaluate the relationship between intersection control types (signalized or unsignalized) and collision types (reducible and non-reducible). These safety indices were used to weight the number of collisions. Reducible collisions were given more weight than non-reducible collisions.

To create the indices, the database was broken down into four categories: reducible collisions at signalized intersections; non-reducible collisions at signalized intersections; reducible collisions at unsignalized intersections; and non-reducible collisions at unsignalized intersections.

The number of fatal, injury, and property damage only (PDO) collisions and total exposure (traffic volume) were assigned to each category. The relative risk method was used to estimate the probability of a collision by severity type and exposure for each collision category. Detailed descriptions of the procedure are provided in the Transportation Research Board paper³. The indices derived from the MTO data set are shown in Table 23.

The safety indices for each collision estimate were used to determine a weighted relationship between the reducible and non-reducible collisions. The weighted relationship was used to determine the net safety change (NSC). Figures 39 and 40 show the result.

In Figure 39, the positive value of NSC indicates that it is likely that installing a traffic signal will result in a safety deterioration at the target intersection (as also shown in Figure 37).

**Table 23 – Collision Severity Indices derived from MTO’s Database
(Based on collision data 2014-2019)**

Collision Types	Collision Severity Index
Reducible Collision at Signalized Intersections	0.25
Non-reducible Collision at Signalized Intersections	0.15
Reducible Collision at Stop Controlled Intersections	0.42
Non-reducible Collision at Stop Controlled Intersections	0.18

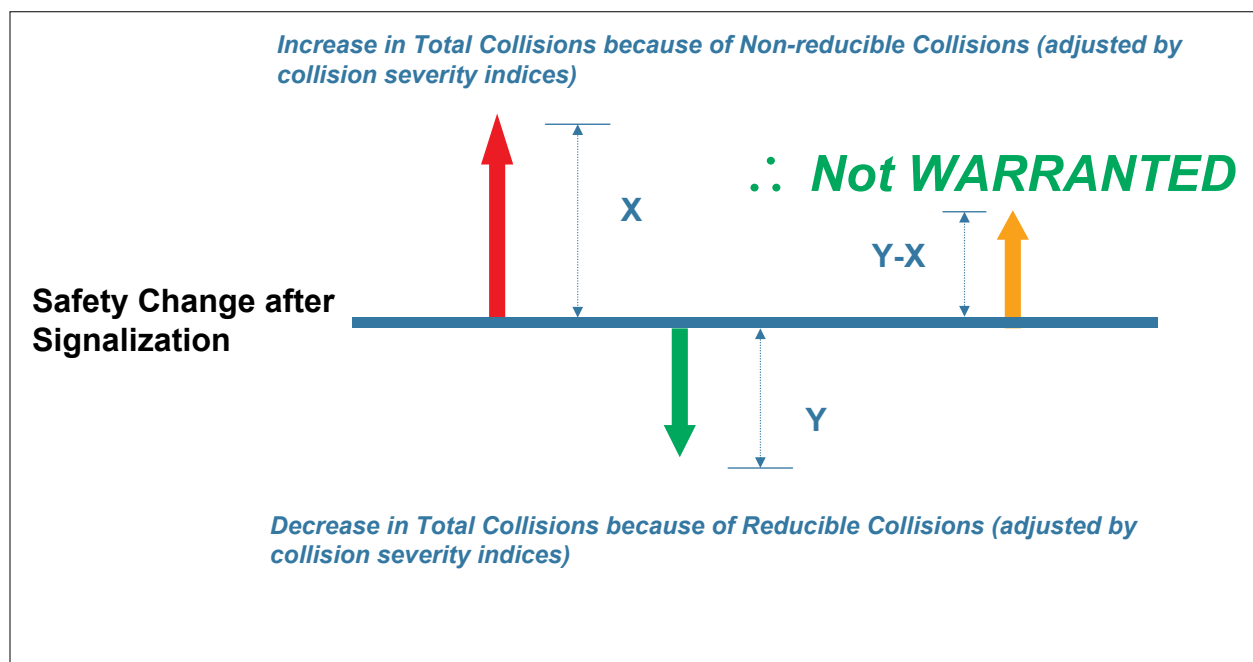


Figure 39 – Safety Deterioration Resulted from Converting an Unsignalized Intersection to a Signalized Intersection

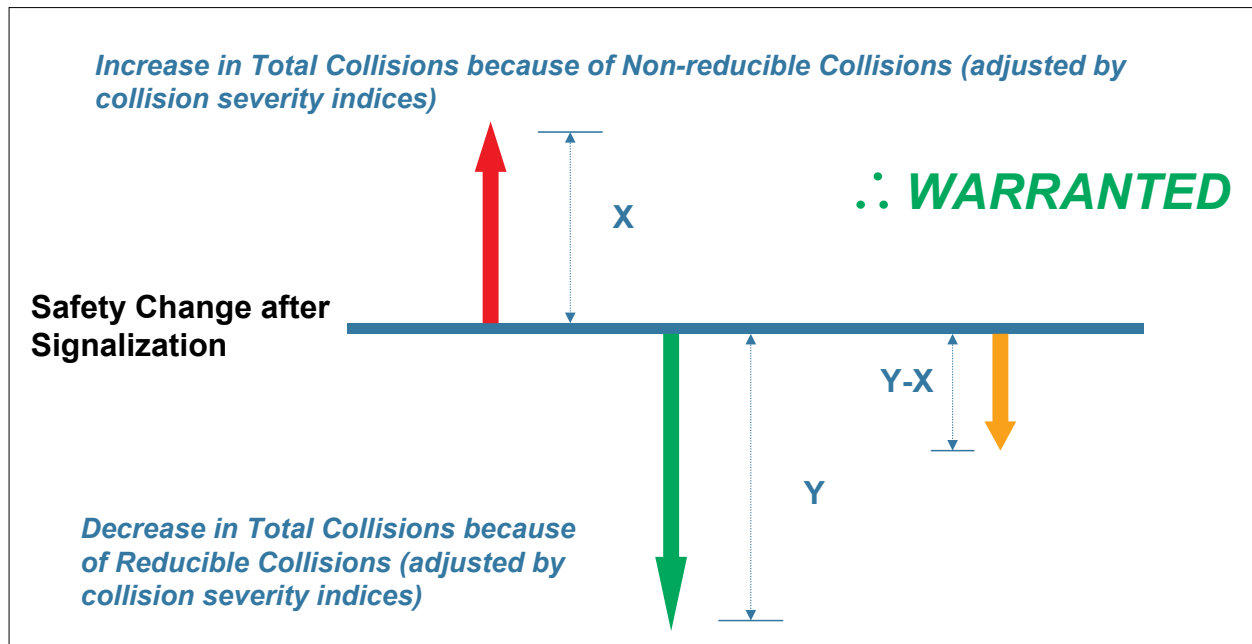


Figure 40 – Net Safety Benefit Resulted from Converting an Unsignalized Intersection to a Signalized Intersection

In Figure 40, the negative value of NSC indicates that it is likely that installing a traffic signal will result in a safety benefit at the target intersection (as also shown in Figure 37).

To facilitate use of the Empirical Bayes approach, a Microsoft® Excel™ spreadsheet was developed to calculate the Empirical Bayes results. The spreadsheet allows designers to conduct a detailed engineering study for estimating the safety impacts of signal installations, but only requires the target location's basic traffic data as input.

The spreadsheet consists of three sections:

1. An "Input Data" section in which the target intersection's basic information (collision impact types and AADTs for each year of analysis) is entered manually. Data requirements are in line with Justification 5, as specified in Table 11.

2. The "Analysis" section shows all the details of the analysis for both reducible and non-reducible collisions including the calculations. The calculations cannot be modified by the user.
3. The "Results" section shows the net safety change that can be achieved by installation of a traffic signal. This section cannot be modified by the designer.

Guidelines

The proposed approach uses the Empirical Bayes (EB) method and collision prediction models for estimating the safety effects of unsignalized intersections that are being considered for traffic signal installation. Collision prediction models or Safety Performance Functions (SPFs) for signalized and unsignalized intersections were

used to explore the relationship between the number of collisions and traffic volume. For each collision type, models for unsignalized intersections (representing the before periods) and for signalized intersections (representing the after periods) were used to assess the expected change in overall collision performance following signalization.

As with the existing collision justification approach, less restrictive measures may be implemented before installing a traffic signal. These measures include: the improvement of control or warning signs; installation of flashing beacons; the provision of safety or channelizing islands; the improvement of street lighting, geometry or visibility; the relocation of bus stops; and/or the prohibition of parking and/or turns.

When applying the approach described in this section, the analyst must also consider the quality of information that is available, particularly the information relating to collisions.

Where “Self-reporting” collision records (as opposed to at-the-scene reporting by police) are collected and used, the accuracy of the information should be closely scrutinized. Data from “Self-reporting” reports may reduce the quality of the determination into whether or not the collision would be preventable by the installation of signals.

The Empirical Bayes justification provides a significant departure from the existing approach. By considering both the safety benefits and drawbacks of installing signals, it is hoped that designers will be able to make more informed decisions. This alternative tool provides an assessment of the potential safety impact of installing a signal, but as with all justifications, the information must be considered in association with a full range of information and with proper engineering judgment.

4.15 Sample Calculations for Traffic Signal Justification

Calculations for the eight Justifications may be conducted using an Excel™ spreadsheet. The spreadsheet consists of five sections:

1. **“Input Data”** sheet in which all the information required for calculation of the justifications is entered manually.
2. **“Analysis”** sheet that shows all the detail of the analysis for all the justifications. This spreadsheet cannot be modified by the designer.
3. **“Results”** sheet that shows the results for each justification. The “Percent Compliance” in the spreadsheet indicates how close the intersection is to achieving the particular justification.
4. **“Justification 5A”** sheet that facilitates calculation of Justification 5A and provides the resulting expected Collision Experience change following the implementation of signals.
5. **“Justification 7”** sheet that facilitates the calculation of Justification 7 and provides the results of proposed future signal conditions.

This section provides a numerical example for illustration purposes.

The input data, analysis, and results sheets required for traffic signal justification are shown below.

The results of the calculation indicate that total collisions will increase after this intersection is signalized, based on Justification 5A analysis.

The results of the calculation indicate that none of the six justifications are satisfied. Although Justification 1 is almost met (99% compliance), the signal is not justified at this time.

Input Data Sheet

Input Data Sheet		Analysis Sheet	Results Sheet	Proposed Collision	GO TO Justification:
What are the intersecting roadways?	Richmond Street / Duncan Street				
What is the direction of the Main Road street?	North-South	When was the data collected?	2023-09-27		

Justification 1 - 4: Volume Warrants

- a.- Number of lanes on the Main Road?
- b.- Number of lanes on the Minor Road?
- c.- How many approaches?
- d.- What is the operating environment? Population >= 10,000 AND Speed < 70 km/hr
- e.- What is the eight hour vehicle volume at the intersection? (Please fill in table below)

Hour Ending	Main Northbound Approach			Minor Eastbound Approach			Main Southbound Approach			Minor Westbound Approach			Pedestrians Crossing Main Road
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT	
7:00	33	132	2	2	3	3	1	411	21	5	47	1	10
8:00	55	221	3	9	5	7	6	530	32	9	58	4	10
9:00	33	222	1	12	12	16	4	521	37	9	35	5	10
10:00	7	330	3	12	10	5	6	318	9	4	3	8	10
15:00	9	309	4	9	8	12	8	339	15	9	9	3	10
16:00	13	544	11	13	21	22	7	296	11	3	18	9	10
17:00	13	557	14	26	22	42	8	371	8	3	9	9	10
18:00	9	522	5	31	61	80	2	386	12	4	6	5	10
Total	172	2,837	43	114	142	187	42	3,172	145	46	185	44	80

Justification 5: Collision Experience

Preceding Months	Number of Collisions*
1-12	4
13-24	3
25-36	4

* Include only collisions that are susceptible to correction through the installation of traffic signal control

Input Data Sheet Continued

Justification 6: Pedestrian Volume

a.- Please fill in table below summarizing total pedestrians crossing major roadway at the intersection or in proximity to the intersection (zones). Please reference Section 4.8 of the Manual for further explanation and graphical representation.

	Zone 1 (if needed)		Zone 2 (if needed)		Zone 3 (if needed)		Zone 4 (if needed)		Total
	Assisted	Unassisted	Assisted	Unassisted	Assisted	Unassisted	Assisted	Unassisted	
Total 8 hour pedestrian volume	20	80	0	15	1	5	0	0	
Factored 8 hour pedestrian volume	120		15		7		0		
% Assigned to crossing rate	100%		50%		0%		0%		
Net 8 Hour Pedestrian Volume at Crossing									128
Net 8 Hour Vehicular Volume on Street Being Crossed									6,411

b.- Please fill in table below summarizing delay to pedestrians crossing major roadway at the intersection or in proximity to the intersection (zones). Please reference Section 4.8 of the Manual for further explanation and graphical representation.

	Zone 1 (if needed)		Zone 2 (if needed)		Zone 3 (if needed)		Zone 4 (if needed)		Total
	Assisted	Unassisted	Assisted	Unassisted	Assisted	Unassisted	Assisted	Unassisted	
Total 8 hour pedestrian volume	20	80	0	15	1	5	0	0	
Total 8 hour pedestrians delayed greater than 10 seconds	10	10	1	6	2	4	0	0	
Factored volume of total pedestrians	120		15		7		0		
Factored volume of delayed pedestrians	30		8		8		0		
% Assigned to Crossing Rate	100%		50%		0%		0%		
Net 8 Hour Volume of Total Pedestrians									128
Net 8 Hour Volume of Delayed Pedestrians									34

Analysis Sheet

Justification 1: Minimum Vehicle Volumes

Restricted Flow Urban Conditions

Justification	Guidance Approach Lanes				Percentage Warrant								Total Across	Section Percent			
	1 Lanes		2 or More Lanes		Hour Ending												
Flow Condition	FREE FLOW	RESTR. FLOW	FREE FLOW	RESTR. FLOW	7:00	8:00	9:00	10:00	15:00	16:00	17:00	18:00					
	☐	☒	☐	☐													
1A	480	720	600	900	661	939	907	715	734	968	1,082	1,123	791	99			
	COMPLIANCE %				92	100	100	99	100	100	100	100					
1B	120	170	120	170	61	92	89	42	50	86	111	187	412	52			
	COMPLIANCE %				36	54	52	25	29	51	65	100					
Restricted Flow					Both 1A and 1B 100% Fulfilled each of 8 hours								Yes ☐		No ☒		
Signal Justification 1:					Lesser of 1A or 1B at least 80% fulfilled each of 8 hours								Yes ☐		No ☒		

Justification 2: Delay to Cross Traffic

Restricted Flow Urban Conditions

Justification	Guidance Approach Lanes				Percentage Warrant								Total Across	Section Percent
	1 lanes		2 or More lanes		Hour Ending									
Flow Condition	FREE FLOW	RESTR. FLOW	FREE FLOW	RESTR. FLOW	7:00	8:00	9:00	10:00	15:00	16:00	17:00	18:00		
2A	☐	☒	☐	☐	7:00	8:00	9:00	10:00	15:00	16:00	17:00	18:00		
	480	720	600	900	600	847	818	673	684	882	971	936		
	COMPLIANCE %				83	100	100	93	95	100	100	100	772	96
2B	50	75	50	75	64	86	66	36	37	47	61	106		
	COMPLIANCE %				85	100	88	48	49	63	81	100	615	77
Restricted Flow					Both 2A and 2B 100% Fulfilled each of 8 hours								Yes ☐	No ☒
Signal Justification 2:					Lesser of 2A or 2B at least 80% fulfilled each of 8 hours								Yes ☐	No ☒

Justification 3: Combination

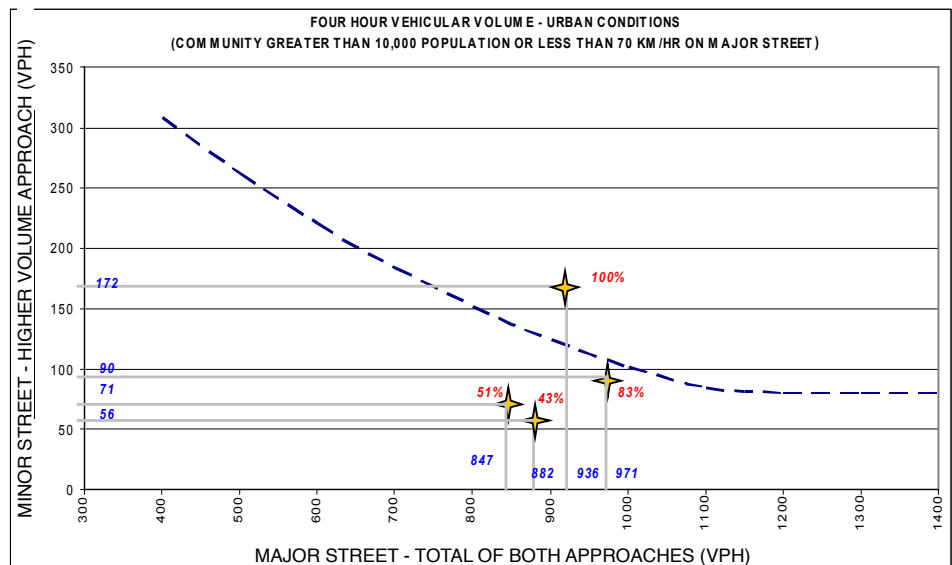
Combination Justification 1 and 2

Justification Satisfied 80% or More				Two Justifications Satisfied 80% or More			
Justification 1	Minimum Vehicular Volume	YES ☐	NO ☒	YES ☐		NO ☒	
Justification 2	Delay Cross Traffic	YES ☐	NO ☒				NOT JUSTIFIED

Analysis Sheet Continued

Justification 4: Four Hour Volume

Justification	Time Period	Total Volume of Both Approaches (Main)	Heaviest Minor Approach	Required Value	Average % Compliance	Overall % Compliance
		X	Y (actual)	Y (warrant threshold)		
Justification 4	8:00	847	71	138	51 %	70 %
	16:00	882	56	129	43 %	
	17:00	971	90	108	83 %	
	18:00	936	172	116	100 %	



Justification 5: Collision Experience

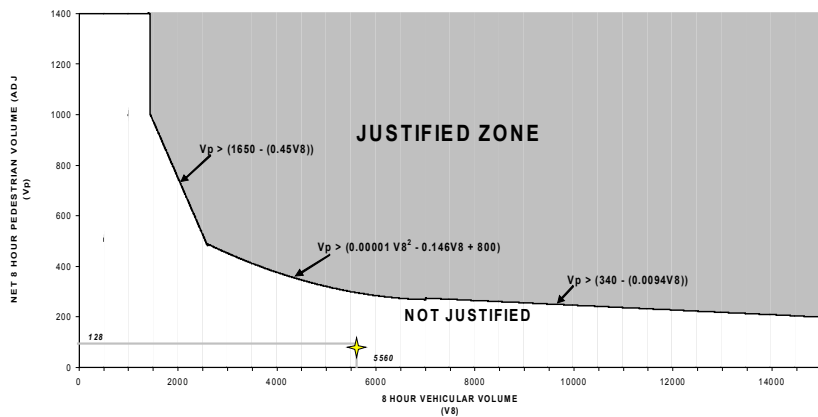
Justification	Preceding Months	% Fulfillment	Overall % Compliance
Justification 5	1-12	80 %	73 %
	13-24	60 %	
	25-36	80 %	

Analysis Sheet Continued

Justification 6: Pedestrian Volume

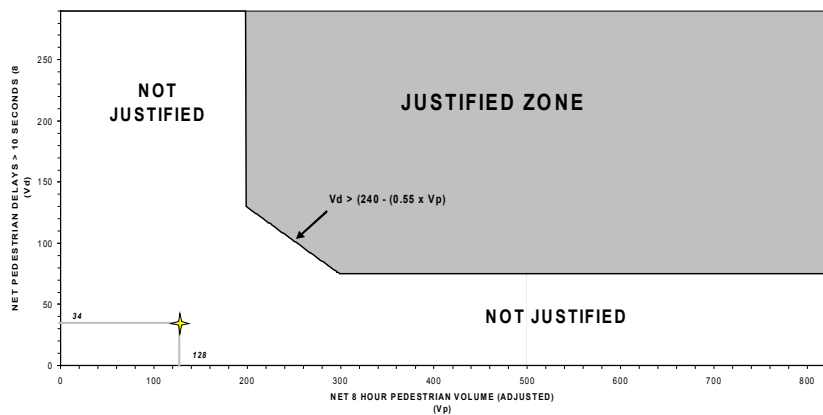
Pedestrian Volume Analysis

8 Hour Vehicular Volume V_8		Net 8 Hour Pedestrian Volume				
		< 200	200 - 275	276 - 475	476 - 1000	> 1000
Justification 6A	< 1440					
	1440 - 2600					
	2601 - 7000	Not Justified				
	> 7000					



Pedestrian Delay Analysis

Net Total 8 Hour Volume of Total Pedestrians		Net Total 8 Hour Volume of Delayed Pedestrians		
		< 75	75 - 130	> 130
Justification 6B	< 200	Not Justified		
	200 - 300			
	> 300			



Results Summary Sheet

Summary Results

Justification		Compliance		Signal Justified?	
				YES	NO
1. Minimum Vehicular Volume	A Total Volume	99	%	☐	☒
	B Crossing Volume	52	%	☐	☒
2. Delay to Cross Traffic	A Main Road	96	%	☐	☒
	B Crossing Road	77	%	☐	☒
3. Combination	A Justificaton 1	52	%	☐	☒
	B Justification 2	77	%	☐	☒
4. 4-Hr Volume		70	%	☐	☒

5. Collision Experience	73%	%	☐	☒
-------------------------	-----	---	--------------------------	-------------------------------------

6. Pedestrians	A Volume	Justification not met	☐	☒
	B Delay	Justification not met	☐	☒

Using Justification 5A

INPUT

a.- Number of Approaches b.- What year is the intersection being considered for traffic signals?

c.- What is the collision history and annual average daily traffic (combined direction) over the past few (3-6) years? (Please fill in table below)

Year	Traffic Volume		Impact Type/Year						
	Major AADT	Minor AADT	Approach- ing	Angle	Rear end	Sideswipe	Turning movement	SMV	Other
2015	21626	3893	0	4	5	1	4	0	0
2016	22059	3971	0	6	4	1	3	1	1
2017	22500	4050	0	7	5	2	2	1	0
2018	23300	4200	0	8	3	3	2	1	0
2019	23648	6528	0	9	0	4	1	0	0

d.- If known, please enter the expected traffic volume after signals are introduced. Otherwise, leave the cell blank.

Year	Main AADT	Minor AADT
2023		

ANALYSIS

Reducible Collisions

	2015	2016	2017	2018	2019		2023 (Signal)
Total Number of Crashes Per Year	8	9	9	10	10		---
Parameter k	1.99	1.99	1.99	1.99	1.99		2.05
Model Prediction	1.300	1.337	1.376	1.448	2.030		2.030
C _{i,y}	0.640	0.659	0.678	0.713	1.000		1.000
Comp. Ratio for Period	3.689						1.000

Non-reducible Collisions

	2015	2016	2017	2018	2019		2023 (Signal)
Total Number of Crashes Per Year	6	7	8	7	4		---
Parameter k	1.36	1.36	1.36	1.36	1.36		1.42
Model Prediction	0.511	0.523	0.536	0.560	0.685		0.685
C _{i,y}	0.746	0.764	0.783	0.817	1.000		1.000
Comp. Ratio for Period	4.109						1.000

	Reducible Collisions	Non-reducible Collisions
Total Number of Historical Crashes	46	32
Expected Annual Crashes without Signalization based on SPF	2.030	0.685
Expected Annual Crashes without Signalization	10.277	5.474
Variance of Expected Annual Crashes without Signalization	2.201	0.898
Expected Annual Crashes after Signalization based on SPF	0.347	0.726
Expected Annual Crashes after Signalization	1.758	5.798
Variance of Expected Annual Crashes after Signalization	1.508	23.674

	Reducible Collisions	Non-reducible Collisions
Weights for Unsignalized Intersections	0.42	0.18
Weights for Signalized Intersections	0.25	0.15

Justification	Compliance	Signal Justified?	
		YES	NO
5. Collision Experience	Net Safety Change -3.992	☒	☐
	Total Collisions will <i>Decrease</i> after this intersection is signalized		

Justification 5A

Justification 5A requires the following inputs in steps A through D.

After this point, all calculations are conducted by the worksheet and require no further input from the practitioner.

The results of the calculation indicate that total collisions will decrease after this intersection is signalized, based on Justification 5A analysis.

Justification 7

Justification 7 relies upon the geometry selections made in steps A through D of the Input Data sheet. These should be filled out according to the future condition to be analyzed as part of Justification 7.

Once complete, Steps A and B of Justification 7 should be filled out on the sheet, and guidance will be provided on the next appropriate step for input beside the Step B dropdown menu.

In this sample calculation, the practitioner is evaluating an intersection with a future additional road and only AM and PM peak hour estimates

available for the future conditions. Accordingly, they are directed to supply these estimates in Step C2.

Step C1 (if the practitioner has 8-hour estimates for the future condition) requires the designer to input the 8-hour future estimate count into the “Input Data” sheet Step E.

Step C2 and C3 require input directly on the “Justification 7” sheet.

After this point, the worksheet selects the appropriate Justification 1 & 2 thresholds and evaluates compliance rates.

If the highest compliance value of Justification 1A, 1B, 2A, or 2B is:

- Greater than 200%, the justification will indicate that it is a “Case 1 -Undoubtedly Warranted”;
- Between 100% and 200% the justification will indicate that it is a “Case 2 – Might be Warranted”; or
- Below 100% the justification will indicate “Case 3 – Warrant is Unlikely”.

In this case, Justification 2B yields a 194.3% compliance rate, which yields “Case 2 – Might be Warranted”.

Justification 7 - Projected Volumes

Intersection: Richmond Street / Duncan Street

Count Date: 2023-01-01

INPUT

PRIOR TO START - FILL OUT GEOMETRY INPUTS IN THE INPUT DATA SPREADSHEET - STEPS A to D

a.- Both Intersection Roads Exist?

b.- What kind of count estimate available?

Proceed to c2

c1.- 8-Hour Count Estimate

Hour Ending	Main Northbound Approach			Minor Eastbound Approach			Main Southbound Approach			Minor Westbound Approach			Pedestrians Crossing Main Road
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT	
7:00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8:00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9:00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10:00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15:00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16:00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17:00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18:00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	0	0	0	0	0	0	0	0	0	0	0	0	0

c2.- Peak Hour Estimate

Peak Hour	Main Northbound Approach			Minor Eastbound Approach			Main Southbound Approach			Minor Westbound Approach			Pedestrians Crossing Main Road
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT	
AM Peak Hour	132	528	8	8	12	12	4	1,644	84	20	188	4	40
PM Peak Hour	28	512	2	5	10	32	23	1,521	12	12	300	3	10
AHV	40	260	3	3	6	11	7	791	24	8	122	2	13
	Main Street AHV Sum			Minor Street AHV Sum									
	1,125			152									

c3.- AADT Estimate - can leave movements without data blank. If midblock reading, can assign demand to through movement.

AADT	Main Northbound Approach			Minor Eastbound Approach			Main Southbound Approach			Minor Westbound Approach			Pedestrians Crossing Main Road
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT	
AHV	0	0	0	0	0	0	0	0	0	0	0	0	0
AHV	Main Street AHV Sum			Minor Street AHV Sum									
	0			0									

d. Justification 7 Result

Justification	Description	Minimum Requirement 1 Lane Highways		Minimum Requirement 2 or more lanes		Compliance		Case?
		Free Flow	Restr. Flow	Free Flow	Restr. Flow	Numerical	%	
1. Minimum Vehicular Volume	A. Vehicle volume, all approaches (average hour)	-	720	-	-	1276	177.2	Case 2 - Might be Warranted
	B. Vehicle volume, along minor streets (average hour)	-	170	-	-	152	89.1	
2. Delay to cross Traffic	A. Vehicle volume, major street (average hour)	-	720	-	-	1125	156.2	
	B. Combined vehicle and pedestrian volume crossing	-	75	-	-	146	194.3	

5. Design Practice

5.1 General

Use of This Section

This section of the manual is intended to provide general design interpretation, recommended practice, and guidance for the design of traffic signals. The advice of experienced practitioners should be sought for intersections with challenging configurations. In addition, each road authority may have its own specific design requirements. Designers should refer to the road authority's design documents for design as this section of the manual provides only general design requirements.

The design practices and guidelines given in this section have the following objectives:

- Provide a standardized basis of design throughout Ontario.
- Provide instructional value to designers of provincial and municipal traffic control systems.
- Suggest standard practice details for use by municipalities that do not have standards.
- Comment on some non-standard practices, conditional on the specific characteristics of the intersection and traffic.
- Provide some pragmatic recommendations on the detail design of traffic control signal layouts.

5.2 Practical Requirements

The responsibility of the designer is to produce a safe, effective, and efficient signal design that is acceptable to the road authority, providing:

- Acceptable levels of service and delay.
- Adequate vertical clearance for traffic signal heads and overhead wiring to ensure that they are electrically safe and free from vehicle acceptable levels of service and delay to road users and meets recognized standards. The design should also be practical. To be practical, the design should:
 - Be free of utility interference.
 - Meet signal head visibility requirements.
 - Be compatible with the roadway, pavement structure, and roadside works.
- Use standardized equipment.
- Be readily expandable to additional phases or movements.

Limitations imposed by boulevard conditions, sidewalk locations, underground and overhead utilities, AODA design requirements, use of cross rides and bicycle signals, etc. mean that it may not be feasible to abide by all the practices and guidelines given. In such cases, some compromise may be necessary, and sound engineering judgment must be used to arrive at designs that follow the practices and guidelines as closely as possible.

5.3 Safety Considerations

The detailed design of traffic signals should include the following safety factors related to placement and electrical risks:

- Adequate pole offsets from the edge of the through lanes of pavement. The offsets are related to the posted speed. The recommended practice is a 3.0 m offset. A minimum offset of 1.5 m from the face of the curb is suggested in urban areas with a posted speed of 50 km/h or less. 0.6 m is the absolute minimum for use at posted speeds of 40 or 50 km/h. The 3.0 m offset must be maintained at all times for King's Highways.
- The use of pole types that meet the requirements of safety clear zones as given in the Ministry's Roadside Design Manual and in municipal policy manuals interference.
- Proper ratings for fusing or circuit breakers in feeders to electrical devices.
- Proper main disconnecting devices for the power to the controllers.
- Proper electrical grounding of the electrical power devices, poles and equipment.
- The use of Uninterruptible Power Supplies (UPS) can be considered to help condition power to help prevent brown outs as well as maintain full signal operation during short term power failures.

Other aspects of signal design, such as phasing, signal head visibility, and synchronization, affect safety with respect to collision risk. These factors are discussed in the Sections 5.5 to 5.14.

5.4 Future Considerations

The prediction of future traffic volumes is based on anticipated traffic demand. A traffic control signal Needs Report or Justification Report should be prepared. The report should address not only current traffic volume, intersection capacity, turning needs, cyclist and pedestrian needs, but also the five year horizon for such needs.

If it can be confirmed that the intersection will be upgraded within five years, the designer should inquire as to future plans for the intersection and should incorporate any features required in the future into the current design.

Overbuilding of the traffic signals may be a waste of money if future reconstruction is anticipated. Conversely, if firm plans for future intersection geometry are available, it is advisable, where practical, to locate items such as electrical chambers and ducts in the locations required for the future reconstruction, or, in some cases, to design aerial traffic signals as an interim measure.

Where traffic control signal studies indicate that traffic control signals are not required at the time of construction/reconstruction of the intersection, but warrant calculations are met to 200% or more within five years, the recommended practice is to install the traffic signals. If the projected warrants are met to between 100 and 200% within the next 5 years, consideration should be given to installing underground plant only. However, if the location is likely to allow directional boring to install underground ducts, it may be worth waiting to install any plant until any development has progressed such that the warrants are based on existing volumes.

5.5 Signal Visibility

General

Signal visibility is critical in ensuring that drivers receive timely information about the need to slow or stop. The recommended practices and guidelines given in this section should be followed as closely as possible.

Apart from geometric considerations, the visibility of signal indications is related to the following:

- Location of the signal heads and their visibility and conspicuity when illuminated;
- Lamp ratings, lumen output, and age;
- Reflectors and refractors;
- Dirt accumulation on the optical system;
- “Sun Phantoms” causing lenses to appear illuminated by reflections of the sun;
- Type of optical system (standard, optically programmed, LED, fibre optic); or
- Size of lenses for traffic signal control.

Accommodating the Needs of Persons with Colour Vision Deficiency

Distinguishing reds from greens is the most common problem for people with colour vision deficiency.

HTA Regulation 626, Sub-section 1.(2) describes the vertical order of the signal lenses within the signal head. Figure 2 in Section 2 of this manual shows the standardized signal heads to be used in Ontario and these are generally consistent with other North American jurisdictions. This standardization of lens positioning within the head increases the effectiveness of the traffic signal for all road users. The standard dictates that red is

always above amber which is always above green. The positional requirement also applies to arrow lenses in that amber arrows are always above green arrows.

This standardization of the number and arrangement of signal sections in traffic control signal heads enables road users who have colour vision deficiencies to identify the illuminated colour by its position relative to other signal sections.

Signal Head Locations

The effectiveness of any traffic control signal installation will largely depend on the ease with which the signal heads can be seen and recognized. Signal indications should be easily noticeable. Signal conspicuity is affected by the following factors:

- Geometry of the roadway and the combined effects of horizontal and vertical alignment on vision from the intersection approaches;
- Visual obstructions or distractions caused by buildings, signs, etc., adjacent to the right-of-way;
- Colours of the signal heads and backboards in contrast with the colour of their background; and
- Placement – standardized locations assist drivers to know where to look.

Signal heads for each approach to an intersection must be provided as follows:

- A minimum of two signal heads must face each approach of the intersection including public-use driveways and laneways within the intersection. At typical intersections, signal heads may be: mounted on poles with double arm brackets; suspended over the pavement on mast arms, gantry arms or structural frames; or mounted on span wire over the far side of the intersection approach.

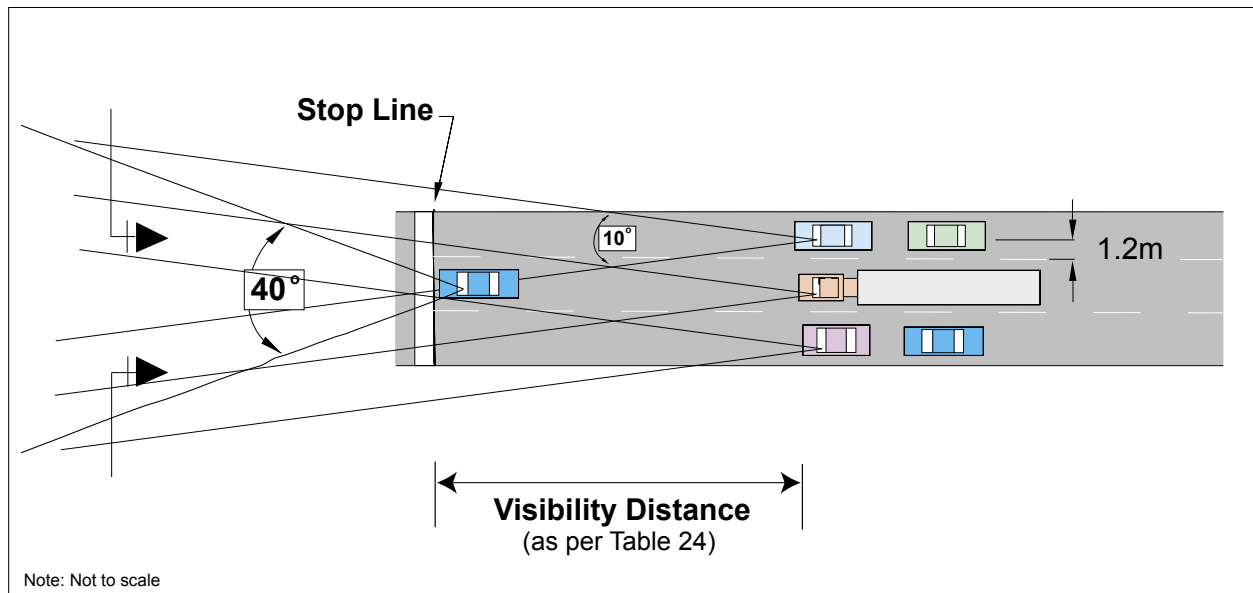


Figure 41 — Cones of Vision for Signal Visibility

- At the stop line, at least one, and preferably both signal heads, should be located within the driver's cone of vision extending 40° horizontally and 15° vertically from the eyes when facing straight ahead. The horizontal position of the signal head is based on the driver's cone of vision and the width of the intersecting streets. The driver has excellent lateral vision up to five degrees on each side of the centre line of the eye position (a cone of 10°), and adequate lateral vision up to 20° on each side. It is therefore desirable that at the stop line, for all approach lanes, at least one signal head be located within the 10° cone of vision with the other head located within the 40° cone of vision. While it is preferable to have the cone of vision at the stop line meet this requirement, the key location is the point where the driver is far enough away to have time to clearly see and recognize the signals before needing to decide whether to proceed or stop (see Table 24) should the signal change to amber. At this point, at least one signal head (and preferably both) must be within the 10° cone of vision for every lane, centred on the approach lanes, excluding any parking lane(s). Figure 41 shows this application of the horizontal cone of vision. Separate turn lanes should be included unless they have their own signal heads. Where a signal head is intended to control a specific lane or lanes of an approach, its position should be clearly in line with the path of that movement.
- Where horizontal or vertical geometry prohibits visibility of at least one signal head within the cone of vision from the visibility distances provided in Table 24, the use of an auxiliary signal head and/or possibly a continuous or activated flasher with TRAFFIC SIGNALS AHEAD (Wb-2) sign should be considered.
- Bicycle signal heads may have slightly different placement requirements and guidance on bicycle signal head placement and design requirements can be found in Section 6 of this manual and OTM Book 18 (Cycling Facilities).

Table 24 — Signal Visibility Distance

85th Percentile Speed (km/h)	Minimum Distance from which Signal Must be Clearly Visible (m)
40	65
50	85
60	110
70	135
80	165
90	200
100	230

Two sizes of lenses are used for traffic signal control displays: 200 mm and 300 mm nominal diameter.

Where the speed limit is 80 km/h or greater, a 300 mm lens must be used for the red ball indication. Consideration should be given to using a 300 mm lens for all vehicular indications. Bicycle signals and transit signal heads typically use 200 mm lenses.

The 300 mm lens is also recommended for all arrow indications and at least the red signal indication for the following situations:

- Signal heads located more than 30 m from the stop line.
- All intersection approaches where drivers may be confused when both traffic control and lane control signals are viewed simultaneously.
- Specific problem locations such as those conflicting or competing with background light.
- Where engineering studies indicate a requirement for increased visibility.

Lateral Signal Head Locations

The primary signal head must be located on the far-right-side of the intersection. At intersections with a signal head on a median island, the primary signal head should be located laterally at least to the edge of pavement (0.5 m over the receiving lane is preferred). Where median islands do not exist, the primary signal heads should be located at the 1/2 to 3/4 point of the receiving curb lane, and at a minimum of 1.2 m into the lane. The signal head should be aimed so that it is centred on the approach.

The secondary signal head must be located on the left of approaching through lanes. The head may be placed on the median or, where there is no median, on the far-left side of the intersection at least as far-left as the left edge of pavement. Where intersection approaches do not align, these reference points may be extended from features on the near side of the intersection.

The secondary head (far-left side) should be located at or as close to the edge of the roadway as practical. Under normal conditions, there should be a minimum of 5.0 m separation between the primary and secondary head, and a maximum (desirable) lateral distance of 15.0 m between the primary and secondary head (22 m absolute maximum distance). See Section 5.6 for details.

Median Mounted Signal Heads

Signal heads mounted on median poles may be face mounted or side mounted. Variations are necessary for signal heads with left-turn arrows and mast arms, multiple heads on a pole, or to accommodate geometric variations at the intersection.

Mounting Height

Signal head mounting heights are legally set under the *Highway Traffic Act* and are covered in Section 2, Legal Requirements.

Secondary heads mounted on the far-left and not over traffic lanes may be mounted at a minimum height of 2.75 m for roadways posted at less than 80 km/h. For long range visibility, secondary heads for roadways posted at 80 km/h or more are preferred to be at the same height as the primary head. Where a secondary head is installed in a median island and where the left-turn lane is often blocked by large vehicles, auxiliary heads may be used on the far-left of the intersection to allow better visibility. Auxiliary heads may be mounted at a minimum height of 2.75 m or as high as necessary to obtain good visibility. The desirable height in most cases is still 5.0 m. For King's Highways and other roads posted at 80 km/h and over, all signal heads should be mounted at a 5.0 m clearance height.

Bicycle Signal head mounting requirements can be found in Section 6 of this manual.

Obstruction by Other Signal Heads

If positioned incorrectly, the back of a signal head for the opposite direction may block part or all of the visibility of a signal for motorists approaching an intersection. Figure 42 shows how a secondary head could block visibility of the opposite primary head. The design must be checked to ensure that the near side heads are not blocking the front of the far side heads, and that at least one signal head is visible to the motorist at all times for at least the minimum distance given in Table 24. Since blockage is a function of signal head heights, intersection width, approach gradient, and lateral positioning, a field check of these requirements is strongly recommended following installation.

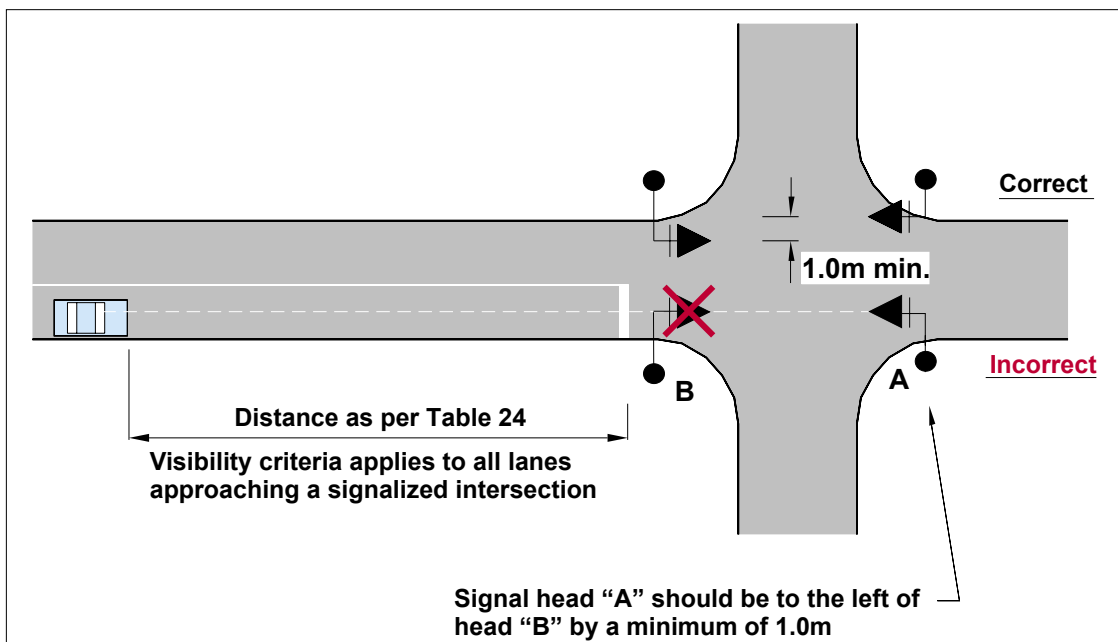


Figure 42 — Secondary Head Blocking Visibility

Obstructions Due to Large Vehicles

Improper spacing between the primary and secondary signal heads may cause loss or restriction of visibility for motorists travelling directly behind large vehicles, particularly where trucks are turning left. The desirable minimum spacing of 5.0 m between primary and secondary heads is intended to mitigate this problem to some extent. Where median islands exist, some municipalities install auxiliary secondary signal heads on the far-left side of the roadway at lower mounting heights to mitigate the visibility impairment caused by large vehicles.

Backboards

Backboards improve the conspicuity of the traffic signal head and the signal display. Backboards are recommended for all primary heads and are preferred on all vehicular heads. Table 25 sets out typical uses for signal heads and backboards.

Under most conditions, backboard faces must be traffic yellow in colour. Dark colours such as dark green or black may be used to enhance the visibility and conspicuity of the backboard faces where current policies dictate certain specific conditions, or where the dark colour improves visibility and conspicuity.

Table 25 — Typical Use of Signal Heads and Backboards

Type of Roadway	Signal Heads and Backboards				
	Posted Speed (km/h)	Signal Head	Type of Head	Backboard	Recommended Mounting Height (m)
Major Roadway (four or more lanes)	80 and over	Primary	Highway	Yes	5
		Secondary	Highway	Yes	5
	60 to 80	Primary	Highway	Yes	5
		Secondary	Highway	Yes	5
	Less than 60	Primary	Highway	Yes	5
		Secondary	Highway Standard	Yes Optional	2.75*
Major Roadway (less than four lanes)	80 and over	Primary	Highway	Yes	5
		Secondary	Highway	Yes	5
	60 to 80	Primary	Highway	Yes	5
		Secondary	Highway or Standard	Yes	5
	Less than 60	Primary	Highway	Yes	5
		Secondary	Highway Standard	Yes Optional	2.75*

*Note: Secondary heads mounted on the far-left and not over traffic lanes may be mounted at a minimum height of 2.75m.

Dark coloured backboards or 200 mm lens signal heads without backboards may be used to help distinguish between regular vehicular signal heads and signal heads used specifically for separate transit vehicle or bicycle movements.

On the rear surfaces, standard traffic yellow is used in most situations, but municipalities may prefer to apply black or grey as long as the corresponding signal head housings are of the same colour and as long as the application is consistent for any particular intersection.

Nighttime visibility of traffic signal heads can be improved by adding a 75mm strip of yellow prismatic retro-reflective sheeting, conforming to

ASTM D4956 Type IX, around the outside edge of the backboard. This strip of retro-reflective tape may also assist drivers with colour vision deficiency to distinguish the signal head lamps from other lights at the signalized intersection.

Auxiliary Signal Heads and Beacons

General

Signal heads may be obstructed by bridges (where close to an intersection), horizontal roadway curvature, vertical roadway curvature, other signal heads, signs, buildings infringing on a zone of restricted right-of-way, large vehicles, or other objects.

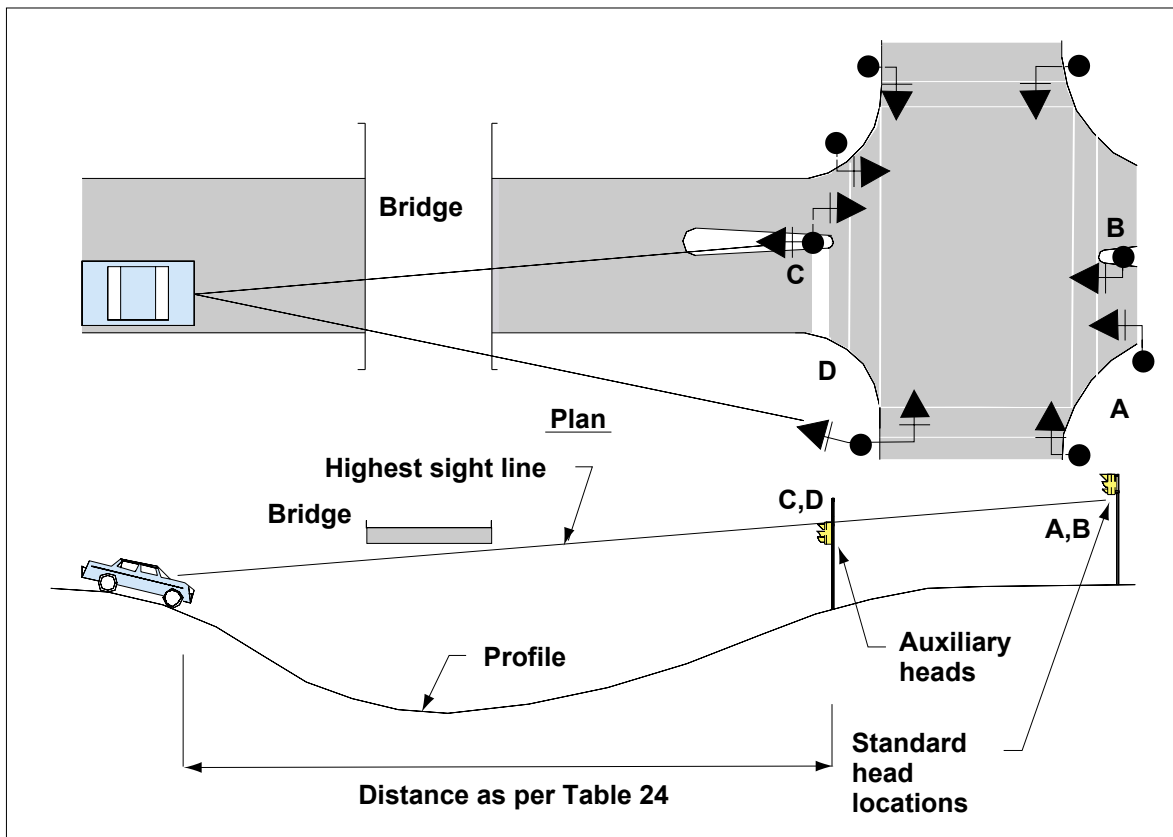


Figure 43 – Auxiliary Heads at Underpass

Auxiliary signal heads are installed to augment the primary signal head, and therefore auxiliary signal heads must display the same indications and have the same timing as the primary and/or secondary heads.

Auxiliary heads, or active or continuous “Signals Ahead” flasher signs, should be used whenever the traffic signal visibility distance given in Table 24 cannot be obtained. The location of the auxiliary heads themselves must comply with the visibility distance given Table 24 or the “Signals Ahead” flasher signs must be used.

The designer must check each design carefully, recognize sight line limitations, eliminate obstructions, and optimize the design to provide drivers with the best possible visibility.

Auxiliary Heads at Bridge Obstructions

Where normal signal head visibility may be obstructed by a bridge underpass, low mounted auxiliary heads may be required. An example is shown in Figure 43.

Auxiliary Heads at Geometric Curve Obstructions

Special considerations may be required to achieve signal visibility on horizontal curves. Auxiliary heads may be required on the near side of the intersection, either on the outside of the curve or on the rear of the median pole, as shown in Figure 44.

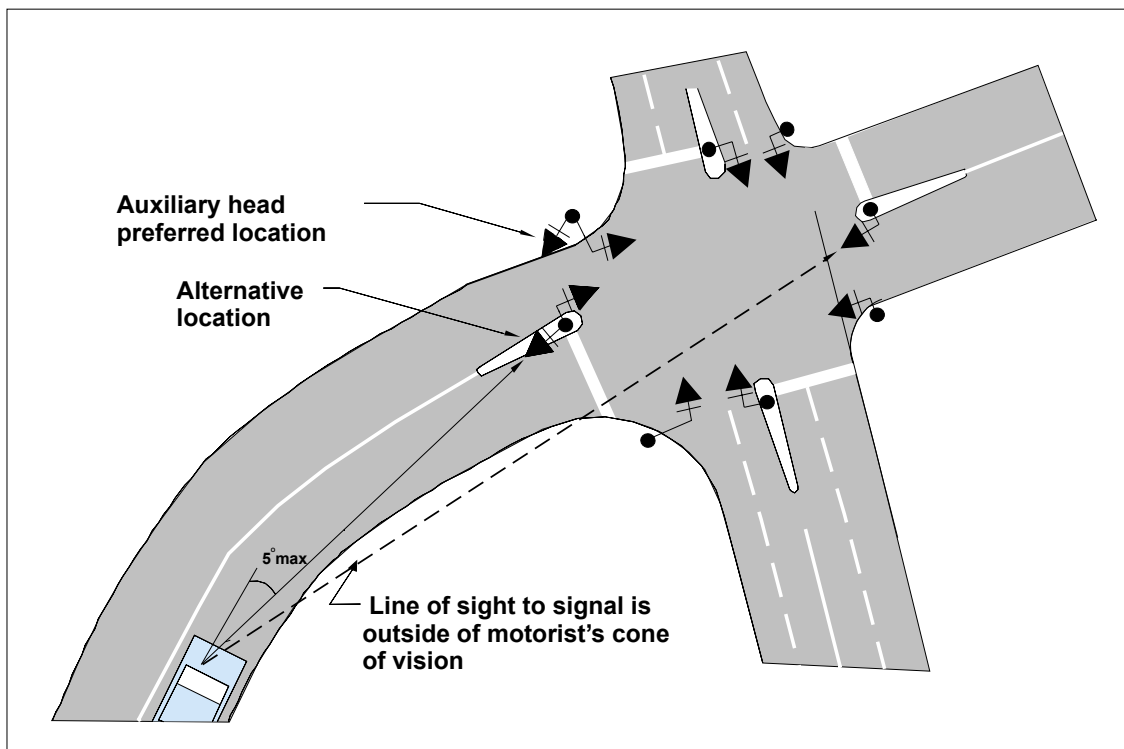


Figure 44 – Auxiliary Heads at Intersection on Curve

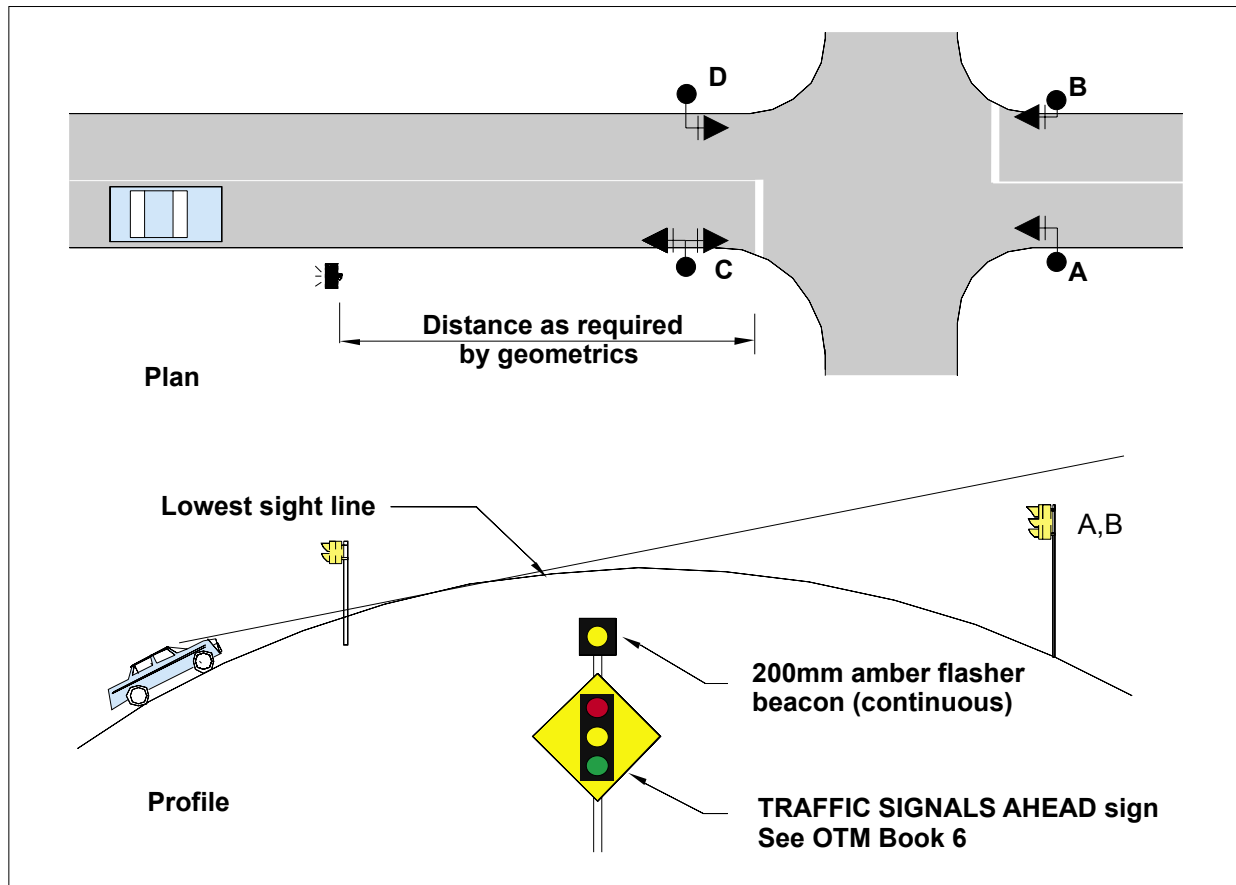


Figure 45 – Use of Continuous Flasher

Two auxiliary heads on the outside of a curve should be avoided because drivers may align their vehicles toward the gap between the heads (mistaking the heads for the primary and secondary traffic signal heads, especially under limited visibility conditions).

Auxiliary signal heads should also be used to improve the visibility along horizontal curves where sight distance may be hampered by buildings, rock cuts, or large signs along the inside of the curve. Similarly, abrupt vertical curves that do not allow a view of the intersection pavement at the stopping sight distance may require auxiliary heads either

at the intersection or at a much higher mounting height.

At locations with sight line limitations, a continuous single flashing beacon with the oversized TRAFFIC SIGNALS AHEAD warning sign (Wb-102) may be required, as shown in Figure 45.

The sign can be located upstream from the signalized intersection beyond the visibility distance shown in Table 24 and in general conformance with the signage guidelines in OTM Book 6 (Warning Signs).

An active double flashing beacon (“Bouncing Ball” effect) with the oversized PREPARE TO STOP AT TRAFFIC SIGNALS HEAD sign (Wb-102A) complete with the word tab PREPARE TO STOP WHEN FLASHING (Wb-102At) should be used in the following circumstances:

- Visibility is poor and the location of an auxiliary head does not suit the installation.
- There are sight restrictions at the bottom of a hill or due to a steep downgrade.

For the following situation, the active double beacon flasher may be required:

- If the signal is the first signal encountered by drivers after travelling a considerable distance on a divided highway, the signal may not be expected.

An example of a situation where an active double flashing beacon may be required is shown in Figure 46. Note that the flashing beacon and sign should operate as described in Section 3.

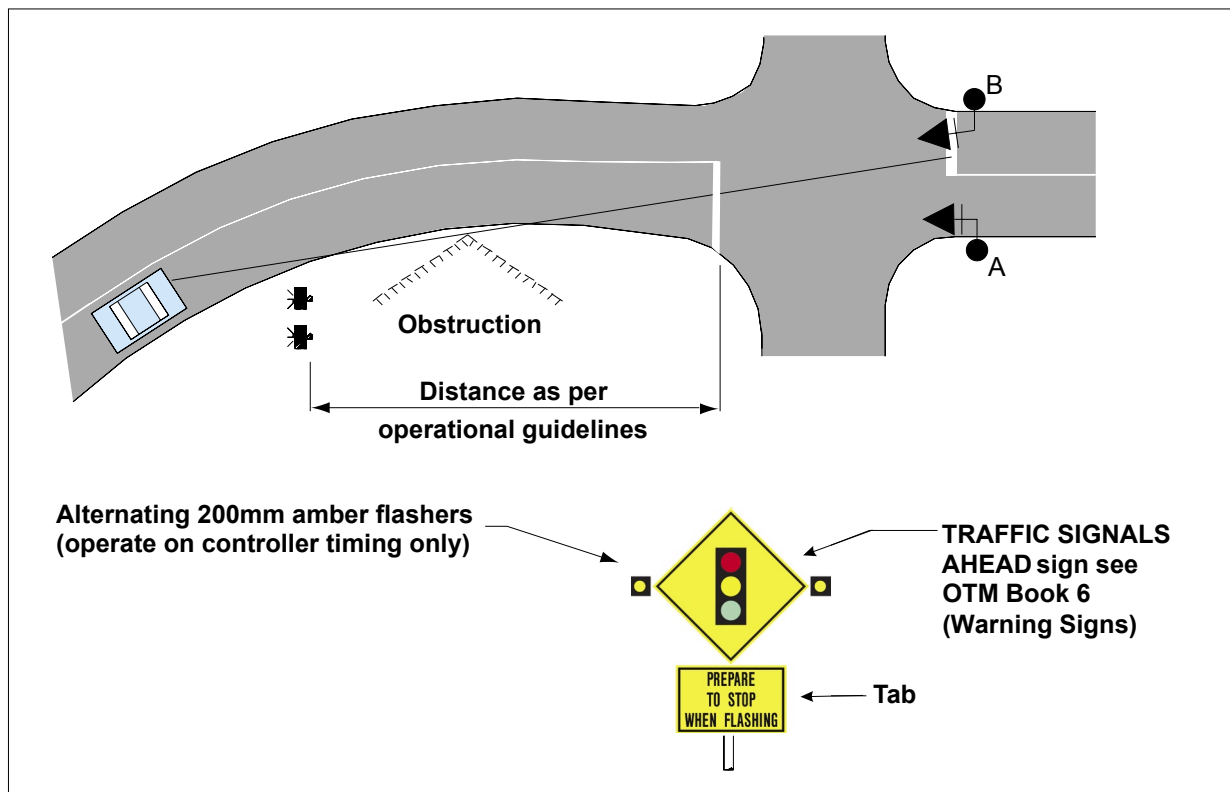


Figure 46 – Use of Active Flasher and Sign

Optically Programmable Signal Heads

Optically programmable signal heads can be used for precise lane control. The heads project an indication that is visible only within the boundaries of a specific area.

Closely spaced, offset, or skewed intersections may require optically programmable signal heads to prevent drivers from mistakenly observing the wrong traffic signal. The heads may be used at

skewed intersections with non-standard turning lanes to avoid confusion for motorists in adjacent lanes. Similarly, signal heads between two separate parallel roadways may require focused lenses to prevent confusion on the non-controlled roadway, as shown in Figure 47.

It is recommended practice to install optically programmed heads where signals need to be visible only within the boundaries of a specific area to reduce motorist confusion.

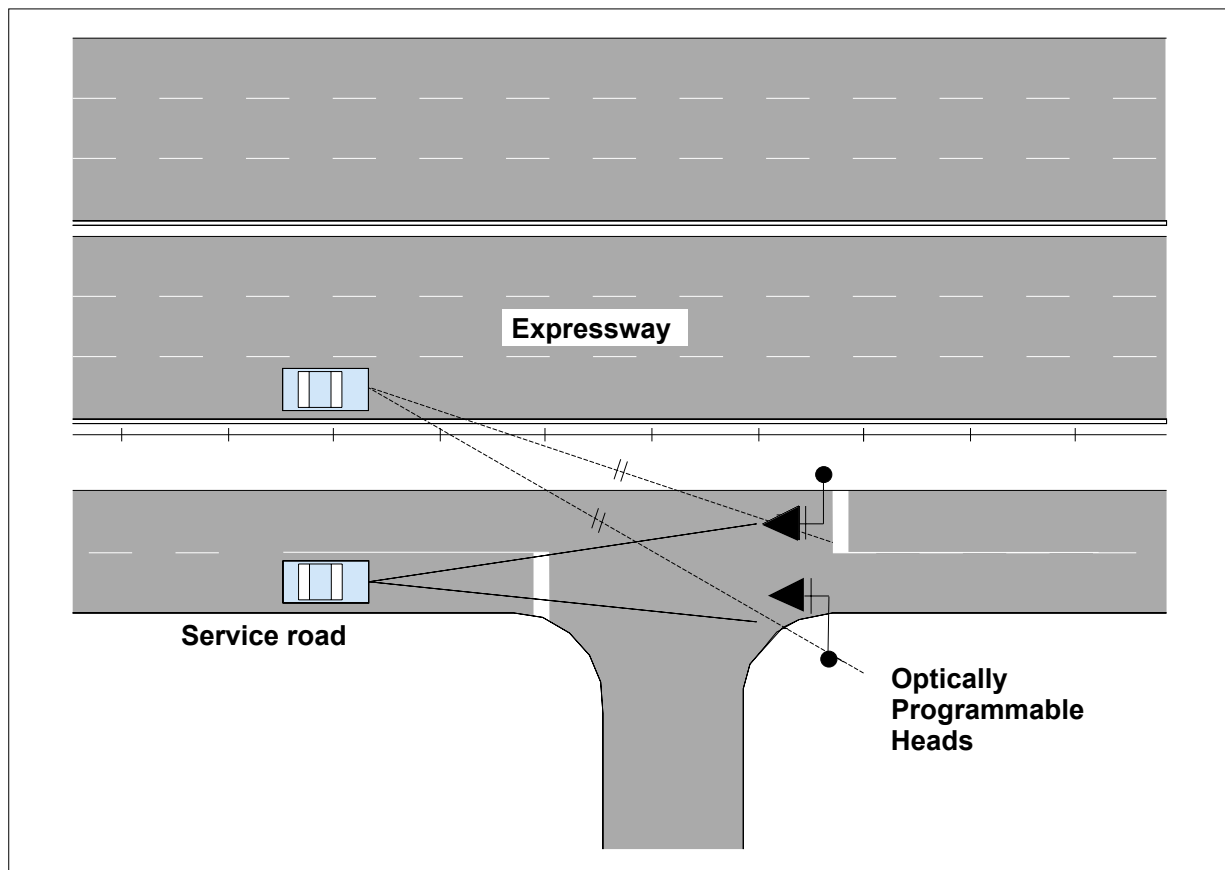


Figure 47 – Optically Programmable Heads, Example on Parallel Roads

5.6 Pole and Signal Head Locations

Primary Signal Head Locations

General

In addition to the guidelines for lateral placement provided in Section 5.5, the primary heads should be located at a minimum longitudinal distance from the approach stop line of 12 m (with 15 m preferred) to a maximum of 55 m (consider 300 mm lenses if close to 55 m). This guideline is shown in Figure 48.

The 15 m distance corresponds to the cut-off for visibility through an automobile's windshield to a signal head mounted at a height of 5.0 m.

Primary heads should be located using the following guidelines:

- The recommended maximum longitudinal distance is 10 m either way from the median pole location measured along the centreline of the roadway, as shown in Figure 48.
- If the above guidelines and standard mast arm lengths allow, it is recommended that the poles be as close to the intersection as practical to allow other attachments such as secondary head mast arms and pedestrian equipment. If practical, the poles should be within 3.0 m of the centre of the crosswalks. The choice of location should take into account aesthetic requirements, utility clearances, and mast arm length restrictions. Iterative trials of the design are normally required.
- The standard 3.0 m offset from the through edge of pavement should be used. This offset is for safety purposes and must be maintained at all times for King's Highways. Where the poles are located within the turning flare area of the pavement, the offset may be reduced to 1.5 m from the back of the curbs to allow a standard 1.5 m sidewalk width between the curbs and the poles. In curbed areas with operating speeds of 40 or 50 km/h, the absolute minimum is 0.6 m. Refer to Subsection 5.3 for safety guidelines.

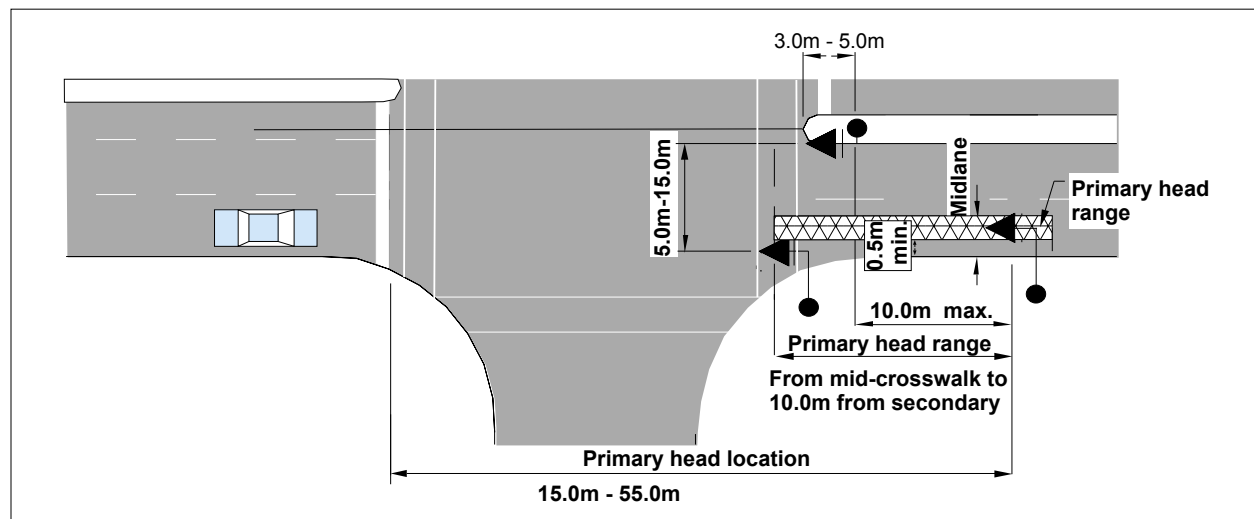


Figure 48 – Primary and Secondary Head Locations

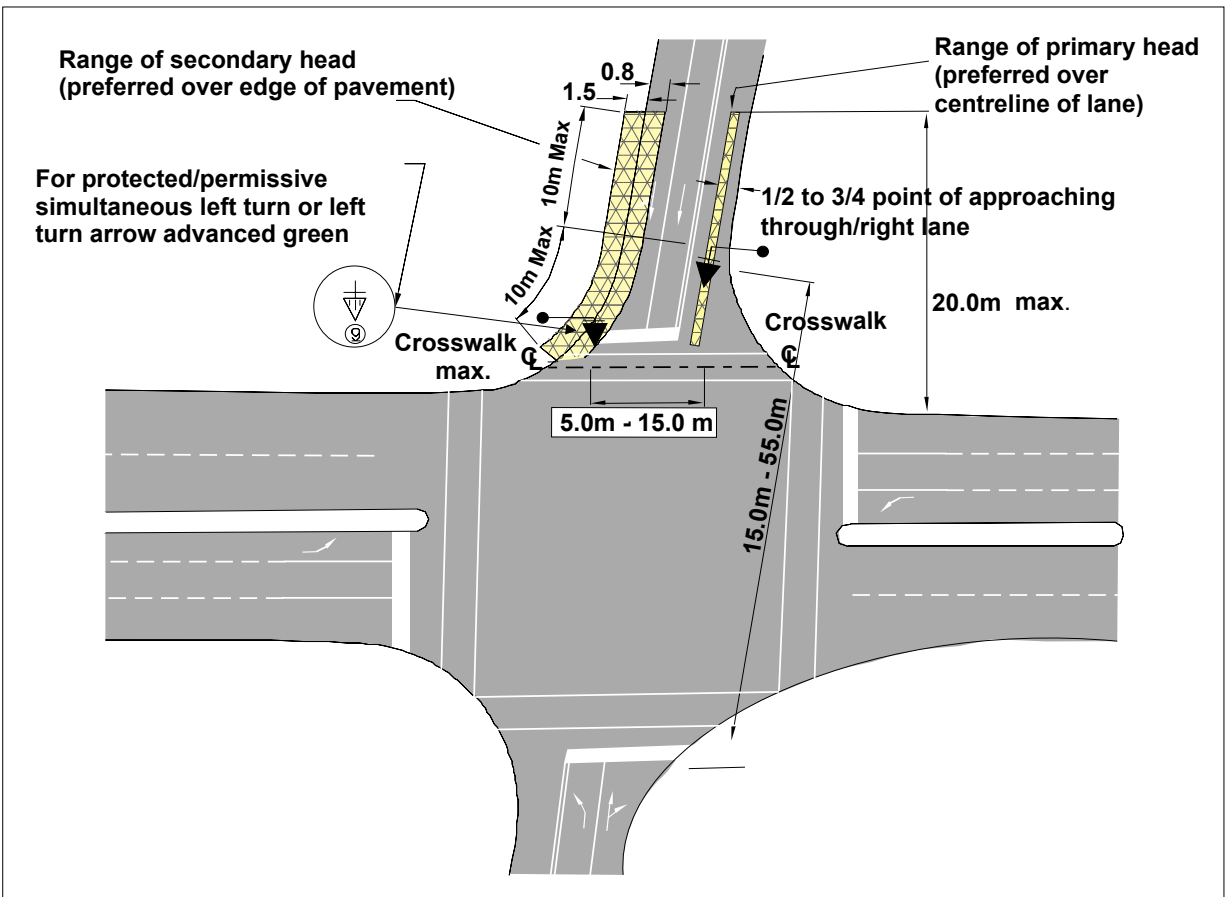


Figure 49 – Primary and Secondary Heads Without Islands

With Median Island

For a straight two-lane approach with a separate left-turn lane and a median island, it is normally desirable to mount the primary head at the minimum 0.5 m overhang of the through edge of the approach curb lane in order to get as much lateral distance as practical between the primary and secondary heads. The primary head should also satisfy the cone of vision requirements shown in Figure 41 for each approach lane.

The primary and secondary heads should be laterally separated by a minimum of 5.0 m, a desirable spacing of 15.0 m, or an absolute maximum of 22 m. The smaller spacing may result

in the visibility of one of the heads being blocked by large vehicles. The larger spacing normally allows for at least one of the heads to remain within the 40° cone of vision at all times.

Without Median Island

Where median islands are not used, it is desirable to position the primary signal head between the 1/2 point and 3/4 point of the projected through edge of the approach curb lane with the head aimed on the centre of the approach (as shown in Figure 49). The preferred position of the secondary head is over the edge of pavement on the left side. During the design, the locations of primary poles and

heads are normally decided before the locations of the secondary poles.

Secondary Signal Head and Pole Locations

General

Secondary heads, other than those on median islands, should be located using the following guidelines:

- A minimum lateral distance of 5.0 m and a maximum (desirable) lateral distance of 15.0 m is required between the primary and secondary heads under normal conditions, and 22 m is the absolute maximum distance. Since the secondary heads are normally located in the flare and use the same rules as for primary heads, trial mast arm lengths are usually required during design.
- A maximum longitudinal distance of 10 m either way from the primary pole location, as measured along the centreline of the roadway, should be maintained where possible.
- Secondary heads with left turn arrows should be located as near to the approach as practical.

With Median Island

Where median islands are present (with two or more receiving lanes), primary and secondary signal heads should not be too close together laterally. Heads should not be too far apart longitudinally to avoid one head appearing to be much higher than the other from the approaching motorist's perspective.

Without Median Island

Normally, opposing secondary heads are laterally outside of the primary heads (further from roadway centreline) by a minimum of 1.0 m, as shown in Figure 42. The preferred location for the secondary

heads in this case is between 0.5 m and 0.8 m from the edge of pavement towards centreline. The secondary heads can be placed directly over the edge of pavement up to 1.5 m from the edge of pavement if necessary to meet placement criteria provided that range distances and visibility criteria are met. Figure 49 shows the range of signal head placement options.

5.7 Pedestrian Signal Heads

Pedestrian Indications

Pedestrian indications must consist of two symbols, the “Lunar White” Walking Pedestrian (outline or solid) and the “Translucent Orange” Hand Outline.

The symbols may be contained in a single minimum 300 x 300 mm (lens) housing or in separate housings. If a single lens is used, the symbols may be superimposed over each other, or they may be offset with the hand outline on the left. If separate housings are used, the Hand Outline section must be mounted directly above or to the left of the Walking Pedestrian section.

When illuminated, the pedestrian signals must be recognizable from a distance of 30 m under normal conditions of visibility. The flashing Hand Outline should be used in all traffic control signals as a clearance interval and warning to pedestrians that the walking time is terminating.

Guidelines for Pedestrian Signal Head Installation

In most cases, it is recommended practice to install pedestrian traffic control signals. Pedestrian traffic control signals are mandatory where it is necessary to control the sequence or length of pedestrian phases independently from vehicular phases, or where it is necessary to eliminate pedestrian confusion at approaches containing traffic control signal heads with arrows. Where one or more of the pedestrian crosswalks at an intersection justify pedestrian signals, it is usually desirable for uniformity and good observance to place pedestrian signals on all crosswalks. A pedestrian should be able to walk to any corner of an intersection. An exception occurs at a ramp terminal where it is not usual practice to have pedestrian crossings on the side of the intersection that receives left-turning traffic from the side

road. It may also be desirable to ban low volume pedestrian movements at specific locations due to large left-turn volumes. Such restrictions must be supported by proper signing as shown elsewhere in the OTM, as well as by-laws or regulations where applicable.

Pedestrian signal heads should be installed in conjunction with vehicular traffic control signals where pedestrians are present and any of the following conditions:

- When a traffic signal is installed under the pedestrian justification.
- When pedestrians and vehicles are moving during the same phase and pedestrian clearance intervals are needed to minimize vehicle-pedestrian conflicts.
- When an exclusive phase is provided or made available for pedestrian movement in one or more directions with all vehicles being stopped.
- When heavy vehicular turning movements require a separate pedestrian phase for the protection and convenience of the pedestrian.
- When pedestrian movement on one side of an intersection is permitted while traffic from only one approach is moving.
- When an intersection is so large and complicated or a road so wide that vehicular signals would not adequately serve pedestrians.
- When the minimum green intervals for vehicles at intersections with traffic-actuated controls are less than the minimum crossing time for pedestrians and pedestrian actuation is necessary (normally by pushbutton).
- When a complex phasing operation would tend to confuse pedestrians guided only by traffic signal indications.

- When traffic signal heads using arrows are used.
- When pedestrians cross only part of the road, to or from an island, during a particular phase.
- When the traffic signal heads fall outside of the normal vision of pedestrians, for example, at “T” intersections, on one-way streets, or at large intersections.
- When the intersection has a collision history involving pedestrians and vehicles.
- When a school, seniors’ facility or transit facility is near the intersection.

Mounting Height and Location

Pedestrian heads must be mounted at a minimum of 2.75 m as measured from finished grade at the edge of pavement to the bottom of the signal housing. This dimension should be used unless unusual circumstances require a greater height, but pedestrian heads must not be mounted at the height of vehicle heads.

If practical, pedestrian heads should be mounted directly behind the sidewalk facing along the crosswalk. Where necessary, the heads may be mounted within 3.0 m of the edge of the sidewalk in the crosswalk-facing direction, and within 1.5 m of the edge of the crosswalk laterally. A check should be made to ensure that the pedestrian heads will not be hidden from pedestrians on the other side of the roadway by vehicles stopped at the stop line.

Accessible Pedestrian Signals

Accessible Pedestrian Signals (APS) are designed to assist pedestrians with vision and/or hearing impairments by providing information that they can interpret to understand when they may cross. APS devices communicate information about pedestrian

timing in a non-visual format. Examples include audible tones, verbal messages, and/or vibrating surfaces coinciding with the beginning of the WALK interval.

Like visible pedestrian signals, APS devices that use audible speakers and/or vibrating hardware provide cues at both ends of a crossing when activated. APS devices that have speakers mounted in, on, or near pedestrian heads emit a “cuckoo” sound for the north-south crossing and the “Canadian APS melody” sound for the east-west crossing.

Where pedestrian signals are being installed or existing pedestrian signals are being replaced or rehabilitated at a traffic signal installation, Mid-Block Pedestrian Signals (MPS) or Intersection Pedestrian Signals (IPS) location, the road authority must ensure accessible pedestrian signals, with the appropriate civil requirements, are installed.

The Accessibility for Ontarians with Disabilities Act, 2005, S.O. 2005, c. 11 and associated regulations identifies the need for Accessible Pedestrian Signals (Sub-Section 80.28) and Curb Ramps (Sub-Section 80.26) or Depressed Curbs (Sub-Section 80.27). Minimum design standards are also included in the above noted regulations.

Additional information on the design and operation of APS is provided in the publication “Guidelines for Understanding, Use and Implementation of Accessible Pedestrian Signals (2008)”¹⁰, available from the Transportation Association of Canada (<http://www.tac-atc.ca>).

A common design for an APS system is fully integrated into the pedestrian pushbutton assembly. Some systems provide vibratory information only, while others augment vibrotactile hardware with a quiet, slowly repeating, tick, click, or tone to identify the location of the pushbutton during the DON’T WALK and pedestrian clearance

intervals, and a faster tick, click, or tone to identify the WALK interval.

Accessible pedestrian signals must be used in combination with pedestrian signal timing. The information provided by an accessible pedestrian signal must clearly indicate which pedestrian crossing is served by each device.

Accessible pedestrian signals must be used in combination with pedestrian signal timing. The information provided by an accessible pedestrian signal must clearly indicate which pedestrian crossing is served by each device.

Pushbutton Location

APS must have a locator tone that is distinct from a walk indicator tone, and they must be installed within 1.5 meters of the edge of the curb and at a level of no more than 1.1 meters above the ground. The APS pushbuttons must have tactile arrows that align with the direction of the crossing.

Where two APS assemblies are installed on the same corner, they must be a minimum of 3 meters apart. However, it is recognized that this separation is not always possible and so two APS pushbuttons can be installed on the same pole. However, when this is done, the units must be able to provide a verbal announcement that clearly states which crossing is active.

Access to the pushbutton shall be unobstructed. The pushbutton pole location shall provide approximately 1.5 meters of clearance for wheelchairs, powered chairs or maintenance vehicles such as sidewalk snowplows. The poles shall not be located on the pedestrian ramp.

When retrofitting existing traffic signals that will utilize pedestrian signal heads, IPS or MPS to include APS curb cuts or depressed curbs must be included in the design. During construction project sequencing it is not always possible to ensure the

depressed curbs or curb cuts with tactile pads are installed at exactly the same time as the above ground APS equipment.

A jurisdiction should ensure that the installation of all items to fully meet AODA build requirements are planned and funded so they can be installed at the same time.

Finding appropriate pole locations that will meet the AODA requirements for curb cuts, pedestrian head and audible pedestrian signal locations while also ensuring persons using mobility devices can negotiate the sidewalk area can sometimes be a challenge and, in some cases, compromises may be required.

The location of poles is often further complicated in urban areas when designing around underground and overhead utilities in confined corners of the intersection.

Supplemental Overhead Speakers

APS beacons may be emitted from the pushbuttons themselves or from supplemental overhead speakers. Where the supplemental speakers are used, they should be mounted between 3 to 4 meters above the ground and be positioned such that they point to a location approximately two thirds of the way across the crosswalk. They should be audible across the entire length of the crosswalk.

Pedestrian Countdown Displays

The Pedestrian Countdown Display (or Pedestrian Countdown Signal (PCS)) may be added to a pedestrian signal head. The display shows a descending numerical countdown that indicates to pedestrians the number of remaining seconds available for crossing.

The following design details are from the TAC Manual of Uniform Traffic Control Devices for Canada (MUTCDC¹⁶):

TAC Recommended Operational Guidelines

- PCS should be adopted as an optional device for installation at locations where pedestrian signal heads are installed.
- The PCS is to count down during the flashing hand pedestrian clearance period only.
- The PCS Information Sign may be installed adjacent to the pedestrian pushbuttons to inform pedestrians of the usage of the PCS.

TAC Recommended PCS Standard Layout and Configuration

- Pedestrian countdown displays should consist of Portland Orange numbers that are at least 135 mm high (220 mm lens height) on a black opaque background. The countdown numbers should preferably be “double stroke” to improve visibility and to provide a certain amount of redundancy.
- Where the pedestrian enters the crosswalk more than 30 m from the countdown pedestrian signal display, the numbers should be at least 175 mm high (30 mm lens height).
- The pedestrian countdown displays should be of the “Separate Countdown Housing” configuration. The “Overlap/Countdown Side by Side” configuration and the “Separate Countdown Housing with no Overlap” configuration may be used in retrofit situations. The Countdown Pedestrian Signal must be located immediately adjacent to the associated HAND pedestrian signal head indication.
- The WALK and the HAND indications must be the same as those used in the conventional

pedestrian signal, and must comply with Section B1.5.4, Section B3.4 and Figure B3-9 of the MUTCDC.¹⁶

PCS should be considered where there are high numbers of seniors, children and other mobility challenged pedestrians who may have difficulty judging speed and distance where PCS would improve their safety and security.

PCS may also be considered at locations that have a history of high pedestrian/vehicle conflicts where the use of PCS may reduce the number of conflicts by deterring some pedestrians from beginning their crossing near the end of the clearance interval.

Additional considerations for when to install PCS can be found in the TAC MUTCDC.¹⁶

5.8 Miscellaneous Traffic Control

Intersection Pedestrian Signals

Intersection Pedestrian Signals (IPS) may be installed at intersections that have considerable pedestrian volumes, but very light traffic on the side road. IPS require that a normal crosswalk be marked in accordance with standardized practice for traffic signals, and that the side road be provided with STOP signs (if not already provided), as shown in Figure 50.

Typical three-section signal heads are used for the main road. Pedestrian signals with pushbuttons are required for the crossing.

Signal heads may be mounted on the same poles, either back-to-back, as shown in Figure 50, or independently.

It is also possible to install the crossing on the opposite side of the side road, or to install dual crossings, one on each side. Details of the latter design approach may be found in the TAC MUTCDC.¹⁶

The installation of a new IPS or modifications to an existing IPS site must meet the *Accessibility for Ontarians with Disabilities Act, 2005, S.O. 2005, c. 11* and associated regulations.

Mid-Block Pedestrian Signals

Where justified by continual disruption of traffic flow, by collision histories, or by heavy pedestrian volumes and delays, pedestrian signals may be installed at mid-block locations. The pavement markings for mid-block pedestrian crossings are similar to the markings for normal signalized intersections with the vehicle stop lines set back a

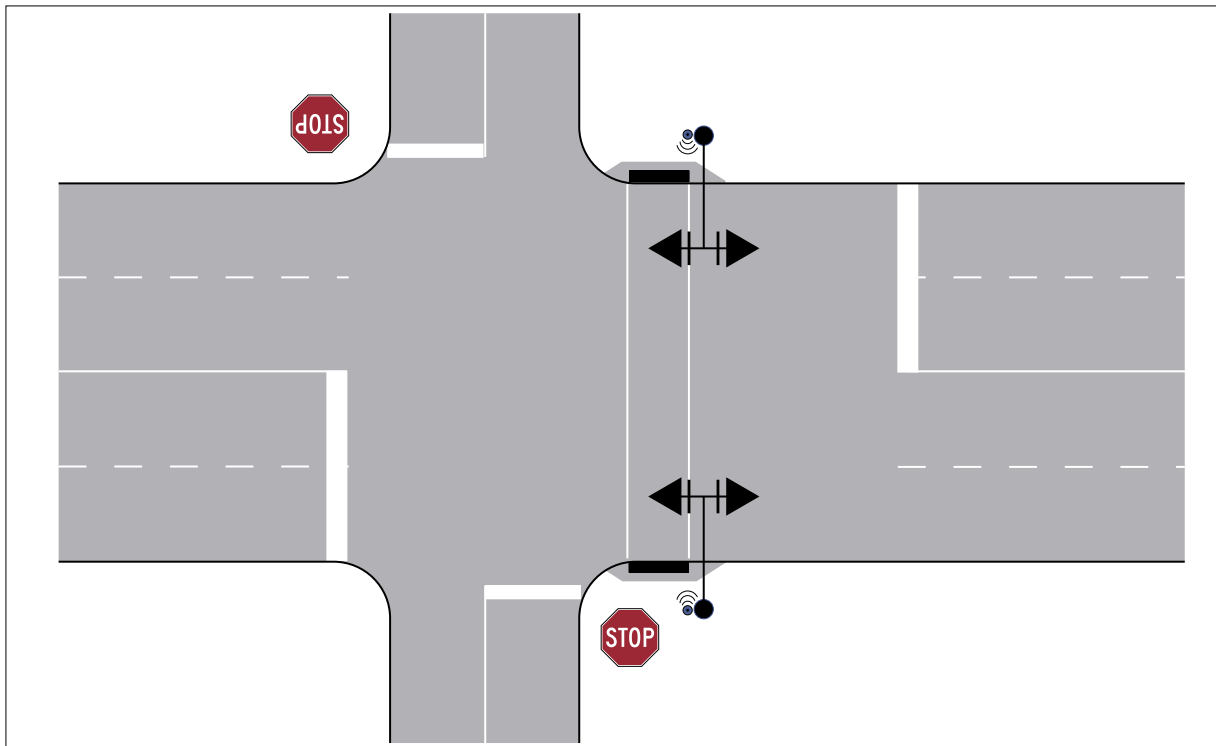


Figure 50 – Intersection Pedestrian Signals

minimum of 12 m from the primary signal head (15 m recommended practice). At mid-block locations, the conspicuity of the pedestrian signals to drivers is paramount. At mid-block locations, the usual cue for the presence of a crossroad, which leads motorists to expect the possibility of a signal, is missing. Section 4 gives justification criteria for the use of mid-block signals. Mid-block signals should be used in lieu of PXOs where the posted speed exceeds 60 km/h, where there are more than four lanes, or where other PXO criteria are not met.

The installation of a new MPS or modifications to an existing MPS site must meet the *Accessibility for Ontarians with Disabilities Act*, 2005, S.O. 2005, c. 11 and associated regulations.

Lane Direction Signals

Lane direction signals are normally used to change the direction of traffic flow for single lanes, multiple lanes, or the full roadway during various times of the day. A common application is characterized by a very heavy morning Peak Hourly Volume (PHV) in one direction and a similar heavy afternoon PHV in the other direction.

Additional information on Lane Direction Signals can be found in the MUTCDC¹⁶ and in the TAC report “Guidelines for the Planning, Design, Operation and Evaluation of Reversible Lane Systems”.⁹

Lane direction signals must be suspended directly over the approximate centre of the lane to which they apply. Signals for different lanes should be mounted at a uniform height and positioned so that they form a straight line and cross the roadway lanes at right angles. Each signal head must be mounted a minimum of 4.5 m over the pavement, with a 5.0 m clearance preferred.

Lane control signals must be carefully located in advance of, or beyond, an intersection controlled by standard traffic control signals in order

to eliminate possible confusion between the indications. A signal indication must always be illuminated in both directions of the lane or lanes controlled.

The signal indications consist of a red “X” and a green arrow (downward pointing), as shown in Figure 24 in Section 3. The layout of the lane direction signals should take visibility into account as follows:

- At least one set of indications should be visible to the motorist at all times.
- A 300 mm size lens should be used for speeds of 60 km/h or less with symbols visible up to 150 m. A 400 mm size lens should be used for operating speeds up to 80 km/h with symbols visible up to 225 m.
- Spacing of the lane direction signals should be set based on minimum visibility (approximately 150 m for 300 mm lenses, and 225 m for 400 mm lenses).
- Lane direction signals in tunnels may need to be mounted elsewhere other than over the centre of the lanes due to height restrictions.

Rectangular Rapid Flashing Beacons (RRFB)

Rectangular Rapid Flashing Beacons (RRFBs) are pedestrian-activated, high-intensity flashing beacons that warn drivers of the presence of a pedestrian in the crosswalk. RRFBs consist of two rectangular yellow indications with two tell-tale end indicators to let pedestrians know that the beacon is flashing.

RRFBs are required components for Types B and C of Level 2 PXOs. Wherever required for an applicable PXO, an RRFB must be used for each direction of travel (see table of components and installation layouts of Types B and C of Level 2 PXOs in OTM Book 15 (Pedestrian Crossing

Treatments)). An RRFB shall not be used where the crosswalk is controlled by YIELD signs, STOP signs, or traffic control signals. The RRFB shall be installed on the same support as the associated PEDESTRIAN CROSSING sign.

An RRFB shall consist of two rapidly and alternately flashing rectangular yellow indications having LED-array based pulsing light sources, and shall be designed in accordance with the following operational requirements:

- (a) Each RRFB shall consist of two rectangular shaped yellow indications with two tell-tale end indicators, each with LED array based light source. Each RRFB indication shall be minimum of 125 mm wide by 50 mm high.
- (b) The two RRFB indications shall be aligned horizontally, with the longer dimension horizontal and with a minimum space between the two indications of 175 mm, measured from inside edge of one indication to inside edge of the other indication.

Details regarding the operation of RRFBs at PXO's and PXO design options can be found in OTM Book 15, Pedestrian Crossing Treatments.

Ramp Metering Signals

Heads for ramp metering are used on freeway entrance ramps and are governed by Regulation 626 (5) of the HTA. The primary head may be mounted at 2.75 m if not over traffic. The secondary head should be mounted at a height of 1.0 to 1.2 m to provide driver visibility since the stop line is directly beside the secondary head.

Signals Near Railway Crossings

Where railway crossings lie within the intersections themselves, special treatment of railway and highway signals must be undertaken to provide

greater protection for vehicles. Examples of this are given in the TAC MUTCDC.¹⁶

Where the railway crossings are so close to the intersections that back-ups from the vehicle signals may occur, the interconnection of railway and vehicle signals will be required. The interconnection allows for preemption of the vehicle and pedestrian signals. Preemptive signals may also be used to activate other devices (such as blank-out signs for turn prohibitions) during train crossings.

Where a railway crossing is in close proximity to an intersection such that vehicles queue towards the tracks and vehicles are likely to be stopped across the tracks, it will be necessary to provide a preemption phase to clear the approach before the train arrival. This will require an analysis of the time it will take to clear the tracks during a preemption phase and must include a suitable factor for safety.

The traffic control signal installation must be discussed with the appropriate railway authority. If pre-empted, the installation and operation must be in accordance with the *Railway Safety Act, Grade Crossings Regulations, the Grade Crossings Standards, the Grade Crossings Handbook, AREMA Communications and Signals Manual, Preemption of Traffic Signals Near Railroad Crossings (ITE) and Transport Canada's Standard Respecting Railway Clearances (TC E-05)*.

Signals that require railway interconnection should not be constructed until the approval of the railway owner has been received and cost sharing has been resolved.

Transit Priority Signals

Transit priority signals (TPS) may be used to assign right-of-way to public transit vehicles over all other non-conflicting vehicular and pedestrian traffic movements within an intersection.

Transit vehicles such as Bus Rapid Transit (BRT), streetcars or Light Rail Transit (LRT) vehicles typically travel within their own exclusive corridor or within dedicated transit lanes which may be in the centre of a roadway or on the right of the roadway in the direction of travel. When these exclusive corridors or lanes intersect with general traffic signals the transit vehicles should be controlled by separate transit signals through a fully protected phase where all conflicting traffic is held on a red signal indication. In these cases, separate and distinct transit signals that control only the transit vehicles are used. It is also recommended that if there are parallel left turns across the LRT tracks or BRT lanes, that the left turns be fully protected. These separate transit signals may use the white vertical bar mounted above the circular red lens, or may use circular red, amber, green lenses with combinations of green arrows. Regardless of the lenses used, there must be two signal heads for redundancy. These transit signals should be located and configured to make it clear they are for

transit vehicles only so general traffic is less likely to be confused. To make the transit signals distinct, typically the signal head housings are either dark green or black and backboards, if used, are also dark green or black. The lenses may also be standardized at 200 mm.

The signal heads can be mounted at a different mounting height from the general traffic signal heads and should be located such the general traffic cannot clearly see the indications being displayed within the transit signal heads. Full tunnel visors and louvres may be used to help with this. “Transit Signal” signs should also be used to help distinguish the transit signal heads from the general traffic heads.

An example of this type of design can be seen in Figure 51.

When transit vehicles such as buses operate in general traffic lanes between signals, they may

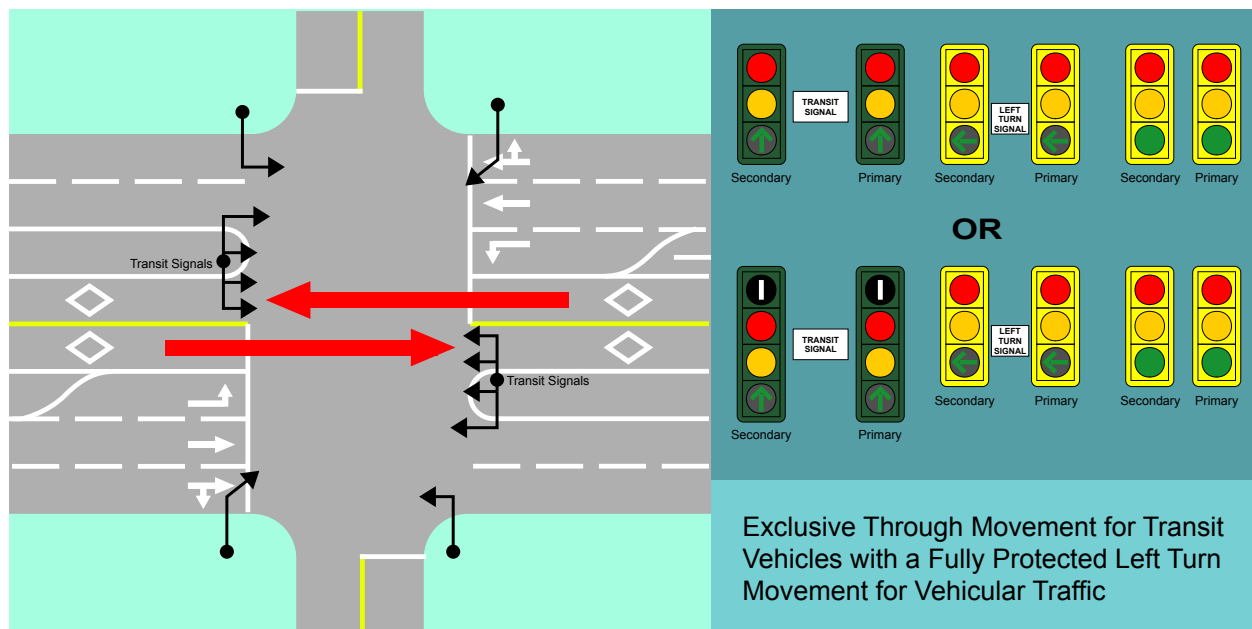


Figure 51 – Dedicated Transit Lanes in Centre of Roadway with Fully Protected Left Turn

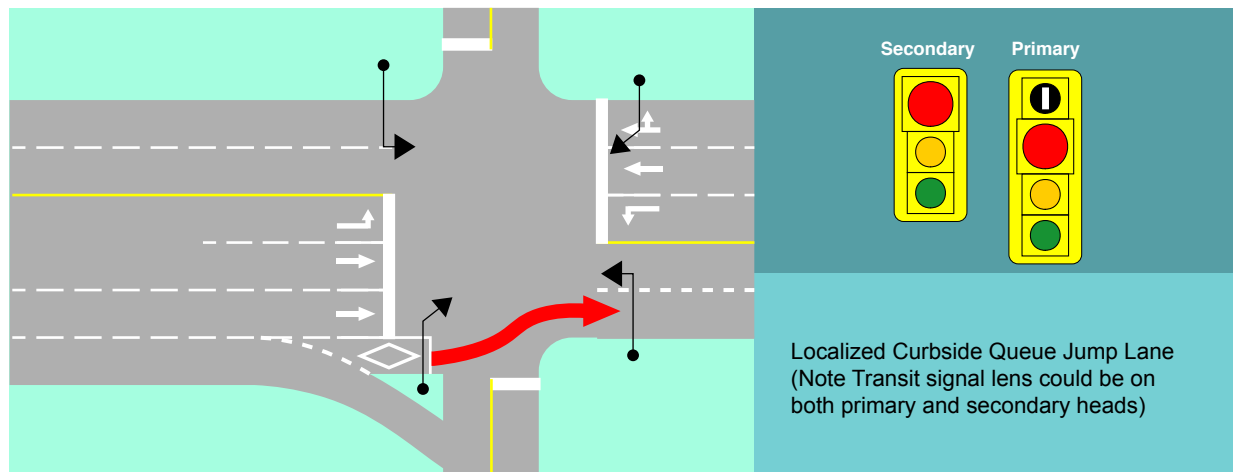


Figure 52 — Bus Bypass Lane

make use of what is known as queue jump lanes. These lanes may be located on the far-right of the roadway at a signalized intersection or they may be dedicated transit left turn lanes. For bus queue jump operations transit priority is achieved by using the white vertical bar as described in the HTA mounted above the red signal lens of the general traffic signal head(s). The white vertical bar may be mounted only on the primary signal head, only the secondary signal head, or both. The intent is that the white vertical bar is illuminated to allow a bus to jump the queue or make a protected movement before general traffic is released.

An example of this design can be seen in Figure 52.

The transit priority signal lens consists of a “lunar white” vertical bar on an opaque background. They may have 200 or 300 mm lenses and be mounted on any type of signal head

Movable Span Bridge Signals

When roadways cross drawbridges, swing bridges, or lift bridges, normal traffic signal heads should be considered in conjunction with control gates or other forms of physical protection.

The needs of large water vessels should be taken into account in the design of bridge signals as large water vessels cannot stop in a short distance and once activated, the bridge mechanism must normally continue to open the bridge. It is good practice to allow a minimum of 15 m between the end of the movable part of the bridge and any barrier protection. This space provides storage for one or two vehicles in an emergency.

Temporary Traffic Control and Portable Lane Control Signals

A temporary traffic control signal is installed for a limited period of time, whereas a portable traffic control signal is a temporary traffic control signal that is designed to be transported and reused at different locations. Four different electrical/electronic traffic control devices are currently available for controlling traffic under temporary conditions. The devices and the restrictions on their use are discussed below.

Automated Flagger Assistance Device

The AFAD is defined in Section 146.1 (7) of the HTA as a self-contained, portable traffic control system that is operated remotely by a Traffic Control Person to control traffic movement and features a circular red lens and a circular amber lens and a gate arm.

The basic design, placement, operational requirements, and the additional signing requirements for its use are stipulated under Regulation 185/22 of the HTA.

Details on the design, operation, duration of work, layout requirements and signing for AFADs are provided in OTM Book 7, Temporary Conditions. Legal approval for installation is not required but approval by the road authority is required for AFADs to be used.

An AFAD may only be used to control one lane, two-way traffic flow during construction activities, and only for durations defined under OTM Book 7 as “Intermittent”, “Very Short” or “Short Duration Work”.

An AFAD shall not be used at an intersection or pedestrian crossover and shall not be placed in any location or in such a manner that it would conflict with a traffic control signal system. Also, if these devices are to be used during night-time activities, proper illumination must be provided.

Portable Lane Control Signals (PLCS)

The Portable Lane Control Signal (PLCS) is defined in Section 146 of the HTA.

The basic design, placement, operational requirements, and the additional signing requirements for its use are stipulated under Regulation 185/22 of the HTA.

Details on the design, operation, duration of work, layout requirements and signing for PLCS are provided in OTM Book 7 (Temporary Conditions).

Approval of the road authority responsible for the roadway must be obtained prior to use. Because of the temporary nature of these devices, legal drawings are not required by law.

Portable Lane Control Signals consist of at least one “standard” vehicle traffic signal head, normally mounted on movable poles at a minimum height of 2.75 m from the roadway surface to the bottom of the heads. The use of portable signals is an alternative to continuous flagging by control persons and is not to be confused with portable temporary traffic signals.

PLCS may only be used to control one lane, two-way traffic flow during construction activities, and only for durations defined considered under OTM Book 7 (Temporary Conditions) as “Intermittent”, “Very Short” or “Short Duration Work”.

The phasing intervals must be a two phase operation only, with the all-red clearance interval sufficiently long to clear the previous approach lane of all vehicular traffic. Access points or side streets within the one lane section controlled by the portable lane control signals must be controlled by the traffic control person working in conjunction with the equipment. The equipment must be removed and two-way flow of traffic resumed when the contractor leaves the site.

It is recommended practice that the use of portable lane control signals must only be allowed where the posted speed is 60 km/h or less, there is a minimum signal head visibility distance of 100 m or more, and where full illumination exists if the closure continues at night.

The signals must not be used at an intersection or pedestrian crossover. It is recommended in these

situations, that portable lane control signals with two signal heads be used, and that the second signal head be located in the standard secondary head location.

Should the contractor leave the site, the equipment must be removed and two-way flow of traffic resumed. If these devices are to be used during night-time activities, proper illumination must be provided.

Portable Temporary Traffic Signals (PTTS)

PTTS consist of traffic signal heads mounted on movable trailers. The trailers are typically positioned to emulate traffic control signals. Approval of the road authority responsible for the roadway must be obtained prior to use.

PTTS may be used to control one lane, two-way traffic flow during construction activities that are considered under OTM Book 7 (Temporary Conditions) as “Intermittent Duration”, “Very Short Duration” or “Short Duration Work”.

If these devices are to be used during night-time activities, proper illumination must be provided. If traffic flow is returned to regular two-way operations, the PTTS should either be removed from the site or the signal heads should be bagged and the PTTS turned off.

PTTS may also be used to control one lane two-way operations during construction activities considered under OTM Book 7 (Temporary Conditions) as “Long Duration Work”. When being used in this way they must be installed to meet the requirements of Regulation 626 and Section 144 of the HTA. If used for “Long Duration Work”, a cost comparison is recommended to investigate whether it is more cost effective to use solar powered portable temporary traffic signals rather than regular temporary traffic signals. Portable temporary traffic signals may not be used if a side street or access point is located within the one lane

section. (Temporary signals with multiple phasing must then be used.) Legal approval from the road authority is required prior to use.

The following material and operational requirements apply to portable temporary traffic signals.

Material Requirements

- Two trailers (one for each approach to the one lane section being controlled) must make up the system.
- Each trailer must have two operating signal heads.
- The head to be placed over the roadway must be a minimum of 4.5 meters from the roadway surface.
- The heads facing each approach must be separated by a minimum of 3.0 meters.
- The head located over the trailer must be capable of being mounted at 4.5 meters and at 2.75 meters from the roadway surface.
- Highway yellow backboards must be used on each signal head.
- Signal heads must be capable of being reversed on the signal mast arm/boom to allow the trailers to be mounted on the same side of the roadway behind a barrier.
- Signal head displays must meet the signal head visibility requirements for the posted speed of the roadway prior to construction activities:
 - Minimum distance from signal heads to stop bar = 12 m.
 - Visibility distance requirements as per Table 24.

- Cone of vision requirements from the stop bar and from the stopping site distance.
- Each trailer must be capable of operating as a Primary Unit or a Secondary Unit, and the trailers must be interconnected to each other by hardwire, licensed radio, or spread spectrum radio communications.
- Trailer units should be solar powered with battery backup capable of sustaining full operation for at least 14 days without recharging. If connection to the power grid is readily available that option should be considered.
- Trailer units must be capable of being operated by generator as a backup power source.
- have a cellular or satellite paging system to alert the contractor that the signals have entered fault mode.
- The system must be capable of pre-timed signal operations where the green time, the amber clearance, and the all-red times can be manually input to the controller.
- The system must be capable of fully-actuated operation using a variety of detection devices including loops, microwave, and video detection equipment that will:
 - Place a call for a green indication when red or amber is being displayed.
 - Extend the green indication from a minimum to a maximum green time by a user selectable amount each time a vehicle is detected during the green display (extension time).
 - Rest in red or the last phase served. The user must be able to select this mode through software input on a construction site.

Operational Requirements

- The system must provide conflict monitoring as follows:
 - Master and local controller watchdog of the controller software.
 - Master and local controller absence of indication (burnt out lamp).
 - Master and local controller conflicting display on the same signal head or heads.
 - Master and local controller conflicting displays on opposing signal heads.
- Upon detection of a conflict, the signal system must enter a fault mode of either flashing red or solid red display on all heads. The determination of solid red or flashing red fault mode must be user selectable. Both modes must be available.
- Upon detection of a fault, the units must
 - PTTS may be used for night-time activities, but only with proper illumination. Proper illumination includes:
 - There must be a minimum of one luminaire over each PTTS trailer.
 - Each luminaire must output a minimum of 22,000 lumens.
 - Each luminaire must be mounted a minimum of 9 m vertically from the roadway surface.

- The luminaires must be on from dusk until dawn.

If required, the contractor must supply, install, and maintain temporary platforms that rigidly support the traffic signals units in a level plane. The temporary platforms must be of sufficient size to permit maintenance and service of the units. At the end of the contract, the contractor must remove and dispose of the temporary platforms. If portable temporary traffic control signals are used in the winter months, the signals must be configured with environmental controls to ensure they will continue to operate at any temperature.

Temporary Traffic Signals

Temporary traffic signals consist of traffic signal heads positioned on span wires and temporary poles. The signals are used to control traffic during construction activities. Temporary traffic signals should be considered for applications that are defined under OTM Book 7 (Temporary Conditions)²⁰ as “Long Duration Work”, meaning the work requires a separate workspace for longer than 24 hours. Temporary traffic signals have a constant power supply, and closely resemble a normal signal installation. The signals may be used at an intersection or pedestrian crossover.

Temporary traffic signal installations require the approval of the responsible road authority before installation. A legal drawing must be prepared prior to installation as per HTA 144(31). The installations must comply with all regulations pertaining to traffic signals identified in HTA Regulation 626.

Operational and timing requirements for fixed temporary traffic signals are the same as for permanent signals. Full NEMA standard conflict

monitoring must be used. Temporary illumination using a standard design is required for all temporary traffic signal installations.

Tunnel Signals

There are two types of “Tunnel Signals”:

- Signals at the ends of a tunnel that are used to prohibit the entrance of traffic in the case of a mishap within the tunnel
- Lane control signals within the tunnel and on the tunnel approaches used for reversible lanes or for the closure of lanes for maintenance

Bicycle Control Signals, Placement

Bicycles are defined as vehicles in the *Highway Traffic Act* and therefore are governed by the rules of the road as defined in the Act. In most cases where cyclists are operating on the road surface either sharing the lane with the general traffic or in exclusive bicycle lanes, standard vehicle displays should be adequate to control bicycle movements through intersections. However, if leading bicycle intervals, separate bicycle movements, or if a bicycle path or multi-use trail intersects a roadway, separate bicycle signals are required.

Details on when separate bicycle signals should be used and how to design and operate them can be found in Section 6 of this manual.

It is recommended that special bicycle detection be used if bicycle volumes are considered high. Detection may consist of bicycle-specific quadrupole or diagonal quadrupole induction loops and detectors, video detection, special

pushbuttons, or other techniques. Bicycle signal detection is discussed in more detail in Section 6.

5.9 Detection

General

A Vehicle Detector is a device for indicating the presence or passage of a vehicle in a designated area of a roadway. Passage detection is the sensing of a road user in motion within the detection zone. Presence detection is the sensing of a road user in the detection zone, whether stopped or moving.

Vehicle detectors typically provide two types of output: pulse or presence. Pulse detectors produce a short output pulse only when a vehicle enters the detection zone. Presence detectors are able to detect the presence or absence of vehicles within the detection zone.

Outputs from vehicle detectors are used as inputs to the traffic controller to provide phasing and to determine timing. The detectors may also provide other equipment with the inputs required to calculate volume (vehicles per hour), average or instantaneous speed (kph), occupancy (percent usage of the roadway), density (vehicles per kilometer), and vehicle classifications.

Vehicle detectors/sensors fall into two major categories: Non-intrusive, or above-ground installation; and intrusive, or in-ground installation.

Non-intrusive detectors are typically overhead. They must be rigidly affixed to a pole or other structure. Detectors placed over the roadway (forward fired) or side fired have a defined detection zone aimed at a specific point. The detectors are subject to weather, lightning and electrical discharges, and vibrations.

When using non-intrusive detection, it is important that maintenance activities include the confirmation or recalibration of the programmed detection zones on a regular basis as cameras and head units mounted on signal poles or mast arms are often moved by high winds. If detection zones shift most non-intrusive detectors can be programmed to place a continuous call to the traffic signal controller, however this results in very inefficient intersection operation.

Intrusive detectors are typically embedded in the ground or road surface. The detection zones of detectors placed within the roadway surface are defined by the placement of the detector element. The success and longevity of these in-ground detectors depends directly on the condition of the ground/road surface, and the quality of the materials used to construct them. Loop assembly failure caused by electrical leakage to the ground and loss of conductivity can most often be traced to physical damage of the loop assembly either during installation or through pavement movement.

Intrusive detectors require cutting into the surface course of the roadway and if not installed properly they can lead to cracking and breakup of the asphalt or concrete surface. Loop detectors can be set into the base course, or prefabricated loops can be laid beneath the surface or base course and then paved over, which helps to eliminate the degradation of the driving surface, however these are more expensive to install and often require good coordination between the paving contractor and the electrical contractor that performs the loop installations. With intrusive detection there is also the consideration that when repaving occurs, loops are often not considered and are ground out as part of the repaving exercise.

Traditional loop detectors when installed properly are reliable and when set in different configurations can be used to count and classify vehicles based on the number of axles as opposed to just by length. Traditional loops if not properly tuned can

be ineffective at detecting bicycles. One option is to stencil a bike symbol with a line before and after it to indicate the best location for a cyclist to stop to be detected by a loop.

Non-intrusive detection devices can be installed and maintained without road closures, and the detection zones can be programmed at the signal controller or even remotely. Depending on the sensor, non-intrusive detection can classify vehicles and detect pedestrians and cyclists. Being able to define the detection zone allows it to be adjusted in shape, width and length as well as sensitivity, thus providing additional flexibility to detect pedestrians and cyclists. Some non-intrusive sensors can replace multiple loops by providing multilane or multi-approach detection. Being able to adjust the detection zones is also a benefit during rehabilitation/maintenance activities at the intersection. The detection zones can be re-programmed without needing to dig up or reposition traditional loop detectors.

Vehicle detectors are commonly installed at actuated traffic signals, urban and highway permanent vehicle counting stations, and parking lots/garages. In actuated traffic signals, vehicle detection devices are used to indicate the need for a call or extension of green time. The detectors respond to the passage of vehicles over a specific point on the roadway. Vehicle detection devices are also used to indicate that vehicles are present and waiting for signal indications to change, and to indicate that vehicles are in line behind other vehicles waiting for signal indications to change (left turn “setback” detectors). At critical intersections, detection zone lengths and gap settings are normally designed to terminate green when headways are greater than two to three seconds.

In areas posted at speeds of less than 80 km/h, there is generally a greater concentration on maximizing intersection efficiency than on dilemma zone protection. The dilemma zone is the area

approaching the stop line in which the motorist, on the start of amber will be momentarily undecided as to whether to stop or continue through the intersection, thereby encountering a dilemma. For higher speed locations, use of a combination of detection and timing techniques to minimize the effects of the dilemma zone is a consideration, even at the expense of some intersection efficiency.

Other forms of detection devices include: pedestrian pushbuttons for detecting the presence of a pedestrian; emergency vehicle detection for detecting a fire truck or ambulance to provide right-of-way at an intersection; bus or transit vehicle detection for detecting a high occupancy vehicle to provide priority at an intersection; and specialized detection devices for cyclists or for Accessible Pedestrian Signals at an intersection or signalized mid-block crossing.

Types of Vehicle Detectors

As there are many brands and types of vehicle detectors, the detectors available should satisfy most applications. A summary of the common types of non-intrusive and intrusive detection devices follows.

Microwave (Non-Intrusive)

Microwave detectors are mounted above the ground and project a cone shaped detection area. They are a form of radar. When a vehicle approaches, the vehicle reflects some of the microwave energy back to the detector, providing a momentary contact closure (pulse) to indicate that a vehicle has been detected. These types of detectors have become very common for traffic signal operations.

These devices can be used for counting, presence and speed detection and can also classify vehicles based on length, not on the number of axles. Smart microwave detectors can also detect

pedestrians and cyclists. There are two types of microwave sensors on the market.

The first transmits a Continuous Wave (CW) to detect vehicles and these are true motion sensors (they cannot detect a stopped vehicle), so either the device must lock in a presence call or the call must be locked in at the traffic signal controller. Microwave detectors that transmit a Frequency Modulated Continuous Wave (FMCW) signal are true presence detectors.

The radar sensor unit may be mounted overhead to measure approaching or departing vehicles or at the side of the roadway (side fire). Both configurations may be able to detect vehicles across multiple lanes of traffic depending on the sensor's field of view, mounting height and distance from the area to be detected. It is important that these sensors be mounted to a rigid structure. Signal poles are rigid enough that any sway in the wind can be compensated for by the signal processor(s) in the device, however mounting these on signal mast arms may result in excessive sway and a reduction in accuracy. Dampening devices are available to mitigate the effects.

This type of vehicle detector is typically insensitive to inclement weather at the short ranges normally encountered during use in traffic management. They are very accurate and easy to install.

Infrared (Non-Intrusive)

There are two types of infrared detectors:

- **Passive** – Passive infrared detectors detect the presence of vehicles by comparing the infrared energy (electromagnetic radiation) naturally occurring in the detection zone with the change in energy caused by a vehicle. Passive infrared detectors may have reduced detection sensitivity in heavy rain, snow or dense fog. These sensors can determine traffic

flow, volume, vehicle presence and detection zone occupancy. An infrared unit with multiple detection zones is required to collect speed data.

- **Active (Includes LiDAR)** – Active infrared detectors detect the presence of vehicles by emitting a low energy beam at the roadway and measuring the reflected signal's return to the device. Active infrared is typically laser radar. It transmits multiple beams for accurate measurement of vehicle position, speed and classification. Multiple units can be installed at the intersection without interference from the transmitted or received beams. Modern laser sensors are able to produce two- and three-dimensional imagery that is suitable for vehicle classification, as well as pedestrian and cyclist detection. Active infrared detectors can be used to detect vehicles over multiple lanes. The operation may be affected by fog or blowing snow.

Active Infrared detectors can be used for volume, speed, presence, and classification. They are very accurate for speed and classification however they can be affected by adverse weather conditions, haze or smoke. They have a relatively high cost compared to some other sensors.

Either type can be mounted overhead to capture approaching and departing vehicles or they can be mounted to the side of traffic lanes.

Acoustic (Non-Intrusive)

Acoustic detectors use pulses of ultrasonic sound which are directed at the roadway. The total travel time of the reflected sound is measured and compared to the previous measurement. A shorter time measurement indicates that a vehicle is present. These types of sensors are very accurate however they are affected by local environmental factors such as temperature changes and extreme air turbulence.

There are two types of Acoustic Detectors:

- Ultrasonic detectors can be used for counts and for presence detection.
- Acoustic Arrays can be used for counts, presence, limited vehicle classification and speed detection.

Video (Non-Intrusive)

Video detection is accomplished through an image processor. The detector consists of a microprocessor-based CPU, and software programmed to analyze video images. The user places virtual “detectors” on the video image displayed on a monitor. Each detection zone emulates an inductive loop vehicle sensor.

Video image detection can capture all desired traffic data with the added benefit that a visual record of events can also be captured and viewed by a human operator. Jurisdictions are making greater use of video detection systems for this reason.

The camera units must be mounted securely to eliminate sway and movement of the image and thus the programmed detection zone. Modern image processing can minimize the impact of camera movement.

Video detection is susceptible to inclement weather such as fog, rain or snow, shadows from adjacent lanes and occlusion. Reliable nighttime signal actuation requires streetlighting, however care should be taken to ensure that the lighting is designed to avoid washout of the camera image. Another consideration is that the camera lenses require regular cleaning which will likely require lane closures if the cameras are mounted over the travelled lanes. In most cases the cameras can be mounted adjacent to active lanes, however for reliable operation they will need to be mounted between 9 and 15 meters above the road surface.

Some benefits of video detection are that one camera unit for each intersection approach can be programmed for multiple lanes and multiple detection zones and the detection zones can be configured in a variety of shapes and size to meet the needs of the signal operation. The more lanes and detection zones required for each approach makes video detection more cost effective.

Pressure Detectors (Intrusive)

Pressure detectors are activated by the weight of a vehicle on a pneumatic tube placed across the roadway or on a metal frame and plates installed in the roadway. The pneumatic tube version is often used with count station equipment temporarily placed by a roadway for short period traffic data collection (typically less than a week). The metal frame and plate version is reliable, but its use is now very limited due to high installation costs and the resulting adverse pavement conditions.

Magnetic Detectors (Intrusive)

There are two main types of magnetic detectors. The first is the magnetometer that measures changes in both the horizontal and vertical components of the earth’s magnetic field produced by a ferrous metal vehicle. These devices can provide pulse detection as a vehicle travels over the magnetometer and presence detection when the vehicle stops over the device.

The second type is commonly known as a micro loop probe. As a vehicle passes over the micro loop the inductance change is sensed by conventional inductive loop detector electronics.

Both of these devices are generally installed into holes bored into the roadway surface. Due to the limited detection area, at least two devices are required in each lane. Communication to the receiving electronics in the cabinet can be through traditional loop lead in wires or through short range radio communications.

These devices are less susceptible to the stresses of traffic on the pavement that has been cut to insert them. They are also not impacted by inclement weather such as snow rain or fog. The biggest drawback of these detectors is that the detection zone is quite small and to get a larger detection zone a number of them must be linked together. Smaller ferrous vehicles such as motorcycles and bicycles do not always provide a large enough shift in the magnetic field to be detected.

The micro loop probe detector cannot sense vehicles moving at less than 8 km/h and therefore cannot provide presence detection. However, magnetometers can detect stopped vehicles.

Loop Detectors (Intrusive)

Many jurisdictions continue to use loop detectors as their standard detection device. This is a mature and well understood technology with a large experience base. Loops can provide volume, presence, occupancy speed headway and gap information for traffic signal operations and they are still the gold standard for accuracy of count data. Although widely used, the installation does require the pavement to be cut, unless prefabricated loops are being installed during paving operations. Improper installation techniques decrease pavement life and the wire loops are subject to the stresses of traffic and temperature changes.

Due to the fact loops are cut into the road surface, lane closures are required to install them. The cost of the loop and its installation is low, however the cost of traffic control during the installation can become more expensive than the loop itself.

Loop detectors consist of an amplifier located in the controller cabinet and coiled wires in the pavement. The coiled wires create an electro-magnetic field that changes when a vehicle is in

the loop area. Loop detectors are the most widely used type of vehicle detection because of the flexibility of their design. Loop detectors can be used to sense vehicle presence, passage, lane occupancy, speed, and volume.

Other types of detection are available and are continually being developed. For the purposes of this section, detector design will be described using loops. If alternative forms of detectors are used, the road authority should ensure that the operational features are similar to those of loops.

The location and correct positioning of detection devices is of the utmost importance if actuated control is to be effective. Good design requires that objects affecting detector performance be taken into account. Objects that may affect detector performance include parked vehicles, maintenance hole covers, transit stops, service stations or other facilities with busy entrances, etc.

System loops may be square or diamond shaped. The detectors are installed in each lane. For a central computer system, detectors are placed only on strategic arterials and in either inbound (towards the central business district) or outbound lanes. The traffic volumes, speeds and volume/densities on only a few sets of detectors may then be used in software algorithms to select timing and phasing plans. For systems such as the Split Cycle Offset Optimization Technique (SCOOT), dual sets of system detectors are placed in each lane well in advance of each intersection so that the optimal cycle length and offset timing may be calculated and transmitted to the next intersection.

Types of Detector Operation

Presence Detectors

Presence detection is used to: detect the presence, or continuing occupancy, of vehicles; provide calls to the controllers; or extend green

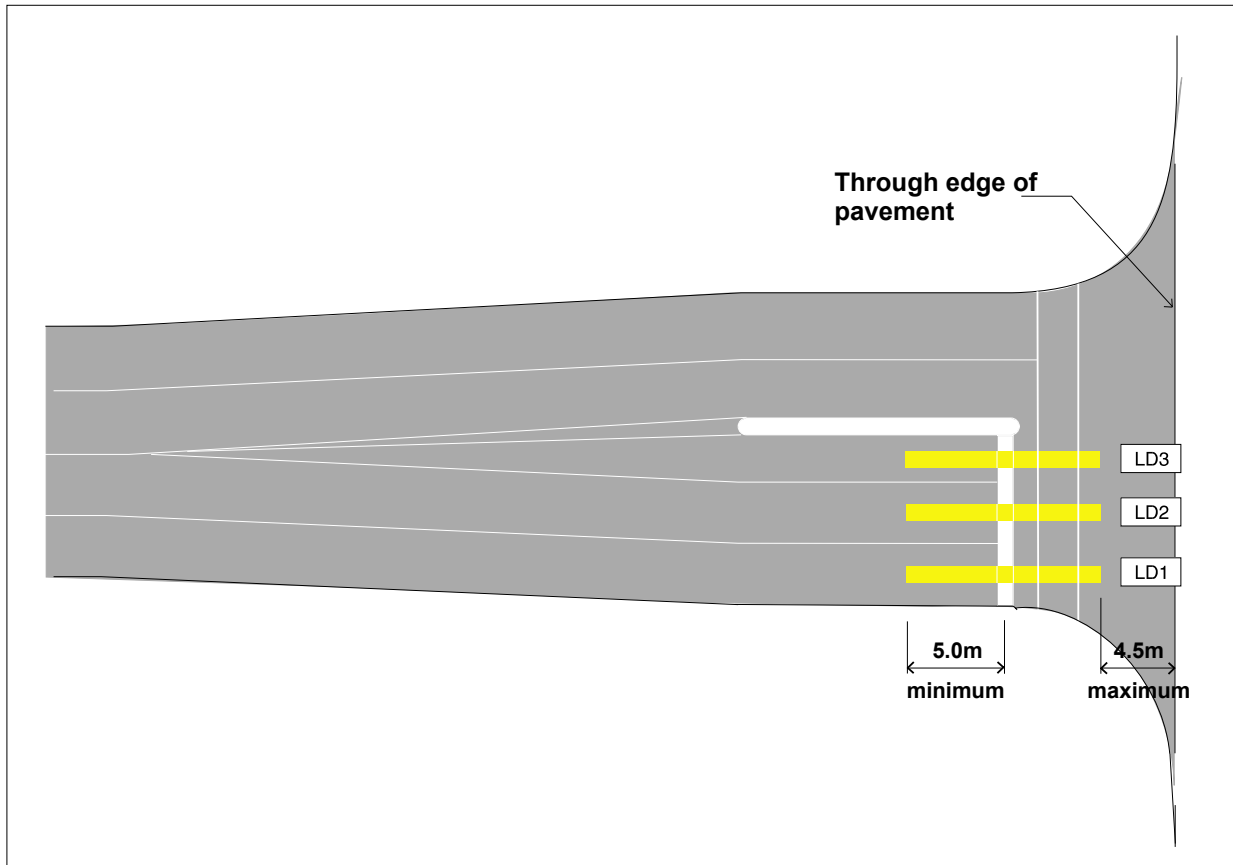


Figure 53 — Presence Detectors

times for vehicles. The detectors can be installed at or near the stop lines at intersection approaches, or as “setback” detectors in turning lanes to detect whether there are two or more vehicles waiting to turn.

Presence detection may: be rectangular or irregular in shape; be lane selective (installed as separate detectors in each lane), or all inclusive (installed as one detector across several lanes); and they may have a user settable time delay (1 to 15 seconds) feature that allows vehicles to stop, pause, and continue without registering a call (as in right-turn lanes).

The recommended placement of presence detectors requires maximum setbacks of 4.5 m from the intersecting through edge of pavement, and a coverage area behind the stop lines of 12 m in length for posted speeds of 80 km/h and above, and 5.0 m minimum otherwise. These configurations are shown in Figure 53.

Long Distance Detection

Long distance detection provides an extra level of safety for motorists travelling at a high speed toward a signalized intersection by providing dilemma zone protection. The system uses detectors located upstream of the intersection to sense approaching vehicles.

In the MUTCDC¹⁶: *“The dilemma [zone] is the location at which the driver, upon seeing the signal indication change from green to amber, must decide either to bring the vehicle to a safe stop before entering the intersection, or to enter and clear the intersection prior to the start of the conflicting green phase.”*¹⁶

When a vehicle passes over the detector, or through the detection zone, the signal controller extends the green time to allow the vehicle to pass through the dilemma zone before the onset of the amber signal indication.

Long distance passage detectors are normally used at intersections to provide actuation of signal phases or extended green times for vehicles passing through the dilemma zone. When used for actuation, the detectors are sometimes called “trip detectors”. When used to extend green times, the loops are sometimes called “extension detectors”.

Long distance detection generally consists of a single detector centred in each through lane of the mainline approach that is located at the upstream edge of the dilemma zone. With actuated signal timing, both approaches receive a minimum green interval, a vehicle extension period, and a maximum green interval. The vehicle extension period is intended to carry a vehicle from the outside edge of the dilemma zone to a point representing at least a one second distance from the stop bar (past the inside edge of dilemma zone).

Long distance detection is most effective where signals routinely “gap-out” just when vehicles are approaching the signal. A maximum green time should be established based on prevailing traffic conditions (on all approaches). Time of Day Functions that alter the maximum green time if traffic demands change through the day can be considered.

Long distance detection should be implemented at intersections on roadways that meet all of the following criteria:

- Operating speed is greater than 60 km/h.
- Traffic signals are fully-actuated.
- The intersection is isolated, non-interconnected, or interconnected with off peak free modes operation.

The key elements for successful operation of long distance detection are the placement of the long distance detector on the mainline approach, and the vehicle extension time provided for each detector activation. If the detector is placed too close to the intersection, vehicles may enter the dilemma zone before activating the detector. If the detector is placed too far from the intersection, providing short vehicle extension periods may result in motorists being in the dilemma zone at the onset of amber, but providing vehicle extension periods that are too long can increase vehicular delay and the probability of max-out during high volume situations.

As a recommended practice, long distance detectors should be used as extension detectors to extend green time on the main road for roadways of posted speed of 80 km/h or more, but the detectors may also be beneficial to signal operations on roadways with lower posted speeds. The loops are normally installed per lane, and are of 1.8 x 1.8 m square configuration or the equivalent size diamond shaped detection zones, as shown in Figure 54. The distance from the stop line to the extension detectors is based on the time of entry of the dilemma zone, as shown in Table 26.

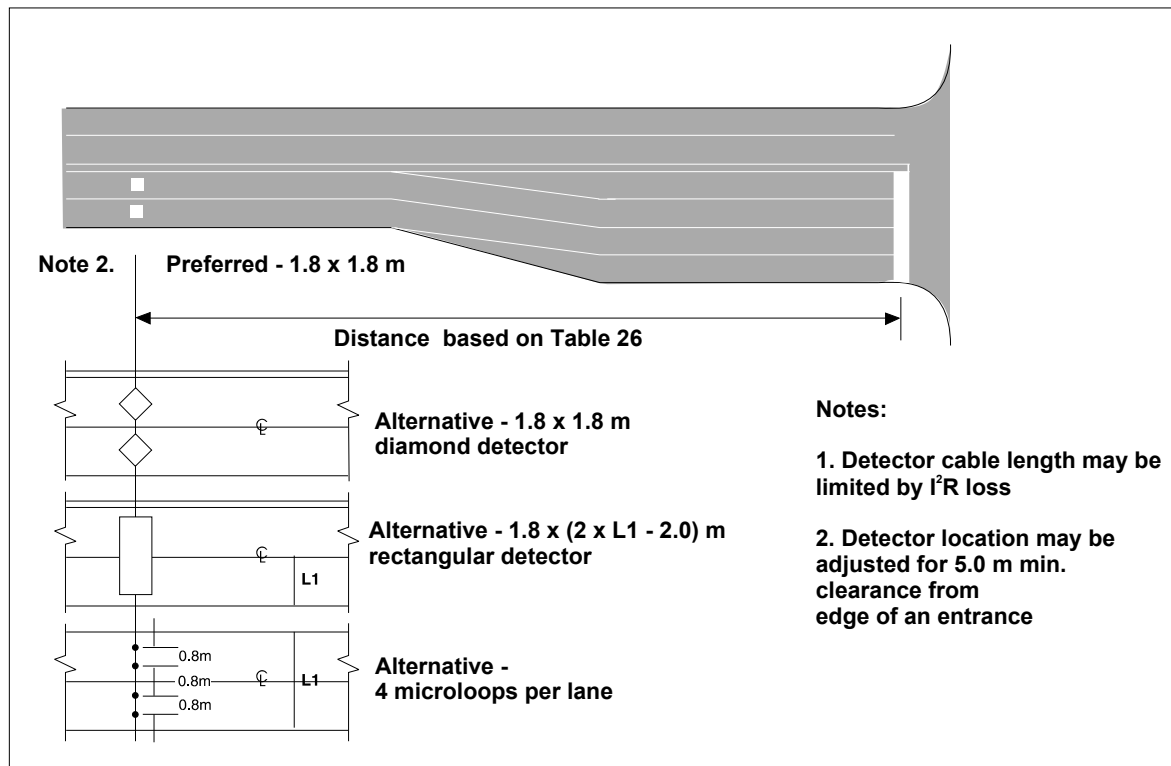


Figure 54 — Extension Detectors

Table 26 — Distance from Stop Line for Long Distance Detectors

<i>Operating Speed (85th percentile)</i>	<i>Distance from Stop Line (m) (based on edge of dilemma zone)</i>	<i>Distance from Stop Line (m) (based on five second line)</i>
60	70	85
70	90	110
80	110	115
90	125	125
100	140	140

Table 27 — Long Distance Detection Operating Parameters

OPERATING SPEED (km/h)	DETECTOR PLACEMENT (DL1) (meters from stop bar)	MINIMUM VEHICLE EXTENSION PERIOD (seconds)
60	70	3.2
65	80	3.4
70	90	3.6
75	100	3.8
80	115	4.0
85	120	4.0
90	125	4.0
95	165	5.3
100	175	5.3
105	190	5.5
110	205	5.7
115	228	6.1
120	244	6.3

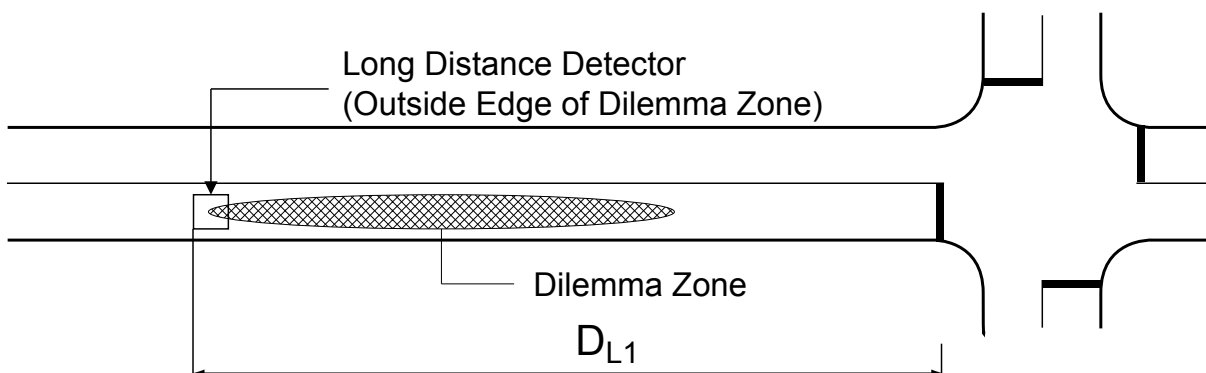


Figure 55 — Long Distance Detection – Recommended Installation

To promote efficient and safe intersection operation, the detector placement and vehicle extension timing parameters summarized in Table 27 should be used.

The distances for detector placement shown in Table 27 are typically taken from the approach stop bar, and represent the outside edge of the dilemma zone for operating speeds up to 90 km/h. For operating speeds greater than 95 km/h, the detector location is based on the ITE stopping distance formula and for this speed range, the formula should be used with an average deceleration rate of 3 m/s² to calculate braking distance as below:

$$d = v^2 / [254(\frac{a}{9.81} \pm \frac{G}{100})]$$

Where:

d = stopping distance (m)

v = velocity (km/h)

a = deceleration rate (m/s/s), typically 3.0 m/s/s for speeds over 95 km/h

G = grade in %, positive for uphill, negative for downhill

Where the operating speed (85th percentile speed) of the roadway is not known, a value equal to 10 km/h above the posted speed limit can be used. It is recommended that a spot speed study be undertaken to determine the actual operating speed of the roadway before installing

Table 28 — Double Long Distance Detection Operating Parameters

OPERATING SPEED	PLACEMENT OF DETECTOR (meters from stop bar) (Based on operating speed)		MINIMUM VEHICLE EXTENSION PERIOD (seconds)	
	LOOP 1 DL 1	LOOP 2 DL 2	DETECTOR 1 (ext) (threshold speed)	DETECTOR 2 (ext + carry) (operating speed)
80	165	115	2.3	4.2
85	170	120	2.1	4.1
90	175	125	2.0	4.0
95	215	165	1.9	5.3
100	225	175	1.8	5.3
105	240	190	1.7	5.5
110	255	205	1.6	5.7
115	278	228	1.6	6.1
120	294	244	1.5	6.3

long distance detection. Figure 55 shows the recommended installation for long distance detection.

Double Long Distance Detection

Double Long Distance Detection is best used where high speed vehicles (vehicles travelling above the operating speed of the roadway) are creating a safety concern. Double long distance detection uses information collected from two detectors to infer whether a vehicle is travelling above or below a predetermined threshold speed (typically set at 10 km/h above the operating speed).

If a vehicle is travelling at or above the threshold speed between the two detectors, a green extension is provided to allow the vehicle to pass through the dilemma zone before the onset of amber. However, if a vehicle is travelling below the threshold speed between the two detectors, the signal will gap-out and the amber will be displayed. Double long distance detection can accommodate a greater range of vehicle speeds than long distance detection while maintaining efficient signal operations.

Double long distance detection consists of two sets of detectors centred in each lane of the mainline approach. The detector closest to the intersection (Detector 2) is located as per Table 28 for the operating speed of the roadway. The detector furthest from the intersection (Detector 1) is located at a fixed distance of 50 m upstream of Detector 2.

In actuated signal timing operation, the mainline approaches receive a minimum green interval, vehicle extensions from Detector 1 and Detector 2, and a maximum green interval. Loop 1 applies an extension interval that is intended to carry a vehicle travelling at or above the threshold speed from Detector 1 to Detector 2. Detector 2 applies the extension interval plus a carryover interval

to carry a vehicle from the outside edge of the dilemma zone to a point representing at least one second in distance from the stop bar (past the inside edge of the dilemma zone).

Double long distance detection is intended to supplement long distance detection and is generally implemented at intersections where long distance detection is already in place. Before considering double long distance detection the 85th percentile speed of the roadway should be determined. The existing long distance detection system should be reviewed to confirm that the detector placement and the vehicle extension period conform to the recommended implementation as outlined in Table 27.

It is recommended that double long distance detection be implemented at intersections on roadways that meet the following criteria:

- The grade approaching an intersection requires more than the normal braking effort (3% or greater).
- Commercial vehicles account for considerable percentage of traffic (e.g., 20 – 25% or above).
- There is evidence that commercial vehicles are having difficulty stopping.
- Operating speed is equal to or greater than 90 km/h.
- Operating speeds exceed the posted speed limit by 20 km/h or more (threshold speed).
- The approach is operating at a level of service C or better.
- The intersection is isolated, rural, or non-interconnected.

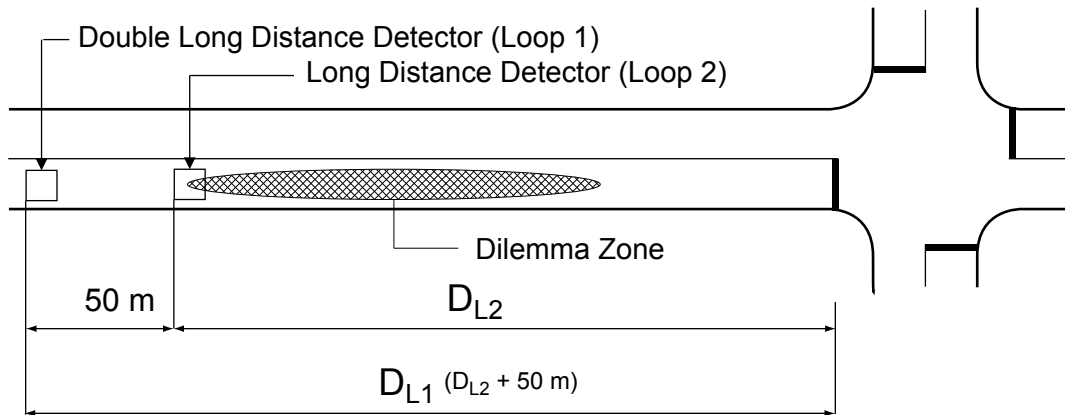


Figure 56 – Double Long Distance Detection – Recommended Installation

Double long distance detection should not be used on approaches that use True Active Advance Warning Signs.

To ensure that the intersection operates in a safe and efficient manner, the intersection should be studied during the peak periods before and after the installation of double long distance detection to determine “Max-out” rates. If the intersection is maxing-out for 25% or more of the cycles during the peak periods before or after the installation of the device, double long distance detection should be turned off during the max-out periods (where signal controller capabilities permit). Turning off the double long distance detector (Detector 1) will result in a higher gap-out (rather than max-out) rate for the intersection during these periods.

The key elements for successful operation of double long distance detection are the placement of the detectors on the mainline approach, and the vehicle extension intervals provided for each detector activation. If Detector 2 is placed too close to the intersection, or too far from it, vehicles may enter the dilemma zone before activating the detector, or they may be in the dilemma zone when the vehicle extension period has terminated. If Detector 1 is not correctly placed,

the signal controller may falsely infer that a vehicle is travelling above (too close) or below (too far) the predetermined threshold speed. In addition, providing excessive vehicle extension periods for both detectors wastes valuable cycle time, and increases the probability of max-out.

To promote efficient and safe intersection operation, the detector placement and associated vehicle extension intervals summarized in Table 29 are recommended. Figure 56 shows the recommended installation for double long distance detection.

The predetermined threshold speed is generally recognized as 10 km/h above the operating speed, where the operating speed is either the 85th percentile speed or 10 km/h above the posted speed.

Where existing double long distance detection is in place and the detector placement differs from the recommendations outlined above, the following formula must be used to determine the proper vehicle extension interval:

$$I = D/V_T$$

Where:

I = vehicle extension interval (seconds)
 D = distance between detectors 1 and 2
 V_T = threshold speed (m/s)

5.10 Layout Design

General

The general requirements of Subsection 5.3 should be closely followed when laying out primary and secondary head and pole locations. This section (Subsection 5.10) uses several examples of intersections to illustrate the various requirements.

Crosswalks and Sidewalks

General

This section on crosswalks and sidewalks gives an overview of the design procedures required to produce the signal and crosswalk/sidewalk designs related to the overall traffic signal design. The material in this section should be treated as the first step in a detailed design.

Design of Crosswalks and Sidewalks

1. Coordinating Crosswalk Locations

Inappropriate designs of crosswalks and sidewalks can significantly hinder the design of a set of traffic control signals. It is the responsibility of the signal designer to ensure that any changes to the preliminary design are compensated for by appropriate changes to the design of crosswalks and sidewalks.

Crosswalk locations are critical to pedestrian signal and pushbutton locations and necessary to ensure AODA compliance. For new roadway construction or reconstruction, the design of the crosswalks must be coordinated between the road designers (sidewalks and dropped curbs are affected) and the traffic signal designers (pedestrian signal facilities are affected).

Sidewalk locations that are designed at the property line and leave a large boulevard between the back of the curb and the sidewalk are unacceptable at signalized intersections because pedestrians must have access to pushbuttons and must cross properly at crosswalks. The sidewalk design should be locally adjusted to meet these conditions, as shown in Figure 57.

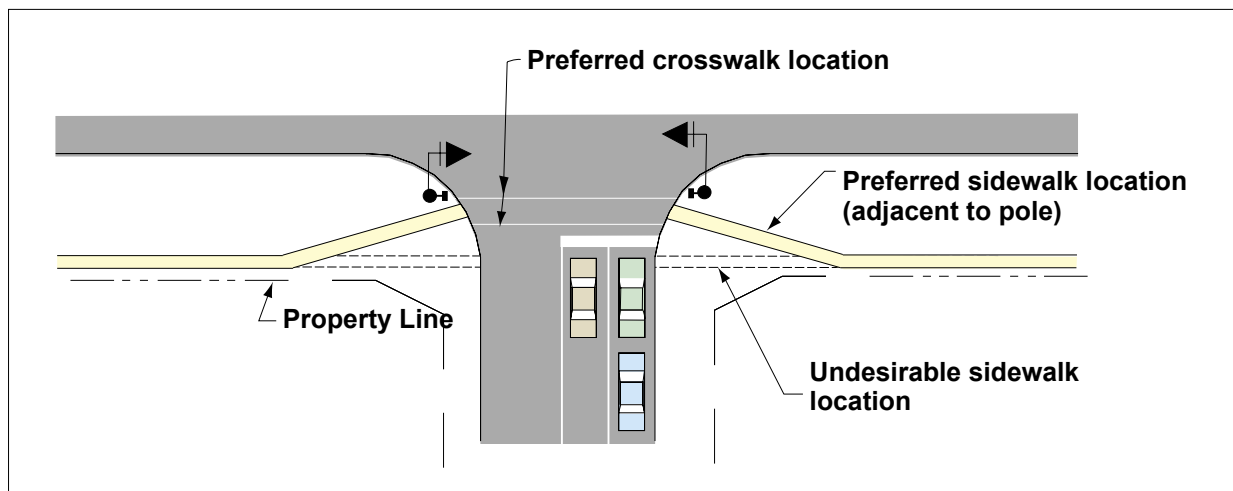


Figure 57 – Crosswalk and Sidewalk Locations

The layout design of pedestrian signals and pushbuttons must be integrated with the other signal elements. Some basic guidelines for the layout of crosswalks and sidewalks are provided below.

2. Crosswalks

The design of pedestrian crosswalks is not a fixed science and is subject to opinions and preferences. The examples given here are representative of systems in use.

Figure 58 shows a typical intersection on which one side is standard and the other side is modified. The crosswalks are laid out according to the following guidelines:

- The minimum crosswalk width is 2.5 m. The desirable crosswalk width is 3.0 m. The width may be increased to match wider sidewalks in downtown areas or to allow greater two-way pedestrian volumes.
- The outer edge of the crosswalk is normally 1.0 m from the edge of the stop line. If necessary, the stop line location can vary from the standard location (which typically starts at the end of the island).
- The inner edge of the crosswalk should be a minimum of 0.5 m from the through edge of the pavement of the parallel roadway for roadways posted under 80 km/h, and 1.0 to 1.5 m for roadways posted at 80 km/h and above.
- It is preferable to have each crosswalk reach

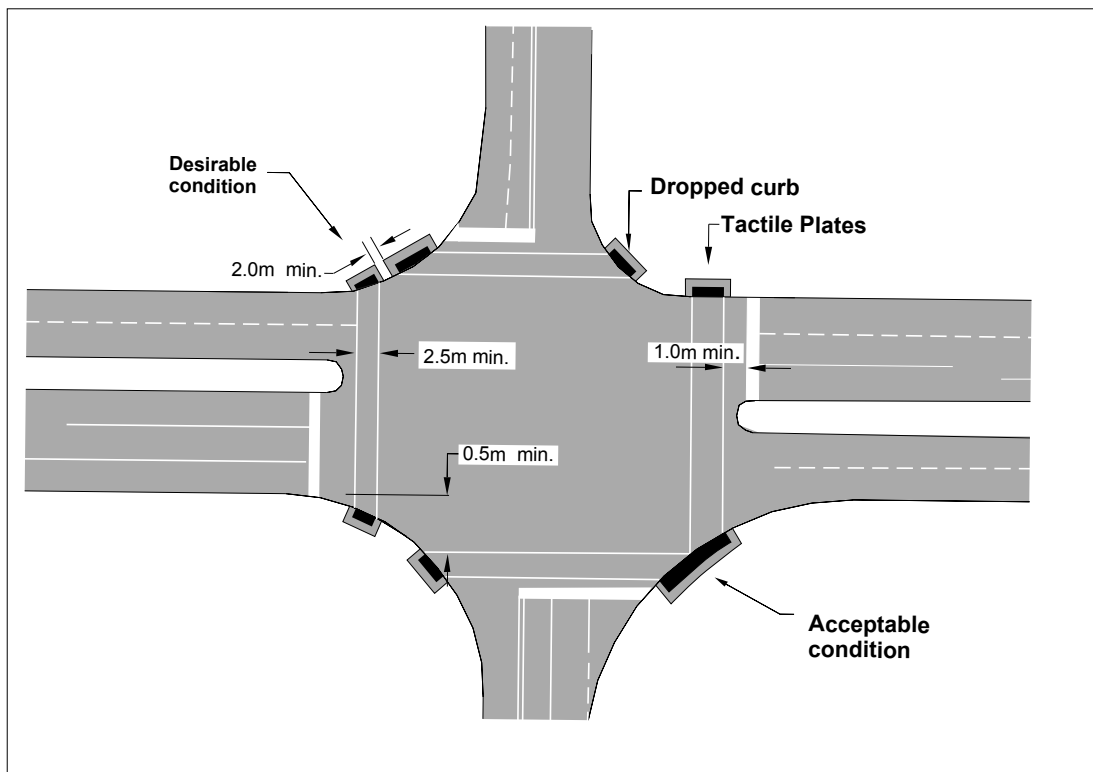


Figure 58 — Crosswalk Design

the far curb without intersecting with the other crosswalk across the other roadway. This layout directs pedestrians to the far sidewalk to await the other pedestrian signal instead of waiting near the curb in the pavement area.

- Where the geometry is difficult and the crosswalks tend to intersect in the turning flare, it is better to have the inner edges intersect at the curb than to carry each set of lines through each other.
- Crosswalks should line up with proposed sidewalks or dropped curbs.
- Where existing geometry is used, the edges of crosswalks should line up with existing poles to improve pedestrian signal head visibility and pushbutton accessibility.
- On roadways with posted speeds of 80 km/h or more, crosswalks should be placed in front of any median island to reinforce that the pedestrian should complete the crossing and not take refuge on the median island. Where a crosswalk does pass through a median island it is preferable that the crosswalk is flush with the pavement so as to ensure pedestrians with impaired vision do not get the impression they have completed their crossing at the median island.
- Consideration should be given to snow-covered roadways where crosswalk lines may not be visible. Wherever possible, crosswalk lines should be within the most direct route from sidewalk to sidewalk.
- Crosswalks should be as short as possible without compromising other design factors.

3. Sidewalks

The sidewalk and dropped curb designs should be coordinated with the road designer after

crosswalks and all other equipment have been designed. The following guidelines should be considered:

- The sidewalk approaches to the curb should fall within the edges of the crosswalks, not on the stop line, etc.
- Where possible, the pole footings (at least for poles with pushbuttons) should be flush with sidewalks or hard surfaces (sidewalk extension, asphalt, etc.).
- Where concrete or asphalt concrete sidewalks are not available, a finished surface such as asphalt should be considered for placement between the pedestrian pushbutton and other hard surfaces.

4. Integrated Design

Care in the placement of the crosswalk markings during the design can improve the intersection's appearance and operation. The dropped curbs and dropped sidewalk ramps should be shown on the roadway plans and must match up with the final pavement markings. Where sections of dropped curbs are separate but close together, the crosswalks should be separated sufficiently to allow a 2.0 m (desirable top-to-top distance) length of raised curb, as shown in Figure 58, or should be brought together with the inner lines meeting to eliminate the curb "bump".

The final markings must be coordinated with the road designers to suit pedestrian pushbutton and pedestrian head locations. It is sometimes necessary to revise median island designs to suit desirable crosswalk schemes while maintaining truck turning radii.

5. Large Radii

Very large truck turning radii may leave a large area of flared pavement. This flared pavement may

increase pedestrian walk time. The possibilities of installing a channelization island, as shown in Figure 59, should be investigated and discussed with the road designers.

A channelizing island removes turning traffic from the intersection, offers a pedestrian refuge area and provides a place to install a traffic signal pole. There are safety concerns associated with designing islands. Under the current legislation, it is difficult at best to provide for clear pedestrian right-of-way and vehicle-pedestrian conflicts can occur. Also, channelized right turns reduce pedestrian mobility. For channelized right turn lanes, crosswalk markings should be carefully considered as they may provide a false sense of security to pedestrians and violate driver expectancy as they are expecting free flow conditions. It is recommended that if channelized

right turns are used for accessing or exiting high speed roadways, consideration should be given to not install crosswalks on the ramp.

For posted speeds of 80 km/hour and greater, the minimum island size should be restricted to 10 m on any one side and should be large enough to obtain a minimum of 3.0 m offset to the pole from any side. For posted speeds of less than 80 km/h, the minimum island size should be restricted to 3.7 m on any one side. The island should be large enough to obtain a minimum of 1.5 m offset to the pole from any side (a 3.0 m offset is preferred if attainable). From an operational perspective, for roadways posted at 80 km/h and greater, a full right-turn channelized lane with adequate storage to remove all right-turning vehicles from the signal operation is preferred. A full acceleration lane for

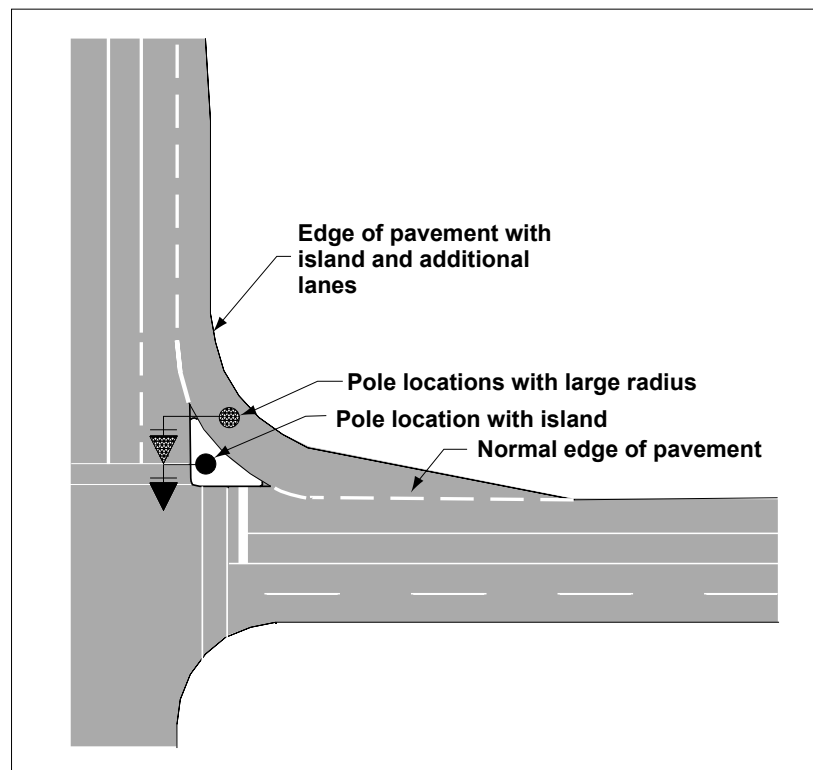


Figure 59 — Use of Right-Turn Island

proper and safe merging on the crossing road is also preferred.

5.11 Utilities

General

The designer must capture the temporary and final location of utilities that will be on site during traffic signal construction. The final locations may include existing utility locations (where relocations are not required for roadway purposes), relocated utilities, or combinations of existing and relocated utilities (as is normally the case if roadway construction is involved). The designer should not assume that utilities marked up from a field visit to the site are to remain in place throughout construction. As most intersection reconstruction projects alter the curb line and or pavement width, most pole lines require relocation, and will not be in the same location at the time of construction.

The road authority's utilities coordinator is responsible for arranging for the location, financing, and timing of utility relocations. The basic co-ordination is normally carried out shortly after grading cross-sections are available. This practice sometimes leaves little time for the designer to co-ordinate the traffic signal work.

The designer must review the final locations of all utilities, with special emphasis on overhead high voltage lines. In some cases, it may be necessary to re-open negotiations and arrange for mutually acceptable pole locations or power line heights. Many utilities have a right to be present on the right-of-way under the *Public Utilities Act*.

(This provision applies to hydro, telephone, sewerage and watermain works, and does not normally apply to natural gas or cable television.) Other utilities owned by the road authority, for example, fibre optic cable, should also be checked. The utilities must co-operate to find a location

satisfactory to the roadway authority. In most situations, locations that are satisfactory to both the utility and the road authority can be found. In many cases, the signal design must be adapted from the standard design to a compromise design.

Guidelines

The designer should be aware that some underground utility plans are not reliable. Many utility plans have not been updated to "As Constructed" status. Utility stake-outs are usually only reliable to within ± 1 m. With these approximations in mind, the designer has two options:

- Arrange for spot excavations. The survey of the exposed utility can be plotted on a plan. This approach is normally required for large and important utilities such as underground high voltage cables, fibre optic cables, and high pressure gas lines. Where the exact location of the utilities is known, signal equipment may be designed for 0.5 m clearance.
- Allow for 1.0 m minimum clearance between the utilities (including infrastructure such as storm sewers, sanitary sewers, watermains, and culverts) and the traffic signal equipment. Note that "Clearance" is to the side of the equipment, not the centreline.

High voltage lines (over 750 V) require a minimum clearance of 3.0 m for local distribution lines up to 44 kV, and larger clearances for higher voltages as defined in the requirements of CSA Standard C22.3 No. 1 M (see www.ccohs.ca/legislation/csa.html). Note that these regulations are enforced under the *Occupational Health and Safety Act*. For transmission lines, Hydro One must be notified. Hydro authorities can normally be employed to protect signal workers and equipment from high voltage lines during installation of traffic signals if it is necessary to work within the clearance zone.

All electrical work on a public right-of-way in the Province of Ontario is subject to inspection and approval by the Electrical Safety Authority (ESA) before energizing the electrical equipment. The traffic signal designer is advised to visit the ESA website to review the ESA requirements and standards (see www.esasafe.com).

Without exception, the designer should inquire as to the voltage present and should be prepared to design the traffic signals to meet or exceed the clearance requirements, or have the electrical utility carry out suitable relocations.

The following guidelines are suggested:

- Where possible, a plan layout should be developed by allowing a minimum of 5.0 m between horizontal centres of electrical pole lines and traffic signal poles. Where distribution cross arm construction exists or is planned, the clearance should be increased beyond that used for the normal standoff type insulators.
- As much clearance as possible is definitely desirable. Good practice suggests that traffic signal poles should be at least 5.0 m from overhead lines (as measured horizontally), or the power lines should be relocated so that the signal equipment can be mounted on the utility pole. In difficult situations, it may be possible to negotiate for an increase in the utility pole and line heights to clear the signal equipment, but in practice this approach is somewhat idealistic and difficult to achieve within congested right-of-ways.
- Where lighting is required, the designer should use the electrical utility poles if adequate luminaire mounting height can be negotiated.

With the exception of the electrical neutral, overhead low voltage lines are insulated. A minimum clearance of 300 mm is required to prevent rubbing of the insulation. In negotiating

with the electrical utility, it is desirable to try to have the neutral and any low voltage cables raised locally from the normal 8.0 m above grade to 9.5 m above grade (one pole length increment of 1.5 m) so that the neutral and low voltage cable locations are well above the tops of 7.5 m signal poles, and so that a lighting bracket attachment height of 10.3 m can be installed.

There is no requirement to maintain a clearance of greater than 150 mm from telephone or cable television lines. Efforts must, however, be made to arrange for these utilities to be raised if the cables will visually obstruct the traffic signal heads.

5.12 Layout Practice

General

In the drawings to follow (Figures 60-70), the “Standard” layout indicated is for an approach with Highway type heads and possibly advanced green arrow heads.

Guidelines by Example

The following examples are provided:

Figure 60	“T” Intersection Approach
Figure 61	Layout at Approach Without Median Island (Standard or Advanced Green)
Figure 62	Approach with Fully Protected Left Turn Heads and Without Median Island
Figure 63	Standard, Advanced Green or Simultaneous Protected/Permissive Lefts
Figure 64	Fully Protected Left Turn Approach With Median Island
Figure 65	Fully Protected Left Turn Approach With Wide Median
Figure 66	Fully Protected Dual LTL Approach
Figure 67	Ramp Terminal Intersection Approach
Figure 68	Short Offset Intersection
Figure 69	Long Offset Intersection
Figure 70	Layout of poles with Pushbuttons

“T” Intersection Approach

Figure 60 shows a typical “T” intersection with two-way traffic on the side road. Note the following:

- Standard Highway heads may be used.
- For safety reasons, the primary and secondary poles should be located clear of the edge of the projected through lane. The desirable setback is 3.0 m clearance for roadways posted at 80 km/h and over, and 1.5 m minimum for roadways posted at under 80 km/h.
- Double left or right turn lanes should not move simultaneously with conflicting pedestrian crossings.

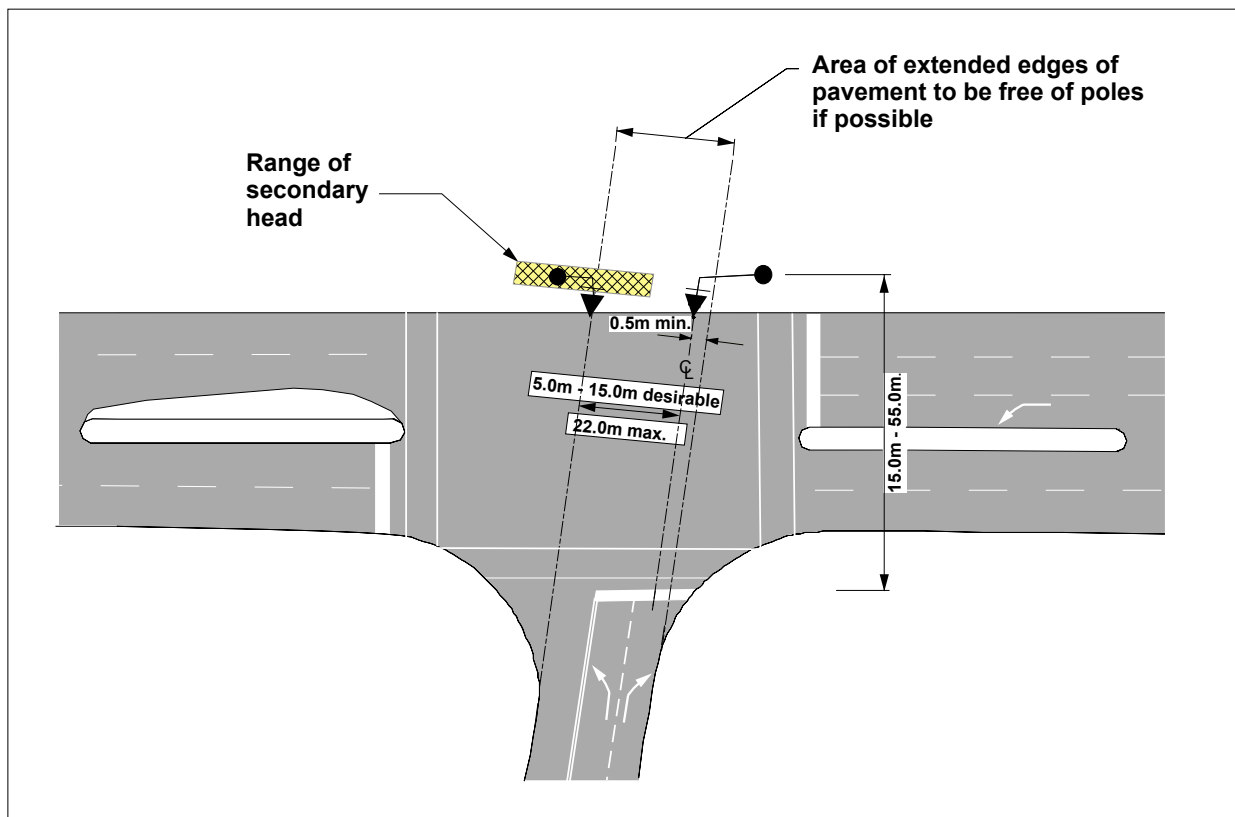


Figure 60 – “T” Intersection Approach

Approach without Median Island (Standard or Advanced Green)

Figure 61 shows a typical simple approach without a median island and with normal or advanced green indications. Note the following:

- There is no median pole and therefore the primary head should be at or close to the centre of the lane.

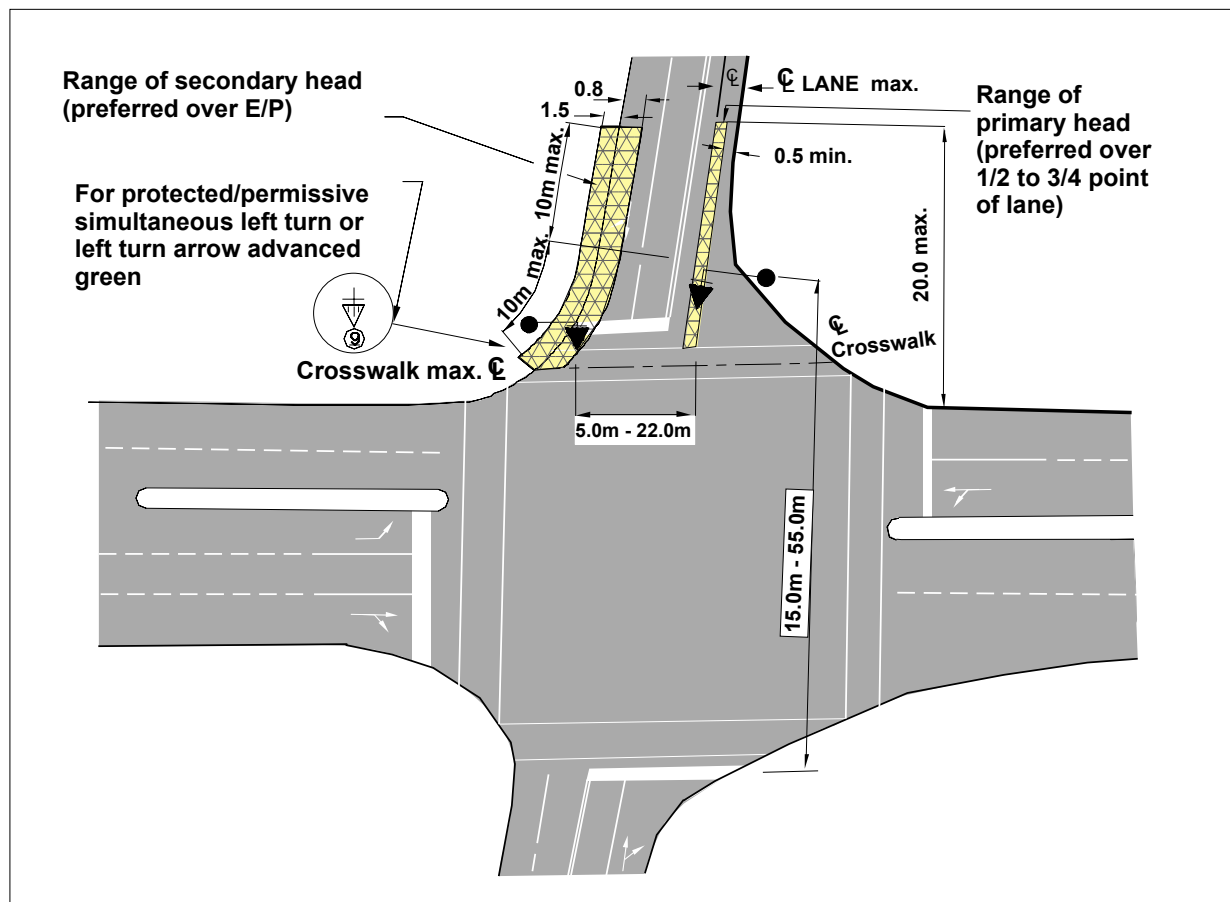


Figure 61 — Layout at Approach Without Median Island

Approach without Median Island (Fully Protected Left Turns)

Figure 62 shows a single lane left-turn approach without a median island and with fully protected left-turn indications. Note the following:

- This application is normally used only as an interim measure until the intersection can be reconstructed with islands.
- This application uses an aerial installation of the left-turn (type 2) heads because of the requirements for placing the primary left-turn head within the projected left-turn lane.

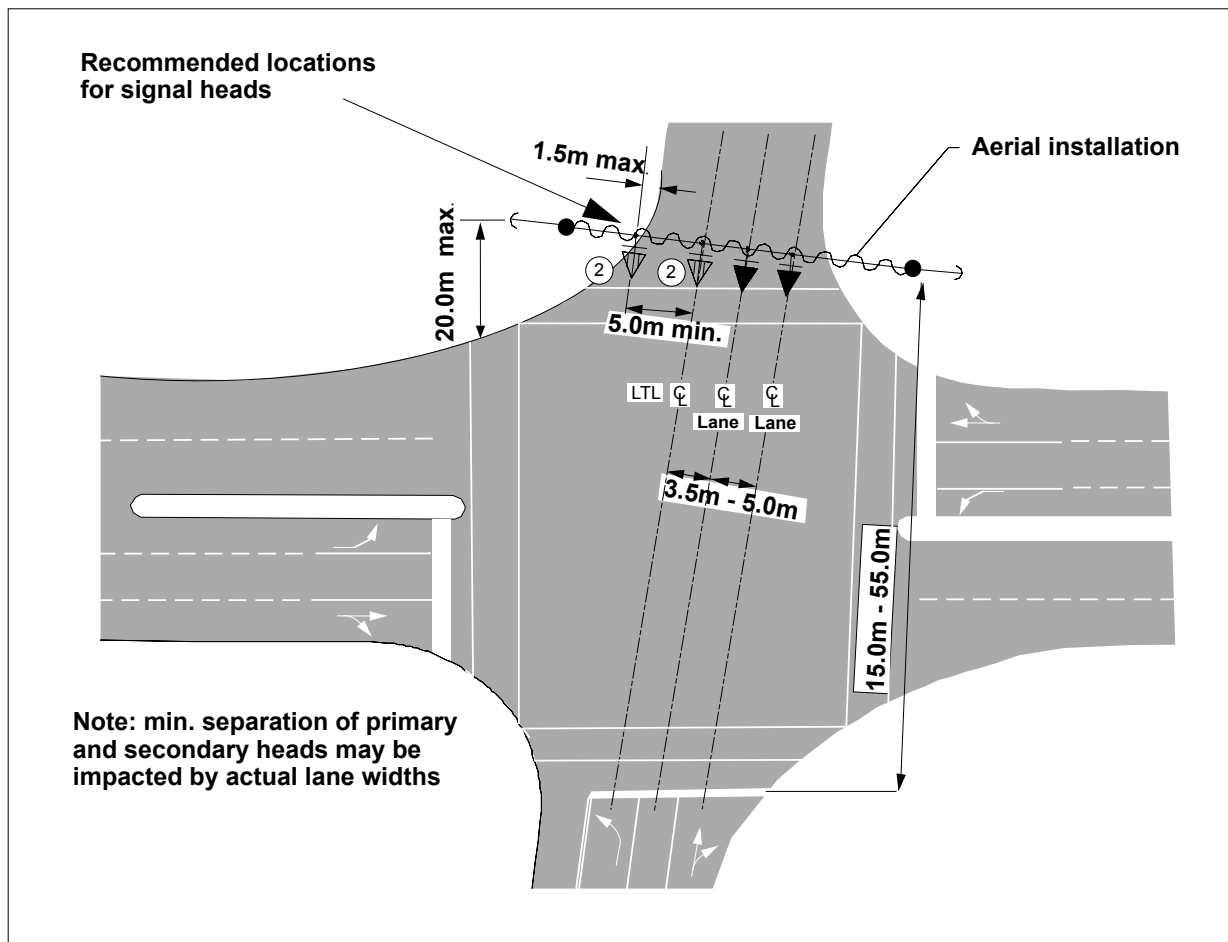


Figure 62 — Approach with Fully Protected Left Turn Heads and Without Median Island

Approach with Median Island (Standard, Advanced Green or Simultaneous Protected/Permissive Lefts)

Figure 63 shows two approaches. One approach has typical Highway heads. The opposing approach has a typical Highway head for the primary head, and a protected/permissive head using the type 8, 8A, 9 or 9A signal head in the median. Note the following:

- As recommended practice, the median (secondary) head is roughly over the edge of the through pavement. Standard mast arm lengths “S” depend on the narrow median width “W”.
- The combination of heads used does not allow for a protected north to west left turn. Simultaneous protected/permissive left turns are possible only where both median indications are type 8, 8A, 9 or 9A.

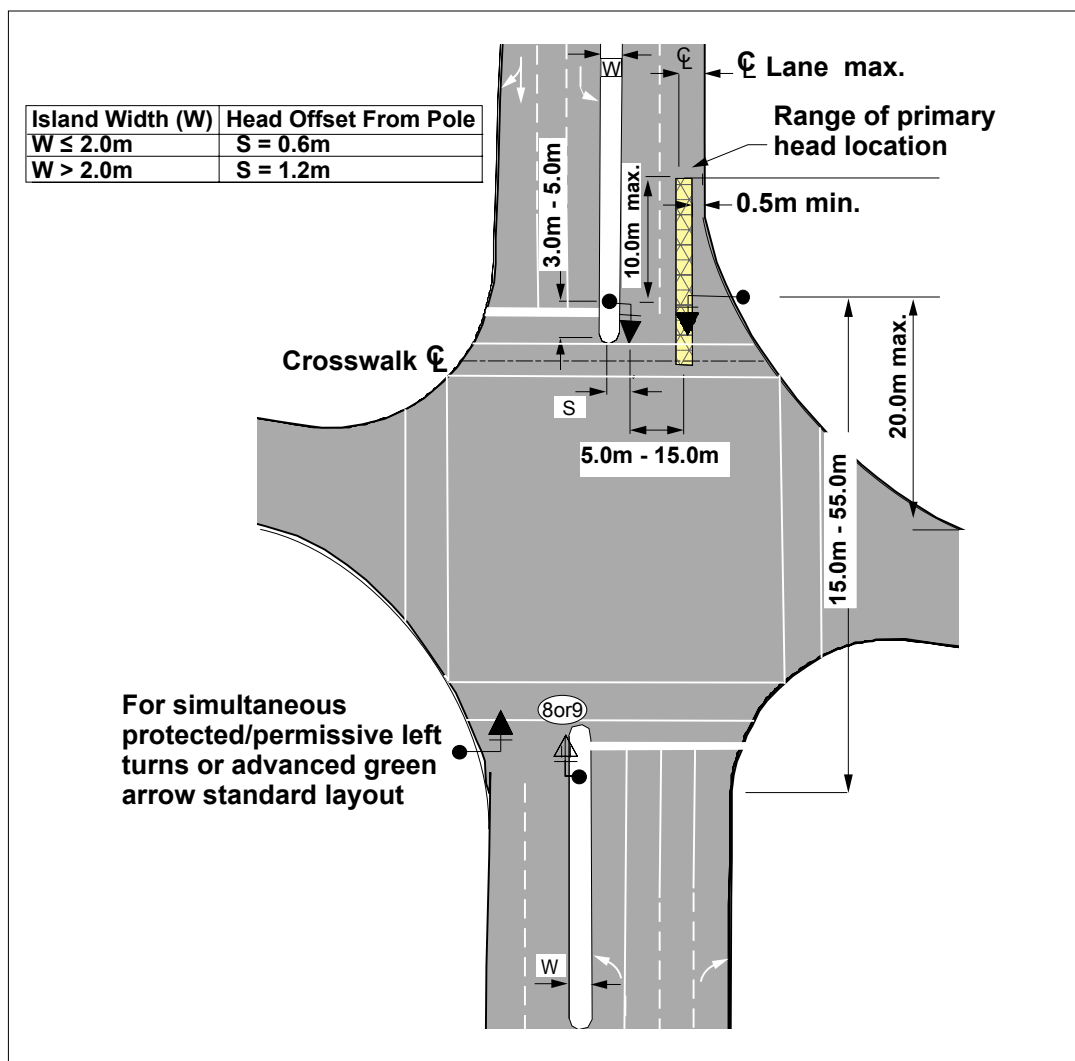


Figure 63 — Standard or Protected/Permissive Layout

Approach with Median Island (Fully Protected Left Turns)

Figure 64 shows a single lane left-turn approach with a median island and fully protected left turn indications. Note the following:

- The left-turn primary head is to be located only within the projected edges of the left-turn lane (LTL).
- The practical mast arm length “S” of the primary left-turn head depends on the narrow median width “W” and is normally 1.2 m.
- The primary left-turn head must be separated from the secondary through movement head by at least 2.4 m. The secondary through movement head must be separated from the primary through movement head by 5.0 m minimum and 15.0 m maximum.

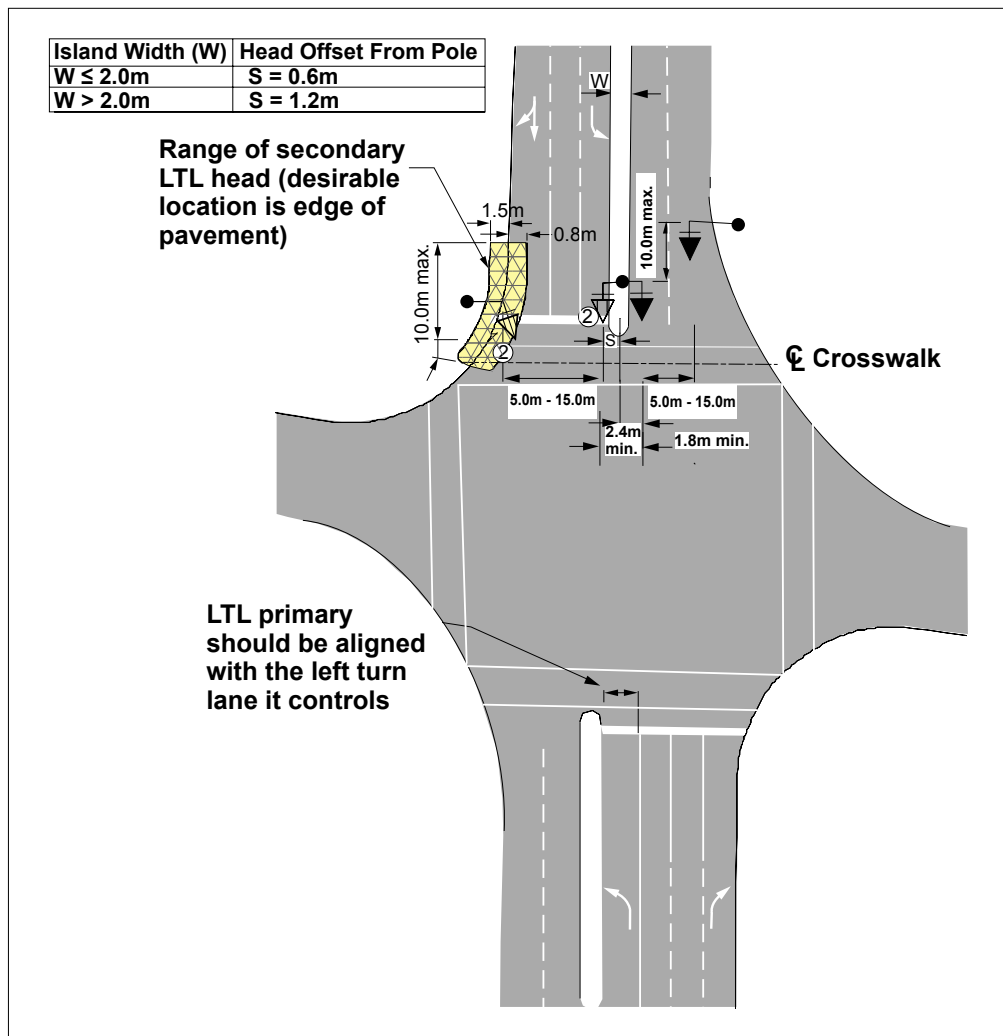


Figure 64 — Fully Protected Left Turn Approach

Approach with Wide Median (Fully Protected Left Turns)

Figure 65 shows a fully protected left turn layout for a wide median of between 2.0 m and 15.0 m. Note the following:

- The left-turn primary head, type 2, is to be located within the projection of the edge of pavement of the left-turn lane (LTL) and a point not more than the apparent end of the median island, as shown.
- A minimum separation of 3.0 m should be obtained between the LTL primary head and the through secondary head.
- The LTL secondary head should be over the edge of pavement by 0.8 m (preferred) and angled towards the LTL at the stop line or toward a point slightly upstream of the stop line.
- Where the median width exceeds 15 m, two sets of separate signals are required in accordance with Section 144 (2) of the HTA.

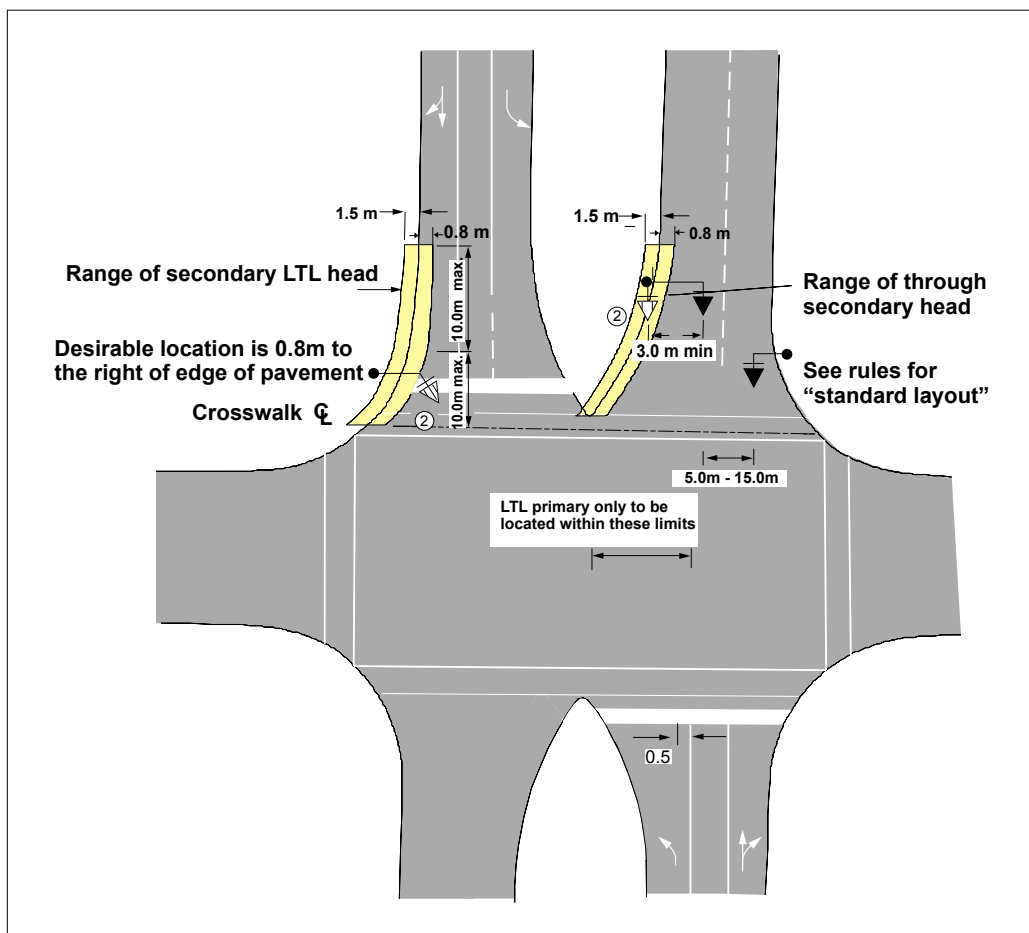


Figure 65 — Fully Protected Left Turn at Wide Median Approach

Approach with Double Left Lane (Fully Protected Left Turns)

Figure 66 shows a fully protected left-turn approach for a dual left-turn lane (LTL). Note the following:

- The mast arm length “S” for the LTL primary head depends on the median width “W” such that the distance between the LTL primary and the through secondary heads is a minimum of 2.4 m.
- The LTL secondary head should be over the edge of pavement by 0.8 m (preferred) and angled towards the LTL at the stop line or toward a point slightly upstream of the stop line.
- The dual LTL shall require pavement marked “Tracking” lanes for guidance of turning vehicles. For safety purposes, where a dual LTL faces a simultaneous dual left from the other direction, there must be sufficient room to separate the outer tracking marks by at least 3.0 m.

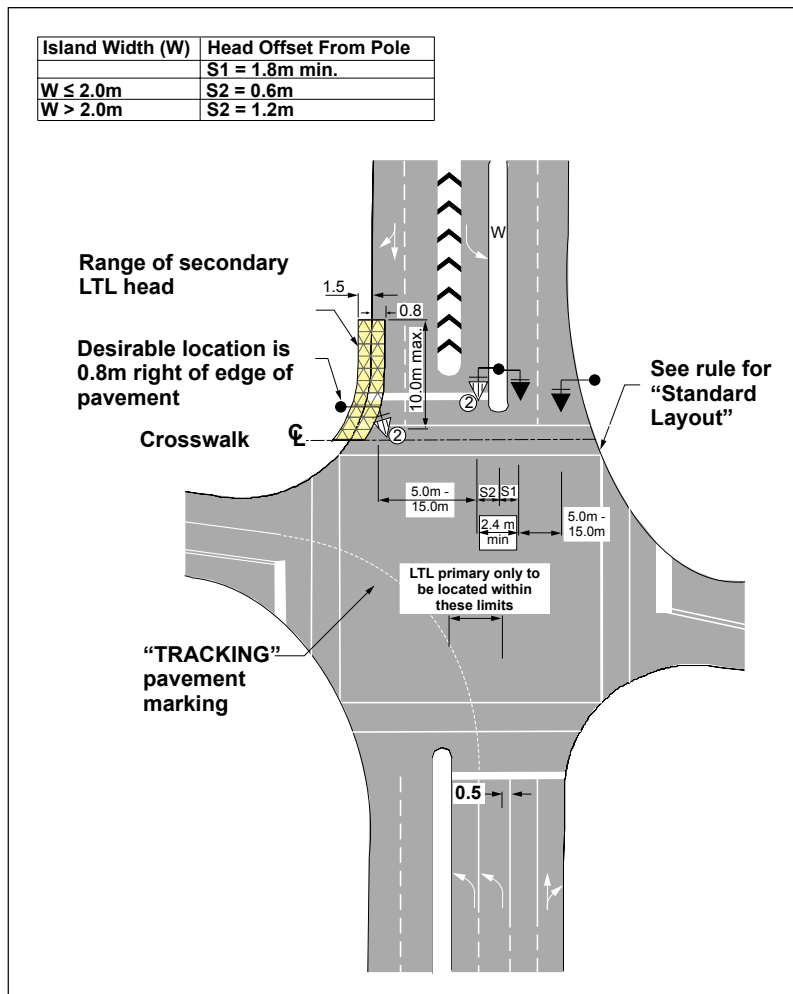


Figure 66 — Fully Protected Dual LTL Approach

Ramp Terminal

Figure 67 shows a full layout for a freeway ramp terminal on an exit ramp to an arterial. Note the following:

- The area between the extended edges of pavement of the ramp should preferably be kept free of poles.
- Typical Highway heads may be used on the arterial provided that proper signage for restricted turning movements is also used.
- Where turning traffic and pedestrian volumes allow, only one crosswalk should be used. It should be aligned on the approach where left-turning traffic from the ramp will not interfere with the crossing.
- Where a double lane left or right turn is allowed, the left and right turn lanes should not flow simultaneously with conflicting pedestrian crossings.
- The through lane primary and secondary heads on the arterial should be the type that indicates that no turns are to be made.
- Arterial secondary heads mounted on median poles require side mounted mast arms of at least 0.6 m length. This is because the islands are in direct alignment, and the near median poles may obscure front mounted heads.

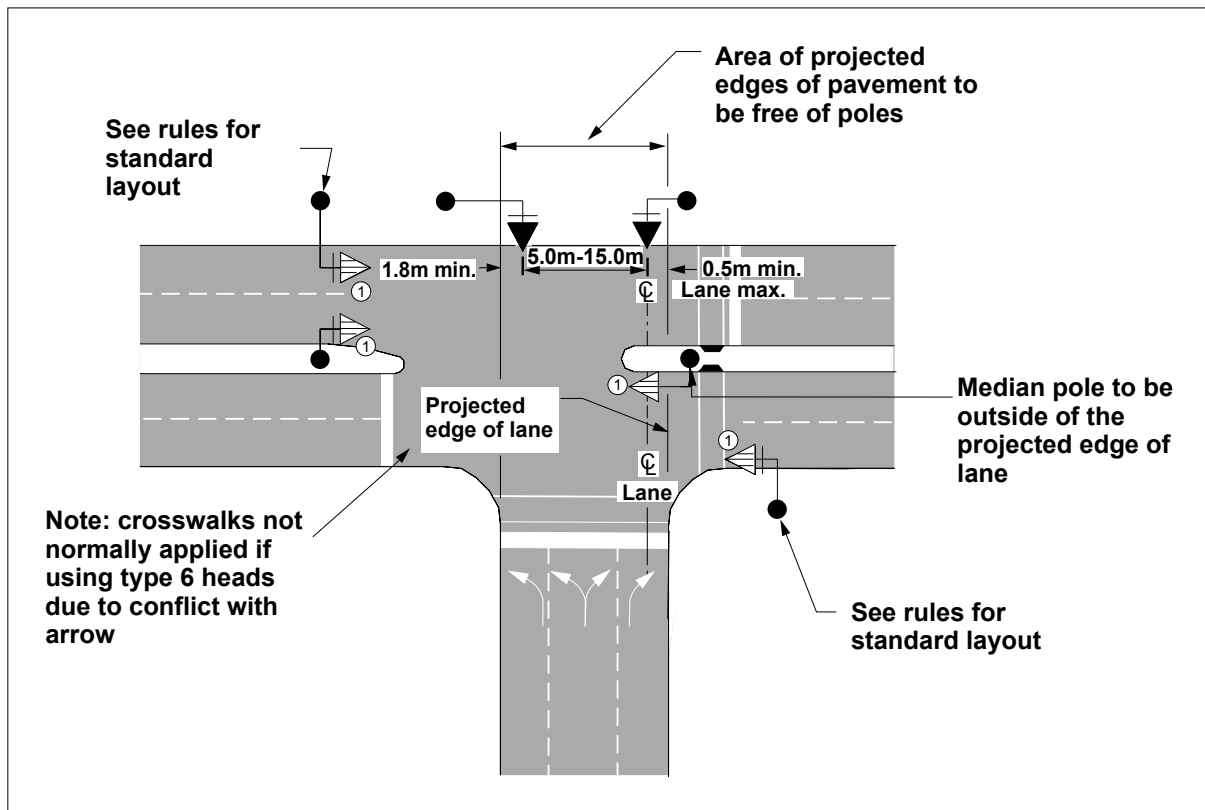


Figure 67 – Ramp Terminal Intersection Approach

Short Offset Intersection

Figure 68 shows a typical layout for a “Short Offset Intersection” where one side road is offset from the other. The configuration shown has been termed a “Far-right” offset because the side road on the right of either approach is farthest from the motorist. A “Near-right” intersection is the opposite with the side road on the right being nearest the approaching traffic.

When installing traffic signals at a short offset intersection, note the following:

- The distance between the side roads can be treated similarly to a wide median. The maximum median width of 15 m for a single set of signals can be applied.
- Pedestrian crossings in the middle, i.e., between the side roads, are not desirable (with normal phasing). The side road approaches are typically served on separate phases,

allowing pedestrian crossings between the side roads during one of the phases. If pedestrian crossings are prohibited on the other approach, the phase for the “No-crossings” approach can be kept to a minimum, and the cycle length kept as low as possible.

- For visibility purposes, the distance from the stop lines to a primary head is limited to a maximum of 55 m. If the distance is longer, the intersection is a “Long Offset Intersection”.
- Pavement marking “Tracking Lines” should be used to reduce motorist confusion.

When a vehicle turns left from either side road, the motorist is confronted by a red light on the arterial and there may be confusion as to whether to stop. Advisory signage does not appear to solve this problem. The designer is directed to City of Toronto’s paper “*Traffic Signal Control at Offset Intersections*”²⁶ for a more thorough treatment of the subject.

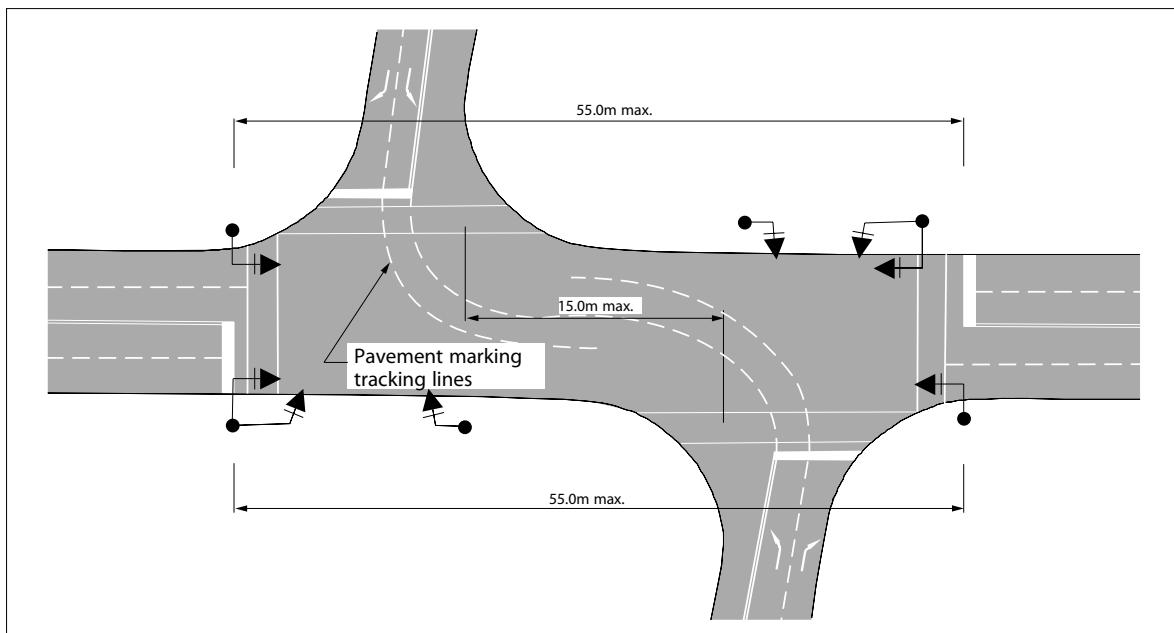


Figure 68– Short Offset Intersection

Long Offset Intersection

Figure 69 shows a typical layout for a “long offset intersection” where one side road is offset from the other, but the offset (although longer than that of the short offset intersection) is not large enough to present entirely independent intersections to approaching motorists. These types of intersections may be divided into “Far-right” (as shown), and “Near-right” where the first side road on the right is the closest to the approaching traffic. The design of traffic control signals at this type of intersection may create confusion because two sets of signals face motorists. Note the following:

- Pedestrian crossings in the middle, i.e., between the side roads, are not desirable unless phasing times permit the holding of turning traffic while pedestrians cross.
- As the maximum viewing distance of 55 m for the primary head from the stop line cannot be obtained, independent sets of signals are required.
- The distance “D” should be as long as possible (15 m minimum is suggested) to accommodate storage of trapped vehicles.
- If the distances to the next intersections permit some variation in signal timing, detection could be added in the lanes between intersections to extend the green or let the next phase activate.
- The use of optically programmable signal heads combined with signal timing may help to reduce the problem of driver confusion created by two sets of closely spaced signals. Optically programmable signal heads on the far set of heads can help to hide the far set of heads from the view of approaching drivers. Signal timing that provides the amber indication for the upstream traffic before the amber for the traffic between the offset legs may also help.
- A subtle solution for motorist confusion may be to paint the far set of signal head housings a different colour than those of the near side, e.g., black faces on the far set, and yellow faces on the near set.
- Where “D” is less than approximately 200m, it is difficult for the intersections to operate independently or in a system without coordinated timing, phasing, and efficiency. Refer to Metropolitan Toronto’s paper “*Traffic Signal Control at Offset Intersections*”²⁶ for a thorough discussion of problems and solutions.

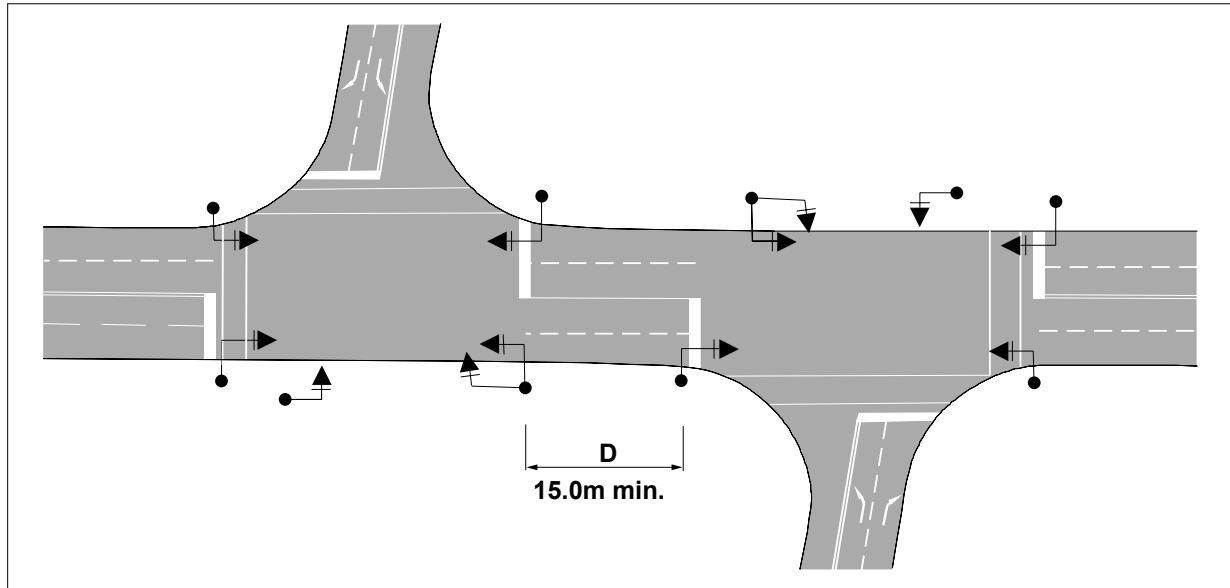


Figure 69 — Long Offset Intersection

Layout of Pedestrian Heads and Poles

General

To be effective, pedestrian heads must be easily noticed by pedestrians. This requires some standardization of pedestrian head locations with respect to crosswalks and sidewalks.

Where pushbuttons are used, the buttons must be compliant with the *Accessibility for Ontarians with Disabilities Act*, 2005, S.O. 2005, c. 11 and associated regulations.

Consideration should be given to placing all hardware in convenient locations that are accessible, but out of the travelled portion of sidewalk.

Curb ramps or depressed curbs must be used to make the crossings mobility device accessible and must meet the minimum requirements of AODA Regulation 191/11 Sub Section 80.26 or 80.27. Tactile walking surfaces must be installed that have tonal contrast with the adjacent surface and be installed at the bottom portion flush with the roadway. These tactile surfaces must be set back between 150 mm and 200 mm from the edge of curb and must be a minimum of 610 mm in width.

Poles with Pushbuttons

Figure 70 illustrates the principles that apply to the location of poles with pushbuttons. Poles with pedestrian pushbuttons/APS pushbuttons should be located in accordance with the following guidelines:

- If possible, poles with pushbuttons should be within the extended crosswalk lines. If this is not possible, the poles should be located within 1.5 m of the edge of the crosswalk being served.

- The poles should be located directly adjacent to, or within, sidewalks or other hard surface areas.
- The poles must be accessible and user friendly. They must not be located beyond reach behind barriers, or in grass (mud) areas, or in areas where snow windrows will occur. Some additional sidewalk or paved shoulder may be required.
- If AODA requirements can be met, it is desirable that APS pedestrian pushbuttons be mounted on traffic signal poles. Where a separate pole is required, the pole should be installed near the intersection of the centre lines of the crosswalks and should include the pedestrian heads to avoid visual clutter. If this treatment is not possible, a short pole with APS pushbuttons only may be used.
- Where a separate pole is required, consideration should be given to locating it at least 6.0 m from other poles to allow room for maintenance vehicles to operate and also for aesthetic reasons.

Poles with Pedestrian Heads

Poles carrying pedestrian heads should be located in accordance with the following guidelines:

- Ideally, pedestrian heads should be located within the extension of the crosswalk lines or at a maximum of 4.5 m laterally from these lines.
- The poles should be located so that standard 38 mm dia. x 400 mm double arm brackets can be used for the pedestrian heads. The use of mast arms longer than 600 mm with hangers is discouraged (unless unavoidable) because of interference with maintenance vehicle operations.

- Pedestrian heads can be mounted on primary, secondary, or auxiliary poles as long as the heads are not more than 10.0 m longitudinally from the end of the crosswalk (see Figure 70).
- The designer should ensure that the pedestrian heads will not be visually blocked by vehicles at the stop line.
- Mounting pedestrian heads on the side of the pole nearest the pavement invites damage by errant large turning vehicles, snowplows, etc.
- The addition of pedestrian heads to poles that support other uses may require re-adjustment of the previously designed locations of these poles or even minor adjustments to sidewalk and crosswalk designs (for new construction only, not rehabilitation projects).

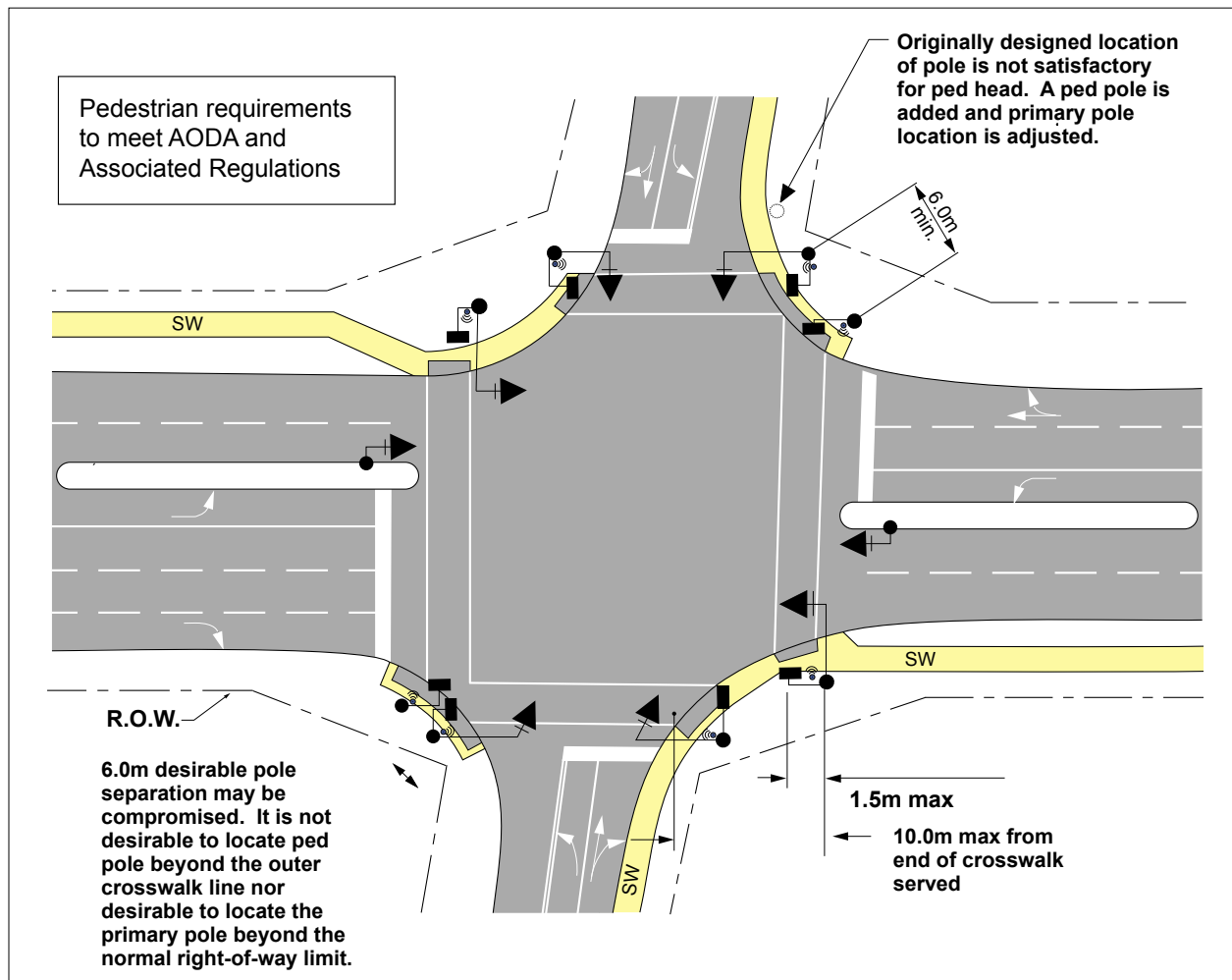


Figure 70 — Layout of Poles With Pushbuttons

5.13 Controller Locations

Coordination

The location of the traffic signal controllers may require grading, re-routing of ditches, etc. Co-ordination with the road designer is required. For detailed information on controller location design, refer to the Ministry's Electrical Design Manual.⁴

Physical Requirements

Locations for controller cabinets must be designed with due consideration to safety, maintenance access, visibility of approaching traffic, service supply, grounding, and electromagnetic interference. The following general guidelines apply:

- Where possible, controller cabinets should be located on the “Far-right” corner of the main road at the intersection. This location gives persons standing at the controller the best view of approaching traffic from both ways along the main road.
- Ideally, the head displays for 50% of the phases should be visible while standing at the controller.
- Where barrier or guiderails are not present, it is desirable to locate the controllers at a location that meets the clear zone requirements in the Ministry's Roadside Safety Manual²⁴ from the edge, or projected edge, of through lanes. Note that on road construction or reconstruction projects, it is sometimes necessary to modify the grading and drainage design to accommodate this requirement.
- Controllers should not be mounted on slopes steeper than 6:1 nor at an elevation difference of more than 1.0 m from the pavement.
- If possible, access to controllers should be directly off the shoulder or boulevard, without crossing ditches, berms, walls, etc. Where road work is included in the contract, widening of the shoulder area with earth and granular materials should be arranged with the road designer.
- Controllers should be located at a minimum distance from the ground electrodes at the supply points.
- Controllers must be located at a minimum distance from overhead high voltage wires to mitigate electromagnetic field interference.
- It is undesirable to have controllers, supply poles, and primary poles in clusters in locations where they can be hit by an errant vehicle. In some locations, controllers may be sited at the proper offset distance from the edge of the pavement and immediately adjacent to the sidewalk.
- In congested urban areas (posted at 70 km/h or less), minimum clearances of 3.0 m from the edge of the pavement are desirable. If this is not practical, controllers should be located as close to buildings as practical, leaving at least a 1.5 m wide sidewalk area. The controller locations should be clear of doors and store-front windows and located outside the clearway for pedestrian travel.
- Controllers to be installed on poles should be provided with hard surfaces at grade so that they can easily be cleared of snow and can be maintained and serviced without muddy conditions.
- Controllers to be installed at ground level should be provided with concrete pads and concrete or metallic pedestals to raise the bottoms of the cabinets above ground and out of the snow. (A 225 mm minimum is suggested, more in snow belts.)

5.14 Design Example

General

This section presents a design example for a typical intersection. The is in a detailed format and is intended to illustrate the principles of traffic control signal design. The example should not be applied to any specific intersection as each intersection has its own idiosyncrasies.

The example is an intersection that is to be reconstructed under a roadway contract, but the principles are equally valid and applicable to an existing intersection that is to be signalized. Practitioners are reminded to review Section 2 for guidelines regarding legal approval requirements.

Preparation of Base Plan

This section emphasizes the importance of the proper preparation of the base plan on which the signal design will be overlaid. The steps necessary to produce the base plan are as follows:

- Obtain the base plan and proposed alignment from the road designer. The plan should be complete with existing and new edges of pavement, islands, sidewalks, right-of-way, and limits of paving (existing conditions preferably differentiated from proposed conditions). It is not desirable to have other road design notes such as “Limit of Construction”, nor items such as side slopes, drainage, or other roadway specific design features on the signal design plan. It is, however, convenient to have limiting factors such as ditches on the plan.
- Obtain the locations of all existing utilities from the road designer or from the utilities coordinator. Obtain any known utility relocation proposals or obvious relocations required at this time (utility locations must be staked and verified during construction).
- Where applicable, obtain the details of the existing signal system from previous contract drawings, signal drawings or legal approval drawings.
- Carry out a site inspection with appropriate stakeholders, including the local power supply authority and the utilities coordinator. At this meeting, attempt to establish the basic routing of the final overhead electrical lines, the possible locations of power supply points, whether metering is required, whether utility pole mounting of the power supply cabinet is allowed, and whether any special details are required by the local supply authority. Try to determine the location of future utility poles that could be used for mounting signal arms. Note that final decisions are not usually possible at this time, but a good basis for the preliminary layout can normally be obtained for further coordination.
- Note that if the project is for the installation of the traffic control signals only, the depths of the utilities may also be indicated on the plan.
- Plot all information accurately (to scale) on the base plan.
- The base plan, showing existing features, utilities, and relocations will be similar to the plan shown in Figure 71.

Note that it is the policy of some road authorities to have utilities relocated before construction. As the road/signal contractor is not usually on site when the utilities are being relocated, the relocation of the utilities may require prior relocation of the power supply cabinet and even minor relocations of the pole or mast arm by the electrical maintenance staff or by the pre-construction contractor. It is the designer’s responsibility to prepare a sketch and outline of the work required and to bring these items to the attention of the roadway project manager and the person in charge

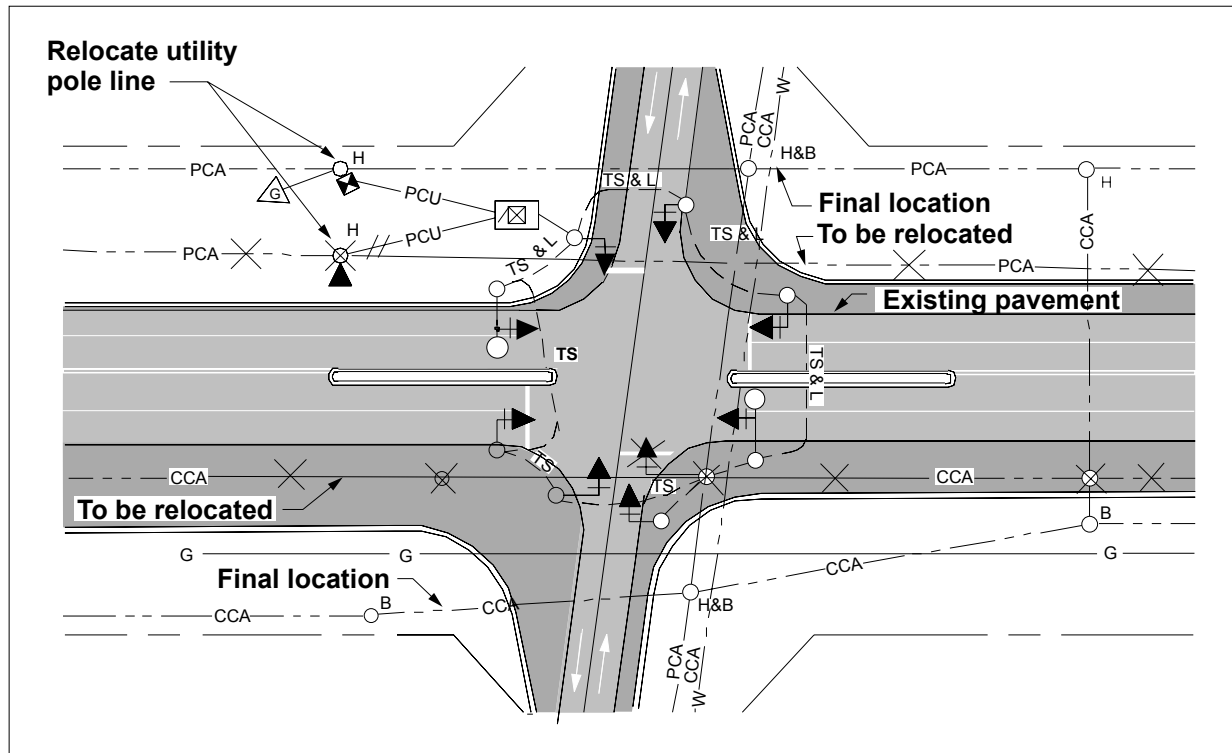


Figure 71 — Base Plan Features

of electrical maintenance so that appropriate arrangements can be made for the work.

If the existing equipment is left in place as an interim measure, relocations may not be required.

Layout of Crosswalks and Sidewalks

The first step in the actual signal layout design is to lay out or confirm the locations of crosswalks, and to confirm or suggest the location of sidewalks. This section uses the principles given in Subsection 5.10 to discuss the layout of the crosswalks and sidewalks.

Figure 72 shows the layouts required and some suggested modifications for the sidewalk design. Note that the locations of the crosswalks and sidewalks are preliminary and remain to be

coordinated with road designers. The signal layout must be undertaken to confirm the most desirable sidewalk layout. A signal layout should also be prepared for cases where only signal provisions are to be installed.

Pole Locations

This section deals with locations where it is impossible or impractical to install traffic signal equipment. Poles are most prone to location restrictions due to the depth of the footings (possible interference with underground utilities) and the height of the poles (possible interference with overhead utilities).

It is important for the designer to recognize restricted areas at all stages of the design. It is suggested that the restricted pole locations be

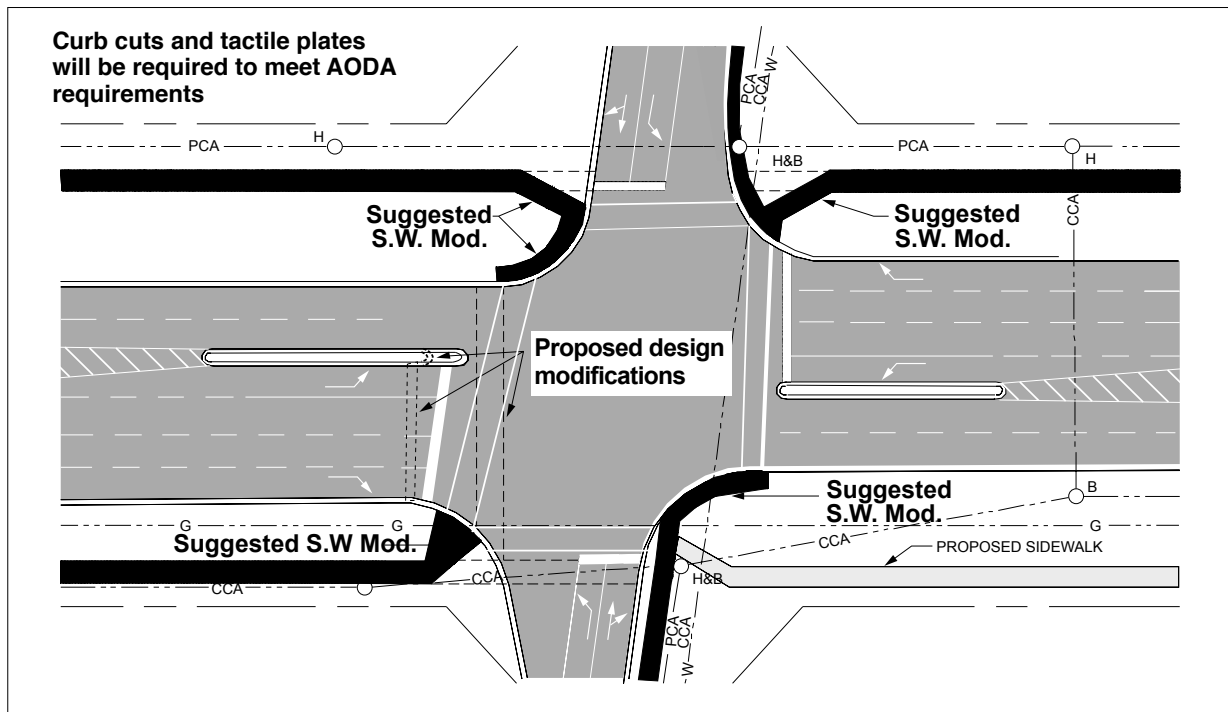


Figure 72 — Crosswalk and Sidewalk Modifications

plotted directly in the working drawing before beginning the layout. Note the following:

- Utility clearance rules should follow the rules given in Subsection 5.11.
- The range of restricted pole areas should follow the information given in Section 5.6.

Figure 73 shows the example working plan with utility restrictions marked.

Pre-Set Head and Pole Locations

This section deals with signal head and pole locations, and follows the guidelines given in Subsection 5.3. The signal heads and poles are the first to be pre-set in any design. Figure 74 shows the standard locations where signal head and median poles should be placed.

Layout of Primary and Secondary Heads

Using the principles given in Subsections 5.6 and 5.12, the primary and secondary heads and poles are laid out as shown in Figures 75 and 76.

Layout of Pedestrian Facilities

Using the principles given in Subsection 5.12, pedestrian facilities are laid out as shown in Figure 77.

Pole locations may need to be adjusted and additional poles and or pushbutton poles may need to be added to ensure the AODA requirements are met. In addition, there may need to be an adjustment to the crosswalks to fit with pole placements.

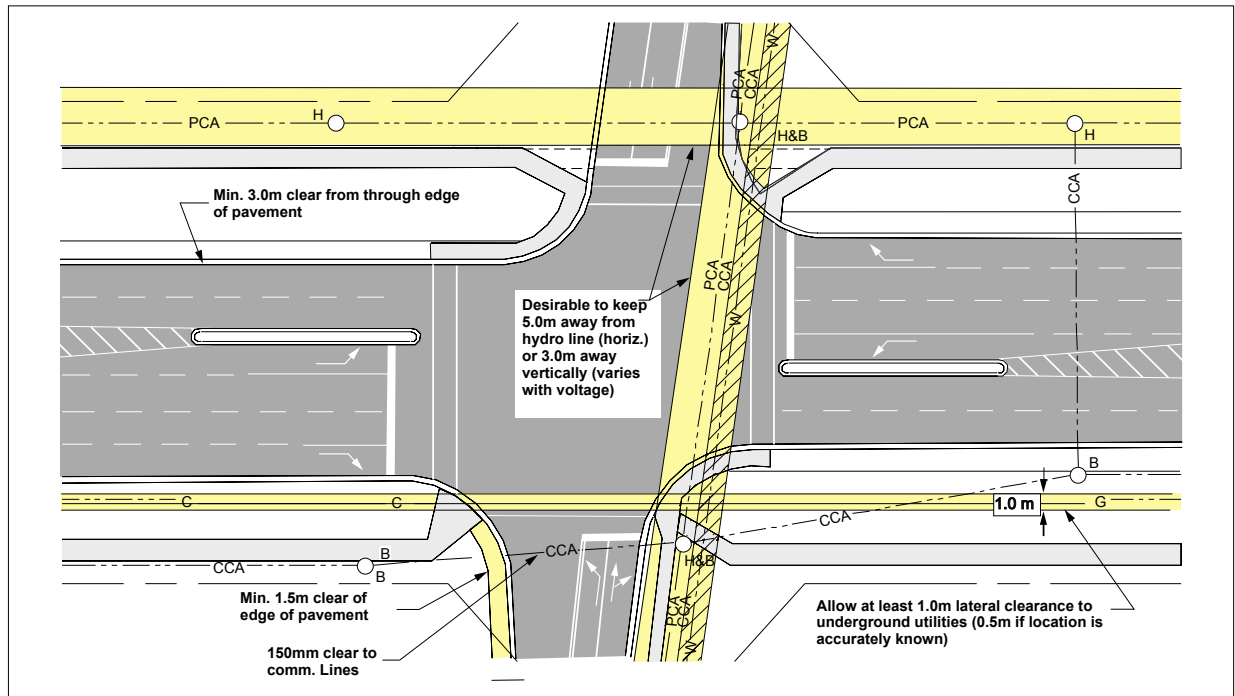


Figure 73 – Pole Locations Restricted by Utilities

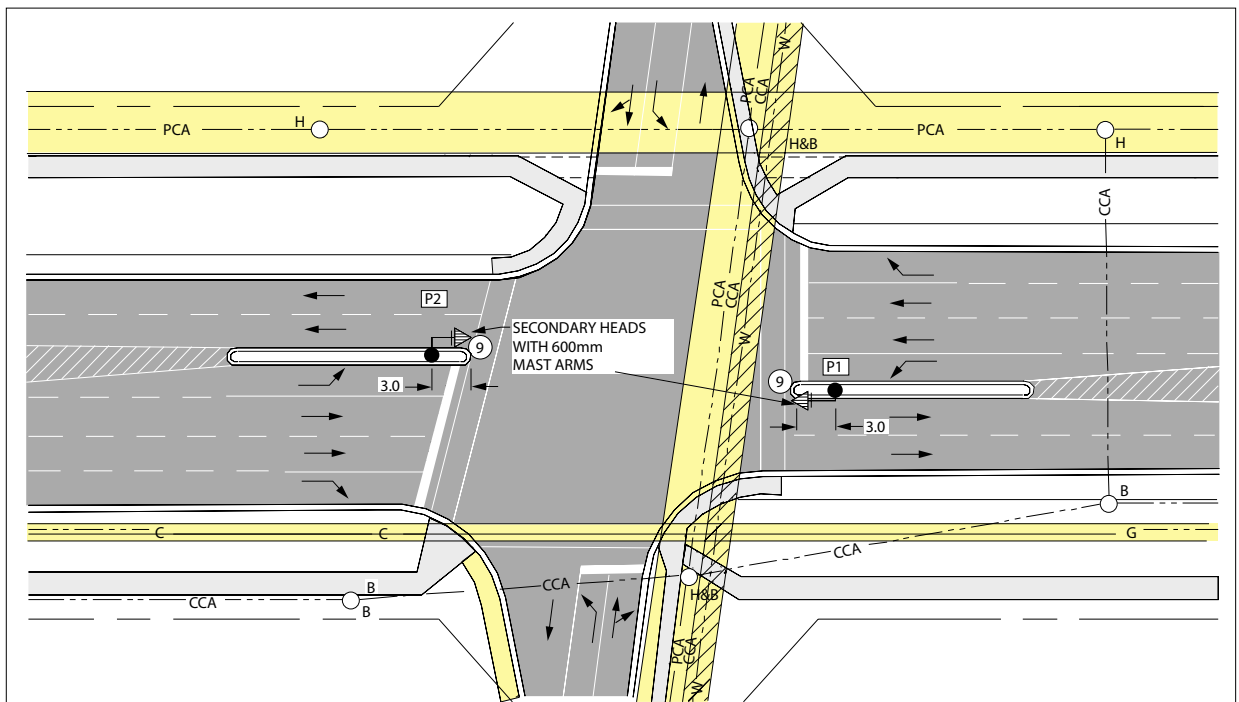


Figure 74 – Pre-Set Signal Locations

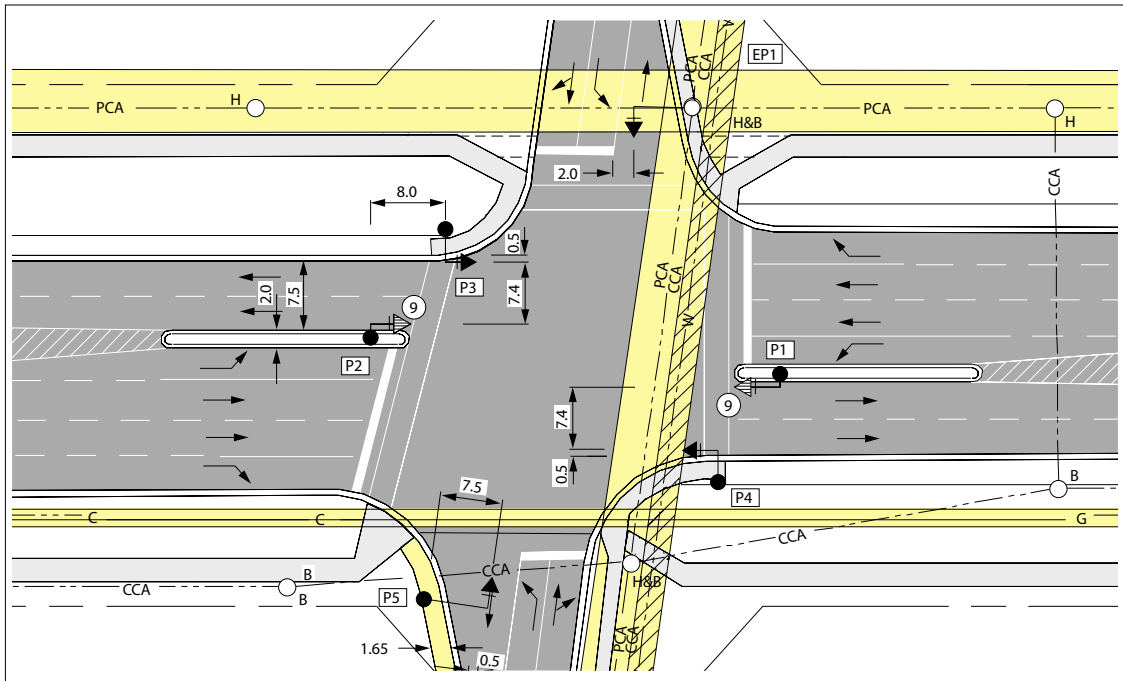


Figure 75 – Primary Head and Pole Layout

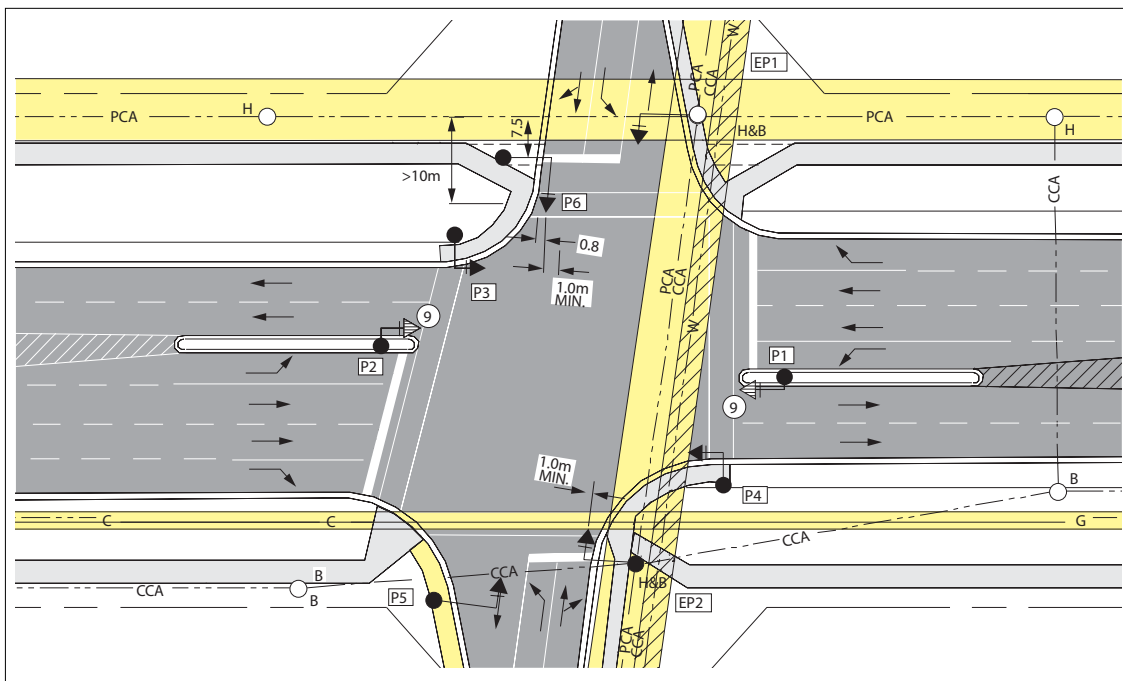


Figure 76 – Secondary Head and Pole Layout

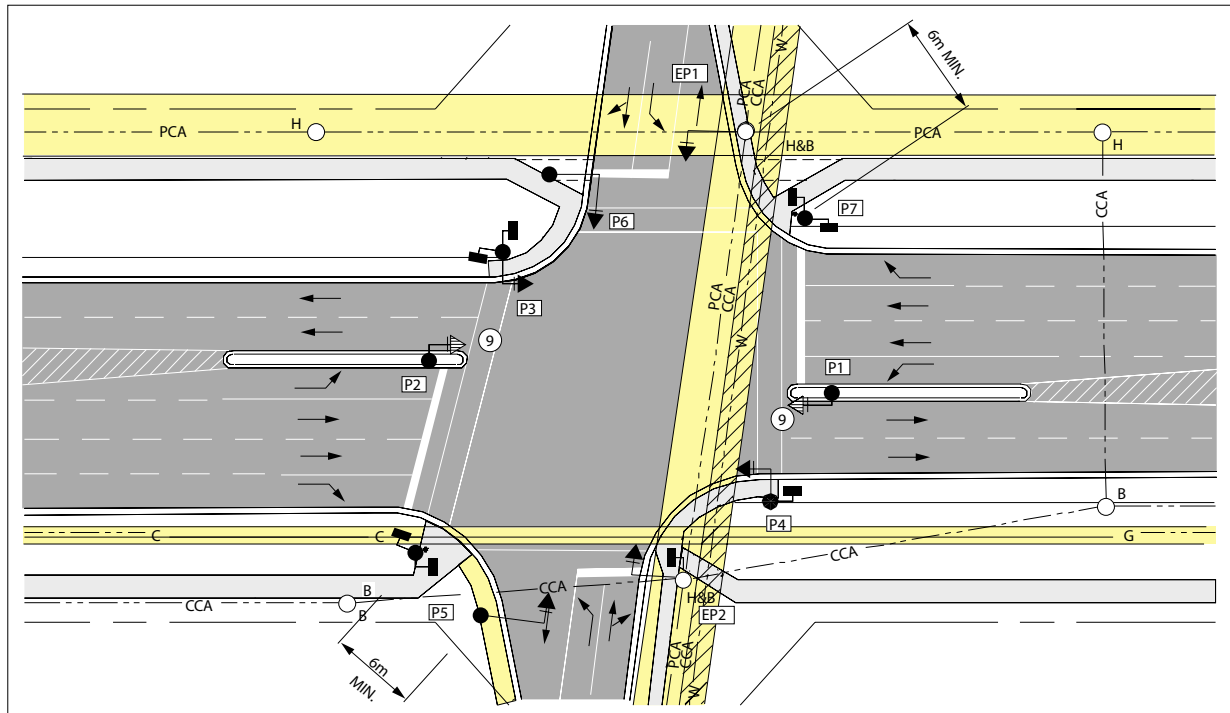


Figure 77 – Layout of Pedestrian Facilities

Checking Layout

Figure 78 shows the checking of the layout design. Checking of the layout follows the principles given in Subsections 5.5 and 5.12. Figure 78 shows how the cones of vision should be checked to ensure that there are no blocked signal heads. The distances between heads and the pedestrian facilities should also be checked for conformance with the principles given in Subsection 5.12.

A checklist is provided in Appendix D.

Controller and Power Supply Locations

The controller should be located in accordance with the following principles:

- Strict attention should be paid to the principles of good grounding and relative freedom from interference from overhead hydro lines as given

in Subsection 5.11. Additional details listed in the Ministry's Electrical Design Manual.⁴

- In areas of 80 km/h posted speed or greater, a controller offset of 10 m from the through edge of pavement is desirable. A 6 m offset is acceptable. As the controller location often interferes with ditches (the roadway should be visible from the controller site), coordination with the road designer is required (see Subsection 5.13).
- Electrical maintenance and traffic staff should be consulted as to their preference for cabinet orientation. Some prefer the front door to face oncoming traffic, and some prefer to stand at the front door and face the intersection. Unless local policies dictate otherwise, the recommended location is at a 45° angle to the intersection, as shown in Figure 79.

- The location of the power supply pole has some bearing on controller location. To reduce the possibility of a double pole knock-down in a vehicle collision, it is desirable to have the power supply 75 m or less from the controller and the controller more than 11 m from the power supply pole.
- Separate ducts are required between the connection point and the controller where interconnection or traffic control system communication cables are used.
- The power supply cabinet should be located in accordance with the following principles:
 - The cabinet may be mounted within a ground mounted pedestal designed for a traffic signal controller. Standard communications pedestals are not strong enough for this application.
 - The cabinet may be mounted on a utility pole if the local Power Supply Authority permits. It is preferred that the utility pole not have a transformer as the transformer ground can cause interference with the power supply ground. The local Supply Authority should be requested to install their grounds at least one pole span away. See the Ministry's Electrical Design Manual, Part 2, Chapter 9, "Grounding"⁴.
- The power supply cabinet should be within 75 m of the controller and should be visible from both the controller and the roadway. The cabinet should also be located at least 10 m from the edge of pavement if possible.

the Ministry's Electrical Design Manual, Part 2, Chapter 2, "Vehicle Detection".⁴

Figure 80 shows the detectors laid out for the example intersection. Note that there are two ways to number the detectors. One method numbers the detectors clockwise beginning at the controller (as shown). This method corresponds with that used in some asset management system software. An alternative method uses the numbers of the phase movements served, and A, B, C, etc. for multiple detectors serving a single movement common to the lanes involved.

Detector Layout

Detectors are laid out as shown in Figure 80 for presence detection. On roadways posted at 80 km/h and over, extension detectors for the dilemma zone are laid out as per Table 27. The detectors are designed using the principles of

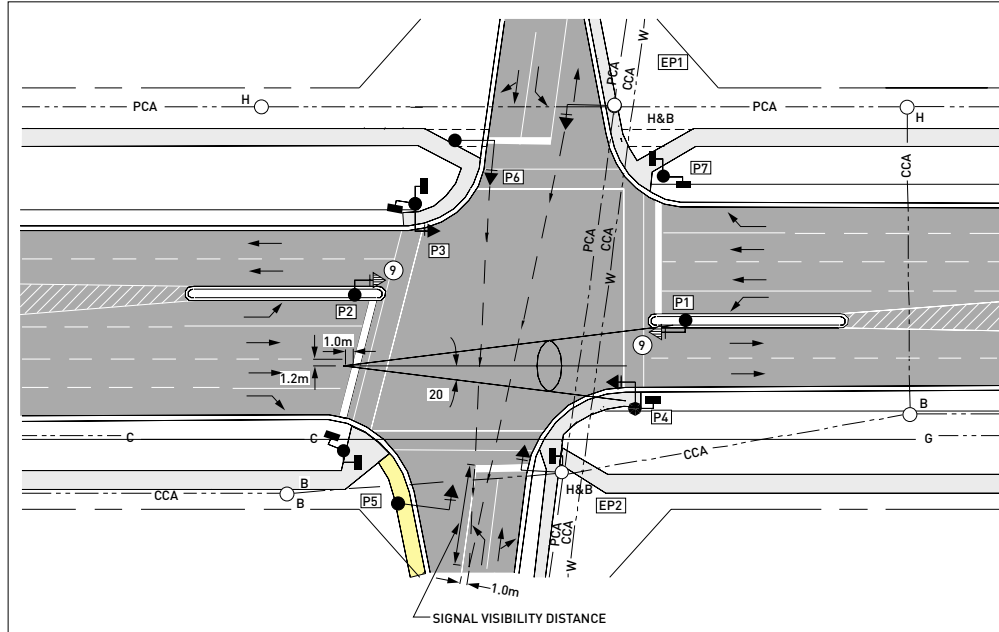


Figure 78 – Checking Signal Head Visibility and Layout

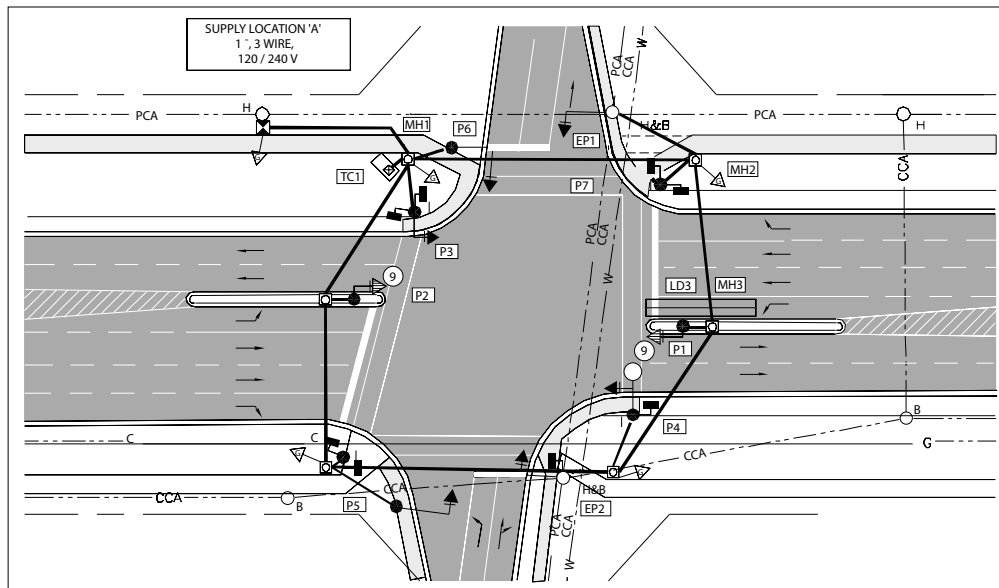


Figure 79 – Controller and Power Location

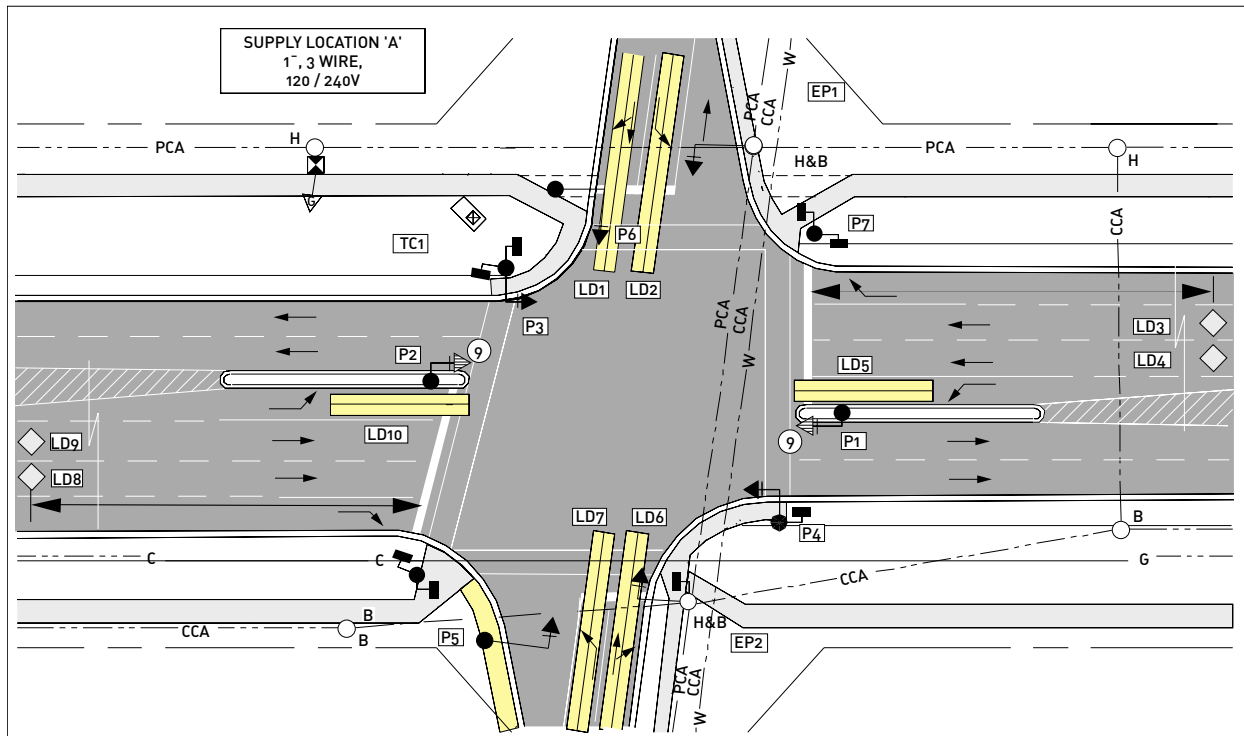


Figure 80 – Detector Loop Layout

Duct and Wiring Systems

Careful consideration must be given to the design of the underground ducts and electrical chambers. Careful consideration is required due to the high costs of underground ducts and electrical chambers, and the possibility of prolonged traffic interference, utility interference, and damage to roadbed structure caused by their installation or failure.

Underground ducts and wiring are not prone to damage from over-height vehicles and are aesthetically preferable to overhead wiring.

Figure 81 shows the underground system designed for the example intersection.

Coordination of Lighting Design

Roadway lighting is required at all signalized intersections. Either partial or full illumination will be required, depending on roadway and traffic conditions. Roadways at isolated rural intersections require at least two lighting luminaires to provide partial illumination. The lighting system should be integrated with the signals according to the following principles:

- Install the lighting on combination signal and lighting poles where possible. Utility poles may also be used if the supply authority allows this.
- All lighting on combination poles should be controlled from a combination power supply cabinet.

- Different voltages and different sources of supply are not allowed by the Ontario Electrical Code without multiple provisions.
- A #6 system ground for the signal pole interconnection is recommended to serve as the lighting system ground. The ground cable must be insulated to conform to the Canadian Electrical Code.

Figure 82 shows a typical partial lighting layout combined with the signals for the example. Partial lighting should be installed on the main road primary signal poles of each approach. The lighting is typically integrated on a combination or joint-use pole with the signals as indicated in Figure 82. Note that a small adjustment in the pole locations may be required to obtain the proper lighting and clearances. Otherwise, separate poles may be installed provided they are a minimum of 6 m from the signal poles and clear of utilities.

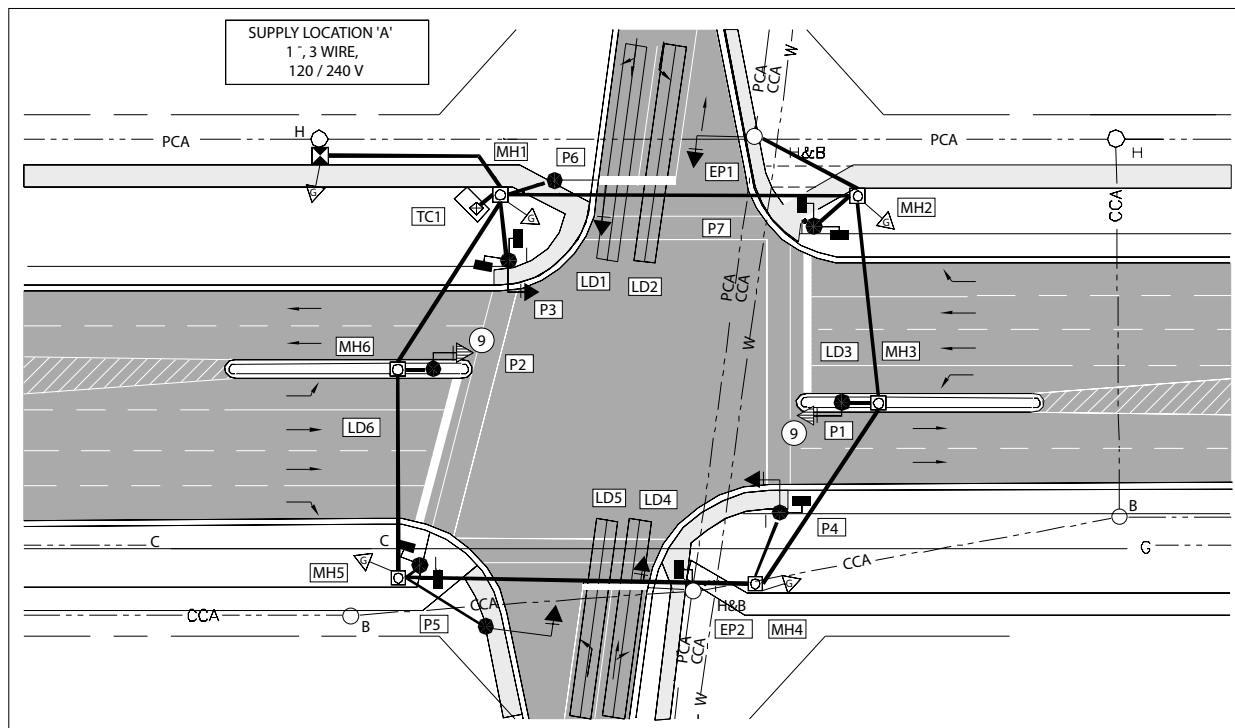


Figure 81 – Underground Duct System Layout

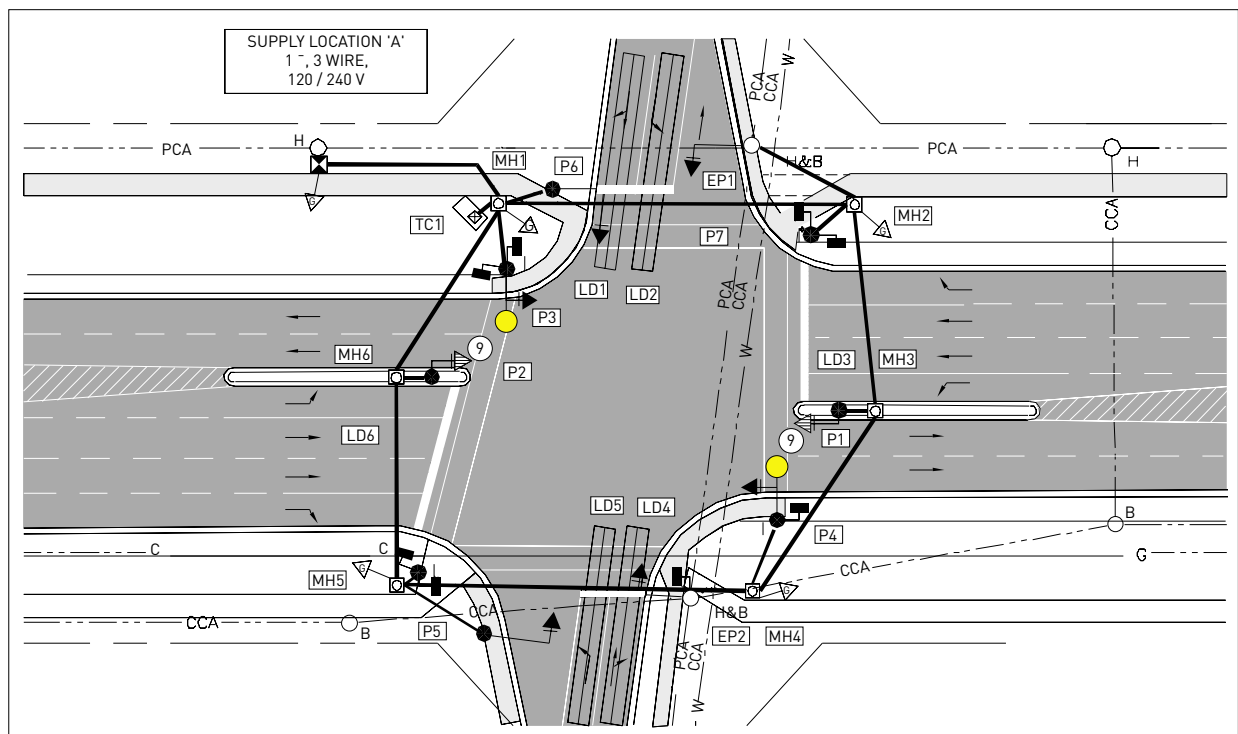


Figure 82 – Partial Lighting

6. Bicycle Signals

The designer should use this section on bicycle signals in conjunction with OTM Book 18 (Bicycle Facilities). The following section is intended to provide details on signal timing, phasing, and signal design considerations. Details on pavement markings and signing and crossrides for all bicycle facilities can be found in OTM Book 18 (Cycling Facilities) as well as OTM Books 5 (Regulatory Signs), OTM Book 6 (Warning Signs) and OTM Book 11 (Pavement, Hazard and Delineation Markings).

6.1 Bicycle Signal Timing

General

Specialized bicycle traffic signal timing must fit within the framework of the vehicular and pedestrian signal timing. Most aspects of standard traffic signal timing are unaffected by specialized bicycle timing, but, when required, there are two potential changes which might be implemented specifically for bicycles. These are: modified minimum green interval and revised vehicle inter green intervals. This section will address these two specific issues.

Background Information

To undertake some of the assessments noted in this section, current information about bicycle volumes and movements is required. If possible, regular turning movement counts as undertaken at signalized intersections should specifically segregate the volume of bicycle traffic by movement. If this is not possible, special counts may have to be undertaken to properly evaluate conditions.

In addition, collision assessments may indicate specific issues which might be remedied through the use of bicycle specific signal timing.

Typical Cycling Operations and Roadway Configurations

The choice of traffic signal operational parameters for bicycles depends on the way in which the cycling traffic interacts with traffic at signalized intersections. A number of different situations are typically found which may suggest changes or special treatments involving the signal timing (Section 3), the signal displays (Section 4) and/or the signal phasing (Section 5). The possible impacts are described in the following sections and summarized in Table 29.

Shared Roadway (includes Signed Routes)

The most basic configuration is bicycle traffic mixed with motorized traffic without any bicycle-specific lanes or facilities. In this situation, cyclists will respond to the same signal heads, signal timings and traffic control indications at signalized intersections as other traffic. No additional traffic signals for cyclists are used. If required, adjustments to signal timings, typically the minimum green or clearance intervals, may be deemed appropriate or beneficial to cyclists. Such changes will affect motorized vehicle operations and must be considered in that context.

Bicycle Lane or Cycle Track

When a bicycle facility is immediately adjacent to the curb lane, but operating in a dedicated space, a range of options are available at signalized intersections. The most basic condition is that bicycles operate as if sharing the lanes with no changes to signal timing, phasing or displays. A slight upgrade would be the addition of bicycle-specific signal displays but operating on the same phasing and timing as traffic. As with the shared roadway situation, adjustments to the signal timing

may be appropriate in some situations. The most complex situations would provide a partial or complete separation in the operation of the bicycle facility from the parallel vehicular and/or pedestrian traffic, through the use of bicycle-specific signal displays, timing and phasing.

In-Boulevard Bicycle or Multi-Use Trail

When the cycling facility is in the boulevard, typical design for signalized intersections places the trail close to the parallel road or just behind the sidewalk, if one is present, when crossing perpendicular streets and roads. The trail becomes a part of the intersection and usually utilizes the same signal timing as the overall intersection. Options exist as to whether the cyclists will be managed by the pedestrian signals (dismount and walk only), by signing or by the addition of bicycle-specific signal displays, timing and phasing.

Contraflow Bicycle Facility

When a bicycle facility is constructed on a one-way street with bicycles travelling in a direction opposite to traffic, at a minimum, bicycle-specific signal displays are required at signalized intersections. The need for adjusted signal timing and/or separate bicycle phasing would be determined by

the road authority based on geometric and safety requirements.

Mid-Block Bicycle or Multi-Use Trail

The intersection of a major roadway and a multi-use or bicycle trail at a mid-block location may require the use of signal control. For a bicycle-only facility, the bicycle traffic will be managed by bicycle signals and the signal timing will be based solely on bicycle needs. For a multi-use trail, pedestrians will also be served by the crossing, and along with separate indications for the two user groups, the timings will be the longer of the two based on the user group needs.

Factors Affecting the Choice of Parameters

There is a wide range of factors which affect cyclist performance and behaviour. As with vehicular traffic, intersection characteristics such as grade, visibility or travel speeds may have an effect on a cyclist's decision-making and performance. Some literature also demonstrates that factors such as the type of rider (recreational, commuter) or whether the cyclist is in a group will impact behaviour. As such, if the designer decides to adjust traffic signal timings from those which would traditionally be used for motor vehicles,

Table 29 — Possible Signal Timing or Signal Phasing Impacts/Changes for Various Types of Cycling Facilities

FACILITY TYPE	SIGNAL TIMING		SIGNAL DISPLAYS		SIGNAL PHASING	
	Revised Vehicle	Bicycle-Specific	Addition-al Non-bicycle	Bicycle-Specific	Existing	Bicycle-Specific
Shared	✓		✓			
Lane/Track	✓	✓	✓	✓	✓	✓
In-Boulevard	✓	✓		✓	✓	✓
Contraflow	✓	✓		✓	✓	✓
Mid-Block		✓		✓		✓

the designer should learn as much as possible about the specific operation of the intersection or intersections in question before implementing changes.

Minimum Green Interval

Description and Justification

A cyclist at rest may not be able to accelerate as quickly as a motorized vehicle. In typical signal timing designs, sufficient time is available at the start of the green interval to allow bicycles to accelerate from rest and cross the intersection prior to the conflicting phase being initiated. The one situation for which special treatment for bicycles might be necessary is at the side street of an actuated intersection with a short minimum green interval. As with most of the recommendations in this guide, the justification for changing the signal timing would be based on a fairly heavy volume of bicycle traffic and/or a known condition or situation relating to bicycles crossing the intersection.

Formulae

The length of time for a cyclist to cross an intersection is based on three major components. These are: the perception reaction time, which includes the time to react to the change of signal to green and to commence pedaling – the Perception Reaction Time (PRT); a period of time to accelerate to regular travelling speed – the Start-Up Acceleration (ACC); and the remaining time to cross the intersection at normal cycling speed – the Clearance Time (TCLEAR).

The first two components can be combined and a constant provided as an alternate. The next section describes how the minimum green time is calculated.

Minimum Green Time Calculation

The minimum green plus amber plus red clearance must be greater than or equal to the total crossing time required. The basic formula is:

$$G_{min} + Y + R_{clear} \geq SU + TCLEAR$$

Where:

G_{min} = Length of minimum green interval (seconds)

Y = Length of amber interval (seconds)

R_{clear} = Length of red clearance interval (seconds)

SU is a start-up time incorporating both perception-reaction time and acceleration to normal speed (seconds), suggested value: 6 seconds

$TCLEAR$ is the time (seconds) required to finish the crossing after accelerating to normal cycling speed, which in this formula does not consider the distance covered during start-up acceleration
 $TCLEAR = (W + L)/V$,

Where:

V is normal cyclist speed (meters/second), with suggested value: 4.0-5.6 m/s (14-20 km/h)

W is the width of the intersection (meters), and;

L is the length of the bicycle (m), suggested value: 1.8m

The complete formula is:

$$G_{min} \geq SU + (W + L)/V - (Y + R_{clear})$$

Parameters Used in Bicycle Signal Timing

It would appear that the science of cycling is still in the developing stages and there have been few

in-depth investigations into cyclist dynamics. As illustrated in Appendix A, there is a wide range of advice in the existing manuals and publications in regard to the specific values for parameters to be used in computational formulae. As such, a range of values has been provided in various guides and manuals for each of the parameters required to calculate this and other formulae.

Appendix D contains summary of parameters available in major guides with suggested typical values. While suggested values are provided for parameters for the formulae in this guide, the designer is encouraged to find as much information as possible about the cyclist population and behaviours in their own jurisdiction before choosing parameters. To ensure that a newly installed bicycle signal works for the greatest number of cyclists, the designer is encouraged to consider both existing and future cyclist demographics in their jurisdiction.

Application Guidance

The use of a longer than standard minimum green affects an intersection's efficiency. If there is a large number of cyclists using the intersection on a regular basis and cyclists are left in the intersection when conflicting traffic is shown the green on a regular basis, it may be appropriate to lengthen the minimum green. Conversely, if there is special detection for bicycles, such as through the use of a pushbutton or non-intrusive detection, it may be possible to implement additional green time only on those occasions when bicycles are present.

Amber and Red Clearances

Description and Justification

Bicycles have very different performance characteristics than motor vehicles. They have a lower top speed and a shorter stopping time and distance. Conversely, if a bicycle enters the intersection just before or during the amber display,

the lower speed may mean that the red clearance interval is insufficient.

This section defines the calculation of amber/red clearance times based on bicycle performance. Section 3.6.4 provides further insight into the need, impacts and alternatives to bicycle-specific clearance intervals.

In the case of a bicycle specific phase, where no motor vehicles are being served, clearance interval timing that is specific to bicycles should be implemented.

Clearance Interval Calculation

The formula for the intergreen for a bicycle is similar to that contained in section 3.6. The formula for the clearance interval is as follows:

$$\text{Amber} + \text{Rclear} = [\text{PRT} + V / (2d)] + [(W+L) / V]$$

Where:

PRT is perception-reaction time (sec), suggested value: 1.0 sec minimum

V is typical cyclist speed (km/h), suggested value: 4.0 - 5.6 m/s (14-20 km/h)

d = bicycle deceleration rate (m/sec/sec), suggested value: 3.0 m/sec/sec

W is intersection width (m)

L is bicycle length (m), suggested value: 1.8 m

$$\text{Amber} = [\text{PRT} + V / (2d)]$$

$$\text{Rclear} = [(W + L) / V]$$

Minimum Bicycle Signal Timing

Information on the values of the parameters used to calculate the minimum green, amber and red clearance times is contained in Appendix A.

The designer is encouraged to find as much information as possible about the cyclist population and behaviours in their own jurisdiction before deciding on suitable parameter values. Typical values for the minimum bicycle phase lengths are provided in Table 29. Bicycle speeds should be measured in the field to determine the appropriate clearance time. At intersections with level terrain, a default speed of 4.5 m/s may be used.⁸

Application Guidance

The vehicle clearance interval timing is the most important safety component of traffic signal timing. It should be adjusted or modified only with extreme care and knowledge of the potential consequences. The 2012 AASHTO guide⁸ states that “the yellow interval is based on the approach speeds of automobiles, and therefore, should not be adjusted to accommodate bicycles”. This implies that any adjustment to the vehicle clearance intervals should be made only in the red clearance interval, which is the appropriate methodology given that the amber required for a bicycle is much shorter than for a motor vehicle and would create an unsafe condition for motor vehicle traffic. As noted in Section 2, the *Ontario Highway Traffic Act* makes more than one provision for a situation in which a vehicle or pedestrian which has legally entered the intersection but has not completed their movement retains the right-of-way over conflicting traffic even if that conflicting traffic is presented with a green indication. Therefore, it is not absolutely necessary to have a full clearance interval for bicycles, and if the intersection is operating safely there may be no need to adjust signal timings specifically for bicycles.

The formula above will generate bicycle timings with very short ambers and very long red clearance intervals. These may be used as calculated, for bicycle-specific phases. However, in mixed traffic, the amber must remain as set for motor vehicle traffic. The overall clearance interval for very narrow intersections (12-15 m) will be almost the same as required for bicycles. With larger intersections, if the red clearances were set based on the full cyclist requirement, the red clearance may be so long that motorists may consider the signal to be faulty. It is suggested that the maximum additional red clearance for bicycle purposes should be limited to 1.0 sec.

Alternative designs of detection, such as long-distance cyclist detection, may also serve to extend the green interval and minimize cyclist interaction with the clearance interval. Serious consideration should be given to any or all alternate techniques before considering modifying the current clearance interval timing.

Table 30 — Minimum Bicycle Signal Timing

INTERSECTION WIDTH "W"	MINIMUM PHASE LENGTH (Gmin + Y + Rclear)
Metre	Seconds
12	9.1
15	9.7
20	10.8
25	12.0
30	13.1
35	14.2
40	15.3
45	16.4
50	17.5
55	18.6
$G_{min} + Y + R_{clear} \geq SU + (W + L) / V$ Assumed: SU = 6 sec, L=1.8 m, V=4.5 m/s	

6.2 Bicycle Specific Signal Displays

Use of Bicycle-Specific Displays

Bicycles integrate with roadway traffic in many ways. Bicycles riding parallel to the flow of traffic may be in one of the traffic lanes, in a specific designated marked bicycle lane, in a separated cycle track beside the roadway or on a multiuse or bicycle trail. In the perpendicular direction, bicycles may cross the road at signalized intersections, at stop controlled intersections or at a mid-block location.

It is generally advisable to consider bicycle signal heads at intersections and crossings of all cycling facilities. However, bicycle traffic signal heads are necessary in the following situations:

- Where bicycle movements differ from motor vehicle movements such as where bicycles-specific signal phasing is implemented.
- Where bicycle movement is in the opposing direction to adjacent motor vehicle traffic such as contraflow facilities or two-way facilities.
- Where a cycling facility is in the boulevard, including cycle tracks and in-boulevard multi-use trail crossings.

To communicate bicycle-specific information to cyclists at signalized intersections, the bicycle symbol signal head, shown in Figure 83, may be used. Traffic signal heads with special lenses containing the silhouette outline of a bicycle have been used to provide direction to cyclists in Europe and North America for some time. In Canada, this type of traffic signal was originally adopted in the province of Québec and was subsequently added to the Manual of Uniform Traffic Control Devices for Canada and is therefore a widely recognized, and unique, traffic control device. The version shown in Figure 83 is the approved Ontario standard as of January 1, 2017.



Figure 83 — Ontario Standard Bicycle Symbol Traffic Signal

The legal implications of a bicycle-specific signal display are detailed in Section 2.

When a bicycle signal head is used to provide direction to cyclists, a sign immediately adjacent to the signal head may be installed to improve visibility and conspicuity. The sign should have the words “Bicycle Signal” or the French equivalent and may be symbolized and/or bilingual. Figures 84 and 85 show two examples.

Prior to January 1, 2017, conventional bicycle signals were used that consisted of two signal heads mounted close together, each with circular red, amber and green lenses and a “Bicycle Signal” sign between them. These conventional bicycle signals did meet the requirements in the HTA’s and so were enforceable. The Ontario standard bicycle signal head shown in Figure 83 must now be used

for all new bicycle signal installations and when the conventional bicycle signals are due for upgrade or replacement.

Differentiating Bicycle Signal Heads

It is important to create differences between bicycle signals and the regular vehicular signals, to minimize motorist confusion, and thereby maximize safety. Where bicycle specific traffic signal heads are used, the bicycle signal heads should be differentiated from the motor vehicle signal heads through one or more of the following options:

- The signal head housing may be a different colour than the jurisdiction's standard colour, preferably one that is less visible to motorists such as dark green or black;
- The signal head may be installed without backboard, which is more effective if the nearby vehicle signal heads are equipped with backboards;
- Positioning one of the bicycle heads near-side;
- Using a smaller signal lens diameter; or
- Wherever possible, the bicycle signal head should be positioned lower and out of the typical line of sight of the motor vehicle driver while being placed in line of sight of the cyclist.

The above can usually be achieved without reducing the effectiveness or value of the bicycle signal head to cyclists.

Bicycle Signal Head Size and Type

For far-side bicycle symbol signal heads, it is preferred to use the 300/300/300 mm lens size, especially for bicycle-only phasing or if the signal head is to be seen at a distance. This is to ensure that the bicycle symbol is clear to both cyclists and motorists. The 200/200/200 mm lens size



Figure 84 — Conventional Bicycle Signals and English Sign – Bicycle Control



Figure 85 — Conventional Bicycle Signals and Bilingual Sign – Bicycle Control

is generally sufficient for near-side mounting or auxiliary signal head uses. If standard circular ball indication traffic signal heads are being used (with signs), given the slower speeds that cyclists are typically approaching specialized traffic signals, the use of the 200/200/200 mm size is generally acceptable, especially if no bicycle arrow signal indications are being used. In general, based on good engineering judgment, the designer may select the use of either of a 300/300/300 mm or 200/200/200 mm as the standard signal head for bicycle use. If a near-side auxiliary head is deployed, it may be smaller than 200 mm and could be mounted at a height less than 2.5 m as determined by the road authority. In the case of auxiliary signal heads using a lens size less than 200/200/200 mm, the bicycle symbol shall be legible and proportioned to fit within the signal lens.

Bicycle Signal Head Placement

Where bicycle signals are implemented, the HTA states that at least one bicycle signal must be placed at the far side of the intersection and if mounted over the roadway it must be at least 4.5 m above the roadway surface. If mounted adjacent to the roadway it must be mounted at least 2.5 m above the roadway surface.

Where bicycles are operating with the same signal phasing as parallel vehicular movements, bicycle signals are considered auxiliary (supplemental) and so may be mounted at a height to ensure they can be easily seen by the cyclist and do not pose a hazard to other road users. If appropriate, a single additional signal head for bicycles may be provided. The bicycle auxiliary signal head should be located as centrally as possible in the cyclists' cone of vision and should operate in agreement at all times with the motor vehicle signal indications.

Where bicycles are operating on a separate bicycle phase, a minimum of two bicycle specific signal heads should be installed to ensure redundancy and safety. The far side bicycle signal head must

meet the mounting height requirements in the HTA. The second bicycle signal head may be installed on the near side of the intersection and because it is an auxiliary head (supplemental) can be mounted at less than the minimum height of 2.5 m, such that it can be seen by a cyclist stopped for the signal. Near-side bicycle signals help cyclists and motorists differentiate between the motor vehicle and bicycle specific signals, which is particularly important when there is separate bicycle signal phasing. Near-side signals can also be used to reinforce the correct position for cyclists to stop. If a bicycle signal head is mounted adjacent to the roadway but over a multiuse path, care should be exercised in finalizing the mounting height as service and emergency vehicles will travel on the multiuse paths.

Bicycle signals should be aligned to serve cyclists, with the understanding that a cyclist's field of vision may be quite low to the ground due to the cyclists' positioning on the bicycle.

It is preferred that the bicycle signals are placed in line or close to the cyclist's line of sight and generally in line with the cycling facility. It is preferable to place them off the travelled roadway, so that they can be installed close to the 2.5 m minimum height requirement. However, a priority is to place bicycle signal heads where they will not impede or potentially injure a passing cyclist or pedestrian or be hit by vehicles.

If far-side and near-side bicycle signal heads are used, the near-side signal head should be located so that it can be seen by a cyclist stopped for the signal.

6.3 Bicycle Signal Phasing

At the vast majority of signalized intersections, bicycles are able to traverse the intersection without the assistance of bicycle phasing to specifically control bicycle movements. There are, however, circumstances which will provide increased safety, throughput or convenience to cyclists at acceptable impact to conflicting or adjacent motorized traffic or pedestrians. In these cases, special signal phasing using bicycle specific signal heads may be employed. In the case of any discrepancies between the schematic drawings “Design Figures” and the illustration photos “Images” in Section 6, the design drawing takes precedence over the image. Additional details on bicycle signal phasing can be found in OTM Book 18 (Cycling Facilities).

Common Applications of Bicycle-Specific Phasing

The term “Bicycle-Specific Phases” includes separate movements, leading or separate phases and contraflow bicycle movements.

Below are some examples of situations in which bicycle specific phasing might be advantageous:

- Where, at a mid-block or intersection crossing (often connecting to a mixed-use trail facility), the bicycle flows are mixed with pedestrian flows. This is particularly true in Ontario with the requirement that cyclists must dismount and walk to use the pedestrian crosswalk.
- Where large volumes of traffic travelling straight ahead on a designated bicycle lane or bicycle track conflict with heavy movements of turning traffic, it may be advantageous to both streams to provide temporal separation using separate signalization.
- At locations where no signal indication would otherwise be provided to bicycle traffic. An

example of this would be a contraflow bicycle lane on a one-way street.

- At locations where bicycles are permitted to make movements which are otherwise prohibited for the rest of the vehicle stream. An example would be the restricted entrance to a residential neighbourhood for which vehicular traffic is required to turn but bicycle traffic is permitted to travel straight ahead to enter the neighbourhood.
- At complex intersections where cyclists may be assisted by the provision of separately defined right-of-way.
- At otherwise traditional locations with high bicycle collision rates that may be mitigated by separating various movements.

Decision criteria are presented formally in Section 6.

Operational Considerations for Bicycle Phasing

Since bicycle phasing is not commonplace, it is incumbent on the designer to use engineering judgment as to the appropriateness of installing bicycle phasing and the best way to implement it. Some factors to be considered are as follows:

- Conformity and Consistency.
 - Driver and cyclist performance improves with familiarity and confidence. Therefore, if special bicycle phasing is used at a location, consideration should be given to using it at all locations similar in nature or at least similar locations along a cycling corridor.
 - Conversely, if bicycle phasing is only intended to be used at an individual intersection which is unique, very careful consideration must be given to the

implementation to ensure clarity to both motorized and non-motorized users.

- Cyclist Behaviour.
 - Because of the energy necessary to accelerate a bicycle from a stop position to travel speed, momentum is valuable to cyclists. Cycling facility designs need to recognize that cyclists tend to be reluctant to stop unless absolutely necessary.
- Overall Benefits.
 - While designing bicycle specific phasing, consideration must be given to not only to the improvements in safety and efficiency for non-motorized users but to the potential decrease in safety and or efficiency for motorized users. It is understood that to promote healthy lifestyles and to promote a move away from the use of single occupant motor vehicles, special promotion of cycling will occur. However, the designer must consider the negative consequences, especially on motorist or pedestrian safety, as well as the advantages.
- Pedestrian Conflicts.
 - Where a bicycle trail or multi-use path crosses a sidewalk, consideration should be given to the right-of-way of pedestrians over bicycles. Designers should refer to OTM Book 5 (Regulatory Signs) and Book 18 (Cycling Facilities) if signing to mitigate the conflict is required.
- Introductory Period.
 - The most difficult time of any new traffic control device or operational condition is immediately after implementation. The unfamiliarity of users can lead to erratic

driving or riding and the risk of collisions is highest directly after any change.

- To maximize the success and safety of any new installation, a combination of the classic 3 E's should be employed:
- Educational campaigns utilizing both traditional and non-traditional techniques are important.
- Law enforcement should be involved and should provide the necessary level of enforcement and encouragement.
- Engineering: Advance information signing or other techniques should be employed on a temporary basis to heighten user awareness. This would be similar to the use of the "NEW" warning sign which accompanies new STOP signs, YIELD signs or traffic signals.

Parallel Bicycle and Pedestrian Crossings (Without Bicycle-Specific Phasing)

This section explores the options for locations where bicycles and the pedestrians cross together or immediately beside each other. The options are presented in increasing complexity, and it is expected that the more complex solutions would only be required where large numbers of bicycles and/or pedestrians and/or motor vehicles interact.

Pedestrian and Bicycle Crossing Configuration

Where a multi-use trail (combination of bicycles, pedestrians and other non-motorized users) crosses a roadway, either in close proximity to a signalized intersection or mid-block, there are two choices. Either the cyclists and pedestrians may be combined in the pedestrian crosswalk (as described in 5.3.2) or a separate crossing denoted by the "Elephant's Feet" pavement marking (called a "Crossride") is provided for bicycles.

Use of the crossride means that the interaction of bicycles and pedestrians in the crossing is in theory greatly reduced or eliminated.

There are four possible crosswalk/crossride configurations. These are shown in Figure 86.

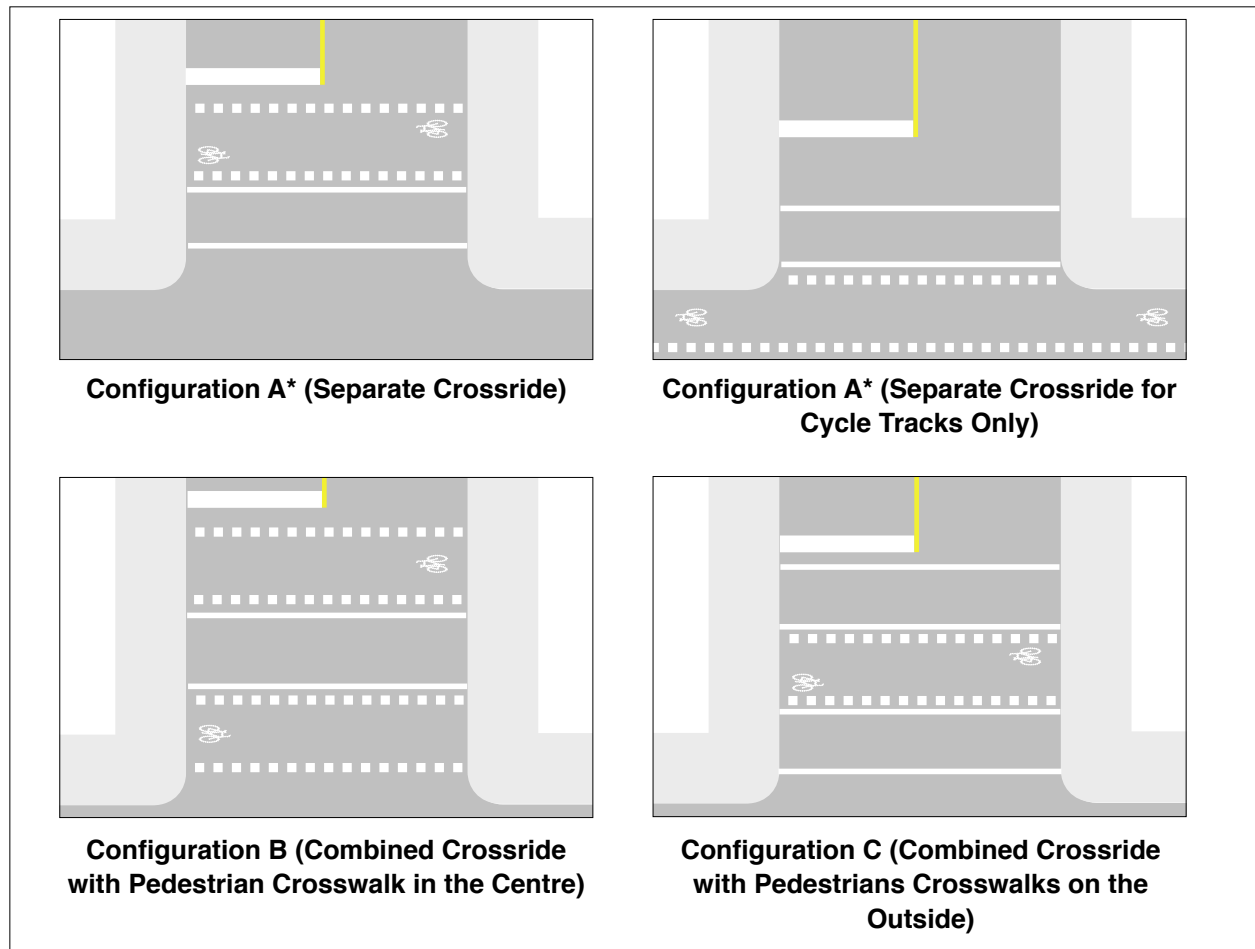


Figure 86 — Crosswalk/Crossride Configurations

Notes:

- For general illustrative purposes and details on pavement marking layout for crossrides can be found in OTM Book 18 (Cycling Facilities).
- Crosswalks and crossrides not to scale.
- * The positions of the crossride and the crosswalk may be reversed for Configuration A
- For Configuration B, the designer may choose to eliminate the inner elephant's feet cross ride lines

The simplest design, Configuration A (termed a Separate Crossride in OTM, Book 18 (Cycling Facilities))²¹, places the pedestrian crossing on one side, which would be next to the sidewalk at a signalized intersection, to serve both the sidewalk and the multi-use trail. This places all bicycles on one side, while a typical multi-use trail operates with the pedestrians on the outside and the faster-moving bicycles closer to the centre, leading to some exchange of positions at the ends of the crossing. The positions of the crossride and the crosswalk in Configuration A may be reversed to reduce conflicts between cyclists and pedestrians. This configuration should operate satisfactorily where the trail users typically must stop before crossing. Due to space limitations, this is the configuration most typically used for the situation where a multi-use trail parallel to a roadway crosses near a signalized intersection. For a cycle track next to a sidewalk, the cycle track layout is shown as Configuration A (for cycle tracks only) in Figure 86.

Configuration B is an alternative (termed a Combined Crossride in OTM Book 18 (Cycling Facilities))²¹. For Configuration B, the inner elephant's feet pavement markings may be eliminated as show in OTM Book 18 Cycling Facilities²¹ which can help minimize how far back the stop bar needs to be placed.

Configuration C reverses the cyclist and pedestrian positions compared to Configuration B, which may be a better match to the user configuration on the path (pedestrians being the slower moving users, are typically on the outside of the path and cyclists are usually closer to the centre), but Configuration C is quite wide, and is therefore typically limited to use at mid-block crossings.

For all crossride configurations, bicycle stencils and arrows may be added to help reinforce the intended use and direction of travel.

Use of the Same Crosswalk – Cyclists to Walk Across

The most basic method of managing the situation at locations where multi-use trails cross the road or where bicycle paths merge with sidewalks at intersections, is to require cyclists to default to the basic HTA requirement to dismount and walk across a signalized intersection crosswalk. The Rb-70 DISMOUNT AND WALK sign should be used. As well, a STOP sign and stop line may be considered on the path or trail to further encourage cyclists to comply.

This configuration would be an option where the addition of a crossride is not possible, but the large volume of pedestrians in a crosswalk and/or the width of the crosswalk suggest that the best configuration is to require cyclists to walk. While this is feasible, in many cases cyclists find the requirement onerous or unreasonable and disobey the regulatory sign; therefore the implementation of a signalized crossride should be considered wherever possible.

Signs and Pavement Markings

In determining the size of signs used for bicycle facilities shown in this guide, it should first be defined whether the signing is for cyclists only, or for cyclists and motorists. Signing for both cyclists and motorists should conform to the requirements in the OTM Books 5 (Regulatory Signs) and OTM Book 6 (Warning Signs). Signs for cyclists only may be smaller and should conform to the TAC Bikeway Traffic Control Guidelines for Canada). If there are situations in which cyclist-specific signing might be observed by motorists and thereby cause confusion, the use of a smaller than standard sign might assist. However, signs such as STOP or YIELD signs which are smaller than the minimum required under the *Highway Traffic Act*, or the OTM Book series are not legally enforceable, and therefore, may not be sufficient.

Crosswalk and crossride pavement markings should generally comply with OTM Books 11 and 18²¹ for line types and spacing. In addition, this guide shows bicycle stencils in the crossrides in specific positions. Only the stencils that are considered required at signalized intersections are shown. If the flow of path users at a particular site suggests the need, the designer may add additional stencils to guide cyclists and provide information to pedestrians.

Parallel Pedestrian and Bicycle Crossings, Signalized Intersection – No Bicycle Signal Traffic Control

If a crossride is implemented at a “signalized” intersection, bicycle signals should be implemented so all modes (walking, cycling and motor vehicles) have the same form of traffic control. At stop-controlled intersection, all users (including cyclists crossing through a crossride) must follow the same rules for a stop controlled intersection.

If for some reason the road authority does not want to install bicycle signals to connect an in-boulevard multi-use path or bikeway, then a crossride should not be installed at a “signalized” intersection. Cyclists would therefore be required to cross as a pedestrian using the crosswalk from boulevard to boulevard. Shown in Figure 87.

Parallel Multi-Use Trail Pedestrian and Bicycle Crossings – No Separate Bicycle Phasing

Figures 88 through 95 show various situations, with the common theme that bicycles are given signal indications. In Figures 88, 89, 90 and 91 there are the two alternative configurations of multi-use trail crossing parallel to a signalized intersection with no separate signalization of the bicycle movements. The wider crosswalk/crossride system in Figure 90 places the roadway stop line further from the intersection, which may impact signal timing or operations. Bicycle movements are

governed by the regular vehicle signal patterns. This configuration may be used if the designer is satisfied that the cyclists will consistently obey the standard vehicle signals.

An auxiliary signal specific to cyclists may also be added, if showing the same displays as the main vehicle signals, to improve cyclist compliance. While only one auxiliary signal for bicycles is required under the HTA regulations, if the designer feels that the vehicle signals are not satisfactory as “back-up” in the event of an indication failure in the bicycle signal, a second bicycle signal may be added for further redundancy.

To best organize the crossing, the PATHWAY ORGANIZATION signs Rb-72a and Rb-72b may be used. The Ra-14L or Ra-14R Signalized Intersection Crossing sign(s) may be used when signal operation is pushbutton actuated.

If there is an observed conflict between path users and turning motor vehicles, a combination of reduced speed warning for the bicycles in the vicinity of the crossing through the use of the SLOW WATCH FOR TURNING TRAFFIC sign and the BICYCLE CROSSING SIDE STREET SIGNS Wc-37L and Wc-37R for both directions of parallel traffic will serve to minimize conflicts between bicycles and turning traffic. The CYCLISTS STOP HERE ON RED sign may be used if lack of signal compliance is noted.

In order to manage the conflict between cyclists on the multi-use path and pedestrians on the perpendicular sidewalk the Ra-16 BICYCLES YIELD TO PEDESTRIANS sign should be used whenever cyclist and pedestrian volumes or conflicts suggest the need.

The pedestrians on the sidewalks walking in a direction perpendicular to the multi-use path are not provided with specific information about the right-of-way status of bicycle traffic on the path.

In the rare extreme case where the painted stop line and the Ra-16 sign are not effective in separating pedestrian and cyclist flows, the pedestrian signal heads could be relocated to extend the pedestrian crosswalk across the arterial roadway to include the multi-use trail as well, although this causes inconvenience to the pedestrians on the sidewalk and could have a significant effect on the signal timing and operational efficiency of the intersection.

Bicycle Path and Track Crossings - No Separate Bicycle Phasing

Figures 92 through 95 show two common on-street bicycle facility types, a bicycle lane and a cycle track. As with the parallel multi-use trail crossings, these facilities will typically operate using the same signal patterns as for parallel traffic. The designs shown have an additional signal head for bicycle traffic, to make it easier for cyclists to determine the signal status.



Figure 87 — Image: Multi-Use Trail Beside Traffic Signal, Stop Control, Crossing

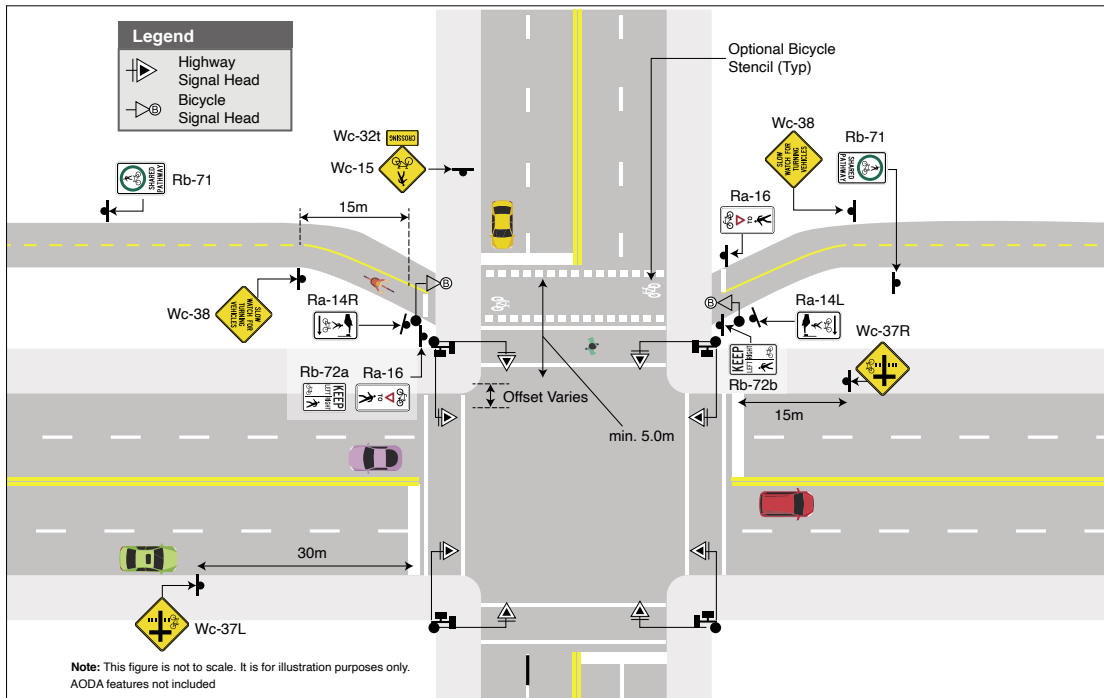


Figure 88 — Design: Multi-Use Trail Beside Traffic Signal, Signal Control, Crossing Configuration A, Auxiliary Signal Head

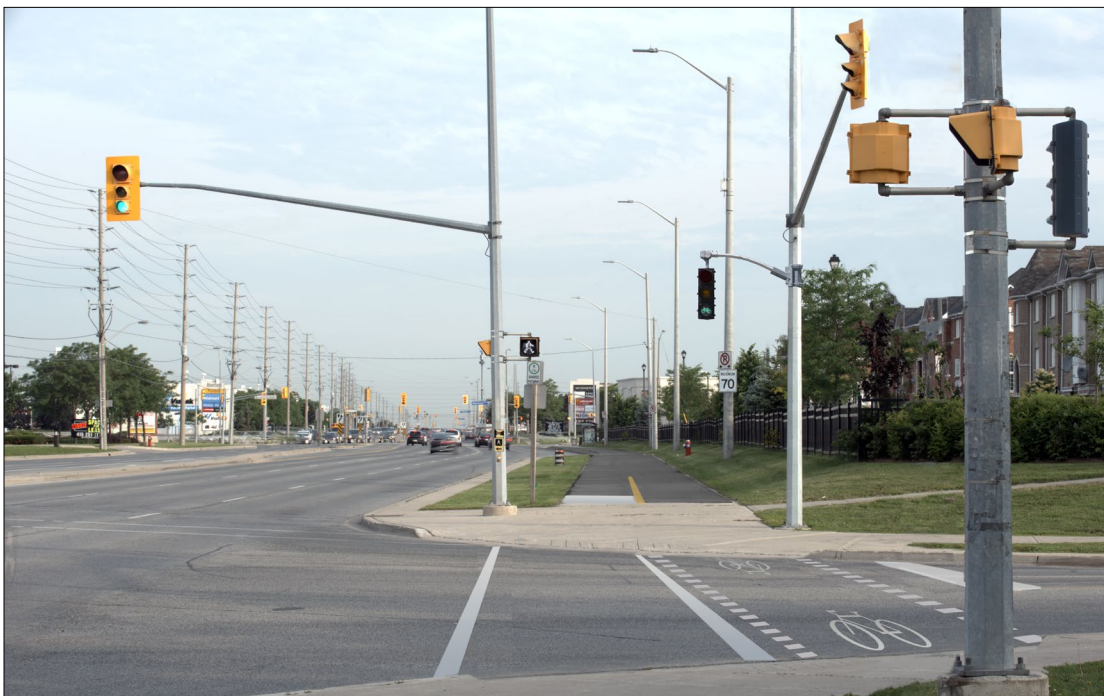


Figure 89 — Image: Multi-Use Trail Beside Traffic Signal, Signal Control, Crossing Configuration A, Auxiliary Signal Head

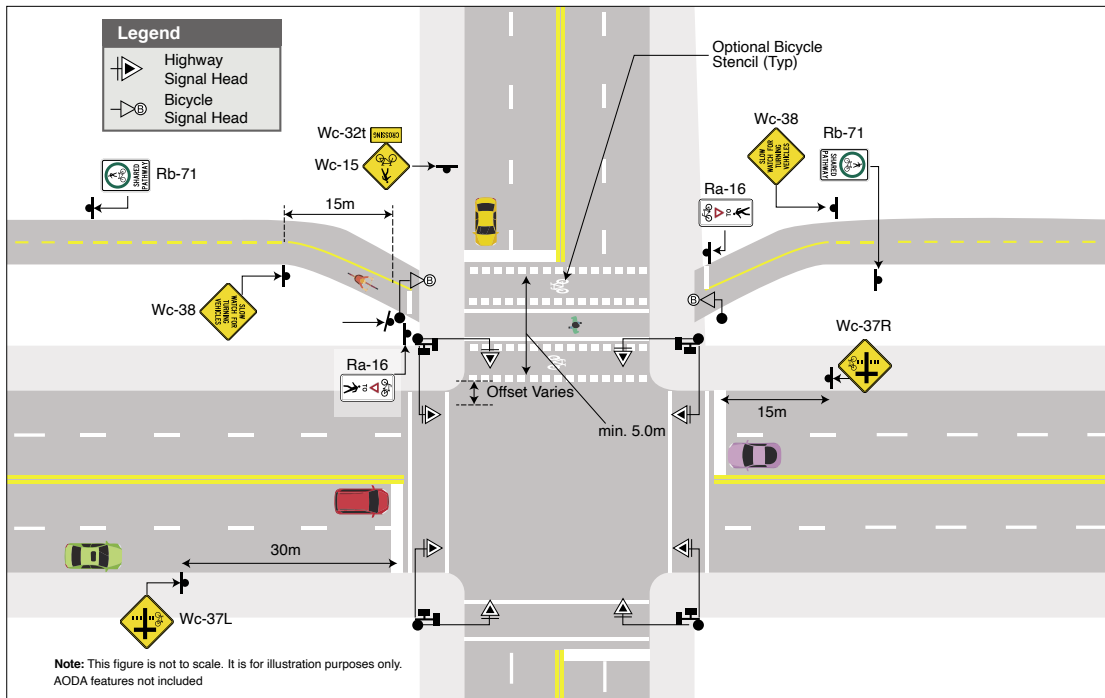


Figure 90 — Design: Multi-Use Trail Beside Traffic Signal, Signal Control, Crossing Configuration B, Auxiliary Signal Head

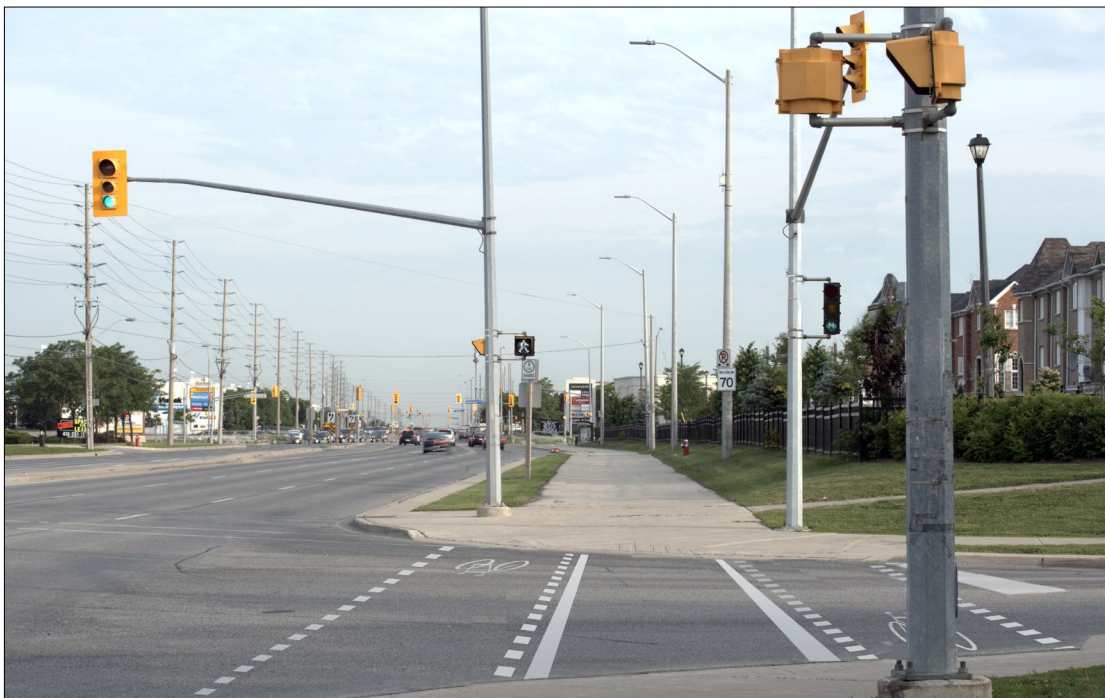


Figure 91 — Image: Multi-Use Trail Beside Traffic Signal, Signal Control, Crossing Configuration B, Auxiliary Signal Head

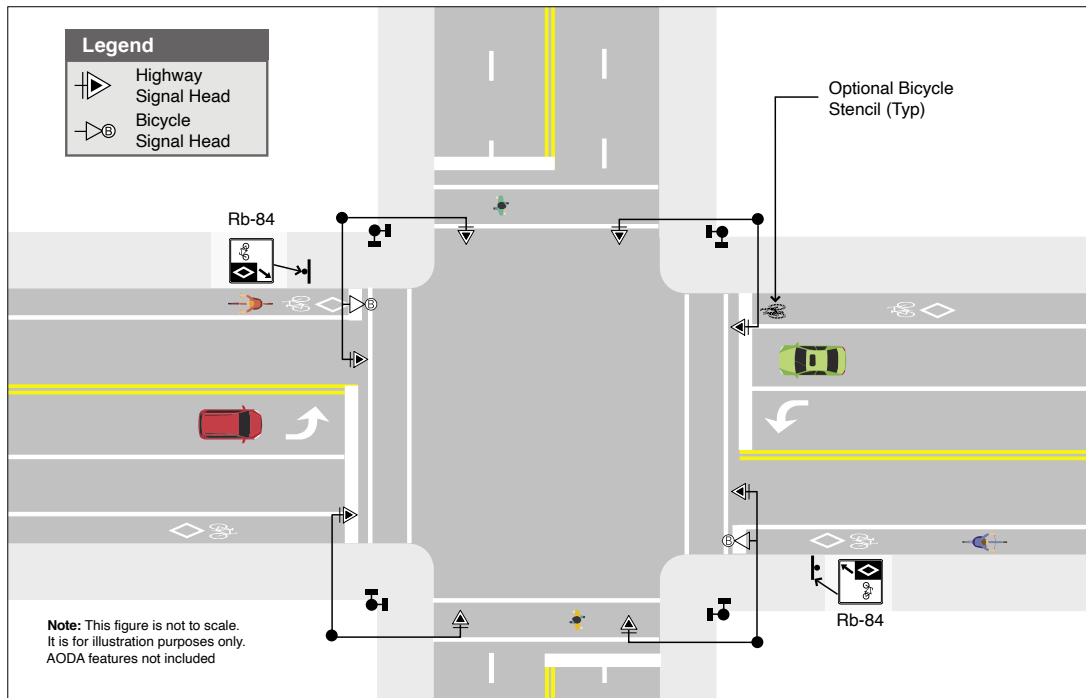


Figure 92 — Design: Bicycle Lane at Signalized Intersection



Figure 93 — Image: Bicycle Lane at Signalized Intersection

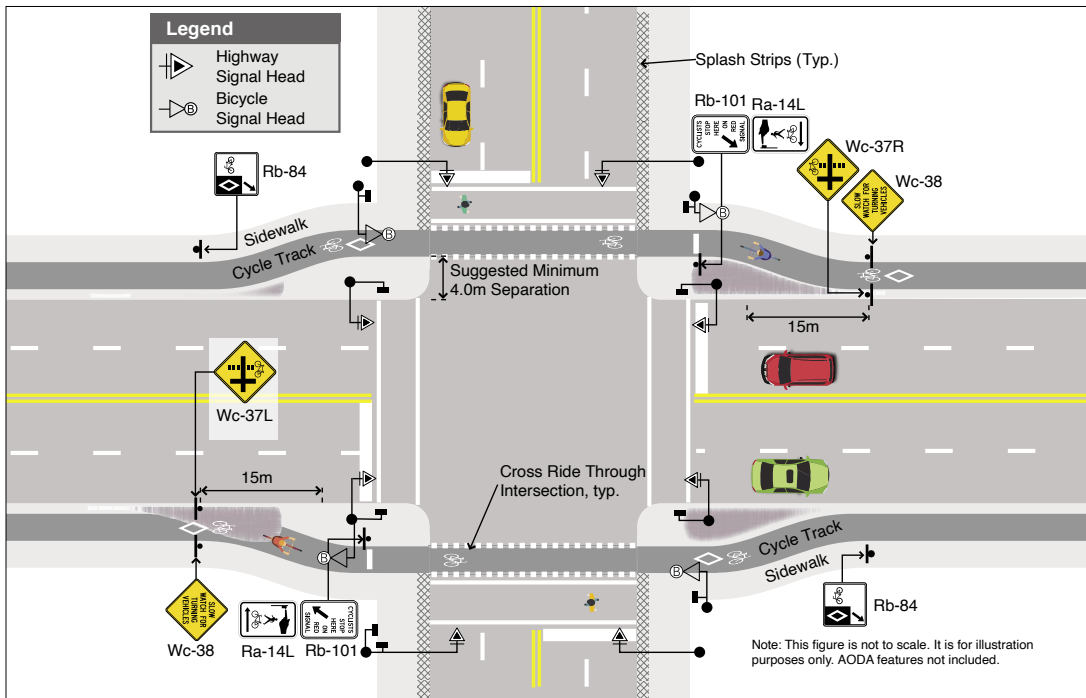


Figure 94 — Design: Bicycle Track at Signalized Intersection



Figure 95 — Image: Bicycle Track at Signalized Intersection

6.4 Bicycle and Pedestrian Crossings – with Bicycle-Specific Phasing

For some situations, bicycle specific signal heads and warning signs may not provide the bicycle crossing with a sufficient level of safety. This may occur due to poor visibility, where the boulevard trail is set back a large distance from the parallel roadway, where cyclists are travelling at high speeds or where there are high volumes of bicycles and/or turning traffic, resulting in conflicts. Options are to partially or completely separate the parallel right and left motor vehicle turning movements from the bicycle phase. For either of the phasing patterns that follow, consideration should be given to adding NO LEFT/RIGHT TURN ON RED signs (RB-79L AND RB-79R) if bicycle/vehicle conflicts occur during the bicycle-specific phase operation. Bicycle-specific detection is required for either form of bicycle phasing, unless the bicycle phasing is operated on fixed-time plans, with time-of-day operation as an option.

Advanced Protected Bicycle Phase

Advanced With Vehicle Through Movement

At locations with a designated bicycle lane or cycle track and heavy through bicycle traffic conflicting with heavy turning traffic, particularly right turning traffic, a leading bicycle phase may be helpful. Vehicular traffic is controlled by a four section head with the straight through green arrow and a green ball. Vehicular traffic is initially shown the straight up green arrow at the same time that the bicycle signal displays green. After a short green bicycle interval, which allows the group of standing bicycles an opportunity to proceed into the intersection and take possession of the conflict space, the vehicle indication changes from straight up green arrow to green ball. The bicycle green remains on for the full phase, changing to amber and red only at the end of the vehicle phase. Figure 96 shows the phasing diagram. The drawback is the somewhat increased

delay for motorists. This is often referred to as a Split Leading Bicycle Interval (Split LBI).

Pedestrian movements may also receive advanced movement status under this phasing configuration. This phasing is applicable to the crosswalk/ crossride combination of crossing, for intersections with bicycle boxes or for reserved bicycle lanes or cycle tracks.

Advanced Without Vehicle Through Movement

At locations with a designated bicycle lane or cycle track with heavy turning traffic, a leading bicycle phase may be used similar to a pedestrian only leading phase. Cyclists are provided with an advanced green signal while motor vehicles face a red ball. After a short green period, which allows the group of standing bicycles an opportunity to proceed into the intersection and take possession of the conflict space, the motor vehicle signal display changes from red ball to green ball. The bicycle green remains on for the full phase, changing to amber and red at the end of the vehicle phase. Pedestrians may be provided with coincidental walk signal to provide a simultaneous advanced pedestrian interval. This is often referred to as a Leading Bicycle Interval (LBI) and is shown in Figure 97.

Bicycle Only Phase

The most restrictive manner of separating bicycles and turning traffic is to allow the bicycles a minimum green to start, and then transition to bicycle amber and red. All parallel traffic, including pedestrians, is held until the bicycle red is displayed. This provides limited signal time for bicycles but provides complete separation of the conflicting traffic streams. This configuration would operate well with bicycle boxes, which would permit the bicycles to be positioned to take advantage of the unrestricted left and right turns. The chief drawback is the short time interval available for bicycles, which may increase delay for motorists.

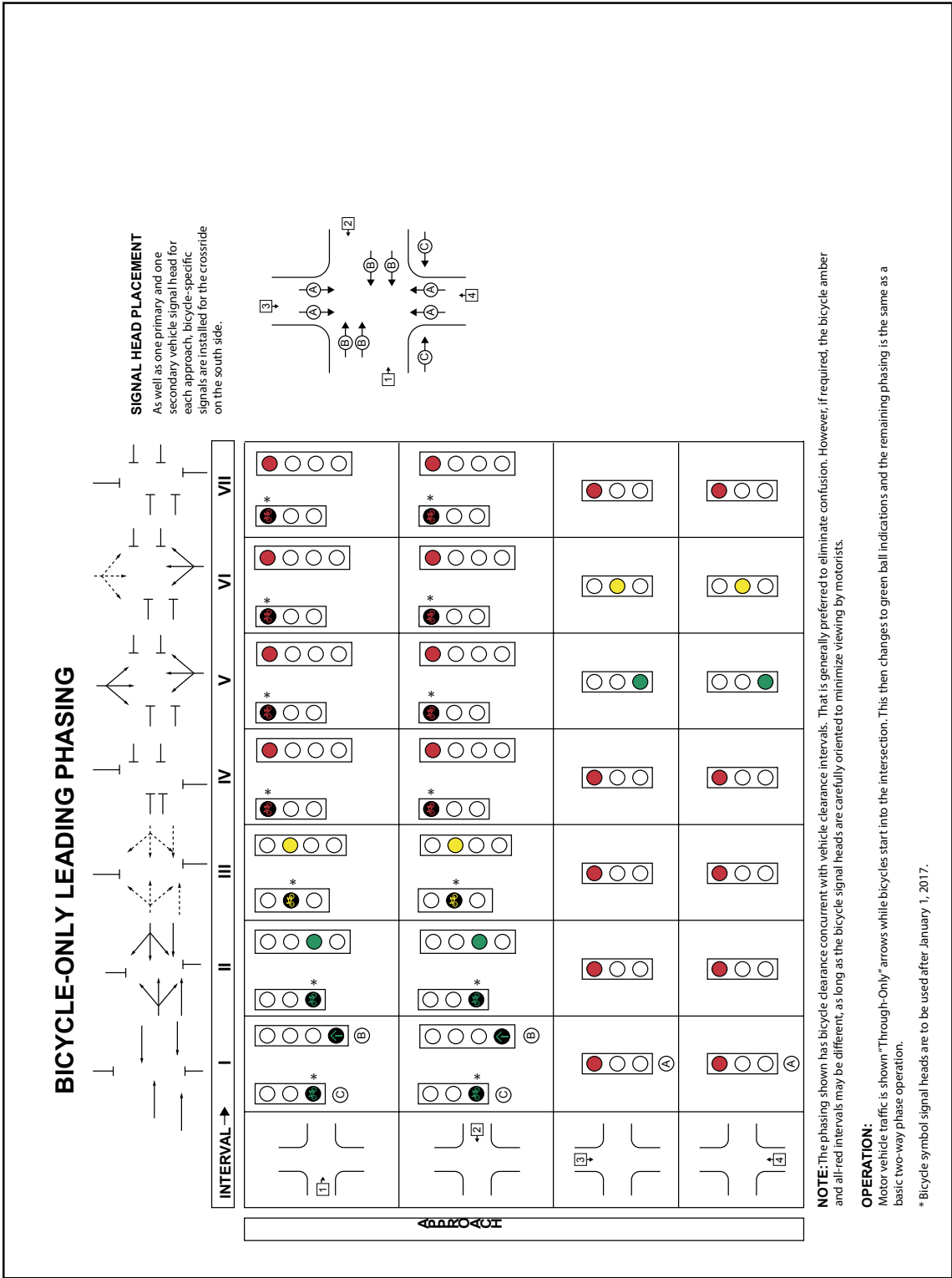


Figure 96 — Signal Phasing: Bicycle-Advanced Through Only Phase (Source: TAC MUTCDC Figure B4-14 (January 2021))

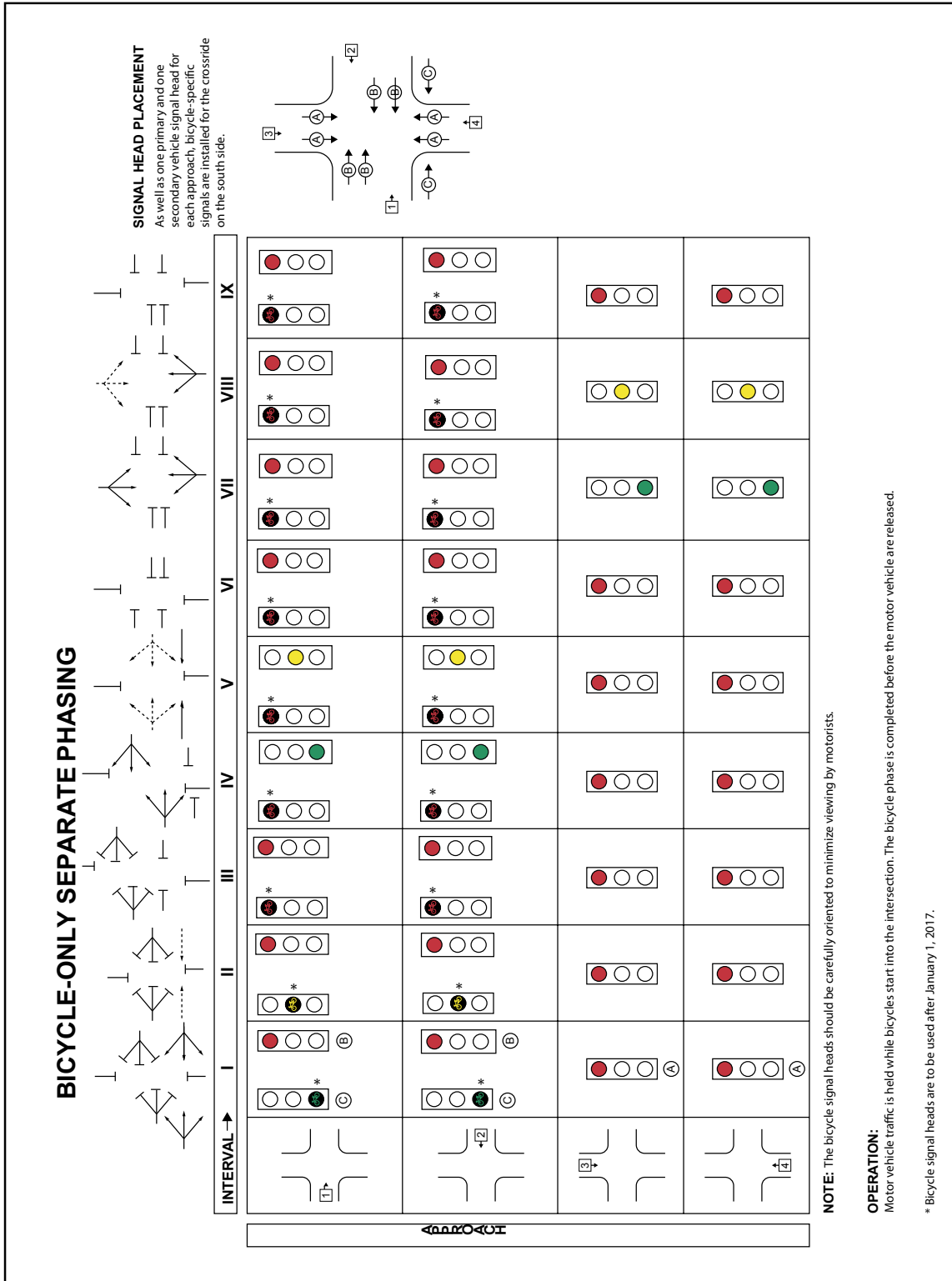


Figure 97 — Signal Phasing: Bicycle-Only Separate Phase (Source: TAC MUTCDC Figure B4-15 (January 2021))

Signalization for Bicycle-Specific Phasing

Figures 98 through 101 show two bicycle signal heads placement each for crosswalk/crossride configurations A and B, which have two bicycle signal heads for each movement. Two bicycle-specific signals for each bicycle movement should be used to provide for display redundancy where separate phasing is employed for bicycle movements that is separate and distinct from the phasing for parallel traffic. Either near-side/far-side or double far-side signal head placements are acceptable. The same basic signal head placements should also be applied to bicycle lanes or tracks, where separate phasing is required.

6.5 Mid-block Crossing Configurations

Mid-block crossings are not as restricted for space and crosswalk/crossride configurations A, B or C can be used. Configuration C may be more compatible with paths where the bicycles, as faster travellers, are in the centre of the path. As noted previously, the final choice of layout will often be a function of the path operating characteristics and width and the designer should make an engineering decision based on typical layouts nearby (for consistency) and other factors.

Figures 102 through 105 show Configuration C with either near-side/far-side signals or double far-side signals. Figures 106 through 109 show Configurations A and B with near-side/far-side signals, although double far-side signals may be used for these configurations as well.

The median island shown in Figures 102, 104, 106 and 108 is optional. The design works equally well with or without it.

Typically, bicycle-specific detection is recommended. The pedestrian pushbuttons may be used if they are accessible and available

to cyclists. If the location of pushbuttons for pedestrians to comply with AODA requirements places them in a position that is not easily accessed by cyclists, then cyclist detection or cyclist specific pushbuttons and signs should be used.

Intersection Pedestrian Signal (IPS) Crossings

The situation will occur where a neighbourhood bicycle route or a designated bicycle lane crosses a major roadway at a location equipped with an intersection pedestrian signal. The cyclist is expected to use the IPS as a vehicle, regulated by the STOP sign. An alternative is to equip the IPS to be activated either by detection in the bicycle lane or by a bicycle specific detection. The option of bicycle signals for the side street is not permitted as it would conflict with the STOP signs (which govern cyclist movements).

Contraflow Bicycle System

To provide continuity in the bicycle network, it is sometimes necessary to operate bicycles in a direction opposite to the vehicular flow on a one-way street. The lanes may be separated simply by pavement markings or by physical barriers such as curbs. Where the contraflow bicycle lane intersects with a signalized intersection, the only indication that is available would be pedestrian signals.

To provide throughput and safety benefits, bicycle traffic signals are preferable for the contraflow direction, as they are less likely to create confusion for motorists entering the road from nearby driveways.

The bicycle signal phasing generally parallels the vehicular signal phasing for the opposite direction (considering turn phases) but may utilize bicycle-specific signal timings and/or movements.

Figures 110 and 111 show signal configurations for a one-way street with the bicycle lanes split.

Figures 112 and 113 show signal configurations for a bi-directional bicycle lane system, all on one side of a one-way street.

Rural Applications

Bicycle facilities in rural situations tend to differ from the more common urban facilities. Typically rural bicycle facilities, if present, are limited to bicycle shoulders. Pedestrian actuation, if available, may be poorly located for bicycle riders to access. Motor vehicle detection is typically by induction loops. Where significant bicycle volumes are present at a rural signalized intersection, especially one on a defined bicycle route, attention should be paid to signal timing, especially clearance time, and to pavement markings and signing that would ensure the cyclist positions him or herself over the preferred location on the detection loop. Detection loop sensitivity should be optimized to pick up bicycle calls.



Figure 98 — Image: Multi-Use Trail Beside Traffic Signal, Signal Control, Crossing Configuration B, Near-Side/Far-Side



Figure 99 — Image: Multi-Use Trail Beside Traffic Signal, Signal Control, Crossing Configuration B, Double Far-Side



Figure 100 — Image: Multi-Use Trail Beside Traffic Signal, Signal Control, Crossing Configuration A, Near-Side/Far-Side



Figure 101 — Image: Multi-Use Trail Beside Traffic Signal, Signal Control, Crossing Configuration A, Double Far-Side

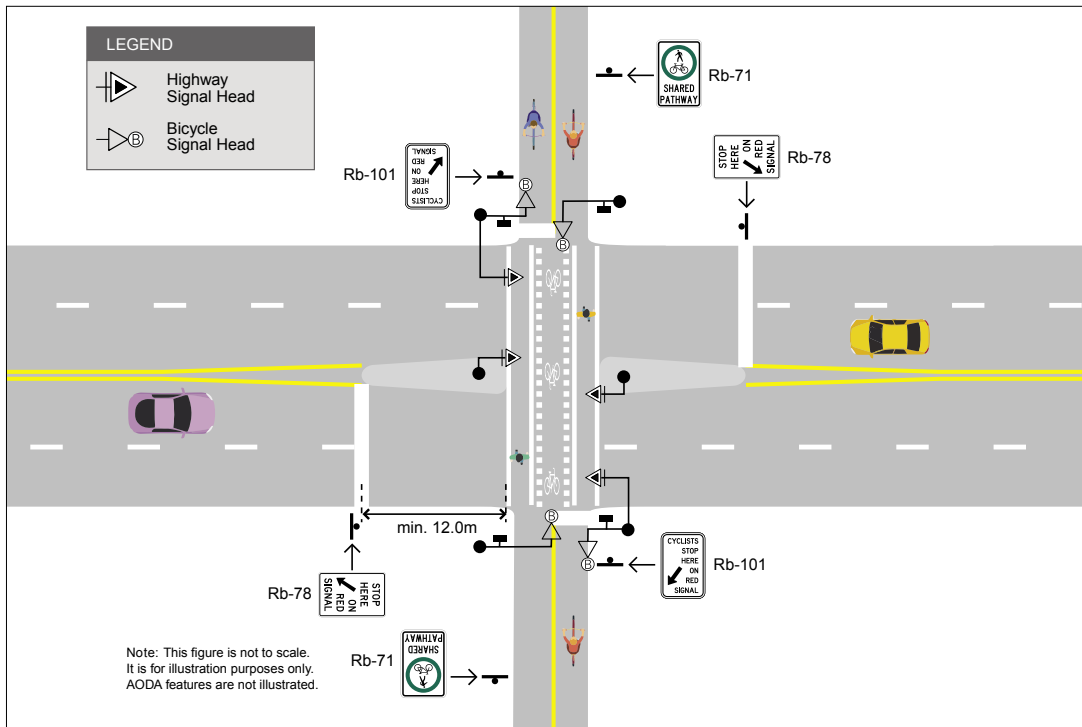


Figure 102 — Design: Mid-block Signalized Trail Crossing, Configuration C, Near-Side/Far-Side



Figure 103 — Image: Mid-block Signalized Trail Crossing, Configuration C, Near-Side/Far-Side

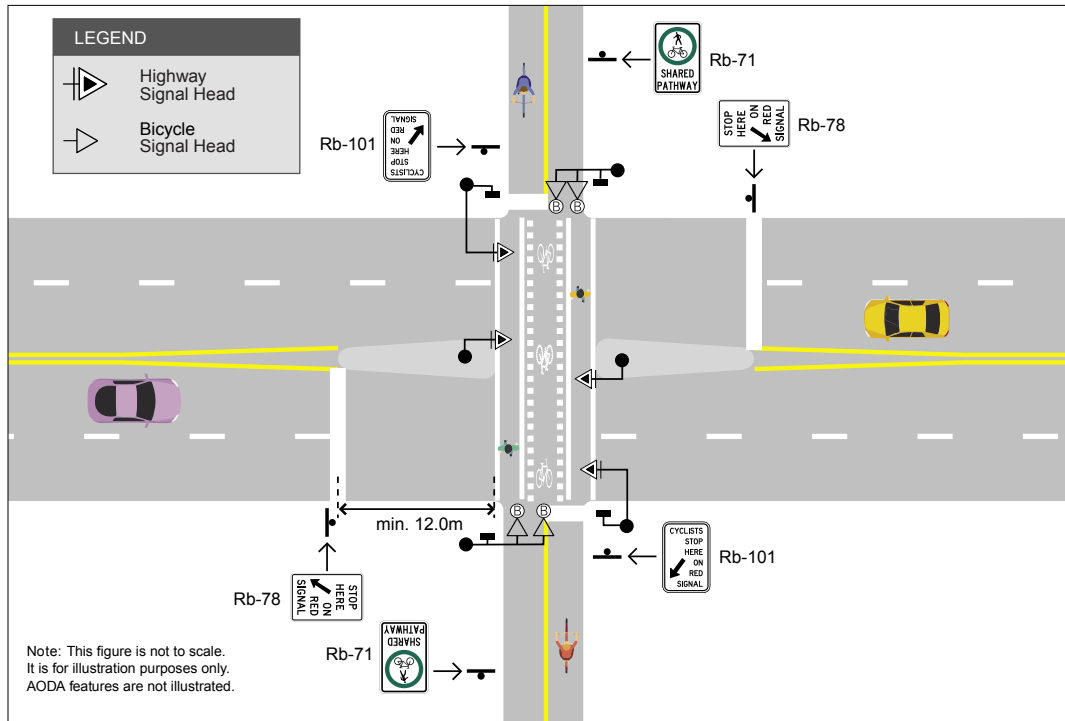


Figure 104 — Design: Mid-block Signalized Trail Crossing, Configuration C, Double Far-Side



Figure 105 — Image: Mid-block Signalized Trail Crossing, Configuration C, Double Far-Side

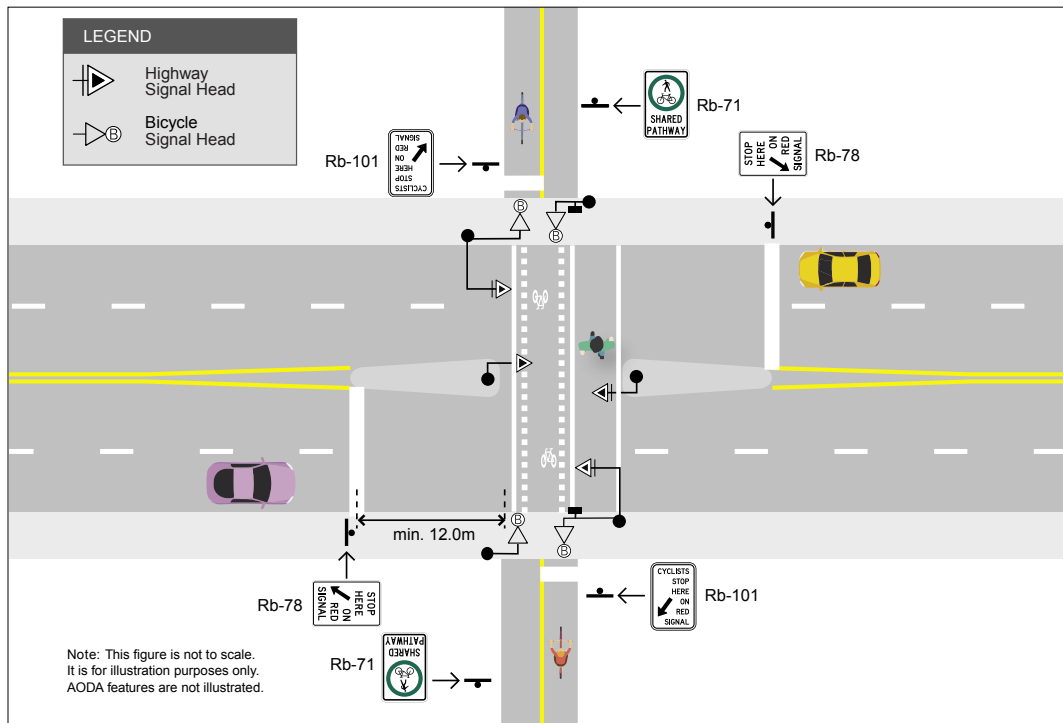


Figure 106 — Design: Mid-block Signalized Trail Crossing, Configuration A, Near-Side/Far-Side

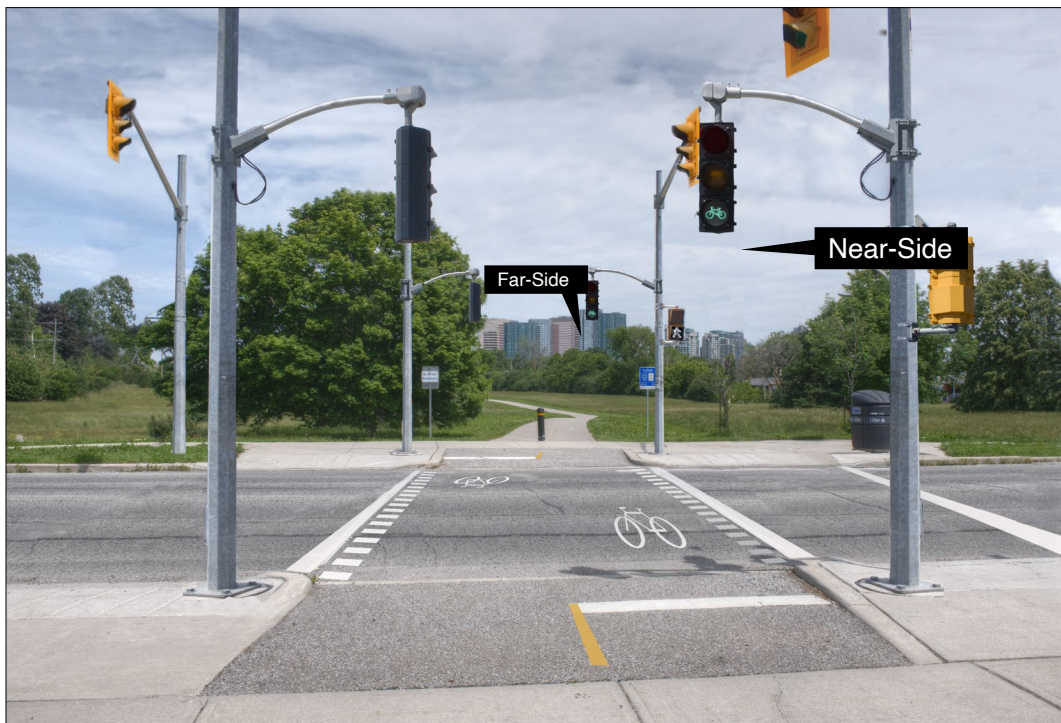


Figure 107 — Image: Mid-block Signalized Trail Crossing, Configuration A, Near-Side/Far-Side

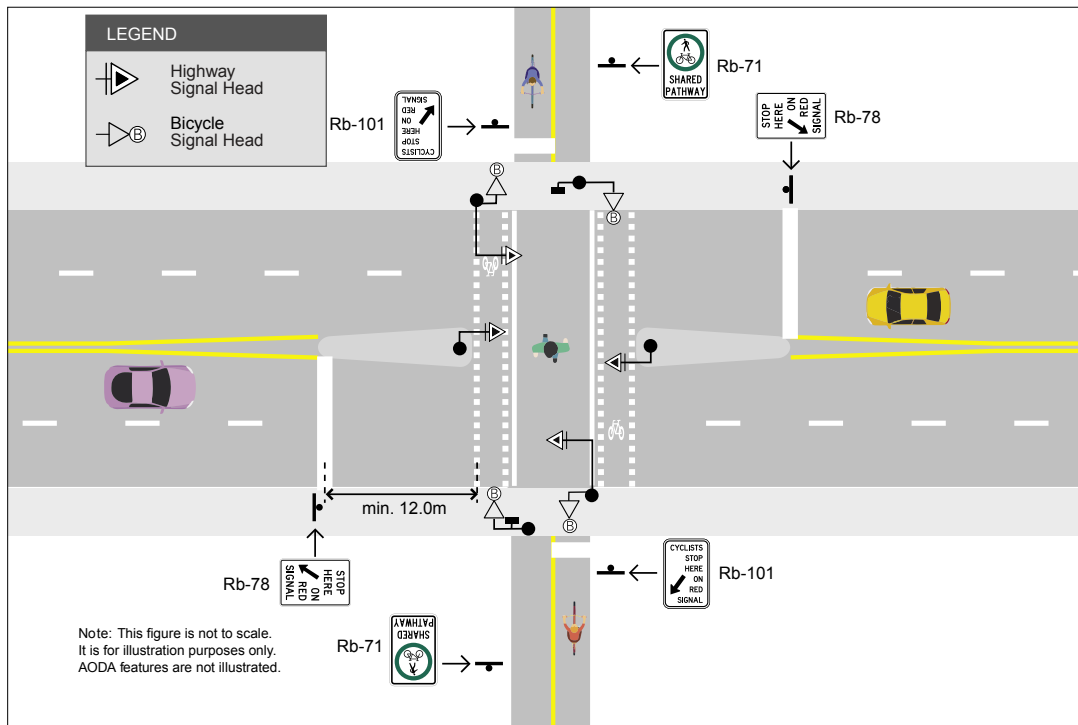


Figure 108 — Design: Mid-block Signalized Trail Crossing, Configuration B, Near-Side/Far-Side

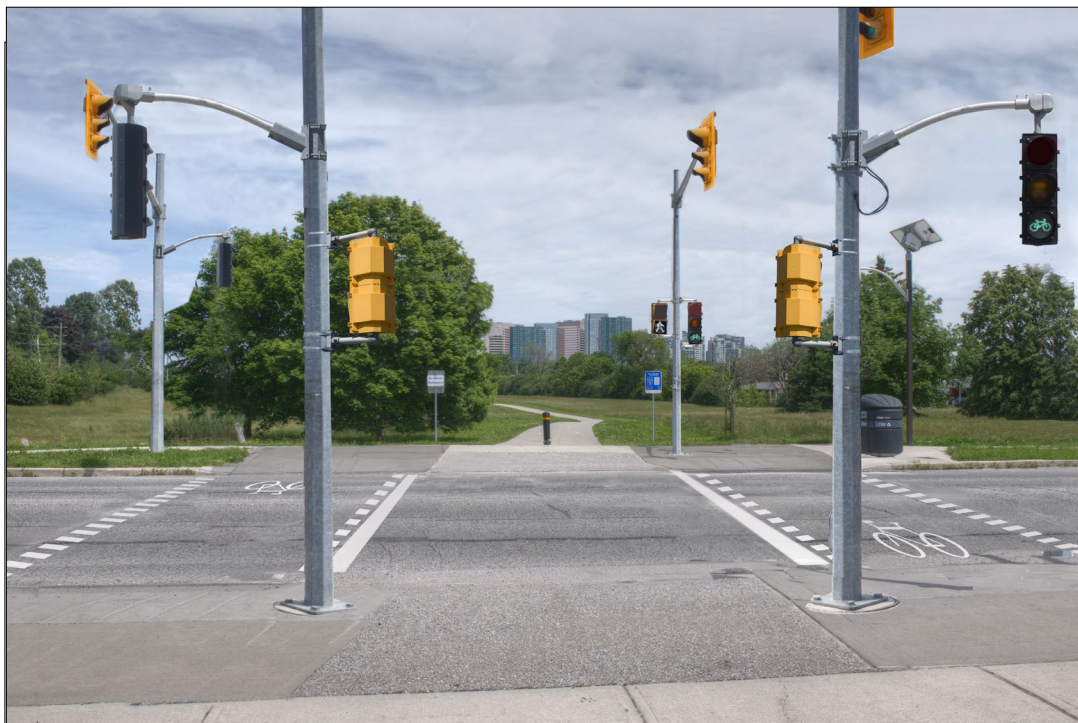


Figure 109 — Image: Mid-block Signalized Trail Crossing, Configuration B, Near-Side/Far-Side

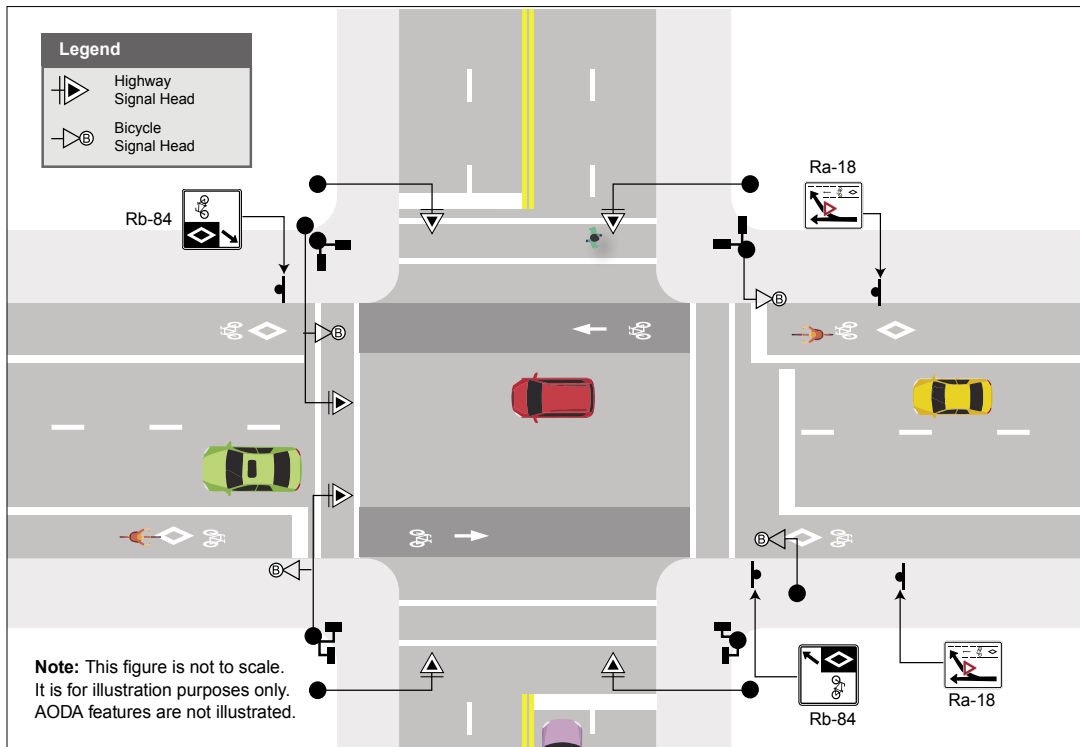


Figure 110 — Design: One-Way Street with Contraflow Bicycle Lane



Figure 111 — Image: One-Way Street with Contraflow Bicycle Lane

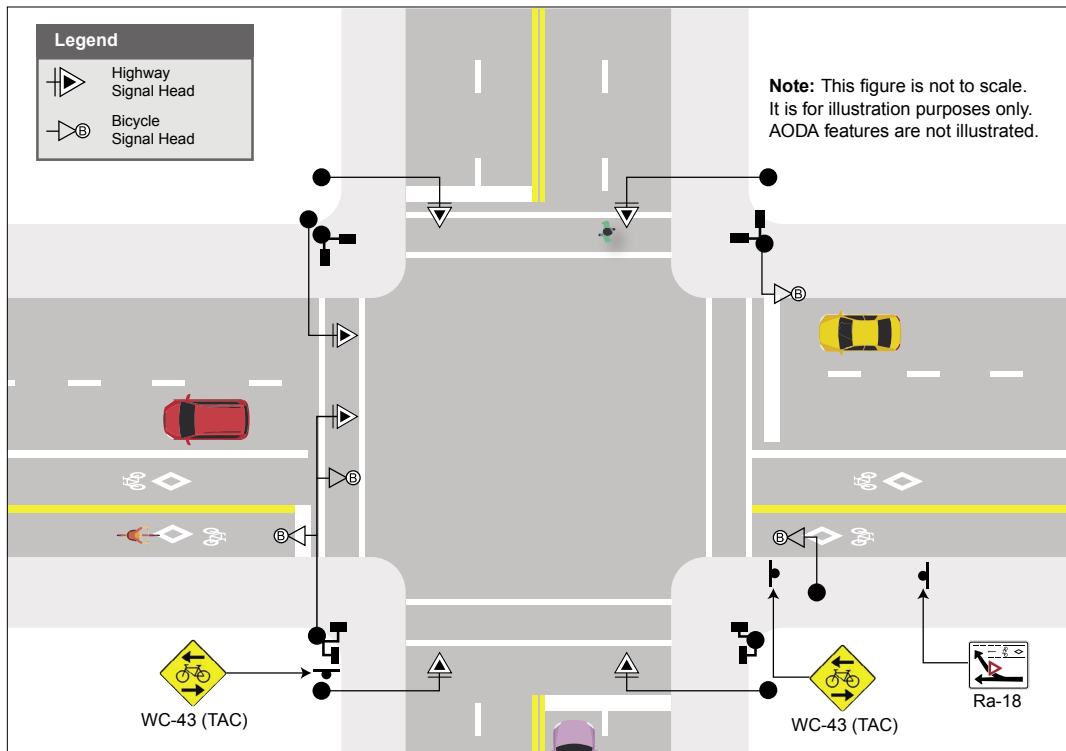


Figure 112 — Design: One-Way Street with Bi-Directional Bicycle Lane



Figure 113 — Image: One-Way Street with Bi-Directional Bicycle Lane

6.6 Decision Criteria

There are two types of decision criteria which are applicable to bicycle signal/bicycle phasing installation. Bicycle signal heads and bicycle signal phasing may be installed where circumstances suggest benefit to cyclists, motorists, pedestrians or all three. Bicycle demand may also be used as a factor in the decision to install a full or partial traffic signal. This section will discuss the two types of justification.

Criteria Which May Be Used When Considering Separate Bicycle Phases

The term “Bicycle-Specific Phases” includes separate movements, leading or separate phases and contraflow bicycle movements. The decision to provide a separate bicycle phase should be based on a need to reduce delays and eliminate conflicts between bicycles and turning vehicles. The following is a summary of the factors which may be considered when assessing the need for a separate bicycle phasing. An engineering study may be required to determine the impact between bicycles and other modes of traffic.

Volume/Delay Criteria

The following scenarios represent good candidates for providing a separate bicycle phase:

- At locations with high volume of bicycle movements where the overall delay is of concern.
- At locations with high volumes of turning vehicles where the safety of cyclists is of concern.
- At locations with a contraflow bicycle movements.

Collision/Conflict Criteria

- A bicycle signal phase should only be considered for use when an engineering study finds that a significant number of bicycle/motor vehicle conflicts occur or may be expected to occur at the intersection and that other less restrictive measures would not be effective.
- Collisions (when two or more bicycle/vehicle collisions of types susceptible to correction by a bicycle signal have occurred over a 12 month period and it is determined by the road authority that a bicycle signal will reduce the number of collisions).
- When there is a need to provide a leading interval for cyclists to increase their visibility and safety.
- Geometric factors – to control the separation of conflicting movements between cyclists and motorists.

Planning Criteria

- Where the addition of a special bicycle phase would complete the continuity of a bicycle system and where the movement protected or encouraged would otherwise be challenging.

Geometric Criteria

- Geometric (a path connection or to allow movement not allowed by vehicles).
- Geometric factors: an intersection that impedes cyclist crossings that could be mitigated with the bicycle phase.
- An approach to a signalized intersection is intended for bicycles only and it is desirable to signalize that approach.

- Examples of geometric configurations that might benefit from the use of a bicycle signal phase include:
 - A bicycle lane to the right of a high volume right turn; and,
 - A multi-use path that comes into the intersection in such a way that motorists may not see or yield to cyclists approaching the intersection.

Timing/Phasing Criteria

- Where paths cross roadways – to provide a shorter green time for cyclists when no pedestrians are present.
- If there is a bicycle movement that is not accommodated by typical traffic signals.

Demographic/Geographic Criteria

- Proximity to schools, parks, and popular bicycle routes should be considered.

Impacts to Consider

- Bicycle signals should be considered in the context of the benefits and impacts to all road users, both vulnerable and motorized.
- Additional delay to all roadway users should be considered.

Costs

- Cost of implementing revised signal operation.

Input to Existing Traffic Signal Warrants

Full Traffic Signal Justification

Bicycles which are part of the general traffic stream or are on designated bicycle lanes or cycle tracks

within the roadway should be included along with motor vehicles when performing traffic counts for the purpose of considering whether a new full traffic signal is justified.

IPS or Mid-Block Pedestrian Signal Justification

While intersection pedestrian signals and mid-block pedestrian signals are primarily devices to aid pedestrians in crossing the roadway, they can serve that purpose for bicycles equally well, as long as provision is made to ensure bicycles can cross the intersection legally and reasonably efficiently. IPS are particularly useful in providing continuity for neighbourhood bicycle routes when crossing an arterial, while mid-block signals fit well with multi-use or bicycle trail crossings. In the case of a new IPS or mid-block signal to be equipped with bicycle detection or a retrofit to serve bicycles, it is appropriate to add the bicycle traffic to the pedestrian volumes when considering the justification for installation of the signal.

6.7 Bicycle Detection

General

Bicycle detection is achieved through the use of inductive detectors, or a variety of other detection technologies including video, radar, microwave, infrared, and ultrasonic. Bicycles may be detected using the equipment already in place for general motor vehicle traffic. Alternately, detection specific to bicycles may be installed. A bicycle detector is a vehicle or pedestrian detector that has been assigned to indicate the presence or passage of bicycles in a designated area of the roadway at a signalized intersection. Detection methods can be either Active or Passive and are defined as follows:

- **Active Detection:** A cyclist push-button is provided. The push-button should be located such that it may be easily accessed from the stop position without dismounting. This type of detection does not allow for extensions should there be a higher cyclist volume.
- **Passive Detection:** Cyclists are detected by means of inductive loops, video, radar, microwave or optical detectors. Where passive detection is used, an optional indicator light may be implemented to provide positive confirmation that a cyclist has been detected.

Things to consider for bicycle detection:

- Use of existing versus bicycle-specific detection;
- Active or passive detection, requiring various levels of involvement by the cyclist;
- Technologies with differing requirements and impacts on the infrastructure, most specifically the roadway pavement; and
- Differing sensitivities to bicycles constructed of different materials, specifically the difference

between ferrous (steel) and non-ferrous frame and wheel materials.

Bicycle detection is typically installed to measure the presence of bicycles:

- On actuated approaches at semi- or fully-actuated intersections;
- Travelling in the general-purpose lanes at intersection approaches without bicycle lanes;
- Travelling in a bicycle lane;
- At intersections with bicycle signals and/or bicycle specific timings and phasing that are actuated; or
- In left-turn lanes where bicycles may turn left.

While it should be a basic requirement to provide bicycle specific detection wherever bicycles are present, the provision of reliable bicycle detection can assist in establishing bicycling as a legitimate mode of transport. The benefits of providing for bicycle detection at signalized intersections include improved efficiency and reduced delay for bicycles, increased safety and convenience, the discouraging of red light running and the provision of adequate green and/or clearance times for bicycles.

It is important to note that bicycles are more difficult to detect with some common types of vehicle detection technologies than a motor vehicle. Therefore, attention should be paid at both the design and installation stages to ensure that bicycle detectors are appropriate to the environment and will operate reliably.

Criteria Which May be Used When Considering the Need for Bicycle-Specific Detection

Bicycle-specific detection is required for circumstances in which bicycles move on their own separate phase(s). At actuated signals, either bicycle-specific detection or detection tuned to recognize bicycles reliably should be considered, based on policy, actual demand and bicycle system structure. In other instances, bicycle-specific detection is optional but may be considered highly desirable.

Factors which can be considered in determining whether bicycle detection is installed may include:

- Bicycle demand or volume;
- Bicycle network considerations, such as signed bicycle routes or bicycle lanes and consistency with similar locations throughout the network;
- Actuated sidestreets with low side street motor vehicle volume and/or short minimum and vehicle extension timing;
- Unusual geometry, such as wide intersections; and
- Detectors which have low probability of detecting bicycles, such as large rectangular detectors.

Common Types of Bicycle Detectors

Induction Detectors

General Vehicle Detectors

The most common type of detector in many jurisdictions is the in-pavement induction detector. When the existing vehicle detection is to be used, specific attention must be paid to the sensitivity settings of the detection amplifier. The goal is

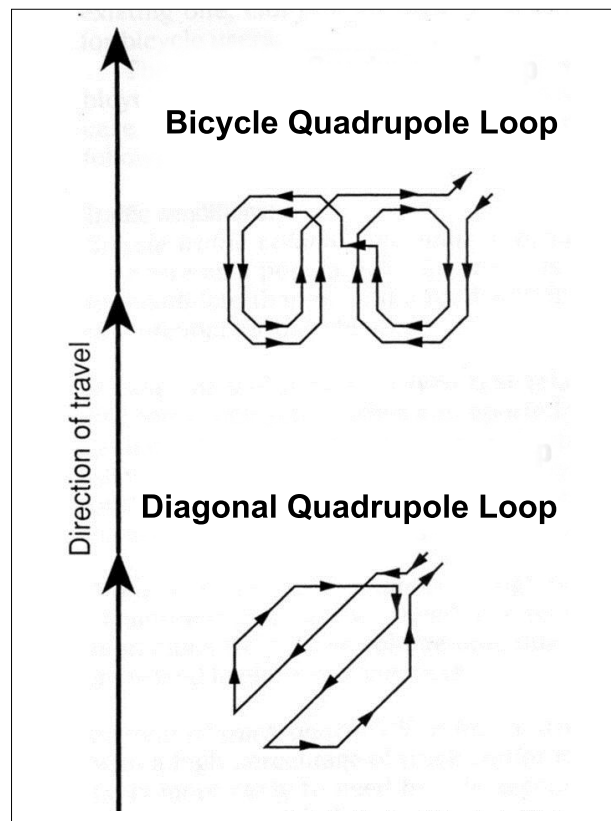


Figure 114 — Quadrupole Detectors

to set the sensitivity as high as possible without having the detection system “lock up” and place a steady call instead of detecting the arrival of vehicles. Testing and site visits to ensure reliable operation may be required. In some cases, such as when there are long lead lengths from the detector to the controller, it may simply not be possible to use existing detectors.

Given the lower sensitivity to bicycles of regular detectors, the use of pavement markings and signing, as discussed later in this chapter, indicating to cyclists where to position their bicycles to have the best chance of being detected, is very important.

Bicycle Specific Detectors

Introducing detectors designed specifically to detect bicycles will improve overall intersection operation for both traffic and cyclists. For bicycles, the detectors have greater sensitivity and will be more reliable over the long run. Generally, these detectors are capable of detecting ferrous and non-ferrous metal bicycles with reasonable accuracy. The regular vehicle detectors can be adjusted with lower sensitivity, meaning higher reliability (less likelihood of lock-up.) It is relatively easy (and not overly expensive) to design in bicycle detection when introducing all-new detection to a roadway approach. However, retrofitting bicycle detectors often means the destruction of the general-purpose detectors, and therefore, other types of bicycle detection may be a better choice.

To help ensure that bicycles are detected, quadrupole or diagonal quadrupole detector detectors are recommended because they are bicycle sensitive over their entire area. Figure 114 shows a typical bicycle-specific detector design. Four turns of #16 gauge copper wire is recommended to effectively detect a wide range of bicycle types.

Ideally, detectors should be placed in locations that are logical and convenient to cyclists, such as close to the edge of the roadway in a through or combined lane, and close to the right-side of a left-turn lane. To maximize the detector's effectiveness, supplemental bicycle detector pavement markings and informational signs may be utilized. These markings are discussed in more detail later in this section.

Other detector designs can work but may be less effective and may require a cyclist to position themselves within a much smaller detection area. Therefore, the importance of the use of the supplementary bicycle detector pavement marking and informational signage is increased with other detector designs.

Some road authorities have successfully implemented long-distance detection using induction detectors placed about 5 to 10 meters upstream of an intersection within a bicycle lane.

Video

Detection methods that utilize image recognition from video detectors are capable of detecting a cyclist at an intersection over a larger area than a detector. However, video detectors have been shown to have a reduced effectiveness in the dark, including registering false calls when shadows appear within the detection zone.

A typical video detector is comprised of a camera and an image processor that is programmed to analyze video images and mimic a detector. Defined detection zones can be relatively easily modified, which offers increased flexibility in detector layouts. Video detectors present an excellent alternative to detector detectors in a variety of situations, including where the pavement quality is poor and installation of in-pavement detectors can be challenging. Costs for video detection are typically higher than for detector installations.

Radar

There are two forms of radar detection. The above-ground is similar to microwave detection. The wireless in-ground detection systems communicate by radio with a backbone paired with the traffic control system and are capable of differentiating between motor vehicles and bicycles in the same lane.

Microwave

Microwave detectors are mounted above the ground similar to video and beam a cone shaped area to an approaching bicycle, which reflects some of the microwave energy back to the detector. This type of detection can be considered

in areas where in-pavement detector installation is not possible.

Optical

Optical detection uses pulsed infrared light-emitting diodes (LEDs) technology to detect the return time of light from the object to the sensor. This technology can detect many types of motor vehicles and bicycles in all weather conditions, any time of the day. The system can also determine the direction of travel of vehicles, thereby preventing false calls to traffic signal controllers.

These non-intrusive detectors are mounted directly to current traffic infrastructure similar to video detection. Some models also include an onboard image processor with the capability to transmit video images back to the jurisdiction.

Pushbuttons

Another form of bicycle detector is a bicycle-specific pushbutton, which has some advantages over other forms of detection:

- Pushbuttons are simple and easy to use compared to other forms of detection that may require the cyclist to position themselves precisely or approach the intersection in a certain prescribed way in order to be detected.
- Pushbuttons allow for feedback to the cyclist that they have been detected (for example by a visual and/or auditory signal produced by the pushbutton when activated), which may increase compliance with the signal indication and ultimately improve safety.
- Pushbuttons avoid missed calls due to technical limitations experienced with other forms of detection (such as induction detectors not detecting a bicycle with insufficient metal content, or other forms of detection affected by weather conditions like heavy snowfall).

However, pushbuttons also have disadvantages:

- As an active, rather than passive, form of detection, they do not automatically detect the cyclist, but rely on the individual cyclist to activate them.
- Pushbuttons are not appropriate for all intersection geometries (for example to detect a cyclist stopped in a left-turn lane at a typical intersection).

Cyclist activated pushbuttons can be used in conjunction with loop detection. While this arrangement increases the cost of detection; it provides the advantages of both active and passive detection.

Pushbuttons are most appropriate where an off-road cycling facility – such as a multi-use trails or a cycle track – meets a signalized intersection or mid-block crossing. They may also be applicable for single lane approaches, for designated bicycle lanes and other forms of operation where the cyclist is naturally riding next to the right-side curb.

If a pushbutton is used, the location of the device should not require cyclists to dismount or be rerouted out of the way or onto the sidewalk to reach it. It should be placed on the right-side of the intersection approach, positioned in a manner that is relatively convenient for the cyclist and away from the radius of the curve where it could be struck by large vehicles making a turn.

The pushbutton can be used either to call a bicycle specific phase or to call the pedestrian phase.

Depending on cyclists to use pedestrian pushbuttons is not generally recommended and should preferably be limited to low bicycle volume locations.

6.8 Pavement Markings and Signage

As opposed to motor vehicles which have greater size and mass and are more easily detected, bicycle detection is highly dependent on the position of the bicycle in relation to the position of the detector. To realize the maximum level of effectiveness from bicycle detectors, it is important that the cyclist position themselves in the area that provides the strongest detection signal from the detector. Cyclists can be aided in improving the likelihood of being detected by in-pavement detectors by careful application of pavement markings, possibly in combination with information signage, which would indicate where to place the bicycle in order to best be detected.

Figure 115 shows the TAC approved symbol which indicates to cyclists where to position the bicycle on the roadway.

Figure 116 shows the typical placement of the pavement marking symbol on various detector configurations.

Figure 117 shows Ontario standard signs OTM Rb-102 & Rb-102 (B) which should accompany this pavement marking stencil, especially for the introductory period.

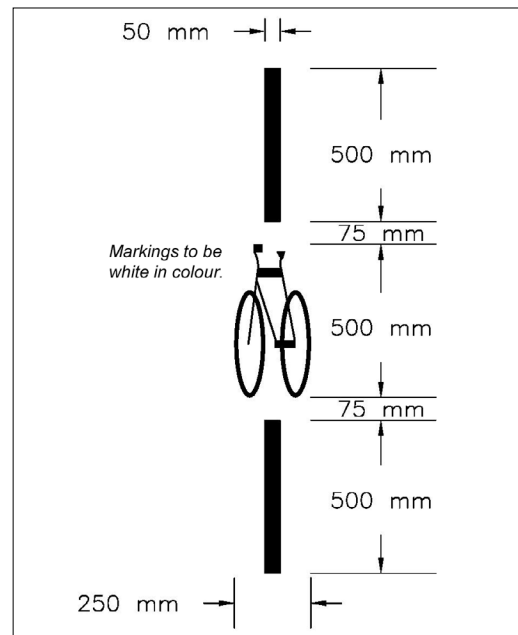


Figure 115 — Bicycle Detector Pavement Marking

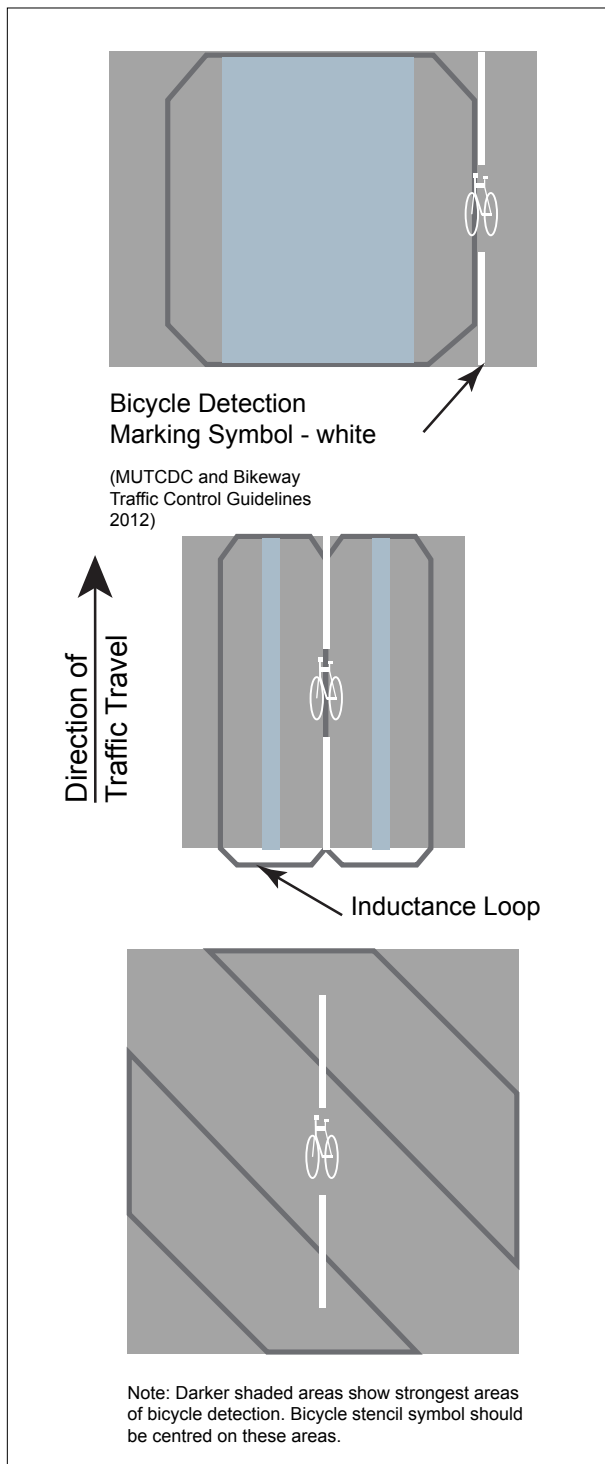


Figure 116 — Signal Detection Areas by Detector Type

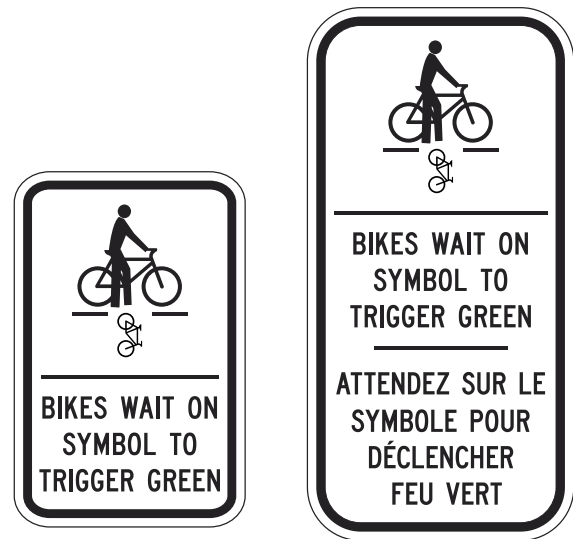


Figure 117 — BIKES WAIT ON SYMBOL TO TRIGGER GREEN (OTM Rb-102 & Rb-102 (B))

PARAMETERS FOR CALCULATING BICYCLE SIGNAL TIMING

APPENDIX A

In the absence of empirical information, the following suggested values may be considered:

Starting PRT = 1.0 s minimum

$V = 4.0 - 5.6 \text{ m/s (14-20 km/h)}$

$a = 1.0 \text{ m/s}^2$

$L = 1.8 \text{ m}$

SU = 6 seconds

W = typically measured from stop bar to far crosswalk line or equivalents if marking is not present

PRT for stopping = 2.5 seconds

d = deceleration rate of 3.0 m/sec^2

Suggested Values From Other Sources

TERM	SOURCE	VALUE
V	NACTO ³¹	14 f/s (15.4 km/h)
W	NACTO ³¹	stop line to mid-point of far lane
V, level	AASHTO (2012) ⁸	13-24 km/h
V, level	California	14.7 f/sec (16.1 km/h)
V	TAC	20 km/h
V	CROW	20 km/h
V, downhill	AASHTO (2012) ⁸	32-50 km/h
V, uphill	AASHTO (2012) ⁸	8-19 km/h
PRT	AASHTO (2012) ⁸	1.0 – 2.5 seconds
PRT	CROW	1.0 second
Deceleration, dry	AASHTO (2012) ⁸	4.8 m/s^2
Deceleration, wet	AASHTO (2012) ⁸	$2.4\text{-}3.0 \text{ m/s}^2$
Deceleration	CROW	1.5 m/s^2
L	AASHTO (2012) ⁸	1.8 m
a	AASHTO (2012) ⁸	$0.5 - 1.5 \text{ m/s}^2$
A	CROW	$0.8 - 1.2 \text{ m/s}^2$
SU	California	6 seconds
Tmin	TAC	5 – 15 seconds

GLOSSARY

APPENDIX B

Acronyms

AASHTO	American Association of State Highway and Transportation Officials	FHWA	Federal Highway Administration (U.S.A.)
AC	Alternating current	HCM	Highway Capacity Manual
AC+	120 V a.c., 60 Hz power bus	HOV	High occupancy vehicle
AC-	The 120 V a.c., 60 Hz neutral bus grounded at the power source	IPS	Intersection pedestrian signals
ASTM	American Society for Testing and Materials	ITE	Institute of Transportation Engineers
AWG	American Wire Gauge	LED	Light emitting diode
CCG	Canadian Capacity Guide for Signalized (Urban) Intersections	LOS	Level of service
CMOS	Complementary metal oxide semiconductor	LTL	Left turn lane
CPU	Central processing unit	LBI	Leading Bicycle Interval
CTS	Clear to send	LPI	Left Pedestrian Interval
DCE	Data communications equipment	MIST for	Management Information System Traffic
DCP	Data channel port	MODEM	Modulate/demodulate communications interface unit
DDE	Data distribution equipment	MOS	Metal oxide semiconductor
DHV	Design hourly volume	MOV	Metal oxide varistor
DTE	Data terminal equipment	MPU	Microprocessor unit
EEPROM	Electrically erasable programmable, read-only memory	MTO	Ministry of Transportation, Ontario
EPROM	Erasable programmable, read-only memory	MTTR	Mean time to repair
		MUTCDC	Manual of Uniform Traffic Control Devices for Canada
		NEMA	National Electrical Manufacturers Association

OTM	Ontario Traffic Manual
PCB	Printed circuit board
PHF	Peak hour factor
PHV	Peak hourly volume
PIT	Pre-installation testing
POP	Proof of performance testing
PROM	Programmable read-only memory
PXO	Pedestrian crossover
RAM	Random access memory
RF	Radio frequency
RTS	Request to send
RXD	Receive data
SCOOT	Split Cycle Offset Optimization Technique
TAC	Transportation Association of Canada
TOC	Traffic Operations Centre (general)
TOD	Time of day
TTL	Transistor-transistor logic
TXD	Transmit data
UART	Universal asynchronous receiver/ transmitter
VDS	Vehicle detection station

Definitions

Actuation:

The operation of a detector in registering the presence or passage of a vehicle or pedestrian.

All-Red Interval:

The time in seconds of a red indication for all intersection traffic. It is used following an amber clearance interval to permit vehicles or pedestrians to clear the intersection before conflicting traffic receives a green indication.

Amber Clearance Interval:

The first interval following the green right-of-way interval in which the signal indication for that phase is amber. A clearance interval to warn approaching traffic to clear the intersection before conflicting traffic receives a green indication.

Cabinet:

An outdoor enclosure for housing a Controller Unit and associated equipment.

Call:

A registration of a demand for right-of-way by traffic (vehicular or pedestrian) at a controller.

Central Computer:

The combination of the application software, operating system, and computer hardware operating a traffic signal system from a single location.

Colour Sequence:

A predetermined order of signal indications within a cycle.

Concurrent Timing:

A mode of controller operation whereby a traffic phase can be selected and timed independently and simultaneously with another traffic phase.

Conflicting Phases:

Two or more phases that will cause interfering traffic movements if operated concurrently.

Conflict Monitor:

A device used to continually check for the presence of conflicting signal indications and to provide an output in response to conflict.

Controller:

The general usage term for the controller unit, cabinet, and associated appurtenances.

Controller Cabinet:

An outdoor enclosure used for the housing of a controller unit and all associated power, control, protection, activation, or interconnection devices.

Controller Unit:

That part of the controller which performs the basic timing and logic functions. A microprocessor based or electro-mechanical timing unit.

Coordination:

The control of controller units in a manner that provides a relationship between specific green indications at adjacent intersections in accordance with a time schedule to permit continuous

operation of groups (platoons) of vehicles along the street at a planned speed.

Cycle:

Any complete sequence of traffic control signal indications. In an actuated controller unit, a complete cycle is dependent on the presence of calls on all phases. In a pretimed controller unit, a complete cycle is a complete sequence of signal indications.

Cycle Length:

The time (in seconds) required for one complete sequence of signal indications.

Cycle Splits:

The times in percent or seconds of the cycle for the phases making up the cycle.

Density:

A measure of the concentration of vehicles, usually stated as the number of vehicles per km per lane.

Detection Zone:

That area of the roadway within which a vehicle will be detected by a vehicle detector.

Detector:

A device for indicating the presence or passage of vehicles, including sensor device, lead-in cable, and detector sensor (amplifier) unit.

Detector Loop:

A detector that senses a change in inductance of its inductive sensor loop caused by the passage or presence of a vehicle in the detection zone of the loop.

Detector Memory:

The retention of an actuation for future utilization by the controller unit.

Detector Mode:

A term used to describe the operation of a detector channel output when a presence detection occurs: (1) Pulse Mode: Detector produces a short output pulse when detection occurs; (2) Controlled Output: The ability of a detector to produce a pulse that has a predetermined duration regardless of the length of time a vehicle is in the detection zone; (3) Continuous-Presence Mode: Detector output continues if any vehicle (first or last remaining) remains in the detection zone; (4) Limit-Presence Mode: Detector output continues for a limited period of time if vehicles remain in the detection zone.

Display:

A display consists of the total illuminated and non-illuminated signals facing the motorist. "Display" is interchangeable with "Indication".

Downloading:

The transmission of data from a master or central computer system to a Local Controller or a Remote Controller Unit.

Dwell:

The interval portion of a phase when present timing requirements have been completed. "Rest" as in "Rest in Green".

Extendible Portion:

In an actuated phase, that part of the green interval that follows the initial green portion when the initial

green portion is extended by traffic actuations. If sufficient number of extensions occur, may reach Maximum Green.

Flasher:

A device used to open and close signal circuits at a repetitive rate.

Force Off:

A command to the controller unit that will force the termination of the current right-of-way (green) interval during the extendible portion.

Fully-Actuated:

(1) A fully-actuated mode of operation is one in which both the side (minor) road and the main (major) road use detection devices. During operation, if no actuation occurs at the intersection, the controller will either rest in the last phase actuated or return to main road green to rest (recalled to main road green). (2) A fully-actuated mode of operation can be one in which passage loops are used on all approaches, or on one of the roads if the other road has detection at the intersection.

Gap Reduction:

A controller feature whereby the unit extension or allowed time spacing between successive vehicle actuations on the phase displaying the green in the extendible portion of the intervals is reduced after each extension, usually in proportion to another parameter. Time Waiting Gap Reduction is a feature whereby the unit extension in the phase having the green is reduced in proportion to the time vehicles have waited on the phases having the red.

Hold:

A command to the controller unit which causes it to retain the existing right-of-way (green) interval.

Indication:

The illumination of a traffic signal lens or combination of signal lenses at the same time. The “Display”.

Initial Portion:

The first timed part of the green interval of an actuated phase.

Interconnected Controller:

A controller which operates traffic control signals under the supervision of a master controller.

Interconnection:

(1) A means of remotely controlling some or all of the functions of a traffic control signal. (2) An electronic, fibre optic, time synchronization, radio, telephone, or electrical connection with coordination units or modems in the controller cabinets; (3) the physical interconnection.

Interval:

A part of a phase that is individually timed by the controller unit.

Interval Sequence:

The order of appearance of signal indications during successive intervals of a cycle.

Load switch:

A device used to switch 120 volt power to the traffic control signal heads. Load switches are normally

semi-conductor devices that are switched by a low voltage signal from the controller unit.

Local Controller:

A local controller is an intersection traffic signal controller that is locally programmed to suit the interval times required at the intersection but is set on the phasing and timing of the system as determined by the master controller or central computer.

Main Road:

The roadway approach or approaches at an intersection normally carrying the highest volume of vehicular traffic (also called “Major Road”).

Master Controller:

An automatic device for supervising a system of controllers, maintaining definite time interrelationships, selecting among alternative available modes of operation, or accomplishing other supervisory functions. A Master Controller controls one or more local controllers.

Maximum Green:

The maximum time the right-of-way can be extended by actuations on a phase, provided an actuation has been registered on a conflicting phase.

Military Specification:

Current issues and/or revisions of standards or specifications issued by the U.S. Department of Defence.

Minimum Green:

The shortest time for which the right-of-way shall be given to a non-actuated phase, or to an

actuated phase provided that an actuation has been registered for that phase.

Module:

A removable assembly with a fixed pattern of pixels, and identical to all other modules.

Motherboard:

A Printed Circuit Connector Interface Board with no active or passive components.

Movement:

A movement is the direction of traffic flow and may be straight ahead (a “Through Movement”), a green left arrow (a “Left Turn Movement”), etc. Several movements may be allowed within a phase (e. g., an advanced green arrow and a circular green display). In some cases, a movement is called a phase as the movement is normally part of a phase.

Non-conflicting Phases:

Two or more traffic phases that will not be in conflict with each other if operated concurrently.

Offset:

The number of seconds, or the percent of cycle length, that a defined time-reference point (the “Yield Point”, normally the start of main street green) at the traffic control signal occurs after the time-reference point of a master controller or of an adjacent traffic control signal.

Opposing Traffic:

Traffic progressing in the upstream or opposite direction to the traffic being considered on a roadway.

Overlap:

A right-of-way indication that is derived from the service of two or more traffic phases.

Passage Detection:

The ability of a vehicle detector to detect the passage of a vehicle moving through the detection zone and to ignore the presence of a vehicle stopped within the detection zone.

Passage Time:

(1) See Unit Extension. (2) The time allowed for a vehicle to travel at a selected speed from the detector to the stop line.

Pattern:

A unique set of coordination parameters including cycle length, split values, offsets, and sequence of intervals.

Pedestal:

Ground mounted enclosure for communications, or a support for a controller cabinet.

Pedestrian Clearance Interval:

The time in seconds during which the orange hand is flashed, starting after a walking pedestrian indication and ending before conflicting vehicles receive a green indication (may include the vehicle amber time).

Phase:

A part of a cycle where one or more traffic movements receive a green indication at the same time. Phase time is the time required from the start to the finish of the phase including amber and all-red interval times.

Phase Sequence:

A predetermined order in which the phases of a cycle occur.

Phase Skip:

A function used to provide omission of a phase in the absence of actuations on that phase.

Plan:

A unique set of timing values, intervals used, and sequence of intervals that is stored in or sent to a controller unit. Different plans may be used for time of day, time of week, special events and so on, or the plan may be traffic responsive as determined by detector actuation.

Poll:

An enquiry message sent from a master to a local controller on a regularly timed basis to solicit the status of the local controller.

Power Failure:

A power failure is said to have occurred when the incoming line voltage falls below 93 (+2) VAC for 50 milliseconds or longer. The determination of the 50 milliseconds interval shall be completed within 67 milliseconds of the time the voltage falls below 93 (+2) VAC.

Power Restoration:

Power is said to be restored when the incoming line voltage equals or exceeds 95 VAC for 50 milliseconds or longer. The determination of the 50 millisecond interval shall be completed within 67 milliseconds of the time the voltage first reaches 98 (+2) VAC.

Preemption:

The transfer of the normal control of signals to a special signal control mode for the purpose of servicing railway crossings, emergency vehicle passage, transit vehicle passage, and other special tasks, the control of which require terminating normal traffic control to provide priority needs of the special task.

Preemptor:

A device or program/routine which provides preemption.

Presence Detection:

The ability of a vehicle detector to sense that a vehicle, whether moving or stopped, has appeared in the detector's field.

Pretimed:

A controller unit mode of operation of traffic control signals with predetermined fixed cycle lengths, fixed interval durations, and fixed interval sequences.

Progression:

1) The time relationship between adjacent signals on a roadway that permits a platoon of vehicles to proceed through the signals at a planned rate of speed. 2) The act of various controller units providing specific green indications in accordance with a time schedule to permit continuous operation of groups (platoons) of vehicles along the road at a planned speed.

Red Clearance Interval:

A clearance interval which may follow an amber clearance interval that in theory allows time at the end of a phase for vehicles in the intersection to clear before release of a conflicting phase.

Right-of-way:

The operation of a controller in causing traffic control signals to display indications permitting vehicles or pedestrians to proceed in a lawful manner in preference to other vehicles or pedestrians.

Semi-actuated:

Operation by a type of traffic-actuated controller in which means are provided for traffic actuation on one or more but not all approaches to the intersection.

Side Road:

The roadway approach or approaches at an intersection normally carrying the least volume of vehicular traffic (also called "Minor Road").

Signal Indication:

The illumination of one or more lenses in a signal head which conveys a message to traffic approaching the signal from one direction.

Split:

For an actuated controller unit, split is a division of the cycle length allocated to each of the various phases (normally expressed in percent). For a pretimed controller unit, split is the time allocated to an interval.

System:

A traffic signal system is composed of a number of traffic signal controllers operating from electronic instructions given by a master controller at one of the intersections or by a central computer at a traffic control/operations centre. A system may be installed on a single roadway with one master controller and one or more local controllers, or on a grid of roadways using either a master

controller or a central computer. A system may use interconnection methods, telephone, television networks, or any combination thereof for communications transmission of data commands to the local controllers.

Through Band:

The time period between the passing of the first and last possible vehicle in a group of vehicles moving in accordance with the designed speed of a signal progression.

Time Base Control:

A means for automatic selection of modes of operation of traffic control signals in a manner prescribed by a predetermined time schedule.

Traffic Control Signal:

Any power operated traffic control device, whether manually, electrically, or mechanically operated, by which traffic is alternately directed to stop and permitted to proceed. Traffic Signal: 1) When used in general discussion, a traffic signal is a complete installation including signal heads, wiring, controller, poles and other appurtenances. 2) When used specifically, the term traffic signals refers to the signal head that conveys a message to the observer.

Unit Extension:

The timing period during the extendible portion of a right-of-way interval that is resettable by each detector actuation within the limits of the maximum period (extension limit).

User-definable Parameters:

Parameters which can be modified on-line by the user via some interactive dialogue with the system.

Watchdog:

A circuit or timer that is used to watch that an appropriate action is taken on a regular basis.

Yield:

A command that permits a controller unit to transfer right-of-way.

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APPENDIX C

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SIGNAL DESIGN AND DRAWING CHECKLIST

APPENDIX D

Requirements and Review Procedures for Traffic Control Signal Drawings

Requirements

1. Signal drawings should be on Form PHM-125 or similar form with CAD drawings preferred.
2. Preferred scale is 1:500 for rural intersections, and 1:250 or 1:200 for urban intersections.
3. Title block with correct road names should be above signature block.
4. Signature block should be on lower right hand side of the drawing and should be visible when drawing is folded.
5. Correct HTA should be shown. Currently HTA 144 (31) must be on the signature block.
6. The signature of the person designated to approve the design under HTA 144 (31) is required on the drawing.
7. A north point is required.
8. Correct road names must be used as the drawing may form a legal document. The title block and body of the drawing must agree.
9. A chart for listing revisions should be on the drawing. Persons carrying out revisions should list them here and enter their signature and date on the revision.
10. A chart indicating equipment specifications, such as mast arm lengths, mounting height, special heads, etc., is required.
11. A chart for special arrow heads should be used on drawings where such heads are used. If a chart is not on the drawing, a key for special heads must be shown.
12. All symbols used on the drawing must be indicated on a key chart.
13. Any signing that is critical to the traffic signal operation, e. g., left-turn signs adjacent to left-turn signal heads for fully protected left-turn lanes, overhead signing for dual left-turn lanes, and active advance warning signs, should be included.

Review

1. Geometrics

- Geometries should be acceptable for signal head placement.
- Drop curbs, etc., are identified, and appropriate curb radius are shown.
- Offset side roads are shown if part of signal.
- Private entrances are shown if part of signal. Heads must be used.
- Residential entrances are shown. Note: residential entrances do not require signal heads, but if they are used or rezoned for commercial purposes, and if they are for public use, heads must be provided.
- A split entrance (two entrances, one on each side of the same approach with each one allowing an in and out movement) are not allowed to operate within the lateral curb lines of a signalized intersection or intersection to be signalized.

- Pavement widths should be adequate.
- Left-turn lanes may not be opposite through lanes.
- Truck turning lanes should be adequate.
- Median islands and channelized islands must not obstruct through lanes.

2. Zone Painting

- Zone painting must be safe, and may not create restricted or conflicting movements.
- Zone painting should be legible.
- Temporary drawings may be exempted from the zone painting scheme if it is not feasible to show the paint during staging.
- Stop lines and pedestrian crosswalks should be indicated.

3. Equipment

- All signal heads and equipment should be under HTA. It is always recommended that the primary head should be a highway head with backboard.
- The secondary head may be a standard head with no backboard, but it is preferred that a highway head be used here also.
- All equipment must be standard as specified in the Ontario Traffic Manual and design manuals.
- Auxiliary heads may be added if required, e.g., visibility restrictions, curves, etc.
- Special heads must have the correct number indicated as per special arrow chart. If there is

no chart, a key must be drawn showing the lens display and lens sizes used.

- If pedestrian heads are used, they must be indicated.
- If bicycle signals are used, they must be indicated.
- Push buttons must be shown if pedestrian actuation is required. Arrows indicating the direction of pedestrian pushbutton actuation are usually shown on the drawing. APS pushbuttons are most commonly used to meet AODA requirements

4. Detection

- Presence detection is indicated on the side road.
- Presence detection is indicated in left-turn lanes if left turn phasing is required.
- Long distance detection is used on the highway if needed to extend the amber display (safe passage).
- Non-intrusive detectors are commonly used for presence detection at signalized intersections
- Microwave detectors can be useful for private driveways and temporary signals where permanent routes may not be possible or the pavement is too poor to cut loops.
- Emergency vehicle preemption detectors are shown facing the direction of travel in which they are used.
- Railway preemption may be required if a railway crosses or is close to a proposed signalized intersection.

5. Phasing

- Phasing appropriate to the design may be used.
- Phasing should not create conflicting traffic movements.
- Phasing must never compromise the safety of pedestrians.

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