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 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 Ontario Manual of Uniform Traffic Control Devices (MUTCD) and the King's Highway Guide Signing Policy Manual (KHGSPM).

The Ontario Traffic Manual is directed to its primary users, traffic practitioners. The OTM incorporates current best practices in the Province of Ontario. The interpretations, recommendations and guidelines in the Ontario Traffic Manual are intended to provide an understanding of traffic operations and they cover a broad range of traffic situations encountered in practice. They 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 judgement 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 judgements, but they should not be used as a substitute for judgement.

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 judgement 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.

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Book 12 Acknowledgements

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The team responsible for the revisions to this book would like to recognize Jim LeSarge for his outstanding contribution to the field of traffic signals over the course of his career. Jim passed away suddenly as a result of a tragic motorcycle accident on Thursday, August 18, 2005. He will be missed.

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1. General Information

1.1 Introduction

Traffic control signals intend to convey control messages to the road user. The objective of these messages is to advise motorists of traffic regulations in order to encourage compliance with the law, warn of intersecting roadways or road hazards, and provide the information necessary for the driver 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 and lose their effectiveness through excessive use. Therefore, simplicity in design, care in placement and a high standard of maintenance are essential. An effective traffic control signal will attract attention, be legible and comprehensible and be appropriate to the road user's needs.

A principal goal in the development of the Ontario Traffic Manual is the achievement of uniformity throughout the Province and compatibility throughout Canada and North America. Achievement of this goal requires that the Manual provide the user with the design and dimensions of devices, and with guidance in the preferred usage and methods of application.

Book 12 of the Ontario Traffic Manual (OTM) is a user manual intended to provide some elementary instructions to beginners and to provide a reference to experienced persons for the design and operation of traffic 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 are 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; all required information cannot be provided in a manual; and extensive knowledge and experience are required to be proficient in the field.

1.2 Sections of this book

This manual is organized in the following order:

- **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 (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, Miscellaneous**, documents recommended practices and guidelines for miscellaneous aspects.

This manual refers to various publications produced by the Ministry 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 Conference (OTC). Links to secure and stable Web sites are listed in the printed version of this manual and live links are provided in the PDF version.

This manual uses acronyms and, of necessity, some industry jargon. A glossary is provided at the back.

Symbols used on layout drawings may be found in Ontario Provincial Standard Drawings[15], Volume 4, Electrical Drawings, Division 2000. An abbreviated version of this legend may be found in Appendix D.

Book 12 of the Ontario Traffic Manual (OTM) was first published in 2001 as a replacement to the Ontario Manual of Uniform Traffic Control Devices (MUTCD), Chapter on Traffic Signals. This second version of the manual includes updates that reflect recent changes in the industry or material that is of wide-spread interest to practitioners that design, operate and maintain traffic control signals in the Province of Ontario. These updates include new information on:

- A Traffic Signal Life Cycle Process Diagram (Section 1)
- Legal requirements and recommended practice for transit signals (Section 2)
- New legal information on portable lane control signals and bicycle signals (Section 2)
- Considerations for Traffic Signal Maintenance (Section 3)
- A New Traffic Signal Justification Process (Section 4)
- Pedestrian Countdown Displays (Sections 3 and 5)
- Optically Programmable Signal Displays (Sections 3 and 5)
- Long Distance Detection (Sections 3 and 5)
- Criteria for Remote Control Devices, Portable Lane Control Signals and Portable Temporary Signals (Sections 3 and 5)
- Active Advanced Warning Signs (Sections 3 and 5)

In addition to this new information, several updates have been made to suggested methodologies, including timing of clearance intervals, timing of pedestrian intervals (Section 3) and aiming of traffic signal heads (Section 5). The content also reflects new standards and guidelines available in the industry and emphasizes human factors criteria where applicable. Links to related information inside the manual are provided as well as links to outside sources of information available at the time of publication.

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 aspects are founded on recommendations established through experience. In this publication, specific terms are adopted to convey the differences between the sources of traffic control aspects. These terms and the corresponding meanings are as follows:

"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[7] (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 HTA[7] and Regulations. The interpretations are given in lay language and may include some industry jargon. The requirement is 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 equipments 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 equipments 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 alternate 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. Maximum efficiency implies the minimum delay to traffic. Safety requires that the traffic control signals operate at the minimum hazard to all road users, including vehicle occupants, bicyclists and pedestrians. 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 generally 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. 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 to the increased use of alternate routes in attempting to avoid these types of signals. Unjustified traffic control signals may alter the type of collisions and in some cases increase the collision frequency, particularly rear-end collisions, as opposed to right-angle collisions prevalent at intersections controlled by stop signs. **Therefore, installation of traffic control signals does not necessarily guarantee a reduction in collision frequency, however 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, for speed control devices, for demand control devices or for the discouragement of motorists and pedestrians from using a specific route.

Justification of traffic signals should be based on studies and needs as outlined in Section 4.

1.5 Driver Needs and Limitations

Traffic control devices are intended to provide vital information to drivers. They will be more effective if they are 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. However, 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/hour, 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 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 have 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 the prevalent considerations for traffic signals at the various stages of justification, design, and operation. The life cycle diagram shown in Figure 1 assists in understanding the interrelationship between these various stages. Broadly speaking, these 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.

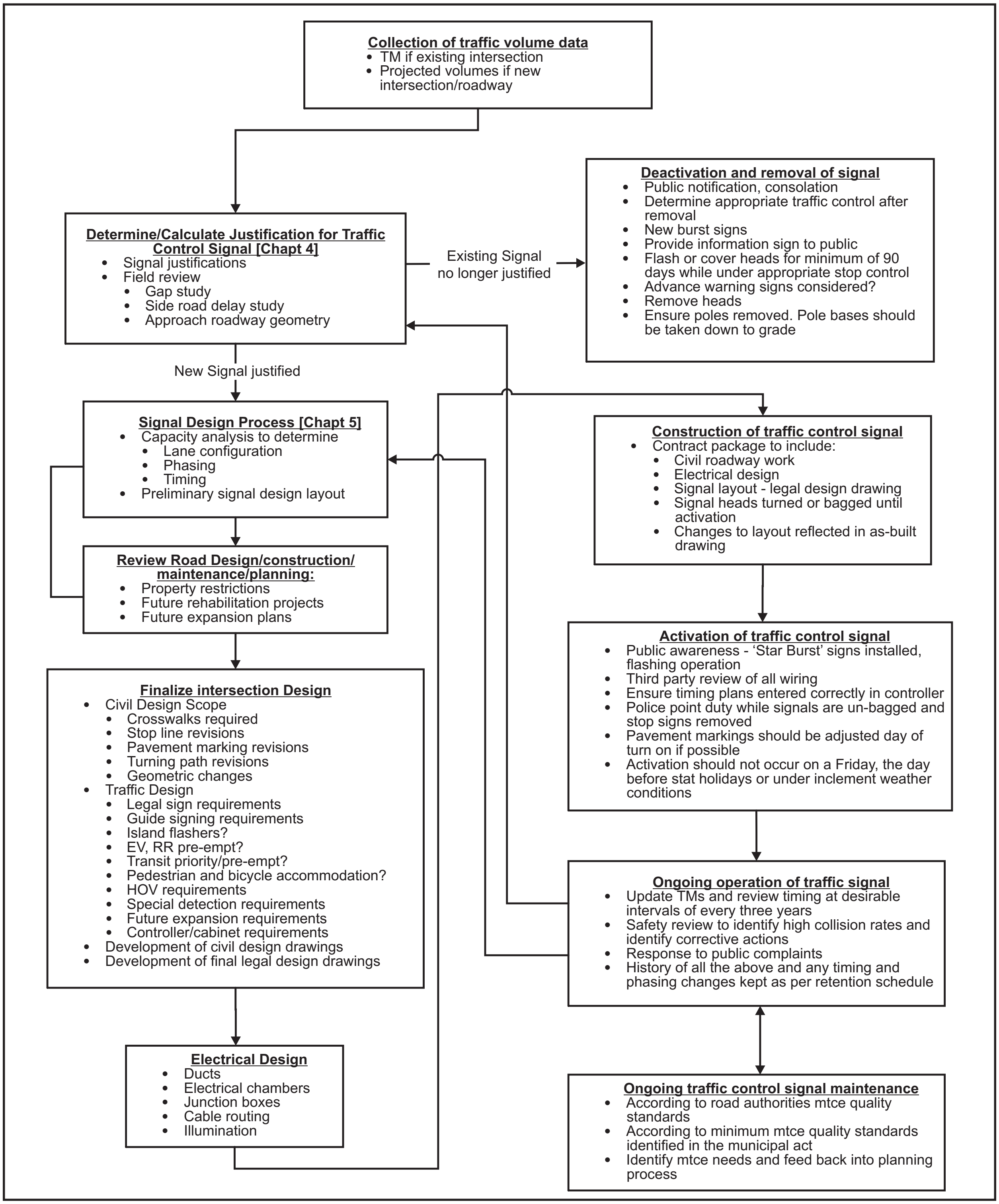


Figure 1 – Life Cycle Diagram

2. Legal Requirements

2.1 General

Section 2 provides an interpretation of various Sections and Regulations of the Highway Traffic Act (HTA)[7] associated with traffic control signal systems and traffic control signals. These Sections include:

- Section 144 (31) – Approvals of Signal Designs
- Section 144 (13) – Flashing Green
- Section 144 (19.1) – Bus Priority Signal Indications
- Section 146 – Portable Lane Control Signals
- Regulation 626 – Traffic Signal Heads
- Regulation 606 – Portable Lane Control Signal Systems
- Unregulated – Bicycle Signals

For the purpose of understanding the Regulations of the Highway Traffic Act, "traffic signal control system" means the entire signalized intersection, which includes all electrical components, signage and pavement markings. The system also includes the "traffic control signals", which are the actual traffic signal heads.

2.2 Highway Traffic Act – Section 144 (31)

HTA Statute 144 (31) – Approvals of Signal Designs

1. General

A revision to The Highway Traffic Act (HTA)[7], Sub-section 144 (31), was proclaimed into law in the Ontario Legislature on March 3, 1997.

2. Legal Requirements

The following is the text of the revision:

(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."*

3. 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 for 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 particular Municipality is responsible for preparing the legal drawing (PHM-125 format) and submitting it to the Ministry for approval.

4. 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.

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 prior to 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 30 m) 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 pedestrian heads and their mounting height
- The exact location of pedestrian signal heads and pushbuttons
- Geometrics as per Appendix C
- 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 devices and their location
- 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
- Lane dimensions

v It is recommended practice that if signal heads are relocated, additional signal heads are installed or the roadway geometrics/lane configurations are modified, then the entire installation be re-approved by the designated approval person(s).

vi It is recommended practice that approval plans should be prepared for both temporary and permanent signals.

HTA Statute 144 (19.1) – White Vertical Bar Indication

1. Legal Requirements

Section 19.1 states "*a driver operating a bus or street car 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.

3. Recommended Practice

i It is strongly recommended that all transit operators be educated on the safe operation of transit signals when 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 (13) – Flashing Green

1. Legal Requirements

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. Consequently, it is recommended that after January 1, 2010 the use of the circular flashing advanced green should no longer be permitted in Ontario. 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 methods.

ii. Road Authorities are encouraged to seek their own legal interpretation of the Highway Traffic Act prior to adopting the use of flashing arrows.

HTA Statute 146 – Portable Lane Control Signals

Legal details for portable lane control signals are listed for Regulation 606 below.

2.3 Regulation 626 (as amended)

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. This type of operation may occur, for instance, at a "T" intersection facing the side road.

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; a "permissive" display), only one additional green arrow indication may be displayed in the same signal head at the same time, indicating that either left or right turns, specifically in one direction only, are "protected" from interference from a conflicting traffic movement.

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. (11). 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).

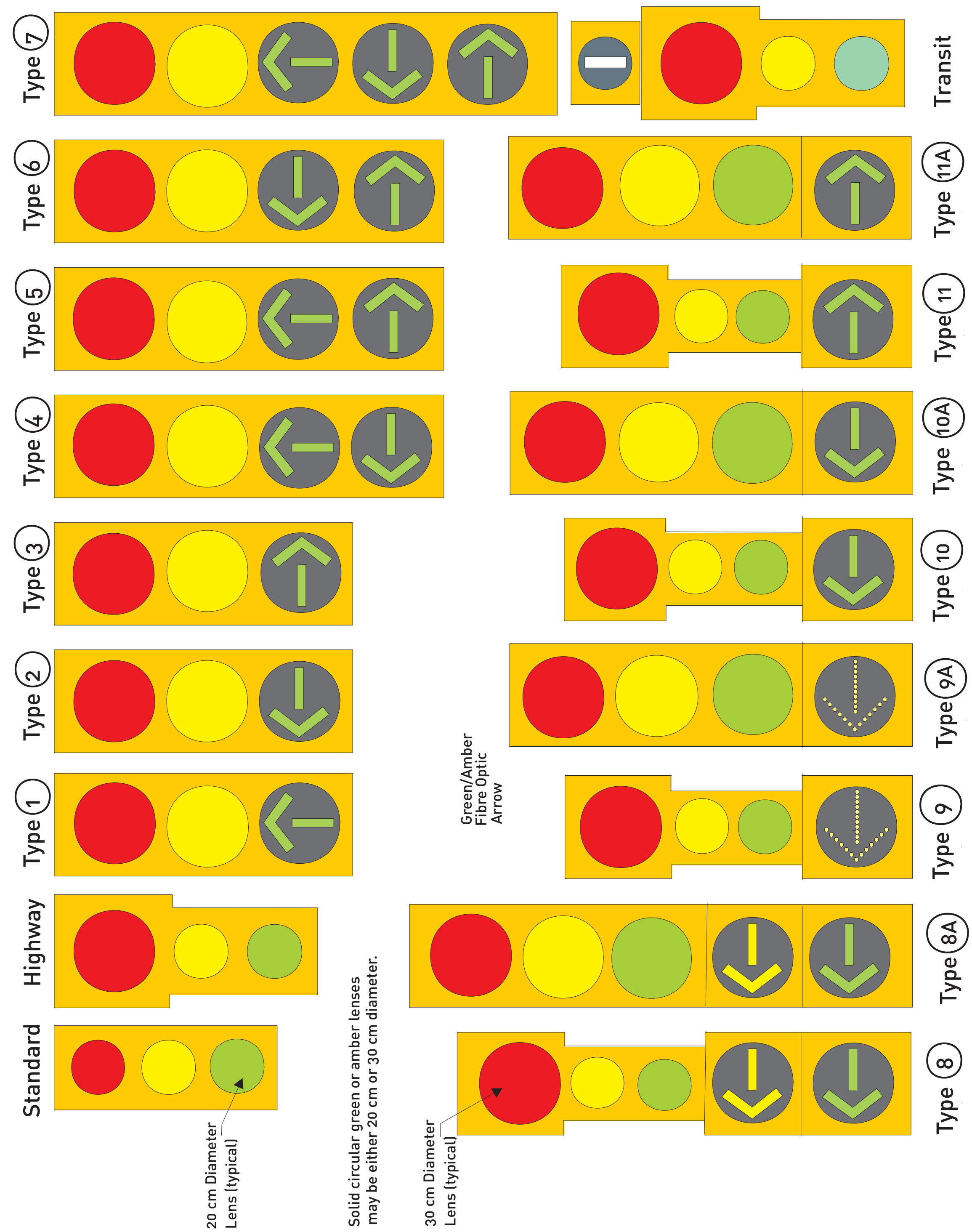


Figure 2 – Traffic Control Signal Heads

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 20 cm or 30 cm 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 30 cm 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 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.

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	Notes 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 below it.
3. A green indication, either a circular green or a green arrow, is mandatory on a signal head.

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 shall be used due to the need to maintain uniformity** in Ontario (with the exception of lens size which may be either 20 cm or 30 cm 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."*

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 is allowed to be displayed at the same time with 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.

ii 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. 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 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.

v **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.

vi **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 is 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 applications 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 At this time, 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 TAC MUTCDC[12] 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 metres above the level of the roadway when adjacent to the travelled portion of the roadway and not less than 4.5 metres 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 over the tops of vehicles from a distance. Intermediate mounting heights between 2.75 m and 5.0 m are useful to improve 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 of 80 km/h and over posted speed, 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 metre 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 metres 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 allow for a 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 since the approach speed is very low and because they 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 thirty centimetres in height or width; and*

(b) *consist of an orange silhouette of a hand on an opaque background as illustrated in the Figure 3."*

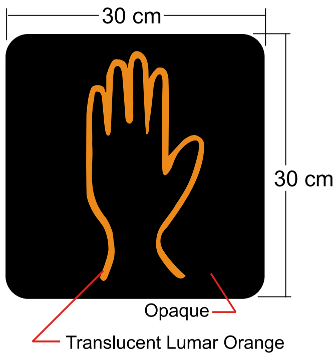


Figure 3 – Don't Walk Signal

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 30 x 30 cm pedestrian control heads should be used.

ii Light sources for pedestrian control indications must meet the colour requirements of ITE Publication ST-217.

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 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 centimetres 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).

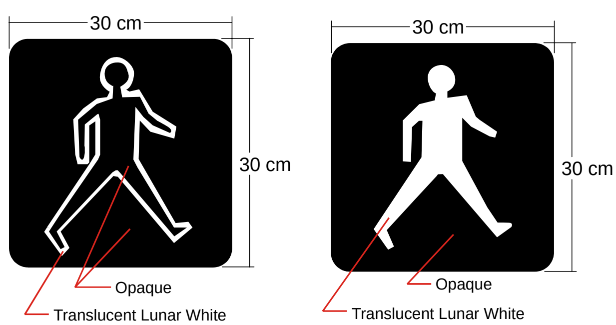


Figure 4 – Walk Signals

2. Interpretation

i Standard 30 x 30 cm 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-217.

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 30 x 30 cm (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:

- "Midblock 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, rail or transit crossings, special factory equipment or material moving crossings of a roadway and 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 installation of traffic signals at the foregoing locations shall give an outward appearance to approaching motorists that is consistent 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 a 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.

iii In the event that a portable lane control signal has to be left unattended or for long term duration work as defined in OTM Book 7, Temporary Conditions, the signals should meet the requirements for temporary signals and a legal drawing should be prepared and approved in conformance with Regulation 626, including the use of at least two signal heads for each approach.

2.4 Regulation 606 (as amended) – Portable Lane Control Signal Systems

HTA Regulation 606 Section 1

1. Legal Requirements

Section 1 states: *"Every portable lane control signal system shall consist of at least one set of green, amber and red signal-lights for each direction from which traffic is to be controlled by the system approaches."*

2. Interpretation

i Portable lane control signal must conform to the standards set out in HTA Section 146.

ii 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, and should be operated during daylight hours where the signal is attended during use.

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

2.5 Unregulated Items

Bicycle Signals

1. Legal Requirements

There are currently no legal regulations or statutes for bicycle signals in the Province of Ontario.

Although bicycle signals do not currently have any formal regulations in Ontario, they have been adopted in other parts of Canada. Currently the Transportation Association of Canada is formulating guidelines for use and recommending the specifications for the symbol.

3. Operational Practice

3.1 Introduction

General

This part of the manual gives an overview of traffic signal operational practice. Operational analysis requires an understanding of the theories of traffic flow and experience in its application to traffic control signals. References may be found in TRB's "Highway Capacity Manual"[8] (HCM), in ITE's "Canadian Capacity Guide for Signalized Intersections"[1] (CCG) and in the Ministry's "Traffic Control Signal Timing and Capacity Analysis at Signalized Intersections" [25] (TCSTCA).

It is necessary to use industry jargon to describe various pieces of 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, traffic control signals refers to the system of equipment (e.g., poles, heads, controllers, detectors, etc.) that control traffic at an intersection. An individual signal indication is referred to as a "traffic signal head" or "traffic signal indication". These terms differ slightly from the legal definitions presented in Section 2.

Standardization

Standardization of many of the aspects of traffic control signal operations 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
- 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
- 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 Operations Study should consider the following elements:

- Collision history at the intersection
- Pedestrian volumes at various times of day
- A turning movement study, including trucks and buses
- Approaching speeds
- Geometric requirements
- Sight distance requirements

- Requirement for phase adjustments (adding or removing)
- Modifications to timing (clearances, minimums, splits)
- Requirements for preemption or priority operations
- Proximity to other intersections
- The need to operate independently or on a system

Chapter 4 provides a methodology to estimate 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. Concentration is on solid state controllers, including the Type 170 controller[16] and the NEMA Standard controller[24, 26]. 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 very simplistic description of their operation follows:

- The controller's Central Processing Unit (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 loadswitch 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.

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

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.

Many municipalities use the NEMA specification[24, 26] controllers, 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.

All modern controllers provide connections for conflict monitors. Conflict monitors detect the interruption of electronic circuits and detect signal conflicts on green, amber and walk signals as well as the absence of sufficient voltage and the absence of all red signal indications for a given approach. The 170 and NEMA controllers must not be operated without conflict monitors according to industry specifications.

Detailed information on controllers may be found in the publications of the major controller manufacturers and in the NEMA[24, 26] and Ministry[16] specifications.

3.3 Determination of Intersection Operation

The mode of control used (see subsection 3.4) 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 of traffic volumes on all approaches throughout the day
- The volume of pedestrians using each crosswalk
- The percentage of large vehicles
- Usage such as bicycles, transit buses and emergency vehicles
- Volumes of turning vehicles
- The seasonal variations in traffic volumes and characteristics
- The length of time that the signal will be in operation (if temporary)
- Pedestrians with special needs

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. To achieve these objectives, the ITE's "Canadian Capacity Guide for Signalized Intersections"[1] (CCG) recommends a four-step 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.[1].

2. Analysis

Analysis includes investigation of intersection conditions and the determination of relevant evaluation, design or planning variables and parameters. This step includes consideration of preliminary signal timing and constraints and the need for the level of detailed traffic input. The balance between maximum efficiency and optimal safety is only derived from traffic control signals when the lengths of the various intervals are set in accordance with traffic demands while considering safety for both vehicular and pedestrian traffic.

3. Planning and Design

This step considers future geometric features and the iterative design of the operational parameters. This may include field surveys for arrival flow, saturation flow, overload factor, average overall delay, average stopped delay and queue length, methods for which are all defined in the CCG.

4. Evaluation

This includes the evaluation of any changes made to the traffic control signals. Because the introduction of new traffic control signals interrupts 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, and clearance intervals
- Timing design for cycle times composed of times for green intervals, walk intervals and clearance intervals
- Intersection capacity, queuing, arrival traffic flow, peaking characteristics, and mode splits

The foregoing factors and their analysis may be found in detail in the Ministry's "Traffic Control Signal Timing and Capacity Analysis at Signalized Intersections" [25] (TCSTCA) and in ITE's "Canadian Capacity Guide for Signalized Intersections" [1] (CCG).

3.4 Selection of Mode of Control

General

The selection of the mode of control at any 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 relationship
- Volumes of pedestrians crossing the main road
- Percentage of buses and heavy trucks

The following modes may be used either for isolated intersections (operating independently) or within an interconnected system or a central system:

Pre-timed or Fixed 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 it 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 set program or plan.

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

- Consistent starting time and interval duration of pretimed control facilitate coordination with adjacent traffic signals. It also provides more precise coordination than does traffic-actuated control, especially when coordination is needed with adjacent traffic signals on two or more intersecting streets or in a grid system.
- Pretimed controllers are not dependent for proper operation 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 confusion may occur with the operation of pedestrian pushbuttons.
- Generally, pretimed equipment costs less to purchase and install, and it is simpler and more easily maintained than traffic-actuated equipment.

Actuated Mode

An actuated signal is a traffic control signal that services movements based on demand. Actuated signals make use of detection to respond to vehicle and pedestrian actuation and are categorized as either *semi-actuated or fully-actuated*. Potential advantages include:

- Traffic-actuated control may provide maximum efficiency at intersections where fluctuations in traffic cannot be anticipated and programmed for with 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 collisions associated with the arbitrary stopping of vehicles.

Semi-actuated Mode

Detectors are located on the side road approaches and in the left turn lanes of the main road. Semi-actuated control is applicable for an intersection 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. Upon the expiration of the minor-street phase, the green indication reverts to the major street, where it must remain for at least a predetermined minimum interval. At the expiration of this minimum interval, the control is again free to respond to minor-street actuation. The semi-actuated control mechanism receives no actuation from traffic on the main road through lanes, and therefore may assign the right-of-way to the side road at inopportune times (i.e., near the arrival of a main road platoon of vehicles). Hence the effective use of semi-actuated control is limited to intersections with either very lightly travelled side roads or intersections in coordinated systems where main road progression can be assured.

In a coordinated system, side road actuation can be limited to a "window" of time each cycle 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 are determined by the side road changing traffic flow at the intersection. This 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 "mainroad 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

This type of 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 with sporadic and varying traffic distribution
- 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 loops may be installed at the stop lines on both roads and the signal phase rests in the green display of the traffic direction last being served. Alternatively, a recall for the main road may be programmed to rest on the main road green in the absence of any other demands.

Many fully-actuated intersections use set back loops, which are located in each lane upstream from the intersection. The loops can be operated in a variety of ways. For example, set back loops 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 variation of fully-actuated operation is commonly used on roadways posted at 80 km/h or greater where the sideroad is actuated but the main road rests in green. Set back loops are used to extend the green. This form of control is referred to as "long distance detection".

Long Distance Detection

Long distance detection is used to provide an extra level of safety for motorists at high speed signalized intersections by providing dilemma zone protection. In the MUTCDC:

"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."

Long Distance Detection uses set back loops located upstream from an intersection to sense approaching vehicles. When a vehicle passes over the loop, the signal controller extends the green time (up to a maximum time) to allow the vehicle to pass through the dilemma zone prior to the on-set of the amber signal indication.

Long distance detection generally consists of a single "simple loop" centred in each through lane of the mainline approach and located at the upstream edge of the dilemma zone. With respect to actuated signal timing, both approaches receive a minimum green interval and vehicle extension periods up to a maximum green interval. Each vehicle extension period is intended to carry a vehicle from the outside edge of the dilemma zone to a point representing one second of travel time from the stop bar (past the inside edge of the dilemma zone).

Long Distance Detection is most effective where signals routinely "gap-out" just at the time vehicles are approaching the signal. A maximum green time should be established according to the prevailing traffic conditions (on all approaches) and consideration can be given to using Time of Day Functions to alter the maximum green if traffic demands change throughout the day.

Long distance detection may be implemented at intersections on roadways that meet all of the following criteria:

- Operating speed is greater than 60 kilometres per hour.
- Traffic signals are fully actuated.
- The intersection is isolated, non-interconnected, or interconnected with off peak free modes operation.
- There are no major entrance points between the loop and the intersection.

The key elements related to the successful operation of this device are the placement of the long distance loop on the mainline approach and the vehicle extension time that is provided each time the loop is activated. If the loop is placed too close to the intersection, vehicles, especially those travelling at high speed, may enter the dilemma zone prior to activating the loop. If the loop is placed too far from the intersection, providing short vehicle extension periods may result in motorists being in the dilemma zone at the on-set of amber. Providing excessive vehicle extension periods can increase vehicular delay as well as the probability of max-out during high volume situations.

Additional information on loop placement for long distance detection is provided in Section 5.

Double Long Distance Detection

Double Long Distance Detection can be used where high speed vehicles (above the operating speed of the roadway) are creating a safety concern. Double Long Distance Detection uses information collected from two loops to calculate 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 loops, a green extension is provided to allow the vehicle to pass through the dilemma zone prior to the onset of amber. However, if a vehicle is travelling below the threshold speed between the two loops, 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 “simple loops” centred in each lane of the mainline approach. As a convention for this manual, the loop closest to the intersection is referred to as loop 2.

With respect to actuated signal timing, the mainline approaches receive a minimum green interval and green extensions for loop 1 and loop 2 up to 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 loop 1 to loop 2. Loop 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 one second of travel time from the stop bar (past the inside edge of dilemma zone).

A maximum green time should be established according to the prevailing traffic conditions (on all approaches) and the road authority’s policies for phase times. Consideration can be given to using Time of Day Functions to alter the maximum green if traffic demands change throughout the day.

Double Long Distance Detection is intended to supplement Long Distance Detection, and is generally implemented at intersections at which Long Distance Detection is already in place. Prior to considering Double Long Distance Detection, the 85^{th} percentile speed of the roadway should be determined. The existing Long Distance Detection should be reviewed to determine whether the detector placement and vehicle extension period conform to the recommended implementation. More details on loop placement are provided in Section 5.

Double Long Distance Detection should only be implemented at intersections on roadways that meet all of the following criteria:

- There is a grade approaching an intersection sufficient to require more than the normal braking effort (3% or greater).
- Large volumes of commercial vehicles (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 kilometres per hour.
- Operating speeds exceed posted speed limit by 20 km/h or more (threshold speed).
- The approach is operating at a level of service C or better.
- Isolated, rural, or non-interconnected intersections.

Double Long Distance Detection should not be used on approaches that use True Active Advance Warning Signs.

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:

- Slave controllers at each intersection controlled by a field master controller.
- Controllers at each intersection 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.

Except for systems using traffic adaptive software, signal 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 normally moves in tight groups or platoons, with gaps between platoons, which may be utilized for vehicle or pedestrian crossing times on sideroads or at unsignalized intersections or entrances between signalized intersections.
- Stops for main road traffic are reduced and overall delay is generally decreased, although this may increase delay on the sideroads.
- Increased intersection capacity by decreasing the volume of queuing vehicles and thereby decreasing startup delays.
- Reduced collisions by reducing the speed differential between individual vehicles.
- Reduced rear-end collisions by reducing the need to stop.
- Reduced fuel consumption, noise and air pollution by reducing the number of stops and delays.
- Maintenance benefits by reducing field visits required to update timing plans as well as by providing quicker response 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 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. For 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 are high enough on the side street that continuous vehicle actuation causes the side road to go to the full phase time allowed.

Design and analysis software is available to perform coordination and network analysis. The coordination is calculated to progress 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 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, 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 have to operate in a coordinated manner and therefore does not need 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.

3.5 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 number of practical phases should always be used to reduce the "lost time" due to clearance intervals between phases.

Guidelines are primarily found in the Ministry's "Traffic Control Signal Timing and Capacity Analysis at Signalized Intersections" [25] (TCSTCA) and ITE Canada's "Canadian Capacity Guide for Signalized Intersections" [1] (CCG).

Where the volume of vehicular or pedestrian traffic entering or crossing one or more approaches is sufficient to impact the operation of the intersection, though 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 exhibited with a through movement is an example of a subordinate phase.

The number and type of phases required will be largely dependent 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[16] and the NEMA type controller[24,26] use similar numerical methods to identify phases. However, by convention, the side street phase numbers used by 170 and NEMA controllers are reversed.

The NEMA convention for traffic movements is shown in Figure 5. "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 (always on the main road) in either the northbound or eastbound location and progressing counter-clockwise around the intersection (clockwise for 170 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 controllers).
- Faze 1 always opposes faze 2. Odd number fazes are always left turn movements and even numbered fazes are always through movements.

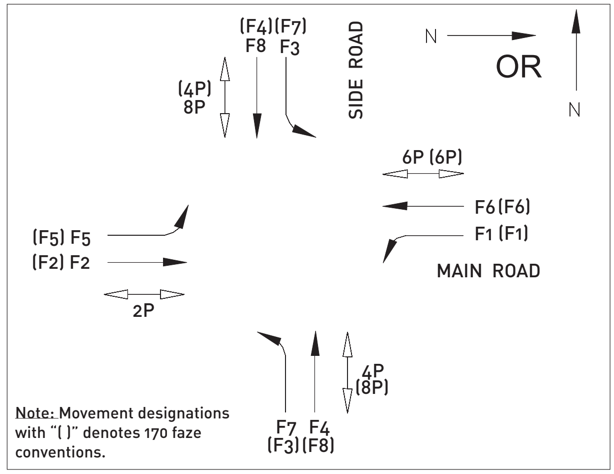


Figure 5 – NEMA and 170 Movements

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 a green ball and green arrow for example, or a solid amber ball indication. The traditional normal sequence of indications is indicated in a phase "diagram".

Phase Diagrams

It is strongly recommended that phase sequence diagrams be on or attached to the approved signal plan to ensure the phasing matches the signal layout shown. They should illustrate 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 devised.

The examples in Figures 7 and 8 illustrate “permissive” and “protected” left-turn movements.

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[23].

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, traffic is prohibited from moving other than when provided a protected left turn indication.

Permutations and combinations of different modes of left turns are possible. For example, a permissive movement may be applied to one approach and a protected movement to another within the same intersection.

In some cases, simultaneous left turns are used where left turning traffic 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 of the 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 for the case 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 6 shows the phase diagram.

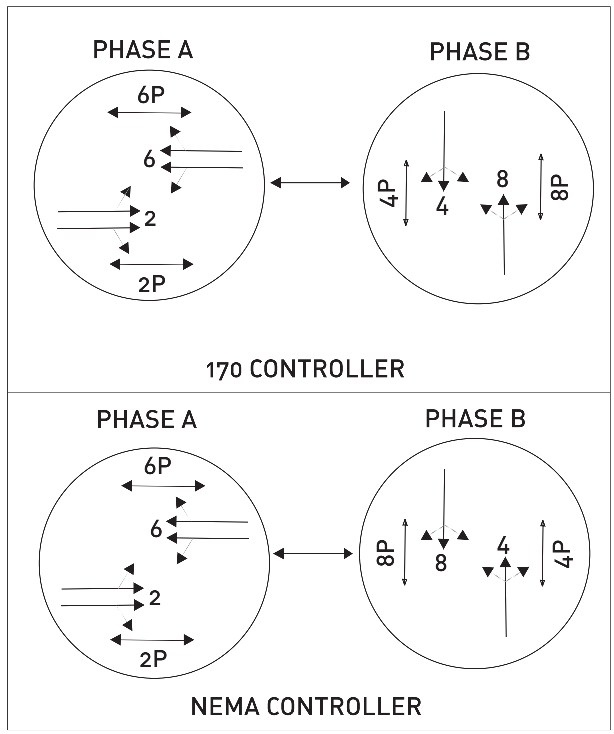


Figure 6 – Two Phase Diagram

Three Phase Operation

A three phase operation adds a left-turn signal on one approach. An example of this operation is shown in Figure 7, 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 7 the phase sequencing arrows show the signal can not sequence from Phase B directly to Phase A and that it first must pass through Phase C. (This operation ensures that a call for an advance green within Phase B does not create a trap situation.) Also the arrows ensure that after serving an advance green phase the signal must sequence to Phase B so as not to violate driver expectancy as drivers do 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 they are required to effectively serve the traffic demands.

For more complete discussions of phase diagrams and allowable phases and interval sequencing within the dual ring configurations, the engineer/analyst should consult the printed materials of the major controller manufacturers, the Ministry's Electrical Design Manual[2] and TCSTCA[25].

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 8. The following should be noted:

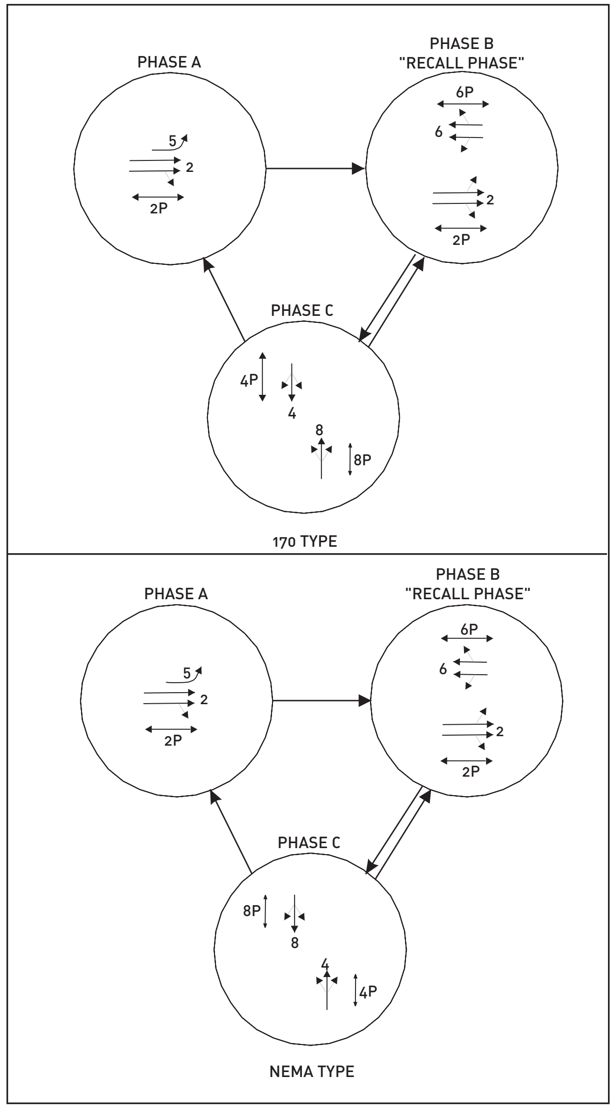


Figure 7 – Three Phase Diagram

- 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.

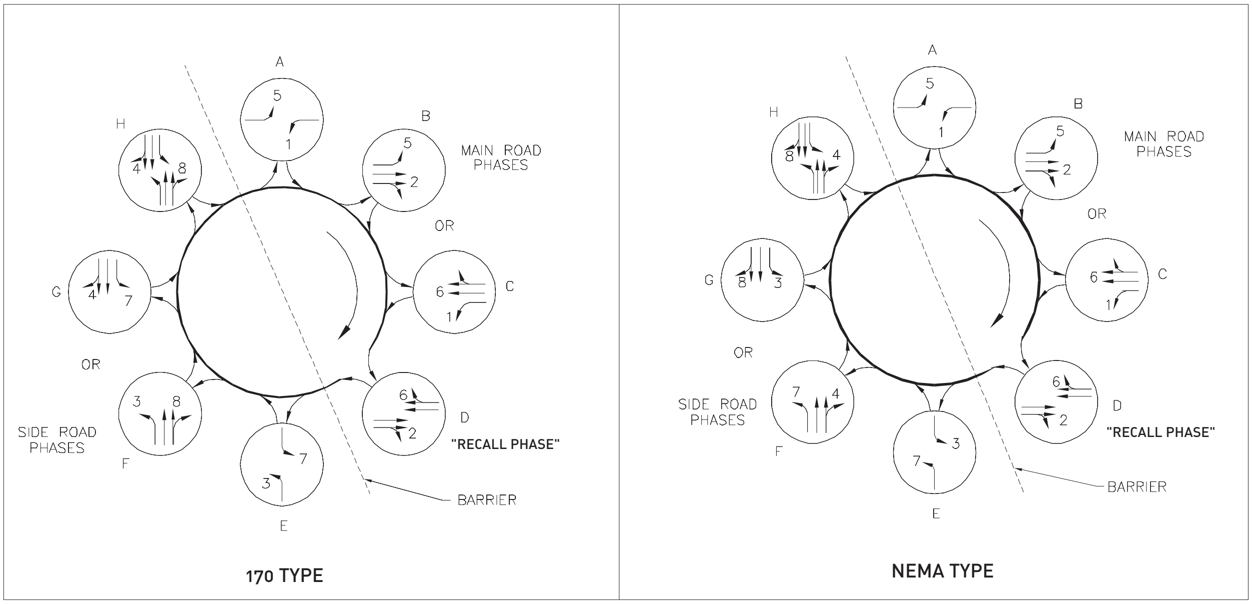


Figure 8 – Multi Phase Diagrams with Fully Protected Operation on the Main Road and Protected/Permissive Operation in the Side Road

Pedestrian Phases

General

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 during an all-red period if special pedestrian phasing is used (such as leading pedestrian intervals or exclusive pedestrian phases). The Walking Pedestrian indication does not necessarily have to be displayed with the green at actuated intersections (where a pushbutton actuation is used) as this 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) should 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 to continue the FDW through the amber or all-red clearance intervals as this may provide additional information or reassurance to crossing pedestrians.
- 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. 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 prior to implementing an exclusive pedestrian phase.

Another form of an exclusive pedestrian phase is the advance pedestrian interval where a walk indication (generally around 4 to 6 seconds in duration) is provided in advance of the corresponding vehicle green indications to give pedestrians a head start on parallel or turning traffic.

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 should be a flashing indication. The clearance interval should terminate (and change to the steady Hand display) at the onset of the accompanying vehicular amber but in practice is 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 indication. Pedestrians who have commenced the crossing while facing the Walking Pedestrian indication may complete their crossing and have the right-of-way over traffic to do so.

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. Pedestrians facing the steadily illuminated Hand Outline indication shall not enter the roadway.

Left-Turn Phase Justification

General

Left-turning movements are affected by turning volume, lane configurations, pedestrian 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 opposing traffic. The left-turning vehicles may also block through vehicles unless a separate left-turn lane is provided with adequate storage.

The contents of this subsection assume that an adequate left-turn lane can be provided. If not, restrict to one direction only or use separate phasing. 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. This case is treated in the TCSTCA[25].

Approximation

A simplified method using traffic volumes to estimate delays may be used to initially 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:

i 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.

ii If the left-turning volume plus the opposing volume > 720 vph.

iii If a field check shows that vehicles consistently require more than two cycles in the queue in order to turn left.

iv. Based on an identified over-representation of left turning collisions at the intersection.

Methods of Analysis

There are several methods used in Ontario to determine justification for separate left-turn phases. Two of these approaches are as follows:

1. Capacity Analysis Method

This method is given in the TCSTCA[25] and is abbreviated and paraphrased here. The method is particularly useful for planning of new signals.

The threshold capacity of a left-turn lane can be stated[25] as [1400 G/C - V_o] taking into account V_o, the opposing volume of traffic. This method checks to determine if 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. The opposing volume, V_o, should be modified by the (f) factor according to the number of opposing lanes as follows:

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

Source: ref. 23

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. The TCSTCA[25] provides nomographs to assist with the analysis.

2. Left-Turn Delay Method

This method is one developed by former Metro Transportation in their "Left-Turn Phase Criteria" study[9]. With this method, left turn phasing is warranted if combinations of conditions are met. The conditions are listed below (as a., b., etc.) and the required combination is a. or (b.& c.) or (b.& e.) or (b.& d.) and any one of f., g., h. or i. is/are true.

A. Needs Criteria:

a. If potential intersection benefits with no delay study needed go directly to B: Impacts section.

b. If the average left turn queue ≥2 vehicles per cycle in an hour within the study period.

c. If ≥10% of left turn vehicles have one or more cycle delays in an hour within the study period.

d. If ≥5 vehicles per hour have one or more cycle delays in an hour within the study period.

e. Any of:

e1: six or more left turn collisions occur within the study period over the past 5 years.

e2: total left turn collisions total 20 or more over the past 5 years.

e3: two or more left turn collisions occur within the study period in the most recent single year.

e4: total left turn collisions total 5 or more in the most recent single year.

e5: more than two evasive actions per hour are observed in an hour within the study period.

f. There are observed more than 2.5 left turn vehicles on the amber/all-red per cycle on average over an hour within the study period (impacts next phase).

g . The left turn queue blocks through lane >30% of cycles for multiple through lanes, (busiest hour) or the left turn queue blocks through lane >10% of cycles for single through lane, within an hour in the period.

h. More than two in-service transit vehicles per hour are observed in the left turn traffic in an hour within the study period.

i. There was a previous request regarding the same left turn movement within the last 18 months.

B. Impacts

Recommend new left-turn phasing if needs criteria are met UNLESS:

a. If the left turn queue spillback is one of the applicable criteria, check to see if lengthening the left-turn bay is possible, cost effective, and would reduce the problem; or

b. There is a policy reason why a left turn phase is not desirable (e.g., left turn phase will encourage left- turn traffic through a neighbourhood or from streetcar tracks).

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 that are 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 traffic engineer/analyst must choose the type of operation and should consider the following items:

1. If a geometric or visibility problem exists at the intersection or there is a historical collision pattern involving left turn vehicles, then consideration should be given to a fully protected left-turn phase.
2. Where capacity analysis indicates that dual left-turn lanes are required, from equivalent left-turning volumes or from queue end requirements, fully protected operation should be considered. Protective/permissive operation may be examined for use with dual left-turn lane operation only when:
   - Geometry of the intersection and approaches allows proper turning treatment.
   - 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.

   Where dual left-turn lanes are needed, the more commonly used fully protected operation should be considered.
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 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 TAC MUTCDC (B4.5.3) defines the trap as entrapment using 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 penetrate opposing traffic which still has a green indication on Approach 1.*"

Types of Left-Turn Phasing

The figures shown in this section are intended only to show the left-turn parameters. They have been adopted from the TAC MUTCD[12]. Additional amber, clearance and other traffic movement phases beyond those shown may be required to accommodate the local conditions of a specific intersection.

1. Advanced Green, Single Direction

This type of signal 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 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.

The use of signal heads 8, 8A, 9, 9A, 10 and 10A are preferred for protected/permissive advance green operations. The amber arrow is optional but is recommended for consistency and to ultimately adhere to TAC's requirements. The use of the circular flashing advanced green or arrow flashing advanced green is also currently allowed under Section 144 (13) of the HTA.

This type of phasing is shown in Figure 9.

2. Protected/Permissive Simultaneous Left Turns

This phasing gives left-turning vehicles from opposing directions a protected left-turn phase at the same time. No other conflicting vehicles 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.

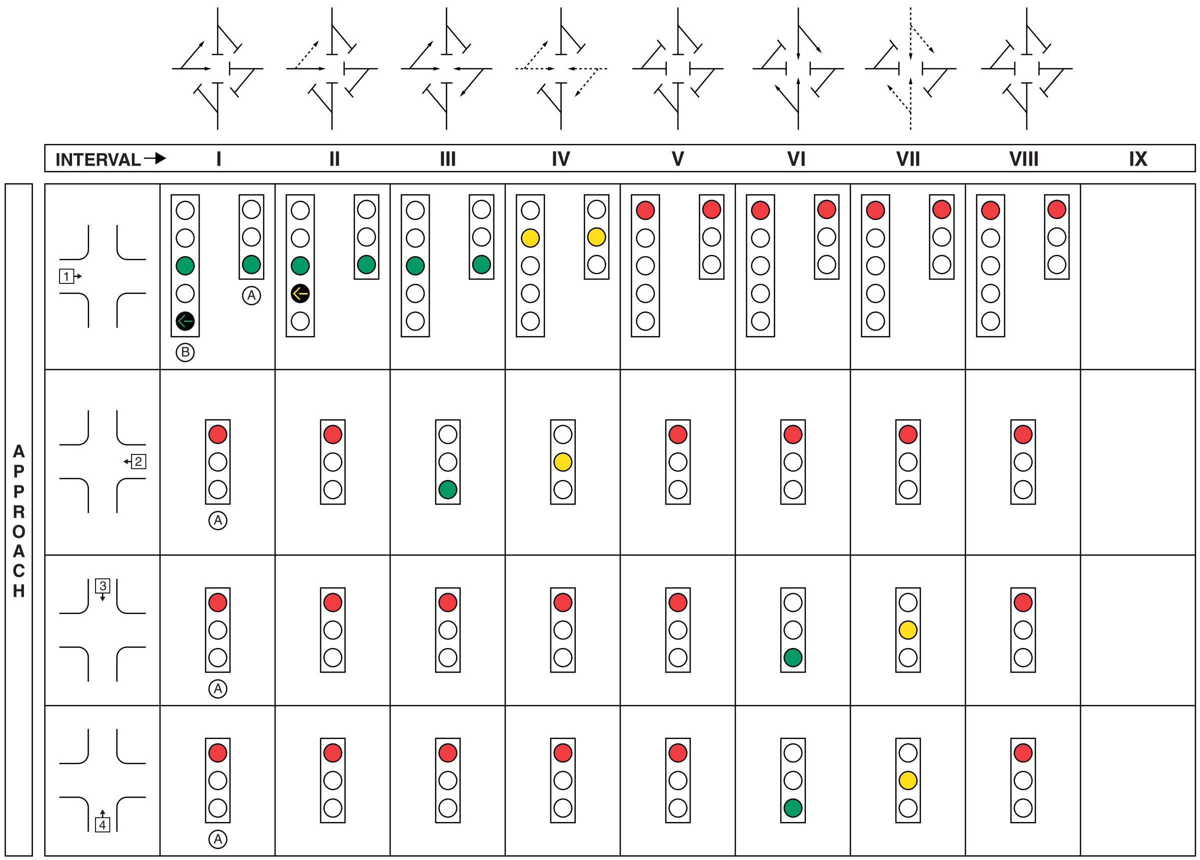
When the left-turn lanes are separately actuated, the protected left-turn phase from one direction may terminate before the other left-turn phase. When this occurs, the associated through and right-turn vehicles are allowed to proceed with the one remaining protected left-turn movement. Also, if there are no opposing left-turning vehicles during a cycle, the opposing protected left-turn phase can be skipped and the operation during that cycle will be similar to an advanced green. Figure 10 shows the basic intervals.

3. Fully Protected Simultaneous Left Turn

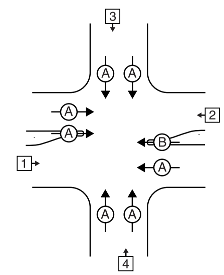
This operation provides left-turning vehicles with their own traffic control signal heads. Left-turning vehicles from opposing directions are given a left-turn indication at the same time. No other conflicting vehicles are allowed to enter the intersection during the left-turn phase. In normal Ontario 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 assist the motorist in recognizing the Type 2 left-turn signal heads, a "Left Turn Signal" sign must be placed adjacent to these heads. The fully protected simultaneous left turn operation is used where the visibility of vehicles making left turns to the opposing traffic is limited, or vice versa or there is a concern or where distractions caused by turning traffic are a concern. It 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. This type of operation should also be used on high speed roads with potential visibility problems due to geometry or where collision problems exist. Double left-turn lanes may also require this type of phasing. Figure 11 shows the basic intervals.

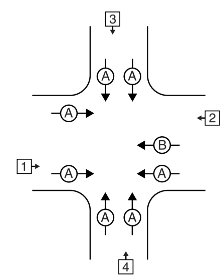
PROTECTED/PERMISSIVE LEADING LEFT-TURN PHASING



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.



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



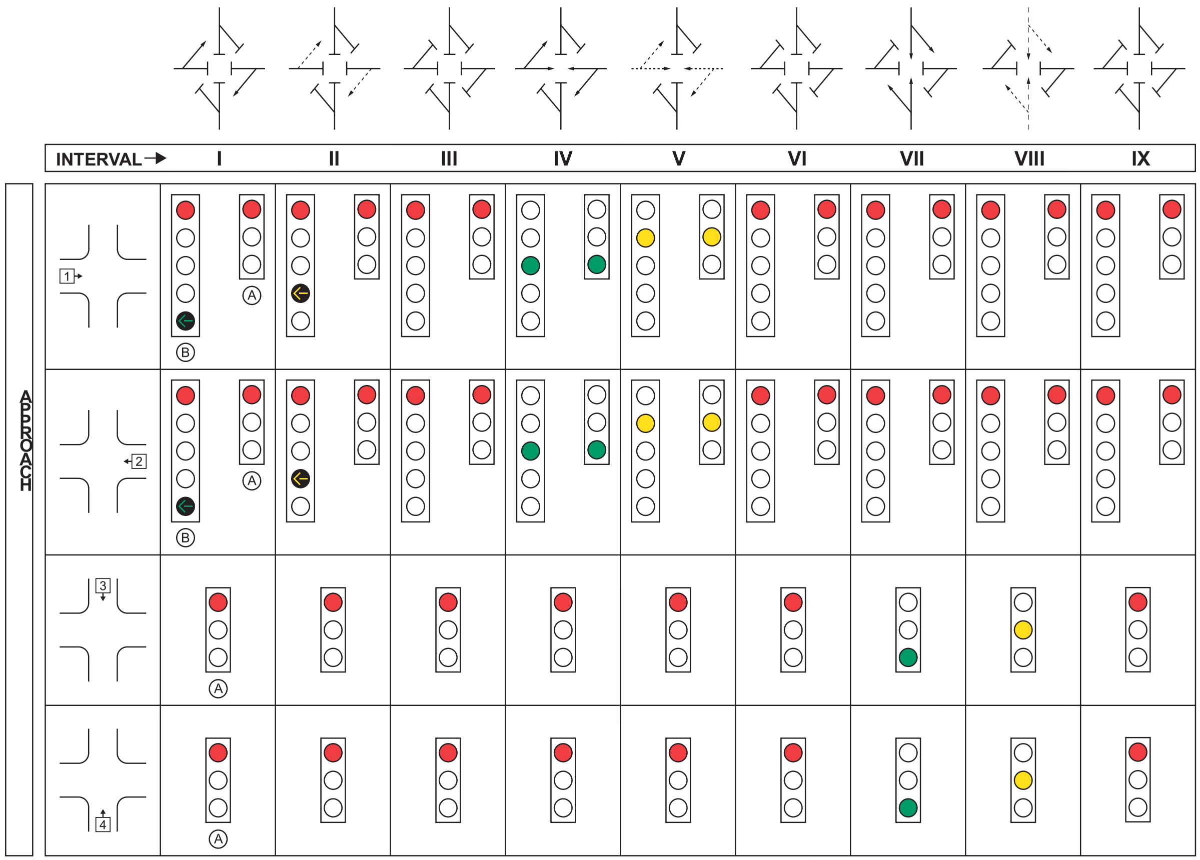
If no median island is present, this can be accomplished by using an extended mast arm, span wire, or a signal bridge that also holds the primary signal head (A) for the through/right-turn movements.

NOTE: Signal head (B) can be a five-section signal head with separate amber and green arrow lenses as illustrated, or a four-section signal head with a single fibre optic green/amber arrow lens.

OPERATION:
The phasing sequence has a protected left turn on approach (1) during which all traffic on approach (1) may exclusively enter the intersection (Interval I). The protected left-turn phase is cleared through the use of an amber arrow indication (Interval II). All traffic on approaches (1) and (2) are permitted to enter the intersection (Interval III) during which time left turns on approaches (1) and (2) are permitted. Traffic on approaches (1) and (2) are cleared with an amber ball indication (Interval IV) and an all-red indication (Interval V). The standard phasing is used for approaches (3) and (4) (Intervals VI to VIII).

Figure 9 – Protected / Permissive Leading Left-Turn Phasing (Source: TAC Figure B4-1)

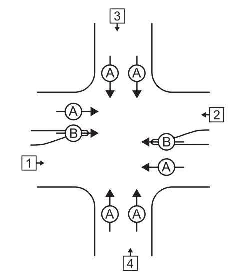
PROTECTED/PERMISSIVE LEADING SIMULTANEOUS LEFT-TURN PHASING



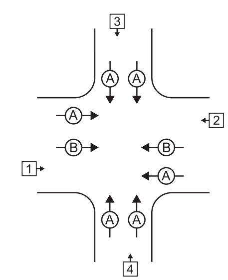
NOTE: Signal head (B) can be a five-section signal head with separate amber and green arrow lenses as illustrated, or a four-section signal head with a single fibre optic green/amber arrow lens.

OPERATION:
The phasing sequence has a protected left turn on approaches (1) and (2) during which left-turning traffic may exclusively enter the intersection simultaneously (Interval I). Each protected phase is cleared through the use of an amber arrow indication (Interval II) and an all-red interval (Interval III). All traffic on approaches (1) and (2) are permitted to enter the intersection (Interval IV) during which time left turns are allowed. Traffic on approaches (1) and (2) are cleared with an amber ball indication (Interval V) and an all-red indication (Interval VI). The standard phasing is used for approaches (3) and (4) (Intervals VII to IX).

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.



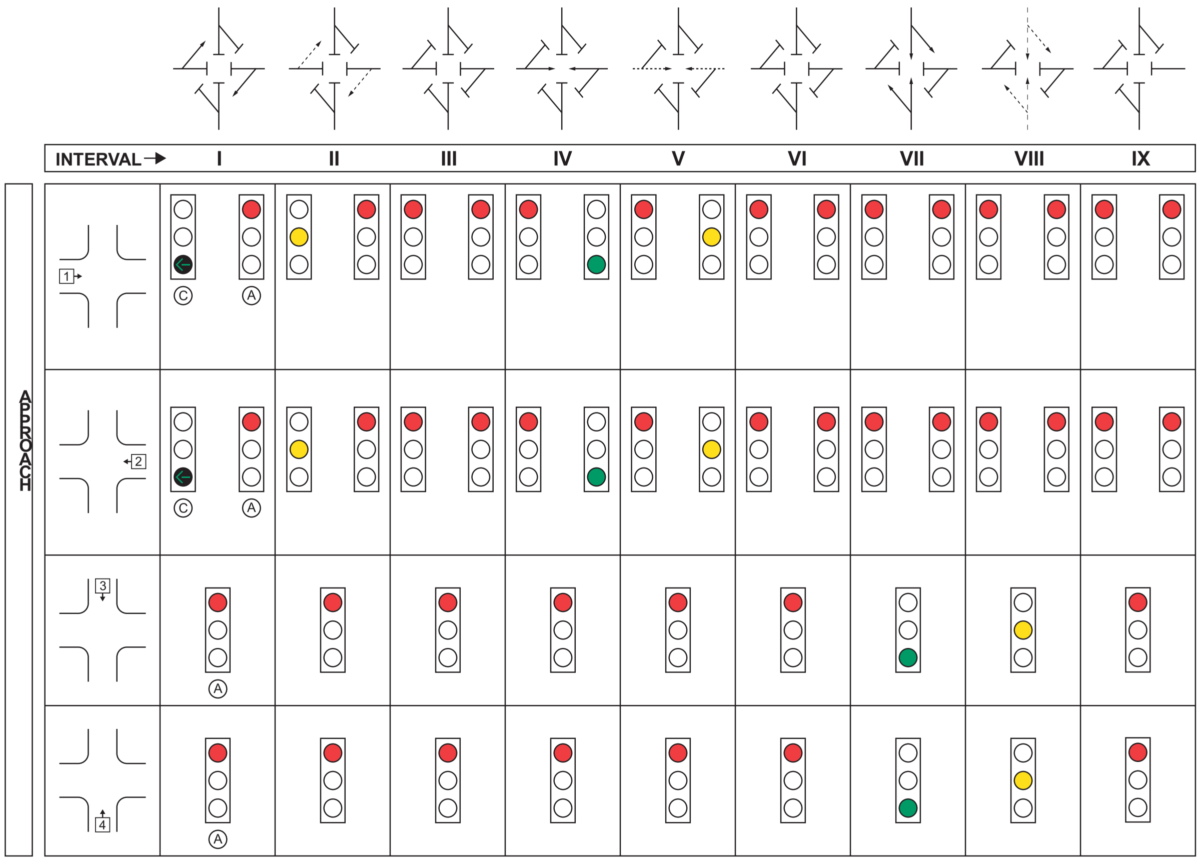
Signal head (B) should be located directly in line with the left-turn lane. It is normally mounted on a signal pole located on the median island.



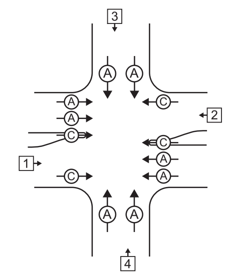
If no median island is present, this can be accomplished by using an extended mast arm, span wire, or a signal bridge that also holds the primary signal head (A) for the through/right-turn movements.

Figure 10 – Protected / Permissive Simultaneous Left-Turn Operation (Source: TAC Figure B4-2)

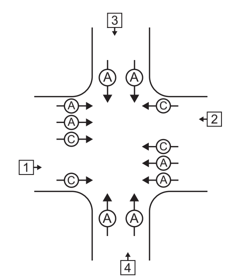
FULLY PROTECTED LEADING SIMULTANEOUS LEFT-TURN PHASING



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).

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 11 – Fully Protected Simultaneous Left Turn (Source: TAC Figure B4-5)

4. Permissive/Protected Lagging Left Turn – Single Direction

This phasing gives a permissive/protected left-turn movement. 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 otherwise, an opposing left-turn vehicle may be trapped in the intersection while waiting for a gap since it is generally expected that the opposing traffic will also receive the same signal indications (specifically an amber display) at the same time. It is also suggested that signs be installed indicating the operation of the extended left turn.

Figure 12 shows the basic intervals.

5. Separate Protected Left-Turn Operation (Separate Phasing)

This type of phasing allows one traffic approach to the intersection to proceed while the traffic on all other approaches is stopped. All movements on the separate phase approach including left turns are permitted to proceed through the intersection.

This method is typically used where intersection geometrics prevent simultaneous left turns or where there are shared lanes. Separate (or split) phasing is generally less efficient than other types of left turn phases, but offers a very effective way to eliminate collisions involving left turns with opposing through traffic.

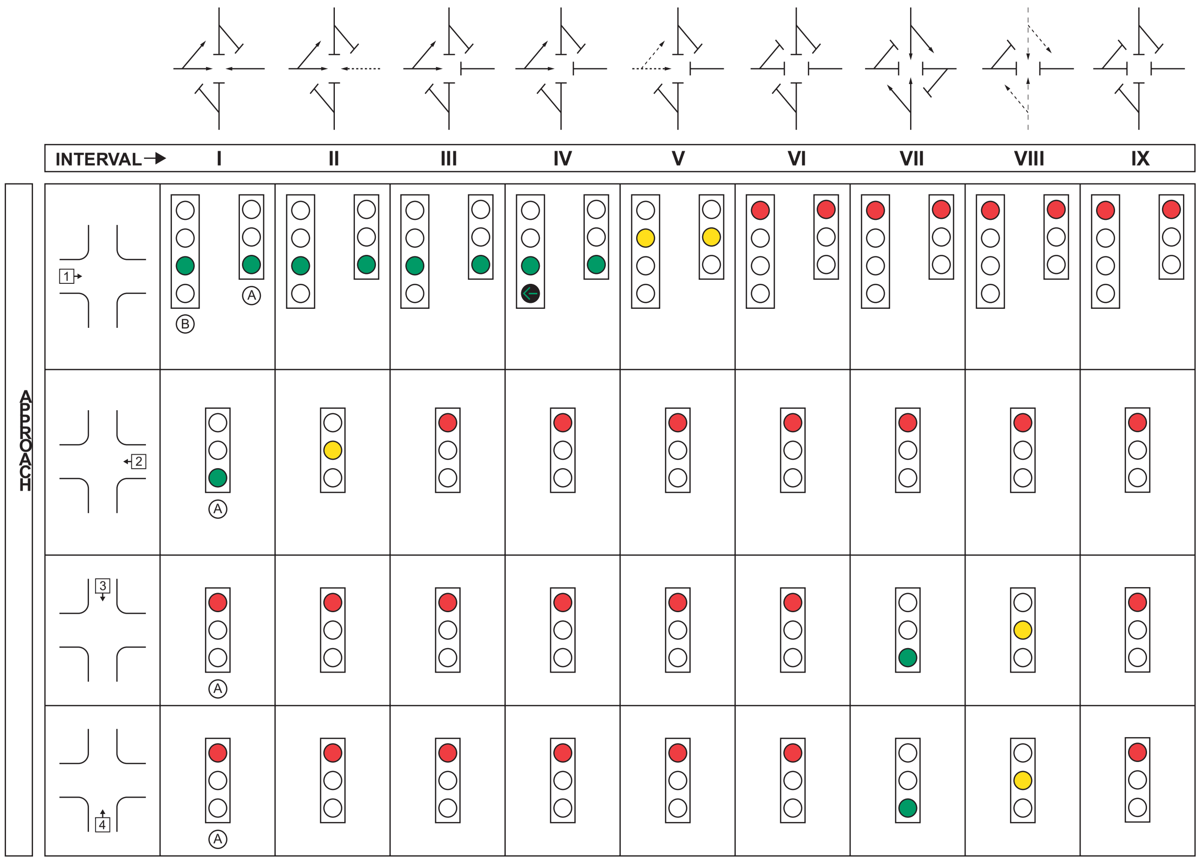
Figure 13 illustrates the basic intervals for this type of operation.

6. Lagging Fully Protected Simultaneous Left Turn

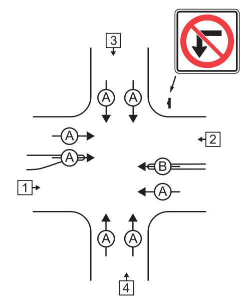
This operation is similar to that for the "Fully Protected Simultaneous Left Turn" described previously except that left-turn movements are given a protected phase after the through traffic phase.

This method is seldom used however, since left-turning displays are normally displayed before the through traffic indications. The general 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.

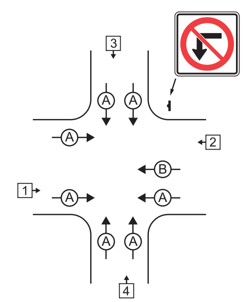
PERMISSIVE/PROTECTED LAGGING LEFT-TURN PHASING



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.



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

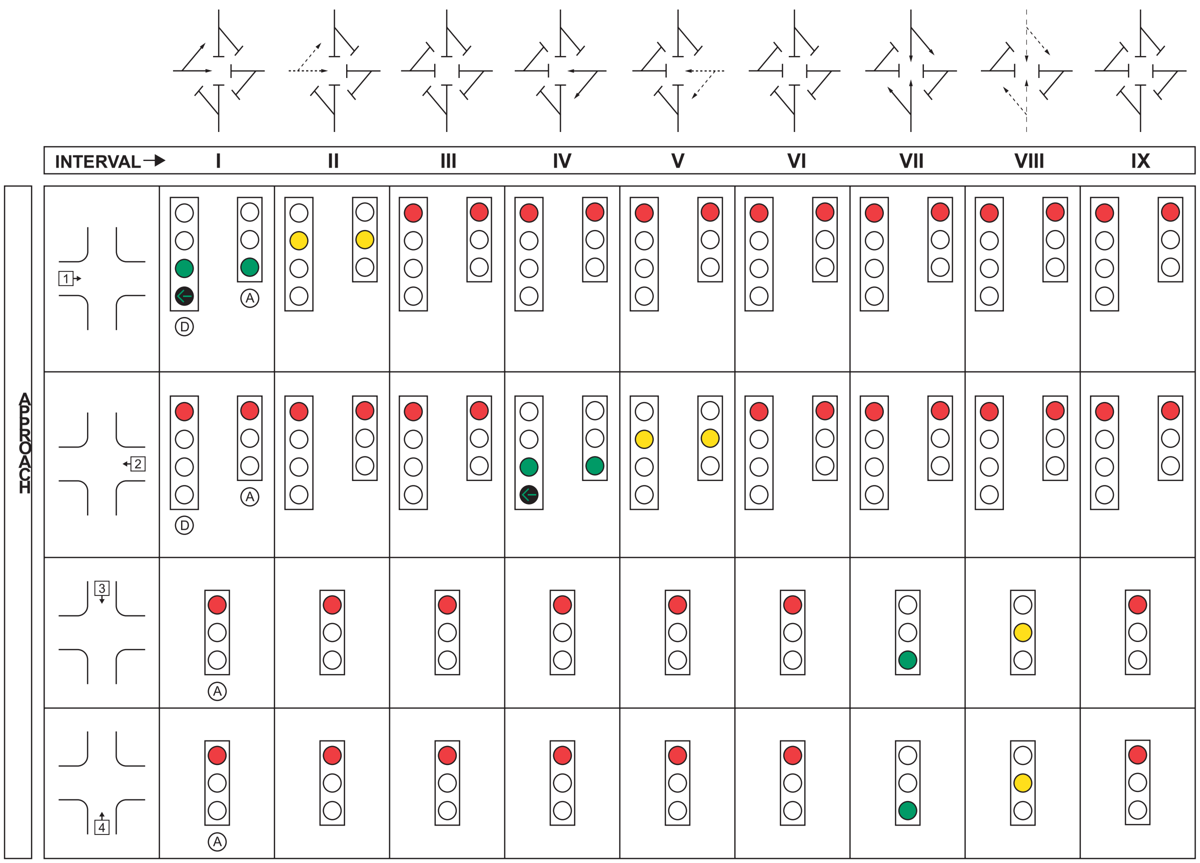


If no median island is present, this can be accomplished by using an extended mast arm, span wire, or a signal bridge that also holds the primary signal head (A) for the through/right-turn movements.

OPERATION: THIS PHASING CAN BE USED ONLY WHEN LEFT TURNS ARE NOT PERMITTED ON APPROACH (2).
All traffic on approach (1) and through and right-turning traffic on approach (2) may enter the intersection (Interval I), during which time left turns on approach (1) are permitted. The traffic on approach (2) is cleared with an amber ball indication (Interval II) and a portion of the red ball interval (Interval III). A protected left turn follows on approach (1) during which all traffic on approach (1) may exclusively enter the intersection (Interval IV). The traffic on approach (1) 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 12 – Extended Green Intervals (Source: TAC Figure B4-4)

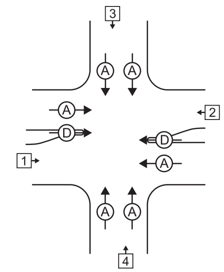
SEPARATE PROTECTED LEFT-TURN PHASING



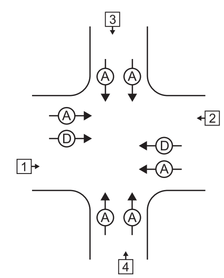
NOTE: Signal head (D) is a four-section signal head with a green arrow.

OPERATION:
The phasing sequence has a protected left turn during which all traffic only on approach (1) may enter the intersection (Interval I). The protected phase is cleared with an amber ball indication (Interval II) and an all-red interval (Interval III). A protected left turn follows, during which all traffic only on approach (2) may enter the intersection (Interval IV). The traffic on approach (2) 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).

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.



Signal head (D) 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 signal head (A) for the through/right-turn movements.

Figure 13 – Separate Protected Left Turn Phasing: TAC Figure B4-9}

3.6 Timing

General

In order to estimate the timing required for intervals and phases, it is necessary to have on hand reasonably up-to-date or predicted traffic volumes per movement. Prior to 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 primarily found in the Ministry's "Traffic Control Signal Timing and Capacity Analysis at Signalized Intersections"[25] (TCSTCA) and ITE Canada's "Canadian Capacity Guide for Signalized Intersections"[1] (CCG).

During the determination of equivalent traffic volumes in accordance with the principles of the CCG[1] or the TCSTCA[25], care should be taken to apply appropriate factors for turning vehicles, heavy vehicles (trucks and buses) and approach lanes. The number of usable lanes may also vary at different times of the day for urban conditions as there may be on-street parking, bus stops, HOV lanes, etc., present. The reference documents use 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 prior to the analysis of the cycle timings.

Minimum Interval Timing

Motorists do not expect an immediate termination of a signal display that has just started[1]. Minimum interval times are used to avoid this situation. Table 3 shows guidelines for minimum interval timing values:

Table 3 – Minimum Interval Time

Interval	Desirable Minimum (seconds)	Acceptable 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)
Advanced green	7.0	5.0
Advanced green clearance	2.0	1.5
Circular amber	3.0	3.0
Amber arrow	3.0	2.0*
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. 1 (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, the 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 the motorist is 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:[1, 23]

$$\text{clearance} = y + r = \underbrace{[t + V/2a + 70.6g]}_{\text{Amber}} + \underbrace{[3.6(W+l)/V]}_{\text{All-Red}}$$

Where:

y = the amber interval clearance(s)

r = the all-red interval clearance (s)

t = perception and reaction time (1 second minimum)

V = approach operating speed (km/h)

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

g = % grade/100

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

l = 6.0 m taken as the length of the average passenger vehicle

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 ($y = t + V/2a + 70.6g$) indicates to the driver that the right-of-way is about to be changed and therefore must provide sufficient time for the approaching motorist to travel the Stopping Sight Distance.

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, the all-red interval should be used at all signalized intersections.

The amber and all-red clearance intervals are given in Tables 4 and 5 assuming a level approach grade and 1.0 seconds as a minimum perception plus reaction time. Larger perception reaction times can be adopted at the discretion of the road authority.

Clearance for Left-Turn Signals

A minimum clearance time of 1.5 to 3.0 seconds must follow the left-turn green (green arrow, or fast flash green ball) before the opposing traffic is released. An all-red of 1.0 to 1.5 seconds may be used after the amber arrow if additional clearance is required.

Where the fully protected mode of operation in a left-turn lane is used, 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[25].

Table 4 – Amber Clearance Interval Times

Posted Speed (km/h)	40	50	60	70	80	90	100	110
Amber clearance for 1.0 seconds perception + reaction time (s)	3.0	3.3	3.7	4.2	4.6	5.1	5.5	6.0

Table 5 – All Red Clearance Interval Times

Clearing Distance (W + L) (m)	Posted Speed (km/h)							
	40	50	60	70	80	90	100	110
12.0	1.1	1.0	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	1.0
15.0	1.4	1.1	1.0	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	1.0
18.0	1.6	1.3	1.1	1.0	1.0	1.0	1.0	1.0
19.5	1.8	1.4	1.2	1.0	1.0	1.0	1.0	1.0
21.0	1.9	1.5	1.3	1.1	1.0	1.0	1.0	1.0
22.5	2.0	1.6	1.4	1.2	1.0	1.0	1.0	1.0
24.0	2.2	1.7	1.4	1.2	1.1	1.0	1.0	1.0
25.5	2.3	1.8	1.5	1.3	1.1	1.0	1.0	1.0
27.0	2.4	1.9	1.6	1.4	1.2	1.1	1.0	1.0
28.5	2.6	2.1	1.7	1.5	1.3	1.1	1.0	1.0
30.0	2.7	2.2	1.8	1.5	1.4	1.2	1.1	1.0
31.5	2.8	2.3	1.9	1.6	1.4	1.3	1.1	1.0
33.0	3.0	2.4	2.0	1.7	1.5	1.4	1.2	1.1
34.5	3.1	2.5	2.1	1.8	1.6	1.4	1.2	1.1
36.0	3.2	2.6	2.2	1.9	1.6	1.5	1.3	1.2
37.5	3.4	2.7	2.3	1.9	1.7	1.6	1.4	1.2
39.0	3.5	2.8	2.3	2.0	1.8	1.6	1.4	1.3
40.5	3.6	2.9	2.4	2.1	1.8	1.6	1.5	1.3
42.0	3.8	3.0	2.5	2.2	1.9	1.7	1.5	1.4
43.5	3.9	3.1	2.6	2.2	2.0	1.7	1.6	1.4
45.0	4.1	3.2	2.7	2.3	2.0	1.8	1.6	1.5

Notes:

1. Values do not apply to left turn clearances.
2. Where the approach to the intersection is on a significant grade, the formula to be used should be: y = t+V/(2a+70.6g) where g = % grade/100 and 70.6 = factor 2x acceleration of gravity (2x3.6x9.81) in km/h/s.
3. Three seconds is the recommended minimum for the amber clearance time; one second is the recommended minimum for All-Red.
4. If posted speeds are less than 40 km/h, use 3.0 second amber and 1.0 second all-red.

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), although it is not unusual to have LOS E under specific circumstances or in congested downtown areas.

The following are the most common methods used to determine LOS:

LOS Based on Delay

The Level of Service for signalized intersections may be defined in terms of delay, which is a measure of driver discomfort and frustration, fuel consumption, and lost travel time as given in the HCM[8]. Table 6 gives LOS for signalized intersections.

Table 6 – LOS Based on Delay

Level of service	Stopped delay per vehicle (seconds)
A	5.0
B	> 5.0 and <= 15.0
C	> 15.0 and <= 25.0
D	> 25.0 and <= 40.0
E	> 40.00 and <= 60.0
F	> 60.0

LOS Based on Probability of Clearing the Arrivals

In this method, 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 the actual arrival patterns could be different). The probability of arrival vehicles clearing defines the LOS as 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 because the headway of the initial vehicles is significantly longer than those further back in the queue (due to start-up lost times).

The analysis of the traffic flow to determine green interval times may be accomplished by several methods. Three of the common methods used in Ontario are as follows:

Ministry of Transportation Methodology

This method uses the Traffic Control Signal Timing and Capacity Analysis at Signalized Intersections (TCSTCA[25]) manual.

The MTO methodology for calculating green times employs the Poisson random probability function.

This 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 a measure 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. There are five levels of service described in this method, each with a different degree of probability of clearing during the first green interval.

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 have been developed for both rural and urban commuter environments that 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.

Canadian Capacity Guide Methodology

The Canadian Capacity Guide for Signalized Intersections, 2nd Edition (CCG[1]), 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 at 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 all measures of effectiveness that are used to evaluate how the intersection operates using the CCG methodology.

The principles employed in the HCM and CCG 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 stopped delay applied in the HCM for the determination of the level of service.

Software based upon this method is available from private sources.

Highway Capacity Manual Methodology

The Highway Capacity Manual (HCM[8]) 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. Simply stated, 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 based upon Webster's delay formula.

This method takes operational objectives into account, and can be used to determine green interval timing based on balanced delays and/or volume to capacity ratios, or maximizing either measure for preferred approaches.

The Highway Capacity Manual is available from the Transportation Research Board. Software ("HCS") based on this method is available from McTrans.

Calculation of Green Extension Time

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 maybe extended up to a set maximum value. The minimum time for the green interval is the fixed initial portion plus one unit of extension. For practical purposes, the initial portion may be taken as (detector to stop line distance as per subsection 5.9) x 0.25 + 4 seconds.

A unit extension may be the time allowed for vehicles moving at average speed to travel from the long distance detectors to within one second from the stopline. 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. This will extend the green interval as long as vehicle actuations are spaced closer than the extension times, unless terminated by a "maxout".

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. The delay time is normally set from 5 to 12 seconds. If the detection device is not cleared by the vehicle after this delay time has elapsed, a call for service will be placed in the controller to service the phase.

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 pedestrian clearance interval ("Flashing Don't Walk" and "Solid Don't Walk"). Pedestrian timings must be generous enough to ensure that pedestrians are given enough time to cross safely and comfortably, yet not over-generous such 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 to the amber, through the amber or through the amber/all-red intervals. The advantage of displaying the Flashing Don't Walk during the amber or amber/all-red clearance interval times is in giving the pedestrians reassurance that they still have the right to be in the intersection during the vehicle clearance. A disadvantage to this approach is the potential conflicts between pedestrians still in the crosswalk and turning vehicles that are trying to clear the intersection.

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

When the vehicle green plus amber and (optionally) all-red clearance times are in total greater than the calculated minimum total pedestrian Walk and pedestrian clearance intervals, the additional time 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 pedestrian total interval times.

The walking speed of pedestrians (W_s) normally varies between 1.0 m/s and 1.25 m/s. A normal walking speed of 1.2 m/s is usually assumed for initial calculations although the time of 1.0 m/s may be used at crossings frequented by young children, seniors and special needs persons. The timing can be field adjusted for such conditions, however, on wide arterials it is normally the total pedestrian time that governs the time available for the non-coordinated phases and therefore 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 the distance from curb to curb along the centreline of the crosswalk.

Pedestrian timing methods may vary between municipalities as a result of prevailing local conditions (as selected by experienced practitioners). In the absence of pedestrian timing policy, the following CCG method may be followed.

CCG Method

This method is included in the Canadian Capacity Guide[1]. For crosswalks without an island refuge (islands less than 1.5 m width), the pedestrian walk interval should allow time for the pedestrians to notice the change of the signal indication and initiate the crossing.

The minimum pedestrian walk interval time is typically taken as 10 seconds with 7 seconds used as an acceptable minimum.

The pedestrian clearance interval time is W_c/W_s (crossing width divided by walking speed, in seconds), which allows a pedestrian to walk the full distance during the clearance interval.

Pedestrian Actuation

When the minimum vehicle green interval is less than the minimum pedestrian crossing time plus the pedestrian clearance time (for vehicles at intersections with traffic actuated controls), and a pedestrian actuation is detected, the green vehicle time may be extended. An exception to this may occur at rural intersections with very few pedestrians and operating in semi-actuated mode. In this case, pedestrian pushbuttons may be used, without pedestrian signals, to change and extend the normal traffic signal indication, provided that a signal head exists on the same side of the road facing the actuating pushbutton.

In most operations, the pedestrian pushbutton actuation is accepted as a call during all times except when the Walking Pedestrian indication is 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. It also requires good judgement on the part of the traffic engineer/analyst.

Guidelines for cycle length selection are as follows[23]:

- The useful range for cycle lengths is between 50 and 120 seconds for 2- or 3-phase operation[25].
- Where roadways are wider (over 15 m), with longer pedestrian walk times (over 20 seconds), or where heavier 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).
- Impacts 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 less vehicles per lane per second traverse the intersection).
- In many situations the pedestrian timing (walk interval plus pedestrian clearance interval) required 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, younger children and/or special needs persons. 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 and pedestrians and provide sufficient capacity to accommodate the highest LOS possible. Starting the analysis with a 90 second cycle length is suggested.

Cycle Composition

The cycle length calculations require that the following points be considered:

- All amber and all-red clearance times are fixed by the speed of the traffic and the width of the intersection; these should therefore be added together to give the "intergreen"[1] times or the "lost times"[25].
- 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.
- Examination should be made of hourly, daily and weekly traffic variations to determine when different timing plans are required. It is not uncommon to use different phase timing and different cycle lengths for the traffic fluctuations at different times.
- Protected left-turn phases should be considered where demand and safety dictates but should be considered against a decline in progression, a degradation in the opposing level of service or if it is not possible 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 the TCSTCA[25] and the CCG[1].

3.7 Signal Spacing

New Signalized Intersections

Where a new "interstitial" intersection is planned, the distance between signalized intersections should be reviewed as follows:

- 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.
- 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 60km/h or less and up to 350 m for roads posted at 80 km/h to allow "back-to-back" left turn lanes and proper tapers (not considering optimal coordination).
- A distance of 215 m between signalized intersections will usually be sufficient to allow motorists to recognize and react to each device (again, not considering optimal coordination).
- Intersection spacing 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 traffic flow. 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. The CCG[1] gives analysis methods for determining whether continuous queues will exist and the delays to be expected.
- The signal spacing should include a progression analysis to ensure proper coordination of the signals is possible for a range of traffic demands.

3.8 Flashing Operation

Advanced Green Flashing Operation

The circular flashing green indication has been used in Ontario to provide a separate advanced left turn phase for a single approach at the intersection when protected/permissive green is necessary in a single direction only. 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 out-of-province motorists. Consequently the use of the circular flashing advanced green should no longer be permitted in Ontario after **January 1, 2010.** 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 methods.

The national standards, as given in the TAC MUTCD[12], use flashing arrow signals only and do not recognize steady arrow or flashing circular displays. The use of the arrow flashing advanced green is at the discretion of the road authority. It is recommended that, if the flashing advanced green arrow is used, that it only be used in an area which does not have any circular flashing advance greens. In areas where circular flashing advanced greens are predominant, it is suggested that a program be undertaken to firstly reconstruct these to steady arrow control and then a separate program to introduce flashing arrows be undertaken.

Standardized Flashing Operation

Traffic control signals that do not use left-turn arrow heads (excluding types 8, 8A, 9 and 9A), may be switched from their normal phase indication 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) but the red-amber mode is an acceptable alternative and is considered safer on roads with posted speeds of 80 km/h and above and with light side road traffic since 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 or of the week, for special events or during a Police over-ride mode of operation.

It should be noted, however, that 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.

Planned flashing operation of signalized intersections may be advantageous to traffic flow under some specific and limited conditions. Flashing operation may be of assistance in reducing vehicle delay and stops in pretimed networks at locations with poor signal spacing. Planned flash 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:

- Sidestreet 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, red flash for the side street.
- There is no emergency vehicle pre-emption capability.
- Pedestrian volumes crossing the main street during planned flashing period are very light.
- The major roadway is not channelized and has no more than four lanes.

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 with 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. The flash rate is slower than that used for flashing advance green indications.

3.9 Preemption and Priority

General

All modern controllers offer both pre-emption 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.

There are two preemption modes of operation in most modern controllers: two railway plans and two to four emergency vehicle 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 pre-emption 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 of the roadways near or within an intersection.
- An approaching emergency fire vehicle is detected on the approach, which causes the signal to return to green for that approach as soon as possible and/or hold the green on the vehicle's approach.
- A manual actuation is received, most typically from a fire station close to a signalized intersection.

Transit 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 extensions, 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 day controllers are capable of providing these functions directly, while in other situations, these functions are provided from a master controller or a central system.

Preemption For Railway Crossings

Where a proposed traffic control signal installation is in close proximity to a railway crossing, the traffic control signal installation should be discussed with the appropriate railway authority and it 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 will be required to provide greater protection for vehicles. Examples of this are given in the TAC MUTCD[12].

In the case of railway preemption, it is extremely important that a preemption sequence compatible with the railway crossing signals provide for safe vehicle, pedestrian and train movements. Because trains cannot stop in time to accommodate traffic at the level crossing, it is essential that the separate intersection and railway signal devices complement rather than conflict with each other[18].

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 towards the tracks, and inadvertent vehicular stoppage may occur on the level crossing, it will be necessary to provide a preemption phase to clear the approach prior to 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 in close proximity 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 in close proximity to the intersection, it is also necessary to disallow turns into the roadway with the railway crossing while the crossing is active. This may be accomplished either by eliminating a phase or activating arrow signal heads or blank-out signs or some combination of these options.

A recommended practice of the Institute of Transportation Engineers entitled "Preemption of Traffic Signals At or Near Railroad Grade Crossings with Active Warning Devices"[18] provides recommendations on when to include pre-emption operations, and some recommended design considerations.

Signals that require railway interconnection should not be constructed until the approval of the appropriate railway authority (and Transport Canada) 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).

Preemption can similarly be activated by simple devices such as a pushbutton inside the fire station. These are used locally and normally allow traffic control signals at or near the fire station entrance to remain on green until the emergency vehicles have left and to activate special preemption phases that allow 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.

The preemption system normally requires a study of the arterials to be covered and the needs of the vehicles to be fitted. Other factors include a review on the impacts of coordination, the capabilities of the existing equipment and an agreement of cost sharing for the participating parties.

3.10 Operation Of Miscellaneous Signals

Pedestrian Signals

Traffic control signal systems that are intended to serve only pedestrian traffic may be installed at desirable pedestrian crossing locations. The locations may be at intersections (Intersection Pedestrian Signals or IPS) or between intersections (Midblock Pedestrian Signals or MPS). Both types require that main road traffic be fully signalized.

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 only pedestrian signal indications used for crossing the main street and regular traffic control signals on main roadway approaches.

Pedestrian timing should be set as for normal intersections, considering the factors of subsection 3.5. 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. However, system control often contradicts the reason a pedestrian signal was installed originally, which is the desire 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

A transit priority signal display (see Figure 14) may be used to assign right-of-way to public transit vehicles over all other vehicular and pedestrian traffic movements within a signalized intersection. The transit priority signal may be operated exclusively during a protected transit movement or concurrently with other non-conflicting vehicular movements.

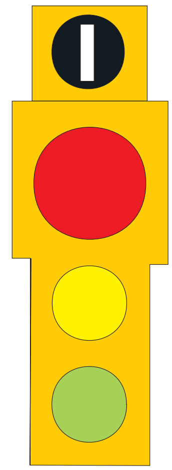


Figure 14 – Transit Priority Signal

Transit priority signals can be used on either the primary or secondary traffic signal heads or on both, depending on the transit movement, location of transit lane and 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.

Upon termination of the transit phase, a normal red clearance interval is required before the signals revert to the 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 use of 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.

More information on transit priority signal timing is 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 prior to activating 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 enter pre-emption mode, resting in red in the direction approaching the bridge, upon activation of the bridge signals.

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 has to continue to open the bridge. It is good practice to allow a significant distance or 15 m minimum between the end of the movable part of the bridge and any barrier protection as a place to store one or two vehicles in an emergency.

Lane Direction Signals

Lane direction signals (see Figure 15) are used to legally 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.

Figure 15 – Lane Direction Signals

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) prior to switching to the reverse direction. Alternatives to this method involve vehicle detection and axle counting as well as controller software modifications to allow reversal on lane clearance.

Remote Control Devices

A remote control device is intended to augment a traffic control person and is used to separate two way traffic operations through a single lane. One remote control device is placed at each end of the lane closure displaying a red or amber lens, generally in conjunction with a control arm. A remote control device is **not** considered a traffic control signal according to the HTA, allowing each road authority to establish their own policies to govern the use within construction zones. More details on the setup and conditions of use for remote control devices are listed in Section 5 of this manual.

Portable Lane Control Signal Systems

Portable Lane Control signal systems consist of at least one "standard" vehicle traffic signal head, normally mounted on a movable pole. These signals are sometimes used to reduce traffic flow to a single lane in alternate directions at very local work areas requiring lane closures. Road authorities may establish their own policies governing the use and application of portable lane control signal systems. More information is provided in Section 5 of this manual.

Portable Temporary Traffic Signals

Portable Temporary Traffic Signals consist of standard traffic signal heads mounted on movable trailers. The trailers are typically positioned at intersections to emulate traffic control signals or can be used as portable lane control signals for short or very short duration work. No legal drawings are required if these devices are operated while attended on site. Road authorities may establish their own policies governing the use and application of portable temporary traffic signals. More details are provided 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 prior to or during re-construction of roadways. More details are provided in Section 5 of this manual.

Accessible Pedestrian Indications

Signalized intersections used by the visually impaired may be equipped with auxiliary audible or tactile devices to provide additional information about the status of the intersection or of the traffic signals, thereby aiding the crossing movement. The use of these devices at traffic signals may be best determined by a recognized agency or body trained in the needs of the visually impaired, such as the Canadian National Institute for the Blind. If an intersection is equipped with an accessible signal system, it can advise the visually impaired pedestrian (and those pedestrians with both visual and hearing impairments) of some or all of the following: that the intersection is equipped with special signalization features for the visually impaired, where the pushbuttons may be found, the direction for which each of the pushbuttons activates the special features and when, and in which direction, to start crossing the street.

The equipment may also include a number of features beyond audible tones for the "Walk" intervals. The additional equipment may consist of tones to locate the pushbuttons, tones to acknowledge the button has been pushed or vibrating features to operate in parallel with the audible sounds, as well as physical features in the sidewalk and crosswalk. The activation of these devices at traffic control signals should include a training program for the user from an agency recognized as dealing with the needs of the visually impaired.

Accessible indications are not covered by the HTA. Basic standards and pushbutton operation options are provided in the TAC MUTCDC[12], however the existing audible signal standard in the TAC MUTCDC is under review and will be updated with a more comprehensive accessible signal standard in the near future. For more information, please refer to http://www.tac-atc.ca/.

Countdown Pedestrian 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). The pedestrian countdown equipment can show the countdown time through both the walk and flashing don't walk together or solely for the flashing don't walk (in which case the numeric display remains blank during the walk indication).

Many of the countdown pedestrian heads available today determine the display time based on the durations of the pedestrian intervals from previous cycle(s). As a result, phases which are more consistent in duration are more appropriate for countdown pedestrian heads because of the associated accuracy in the countdown display time.

At the time this book was printed, a TAC study was underway. See http://www.tac-atc.ca/ for current information.

Tunnel Signals

"Tunnel Signals" may consist of signals at the ends of a tunnel that are used to prohibit the entrance of traffic or lane control signals within the tunnel, and on the tunnel approaches. They 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 in order 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 to the signal controller. The preempt signal may come from the tunnel alarm systems for fire, collision, noxious gases or water leakage, for example. The signals operate similarly to those for railway preemption.

The principles of the symbols, visibility and operations 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. The operation of the metering signals is normally carried out only during rush hours and in a preferred direction (normally toward the CBD in morning and outbound from it in the evening).

The ramp metering signals are normally controlled by the traffic management computer software from the Traffic Operations Centre. The signals have a controlled cycle length that is dependent 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) such 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 even faster (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 where signals are very closely spaced. Example applications include left turn indications on high speed roadways with centre medians and unusual geometric intersection configurations.

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). Generally, this process is 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.

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, for example, 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

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. Under the vast majority of circumstances, standard vehicle displays are adequate to control bicycle movements through intersections. The use of bicycle signals should, therefore, be limited to special circumstances and not randomly or universally applied to all signalized intersections.

It is recommended that practitioners refer to the TAC Traffic Signal Guidelines for Bicycles dated July 2004 (available at http://www.tac-atc.ca/) * as a source for the justification, review and installation of bicycle signals.

It is also recommended practice that in the installation of the signal heads specifically for cyclists, the requirements of the HTA be satisfied such that two heads are provided in the direction of travel. In addition, it is noted that careful selection of the size and colour of the signal head, the lack of backboard combined with the signing and proper positioning are acceptable features that may be used to ensure the bicycle signals are distinct from all other indications.

3.11 Flashing Beacon Signals

General

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

* Some of the symbols identified in the TAC guideline are not identified in the HTA. If a road authority chooses to use them, they may need to apply for an exemption for use of the symbols.

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 their disregard by motorists.

Hazard Identification Beacons

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

Beacons with flashing amber indications may be used to emphasize the need for caution. Studies can be used to determine the justification for hazard beacons based on problems identified at the intersection, collision experience and where one of the following conditions exist:

- 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
- A divided highway (median) begins

Beacons in Advance of a Signalized Intersection

An amber “Keep Right” flasher 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.

Generally these beacons are considered only in locations that are a minimum of 300 m away from signals.

Intersection Control Beacons

General

An intersection control beacon consists of either 20 cm or 30 cm diameter lenses with continuously flashing red or amber indications. Applications include overhead beacons mounted on suspension wire at the centre of an intersection and visual assistance where stop signs are not conspicuous, the sightlines to the major road are poor or because the driver has not needed to stop for some distance and may not be expecting to have to do so.

Flashing beacons may be used when two major high speed roads intersect in a rural area or when collision history suggests additional treatments are required.

It is generally intended that intersection control beacons operate on a continuous basis (aside from power failures, mechanical problems or other unforeseen events).

1-Way or 2-Way Overhead Red Flashing Beacons

These types of beacons are used where the visibility of intersections or stop signs is poor due to abrupt vertical curves or other visibility restrictions, resulting in poor stop sign compliance and/or collisions. The application is used basically to provide visual assistance to normal stop signs.

These types of overhead beacons should use 30 cm red lenses and be positioned to aim 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

These types of beacons are used where "all-way" stop conditions are in place but traffic control signals are not justified. The beacons are used in conjunction with geometric or visibility conditions or collision histories that require reinforcement of the normal usage of stop signs.

These types of overhead beacons should be positioned to aim along each approach. Stop signs must also be used on each approach.

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

These types of beacons are used where stop conditions are required on the side roads and caution conditions are required on the main road but traffic control signals are not justified. The beacons are used in conjunction with geometric or visibility conditions that require reinforcement of the normal usage of stop signs and where side road traffic may have difficulty turning due to a limited sight distance.

These types of overhead beacons should be positioned to aim 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

This type of beacon is normally used above an oversized stop sign on visible approaches to intersections that do not justify traffic control signals. The beacons should be 20 cm 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

Continuous Advance Warning Beacons for Traffic Signals

These types of single 20 cm diameter beacons are used as reinforcement to the "Traffic Signals Ahead" symbolized warning signs where 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.

The 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, continuous single flashing beacons with the oversized "Signals Ahead" sign (Wb-102A) may be required. The location of the signs shall be in conformance with the requirements shown in Book 6 - Warning Signs.

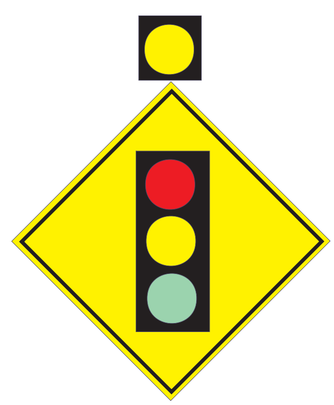


Figure 16 – Signalized Intersection Warning Beacon

Active Advance Warning Beacons for Traffic Signals

These beacons consist of a special oversized Traffic Signals Ahead warning sign (Wb-202A), two alternating flashing amber beacons (20 cm) mounted on either side of the sign, and a word tab (Wb-102At) mounted below the sign that reads "Prepare to Stop When Flashing". This tab must be bilingual in designated areas. These signs should be illuminated with a down light at night to prevent message washout from the flashing beacons. 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.

Active Advance Warning Beacons 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 such that a safe stopping sight distance is not available.

Figure 17 – Active Advance Warning Beacon

- Drivers are exposed to many kilometres of roadway without encountering a traffic control signal.
- Freeway conditions come to an end at a signalized intersection.
- There is a grade approaching the intersection sufficient to require more than normal braking effort.
- As a supplement to double long distance detection on downhill grade approaches.

Successful operation of this device 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.

In order 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 (metres)

V = Operating speed (85th percentile speed or 10 kilometres per hour above the posted speed limit (metres per second)

t_y = Amber time (seconds)

Vt_y = Amber distance (metres)

D_p = Minimum distance at which the flashers can be perceived

= 21.3 metres

True Active Advance Warning Beacons for Traffic Signals

True Active Advance Warning Signs are interconnected with the traffic signal controller, start to flash prior to the onset of the amber signal indication and continue to flash until the approach receives the next green signal indication. These devices consist of a Signals Ahead warning sign (Wb-102A), two alternating flashing amber beacons (20 cm) mounted on either 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. These signs shall be illuminated with a down-light at night to prevent message washout from the flashing beacons. The operation of this device is intended to provide motorists with additional information describing the operation of the traffic signals in order to assist the driver in making decisions. The sign should also flash if the signal goes into flashing operation. The sign must be accurately located in order to be effective.

True Active Advance Warning Signs 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 just past the sign as it is activated are provided with sufficient time to carry them through the pre-defined dilemma zone before the amber is displayed.

True Active Advance Warning Signs should be considered if one or more of the following conditions are present:

- The view of the signals is obstructed due to vertical or horizontal alignment, such that a safe stopping sight distance is not available.
- Drivers are exposed to many kilometres of roadways with operating speeds greater than 60 km/h, regardless of the posted speed limit, and then encounter a traffic control signal.
- Freeway conditions come to an end at a signalized intersection.
- There is a grade approaching an intersection sufficient to require more than normal braking effort.

True Active Advance Warning Signs **should only** be implemented when the intersection operates fixed time or semi-actuated (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 Signs 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 related to the successful operation of this device are related to the accurate placement of the sign and advance flash time that is 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. The recommended sign placement is summarized in Table 8, and 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 Sight Distance in metres)

V = operating speed (85th percentile speed or 10 kilometres per hour above the posted speed limit (metres per second))

T_{pr} = perception reaction time

= 1.8 seconds (recommended)

a = average deceleration rate

= 3.06 metres per second per second (11km/hr/sec)

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 8, 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 metres

V = operating speed (m/s)

t_D = 1 second

Table 8 – True Active Advance Warning Sign Placement

OPERATING SPEED (km/h)	PRE-AMBER FLASH TIME (AW) (seconds)	SIGN PLACEMENT (D_{TA})* (metres)
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.

Figure 18 illustrates the recommended installation of a True Active Advance Warning Sign.

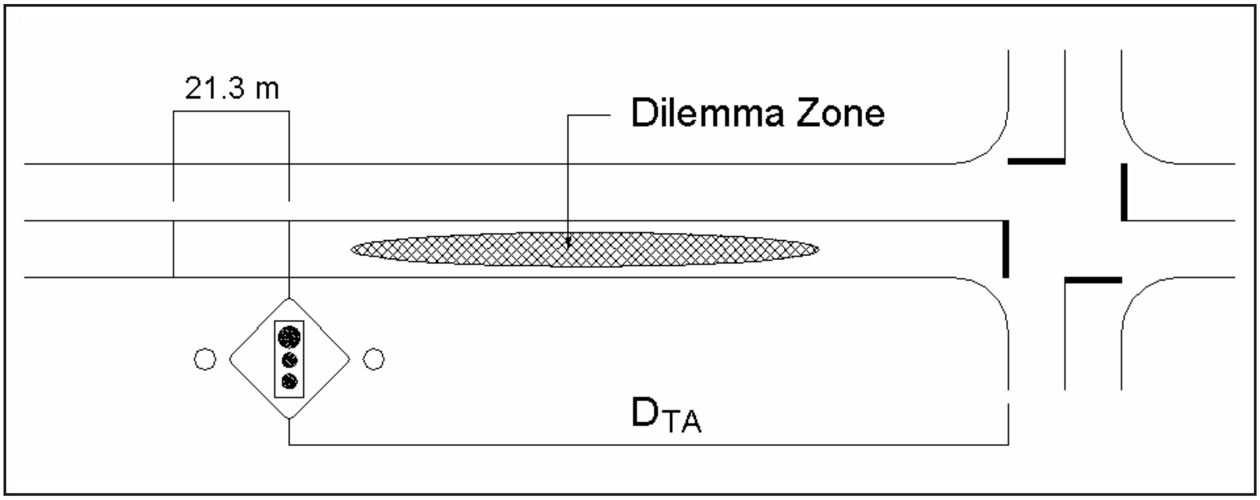


Figure 18 – True Active Advance Warning Sign - Recommended Installation

3.12 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 or more dynamic forms of control are required or 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://www.its-sti.gc.ca/en/architecture.htm).

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

3.13 Maintenance Considerations

Traffic Control Signals require regular maintenance in order to ensure that they are functioning properly, to maximize safety to the public and to proactively avoid potential operational problems. The required maintenance of traffic control signals is provided 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 maintenance standards for consideration (including those listed in the Municipal Act) for traffic signals include:

Every 6 months

Traffic Control Subsystem

- Conflict monitor check

Every 12 months

Traffic Control Subsystem

- Vacuum cabinet
- Change filter
- Check cover plates
- Check heater/fan
- Pest control
- Check/service cabinet joints and sealants
- Verify maintenance logs are being used
- Check supporting documents/drawings are in cabinet
- Verify operation of system connection and communications

Display Subsystem

- Re-lamp signals (incandescent)
- Clean lenses
- 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

External Detection Subsystem

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

In consideration of the information provided above, 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.

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 alternative available to provide right-of-way control. There are a range of other choices that exist, such as stop signs, yield signs or roundabouts, and traffic signals should be selected with due consideration of the appropriateness of other traffic control devices. 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.

Traffic signals have advantages, but they can also have disadvantages that users should be aware of. Traffic signals can provide an efficient movement of traffic, using displays to judiciously distribute time and alternate the right-of-way. They can also be beneficial in the reduction of certain types of collisions. However, if a signal is poorly timed it can be inefficient in serving traffic. Users should also be aware that the installation of a traffic signal does not guarantee the elimination of all collisions, and some types of collisions may increase following the installation of traffic signals.

Background/Context

The decision to install a traffic signal should be based on sound engineering judgment. This section provides guidance on a number of justification procedures that should be used to assist in determining the need for traffic signals. The fulfillment of a traffic signal justification or justifications 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. The satisfaction of the signal installation justifications is only one criterion for determining the suitability of traffic signals for any location.

Even if a location being evaluated meets a justification, a traffic signal should not be installed if it will result in operational problems that create a potential for collisions and/or significantly increase delays to all users. Appendix A of this section provides guidance for a procedure that can be used to assess the potential for impact on collisions as a result of signalization. Other potential problems should also be assessed, including the extension of vehicle queues through upstream intersections, or impacts on existing signal progression. These broader network considerations must be taken into account and necessitate the application of engineering judgement over and above strict reliance on justification criteria alone.

This section identifies seven distinct types of justifications for traffic signal installation. Other considerations may also be encountered that support justification for a signal installation. For example, if visibility at a location is inadequate for the safe and efficient operation of the intersection in its unsignalized form, and geometric or operational improvements cannot resolve the situation, experience and professional judgement may support signal installation. Other relevant issues may be considered by the experienced analyst, such as the disproportionate benefits that can be provided when public transit use is taken into account.

4.2 Information Requirements

Basic Input Data

A number of basic input data and location attributes are required for the analysis of signal justification. Table 9 outlines and describes the basic input data required for the volume, collision and pedestrian components of the signal justification. Not all information items need be collected, only those relevant to the likely justification to be applied (e.g., there is no need to gather pedestrian data at a high-volume intersection for which Justifications 1 through 4 will govern).

Table 9 – 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.
Traffic Volumes	Number of vehicles entering the intersection during the eight highest hours of an average day categorized by left, through and right.	Vehicles should be categorized into passenger cars, trucks/buses and bicycles.
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.
Roadway Speed	Design, actual 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 to assist in determining if the intersection is operating under free flow (rural) or restricted flow (urban) conditions.

Justification 5 – Collision Warrant

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. Expected volume after signalization.	At least three years of historical AADT volumes should be provided, corresponding to collision data years. If known, expected traffic volume following the installation of the signal.
Collision Data	Most recent three or more year history of reported collisions. Initial Impact type detail.	Collision history should be as current as possible. A shorter time period may be used if major changes to the intersection have taken place. Collision data must be sufficiently detailed to allow the determination of initial impact type, such 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 Warrant		
Information Required	**Description**	**Notes/Comments**
Roadway Configuration	Number of lanes on the main road. Presence of median island.	Divided into left, through, right and channelized right turn lanes. 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 or mobility challenged) 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; however, 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 to apply to the justification calculation.	A qualitative assessment of the percentage of pedestrians crossing in each zone that would choose to use the proposed crossing control.

Provided below is additional guidance relating to the collection and application of the above data input requirements.

Flow Conditions

The justification for traffic signals has been developed for two types of flow conditions. This division is necessary to reflect the different operating characteristics that exist under each condition. Engineering judgment should be used in determining which of the following conditions best describes the study location under its existing operating conditions or at a predetermined future analysis scenario:

- Restricted Flow Conditions represent roads with operating or posted speeds less than 70 km/h and are normally encountered in urban areas where side friction on the roadway such as parking and numerous entrances reduces the operating speed of the road.
- 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. Also, since the driving characteristics in small urban communities can be different from those in larger urban areas, free flow conditions are used for isolated communities with a population less than 10,000 and located outside the community influence of a large urban center, even if the operating speed is less than 70 km/h.

Intersection / Roadway Configuration

Main Street Approach Characteristics
The minimum justification values in Justifications 1 and 2 for the volume on the main road are given for a two-lane, two-way roadway as well as 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. Two-lane, two-way roadways with exclusive left-turn lanes are generally not classified as multi-lane roadways; however, engineering judgement should be used to determine if 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.

Roadway Type
Vehicle volume justifications for multi-lane roadways having four or more through lanes on the main road should be 25% higher. Two-lane, two-way roadways with exclusive left-turn lanes are not classified as multi-lane roadways.

Traffic Volume Data

Main Road
The main road should be taken as the road carrying the greatest hourly vehicular traffic volume over the period of study. The “main road”, however, may not always carry the greater volume during each of the hours studied; refinement of the definition to incorporate analysis on an hour-by-hour basis is possible. Where the intersecting volumes are approximately equal, the road having the least 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 those likely to be experienced on an average day, which reflects the operating conditions that the signal is intended to address. When signal justifications are met on days other than weekdays, signals may be justified on the basis of 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 generation during periods outside typical morning and afternoon weekday peak travel demands
- Special event areas such as stadiums, arenas, exhibition grounds, theme parks and community centres, which have reoccurring congestion on a relatively frequent basis

In each of the above cases, the signal should be operated so as not to cause undue delay during the majority of the days during which the demand is reduced.

The hours counted should reflect the eight highest hours of the day. Traffic volumes normally vary hourly, daily, monthly, seasonally and annually. If available counts are for the periods other than the one(s) of interest, they may be factored appropriately with reference to local or provincial experience. Guidance relating to these temporal variations and appropriate adjustment factors is provided in the Traffic Characteristics section of the Geometric Design Standards for Ontario Highways (MTO 1999)[28]. Alternative references include Section 4 of the Institute of Transportation Engineers Traffic Engineering Handbook[29] and Chapter 8 of the Highway Capacity Manual 2000[8].

Vehicle Counts

Only vehicles entering the intersection should be considered, whether they turn right, go straight through or turn left. If the right turns are channelized and are effectively segregated from the through traffic by means of a physical island, right-turning vehicles are not considered to enter the intersection and therefore should not included in any justification calculations.

Bicycles

For the purposes of traffic signal justification analysis, bicycles must be treated as vehicles when on the road and included in vehicle volume counts as such; bicycles should be treated as pedestrians at the intersection of roads and park paths where cyclists dismount to cross the road.

Heavy Vehicle Movements

At locations in heavy industrial, manufacturing, agricultural or natural resource extraction areas, heavy vehicle travel may be predominant on one or more of the side street approaches. In these cases, engineering judgement and visual observations of delay, roadway grades and conflict potential will be required to determine if a heavy vehicle adjustment factor should be applied to reflect the 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. The Canadian Capacity Guide for Signalized Intersections (ITE, 1995)[1] provides some guidance with respect 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, disabled pedestrians and other pedestrians requiring special consideration or assistance are considered "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 their judgement to place each pedestrian into one of the two categories.

The factored pedestrian volume is calculated as follows:

Adjusted volume = Unassisted Pedestrian Volume + 2 x Assisted Pedestrian Volume

Collision Data

Reportable Collision: Collisions involving personal injury or property damage that appear to be serious enough to be reported to police.

Supplementary Input Data

The following data may provide a more precise understanding of the operation of the intersection and assist the analyst in applying additional engineering judgement to the results of the signal justification analysis. Such information may be obtained during the time periods for which the relevant Justification applies:

- 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. To supplement the above basic data, 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.

4.3 Principles of Justification

General

The initiative to consider installing a traffic signal at an existing intersection or mid-block location will generally arise from complaints or analysis regarding delay, congestion, safety, or pedestrian crossing problems. The resultant investigation of the need begins with the collection of traffic, pedestrian, collision and geometric data (as described in Section 4.2). Then, an assessment of whether or not a signal is technically justified is made, using the following criteria:

Justification 1 – Minimum Vehicle Volumes (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)

Justification 6 – Pedestrian Volume (Section 4.9)

Justification 7 – Projected Volumes (Section 4.10)

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 have a negative impact on intersection safety.

4.4 Justification 1 – Minimum Vehicle Volume

Purpose

The Minimum Vehicular Volume Justification is intended for applications where the principal reason to consider the installation of 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 in which signalization can be used to minimize total average vehicle delay at the intersection.

As volumes increase over the threshold criteria, delay to traffic on the minor road will increase such that the overall delay for the intersection is greater than if minor delays are distributed between both roadways.

Standard

The need for a traffic signal must be considered if both Justification 1A and Justification 1B are 100% fulfilled.

If Justifications 1A and 1B do not surpass 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 1 (Minimum Vehicle Volume) for "T" intersections, the justification values for the minor street are increased by 50%. This reflects the reduction in traffic volumes given the elimination of one of the approaches.

Use Table 10 or Justification 1: Minimum Vehicle Volume. Restricted Flow is applicable to Urban Conditions, while Free Flow is applicable to Rural conditions (see Section 4.3.2 for definitions).

Guidelines

Justification 1 compares total intersection volume with 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 are compared to the justification value and the justification should be met for each of the eight hours. "Section Percent" is calculated in Table 10 for reference purposes, and may indicate how close an intersection is to achieving full justification. "Total Across" is calculated by adding all 8-hour compliance percentages. The Compliance % figures used in Table 10 must not exceed 100%.

Table 10 – Justification 1 – Minimum Vehicle Volume

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. ALL APPROACH LANES	480 (385)	720 (575)	600 (480)	900 (720)										
	100% FULLFILLED													SECTIONAL PERCENT
	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% FULLFILLED													SECTIONAL PERCENT
	80% FULFILLED													
	ACTUAL % IF BELOW 80% VALUE													
												TOTAL DOWN / 8 =		

4.5 Justification 2 – Delay to Cross Traffic

Purpose

The Delay to Cross Traffic Justification is intended for application 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 must be considered if both Justification 2A and Justification 2B are 100% fulfilled. If Justifications 2A or 2B do not surpass 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.

Use Table 11 for Justification 2: Delay to Cross Traffic. Restricted Flow is applicable to Urban Conditions, while Free Flow is applicable to Rural Conditions (see Section 4.3.2 for definitions).

Table 11 – 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									
FLOW CONDITION	FREE FLOW	RESTR. FLOW	FREE FLOW	RESTR. FLOW									TOTAL ACROSS	
A. MAJOR STREET BOTH APPROACHES	480 (385)	720 (575)	600 (480)	900 (720)										
	100% FULLFILLED													SECTIONAL PERCENT
	80% FULFILLED													
	ACTUAL % IF BELOW 80% VALUE													
												TOTAL DOWN / 8 =		

B. TRAFFIC CROSSING MAJOR STREET	50 (40)	75 (60)	50 (40)	75 (60)									TOTAL ACROSS	
	100% FULLFILLED													SECTIONAL PERCENT
	80% FULFILLED													
	ACTUAL % IF BELOW 80% VALUE													
												TOTAL DOWN / 8 =		

Guidelines

Justification 2 compares major road volume with 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 to 100% if the justification value is met for each of the eight hours.

“Sectional Percent” is calculated in Table 11 for reference purposes, and may indicate how close an intersection is to achieving full justification. “Total Across” is calculated by adding all 8-hour compliance percentages. The Compliance % figures used in Table 11 must not exceed 100%.

Right turns are not considered as traffic crossing a road; therefore 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 the opposing volume is greater than 720 vehicles per hour

4.6 Justification 3 – Volume/Delay Combination

Purpose

Signals may occasionally be justified where neither of Justifications 1 or 2 are 100% satisfied, but both are satisfied to the extent of 80% or more of the stated values.

Standard

The requirements for the Volume/Delay Combination Justification are given in Table 12.

Guidelines

Justification 3 should only be applied after an adequate trial of other remedial measures that could cause less delay and inconvenience to traffic has failed to solve the operational issues at the intersection. Explicit consideration should be given to the safety benefits and disadvantages of placing the location under traffic signal control. **Appendix A** provides a proposed recommended practice to undertake and assess these relative safety effects.

Table 12 – 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 ☐		

4.7 Justification 4 – Minimum Four-Hour Vehicle Volume

Purpose

The Minimum Four Hour Vehicular Volume Justification is intended for applications where the intersection experiences excessive delays for four or more peak hours of the day, but do not have the prolonged demands throughout the day to meet an eight hour warrant. The application of the four-hour warrant is focused on locations such as:

- Commuter-dominated roadways – with heavy demands for two or more hours in each of the AM and PM peak, 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 or industrial areas/ accesses – where minor street exiting traffic experiences considerable delays when entering the major street during the mid-day and PM peak periods but the AM arrive peak realizes little side street demands

Standard

The need for a traffic signal must 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 approaches on the major street and the corresponding vehicles per hour on the highest minor street approach falls above the applicable curve outlined in Figure 19 (Rural - Unrestricted Flow Conditions) or Figure 20 (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 may be required to determine a portion of the right turn volume should be excluded from the approach volume with evaluating it against the volume on the other minor street approach and the overall signal justification thresholds.

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: Plot the four highest hour volumes on the applicable figure below. If all four points lie above the applicable curve then the justification is satisfied.

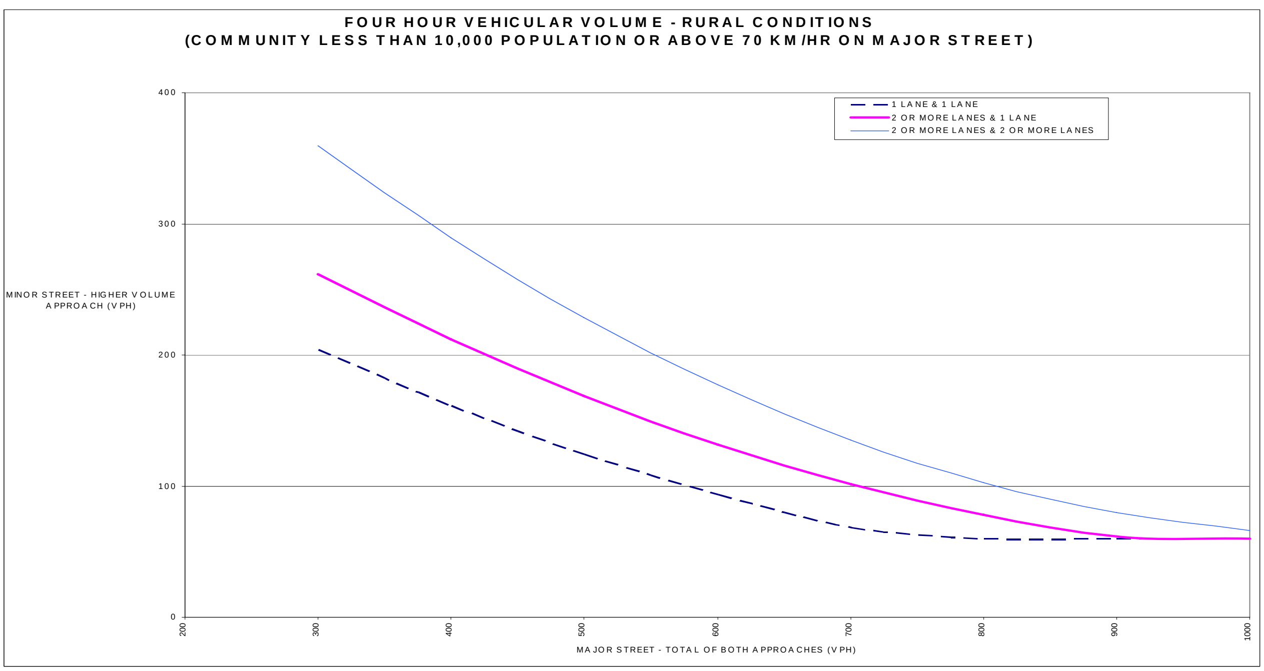


Figure 19 – Justification 4 – Minimum Four Hour Justification, Unrestricted Flow

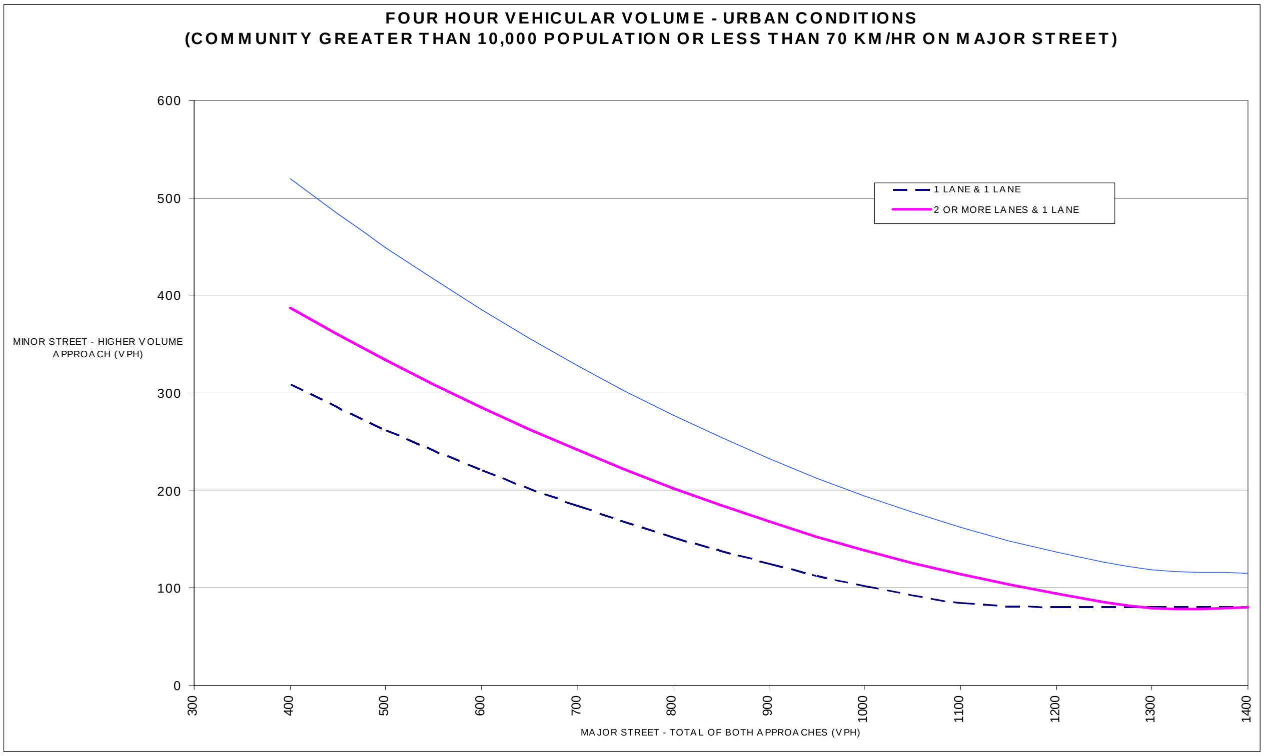


Figure 20 – Justification 4 – Minimum Four Hour Justification, Restricted Flow

4.8 Justification 5 – Collision Experience

Purpose

Traffic signals may be considered as one means of improving intersection safety where an unsignalized intersection has an unusually high collision history.

Standard

The installation of traffic signals may be justified when the conditions presented in Table 13– Justification 5 – Collision Experience are satisfied:

1. Average of five or more reportable collisions of types susceptible to correction per 12 month period average over a 36 month period. Collisions susceptible to reduction are those involving vehicles, which under signalized conditions would move on completely separate phases.
2. Adequate trial or consideration of less restrictive remedies with satisfactory observance and enforcement has failed to reduce collision frequency.

Table 13 – Justification 5 – Collision Experience

Reportable Accidents within 12 month period averaged over 36 consecutive months susceptible to correction by a traffic signal		
WARRANT VALUE	AVERAGE NUMBER OF CRASHES	OVERALL % COMPLIANCE
5	…….	……%
Adequate trial of less restrictive remedies has failed to reduce accident frequency		Yes ☐ No ☐
Justification 5	100% Fulfilled	Yes ☐ No ☐
	80% Fulfilled	Yes ☐ No ☐

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 this justification, consideration should be given to whether self-reporting or police reported collisions are most prevalent. The accuracy of the collision history may be reduced in situations where self-reporting collisions are prevalent.

The justification is intentionally designed so that installation of 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.

Analysis methods that assess the expected collision performance of a location following signalization are available and can be used to assist with the determination of the net safety change that can occur from a signal installation. Details of this procedure are included in Appendix A of this section.

4.9 Justification 6 – Pedestrian Volume and Delay

Purpose

The minimum pedestrian volume conditions are intended for application 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 may occur at either an unsignalized intersection or at a mid-block location.

Once a justification has been established, determination of the appropriate crossing protection device should be subject to site-specific engineering judgement (see Guideline 3 for options).

Standard

The need for a traffic control device at an intersection or mid-block location must be considered if both the following minimum pedestrian volume and delay criteria are met:

1. The total eight-hour pedestrian volume crossing the main road at an intersection or mid-block location during the highest eight hours of pedestrian traffic fulfils the justification requirement identified in Figure 21.

2. The total 8-hour volume of pedestrians experiencing delays of ten seconds or more in crossing the road during the highest eight hours of pedestrian traffic fulfils the justification requirement identified in Figure 22.

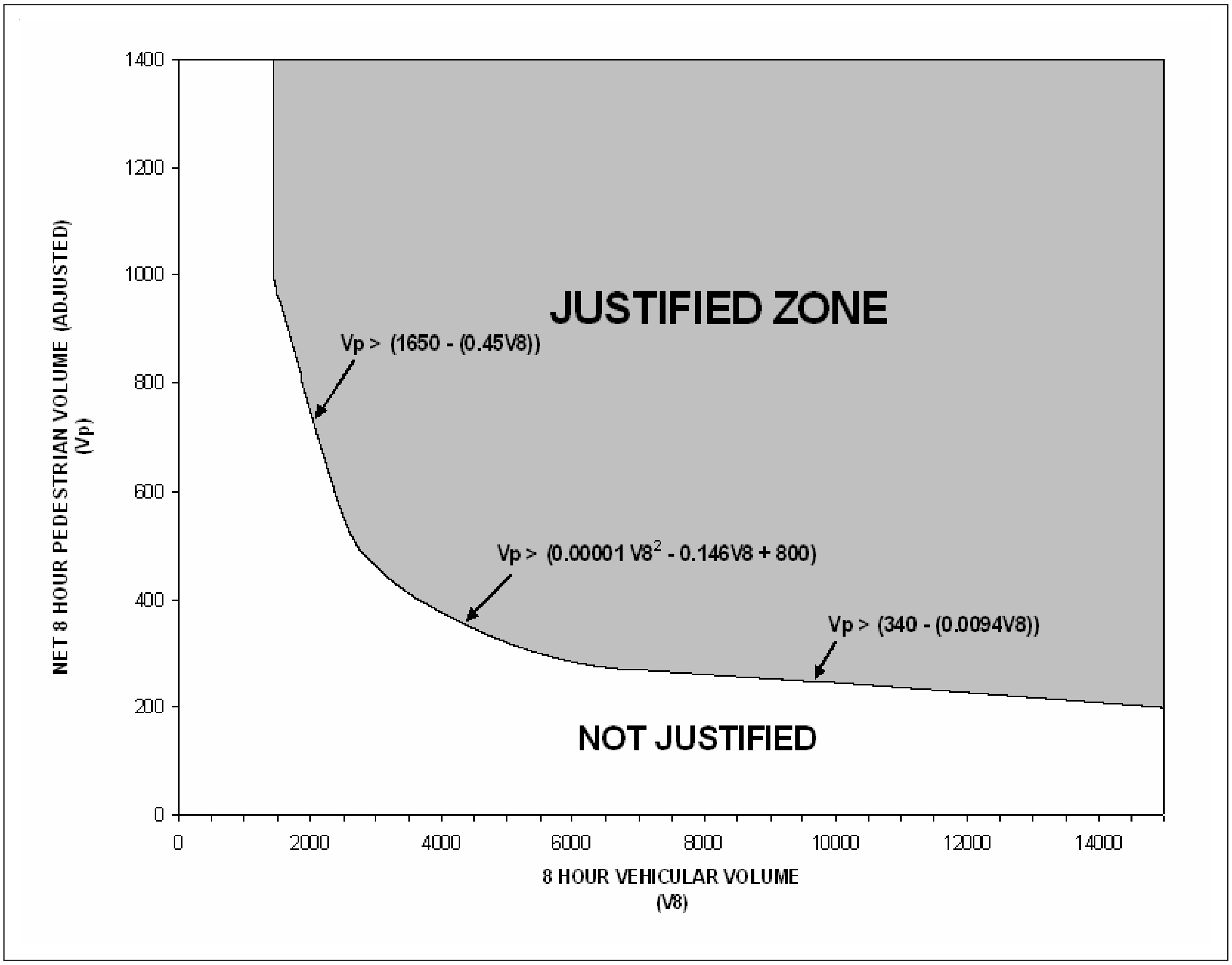


Figure 21 – Justification 6 – Pedestrian Volume

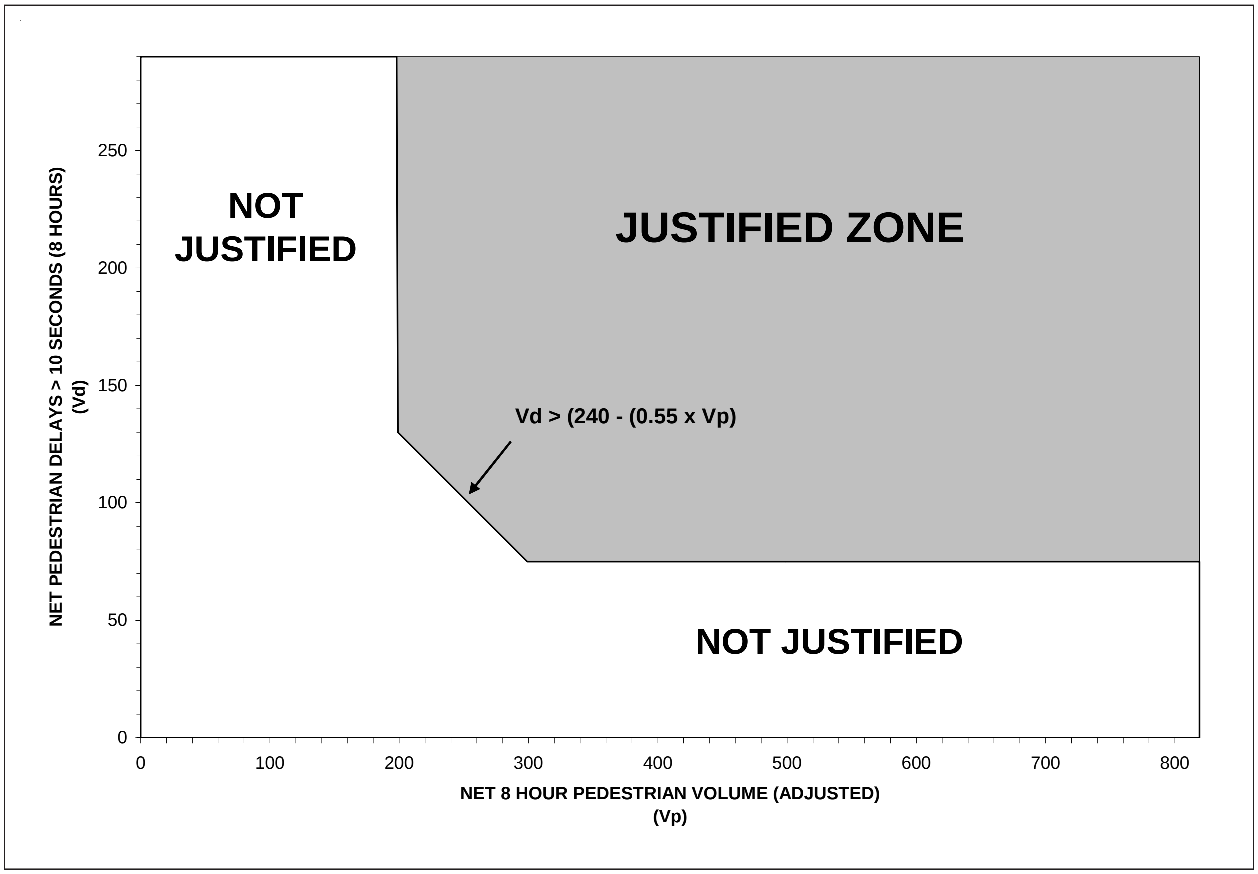


Figure 22 – Justification 6 – Pedestrian Delay

Guidelines

1. If a roadway is crossed by pedestrians in several locations and the introduction of a signal-protected crossing is likely to serve to consolidate the crossings at a single point, the road segment may be divided into zones and appropriate proportion of crossings in each zone reassigned to the signal-protected crossing zone, included in Tables 14 and 15.
2. In the case of a divided roadway with a raised median of at least 1.2m in width, the justification may be calculated separately for each direction. The "worst case" direction will govern the outcome, such that if a protected crossing is justified in one direction 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 available. Consistent municipal practice is desirable in terms of pedestrian crossing types, application thresholds and crossing design. This promotes motorist familiarity with the crossing, and aims to prevent motorists from running the signal or undertaking other unsafe maneuvers. Application of a single use of one crossing type should be avoided.

Table 14 – Pedestrian Volume Data Summary

	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 PED. VOLUME COUNT									
FACTORED 8 HOUR PED. VOLUME									
% ASSIGNED TO CROSSING RATE***									
NET 8 HOUR PEDESTRIAN VOLUME AT CROSSING									
NET 8 HOUR VEHICULAR VOLUME ON STREET BEING CROSSED									

* Assisted = senior citizens, disabled pedestrians and children under 12 assisted in crossing road
**Factored volume = unassisted + (2 x assisted)
*** See guideline No. 1

Table 15 – Pedestrian Delay Data Summary

	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 TOTAL OF PEDS.									
8 HOUR TOTAL OF PEDS. Delayed > 10 SECONDS									
FACTORED VOLUME** OF TOTAL PEDS.									
FACTORED VOLUME OF DELAYED PEDS.									
% ASSIGNED TO CROSSING RATE***									
NET 8 HOUR VOLUME OF TOTAL PEDESTRIANS									
NET 8 HOUR VOLUME OF DELAYED PEDESTRIANS									

* Assisted = senior citizens, disabled pedestrians and children under 12 assisted in crossing road
** Factored volume = unassisted + (2 x assisted) volume
*** See guideline No. 1

The available pedestrian crossing protection devices include:

a) *Intersection Pedestrian Signals (IPS)* If the pedestrian crossing under consideration is to be at an intersection, justification should be made on the basis of Justification 6 being fulfilled but the crossing vehicular traffic should be so light as to not meet one of the other justifications (1 through 5).

b) *Pedestrian Crossovers (PXOs)* Pedestrian Crossovers are intended for low to moderate volume, low speed roadways (60km/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 or three lanes of one-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. Justification for PXOs should be based on the above factors plus a percent justification of that given in Tables 16 and 17, which is set by the authority as the threshold of need.

c) Midblock Pedestrian Crossings Midblock pedestrian crossings 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 21 and 22, which is set by the authority as the threshold of need.

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 not in the preferred traffic control device within the municipality. In such cases, it is desirable that at least one of the justifications 1, 2 or 3 is met 80% or more in addition to justification 5 being met.

e) Pedestrian Grade Separations In cases of very heavy pedestrian and traffic volumes, it may be economically viable to construct pedestrian bridges or tunnels.

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.

Table 16 – Pedestrian Volume Justification 6A

8 HOUR VEHICULAR VOLUME (V_8)	NET 8 HOUR PEDESTRIAN VOLUME				
	<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 net 8-hour ped vol. $> (1650 - (0.45V_8))$

EQUATION 2: Justified if net 8-hour ped vol. $> (0.00001\ V_8^{\,2} - 0.146V_8 + 800)$

EQUATION 3: Justified if net 8 hour ped vol. $> (340 - (0.0094V_8)$

% Justification = ((net 8 hour pedestrian volume)/(Equation 1, 2 or 3 as appropriate)) x 100%

Table 17 – Pedestrian Delay Justification 6B

NET TOTAL 8 HOUR VOL. OF TOTAL PEDESTRIANS	NET TOTAL 8 HOUR VOLUME OF DELAYED PEDESTRIANS		
	<75	75 - 130	>130
<200	NOT JUSTIFIED	NOT JUSTIFIED	NOT JUSTIFIED
200 - 300	NOT JUSTIFIED	JUSTIFIED IF VOL. OF PEDS. > (240 - (0.55 x VOL. OF TOTAL PEDS))	JUSTIFIED
>300	NOT JUSTIFIED	JUSTIFIED	JUSTIFIED

% Justification = ((net 8 hour delayed pedestrian volume) / (threshold volume for justification)) x 100%

Signal Justification:

Both Justification 6A (volume) and Justification 6B (delay) met?

___ YES = Traffic Control Justified

___ NO = Traffic Control Not Justified

Table 18 presents minimum requirements for installation of traffic signals for Justification 1 to Justification 6.

Table 18 – Summary Table of Traffic Signal Justification

JUSTIFICATION	DESCRIPTION	MINIMUM REQUIREMENT FOR FREE FLOW: OPERATING SPEED GREATER THAN OR EQUAL TO 70 km/h	MINIMUM REQUIREMENT FOR RESTRICTED FLOW: OPERATING SPEED LESS THAN 70 km/h	COMPLIANCE: SECTIONAL %	COMPLIANCE: ENTIRE %**
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 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 Pedestrian Volume vs. 8 Hour Vehicular Volume Fall in Jusfied zone, and	YES ☐	NO ☐		
	B. Plotted Point Representing 8 Hour Volume of Pedestrian Experienceing Delays of 10 s or more vs. 8 Hour Pedestrian Volume Fall 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 Sectional Percentage Governs the Entire Warrant

*** For "T" Intersections the Values for Warrant (1B) should be increased by 50%

4.10 Justification 7 – Projected Volumes

a) Traffic Signal Justification for Future Development – Traffic Impact Studies

The prediction of future traffic demands is usually based on knowledge of roadway usage growth, growth of local traffic generators and predicted traffic volumes. For future development, eight-hour volumes are difficult to obtain and predict with the necessary accuracy. Peak Hour Volumes (PHV) are estimated as part of a Traffic Impact Studies and reduced to Average Hourly Volumes (AHV) for comparison with traffic signal justifications for projected volumes.

The Average Hourly Volume for the four or eight highest hours of an average day can be estimated from the Peak Hour Volumes using the following relationships:

$$AHV = \frac{PHV}{2} \quad \text{or} \quad AHV = \frac{AmPHV + PmPHV}{4}$$

Use Table 19 for the justification of traffic signals using Projected Volumes. Restricted Flow is applicable to urban Conditions, while Free Flow is applicable to rural case (see Section 4.2 for definitions).

Due to the increased uncertainty of volume projections for proposed new developments, an increased justification threshold is used in those cases. Justification 1 and Justification 2 are used only and the justification is required to be met to 120% in the case of an existing intersection and 150% in the case of a new intersection for traffic signals to be considered.

Note that future volumes may reflect side street traffic attracted to the new traffic signal upon a significant reduction in delay. It is recommended to construct the necessary underground provisions as part of the road works where justification of a signal is met to 100%.

Table 19 – Justification 7 – Projected Volumes

100% SATISFIED – YES ‟ NO ‟
80% SATISFIED – YES ‟ NO ‟

Justification	Description	Minimum Requirement 1 Lane Highways		Minimum Requirement 2 or more lanes		Compliance		
						Sectional		Entire %
		Free Flow	Restr. Flow	Free Flow	Restr. Flow	Numerical	%	
1. Minimum Vehicular Volume	A. Vehicle volume, all aproaches (average hour)	480	720	600	900			
	B. Vehicle volume, along minor streets (average hour)	120	170	120	170			
2. Delay to cross traffic	A. Vehicle volume, major street (average hour)	480	720	600	900			
	B. Combined vehicle and pedestrian volume crossing artery from minor streets (average hour)	50	75	120	170			

b) Traffic Signal Justification for Planning Studies (Existing Roadways)

In some cases, it is desired to determine the need for traffic signals at a study location at some time in the future. If significant changes in traffic volume or intersection layout are anticipated in the near term, these should be quantified.

Horizon Year - Up to Five years

Hour by hour eight-hour volumes should be used to predict the future traffic conditions for the horizon year as these volumes can be developed with some accuracy. The need for traffic signals must be considered if an engineering study finds that the intersection meets one or more of the following criteria:

Five-year eight-hour projected volumes that satisfy one or more of:

- Justification 1 – Minimum Vehicle Volume (Table 2) met to 100%
- Justification 2 – Delay to Cross Traffic (Table 3) met to 100%
- Justification 3 – Combination Warrant (Table 4) met to 80%

Where it is not possible to obtain an eight-hour traffic count that represents future traffic conditions, traffic justifications for future conditions may use Average Annual Daily Traffic (AADT) for the horizon year. Table 19 is used for the justification of traffic signals using the AADT Projected Volumes reduced to average hourly volumes.

Horizon Year - Over Five years

Hour by hour projected eight-hour volumes can be used to predict the future traffic conditions for the long term horizon. Where projected eight-hour traffic counts are not available, the AADT for the horizon year should be used.

Table 19 is used for the justification of traffic signals using the AADT Projected Volumes reduced to average hourly volumes. The Average Hourly Volume (AHV) for the eight highest hours of an average day can be estimated from Annual Average Daily Travel (AADT) volume using the following relationship:

$$AHV = \frac{AADT}{16}$$

Where: AHV = Average hourly volume
AADT = Annual average daily travel

4.11 Signal Installation Prioritization

On a network-wide scale, funding limitations or other constraints may lead to an inability to implement all signals that meet the minimum technical justification criteria. It is therefore important to understand the relative value of each candidate set of traffic signals so that effort maybe 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 basic manual approach is to examine the justification analysis for each potential location and rank the sites by the degree to which they meet each justification as shown. This approach should ensure that 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.

4.12 Removal of Existing Signals

If the conditions under which a signal was installed change significantly and concerns arise that it is no longer justified, it may be analyzed using Justifications 1 to 6 on the same basis as if it were a "new" installation. If, under current conditions, the signal fails to meet any of Justifications 1 to 6 then it 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 in conjunction with traffic signal removal consideration are taken from ITE Recommended Practice for the Removal of Traffic Signal Control Systems[30], and the User Guide for Removal of Not Needed Traffic Signals[31]:

A. Determine the appropriate traffic control to be used after removal of the signal.

B. Remove any sight-distance restrictions as necessary.

C. Inform the public of the removal study, for example by installing an informational sign (or signs) with the legend TRAFFIC SIGNAL UNDER STUDY FOR REMOVAL at the signalized location in a position where it is visible to all road users.

D. Flash or cover the signal heads for a minimum of 90 days, and install the appropriate stop control or other traffic control devices.

E. Remove the signal if the engineering data collected during the removal study period confirms that the signal is no longer needed. Instead of total removal of the traffic control signal, the poles and cables may remain in place after removal of the signal heads for continued analysis.

Appendix A - Collision Experience / Safety Change Estimation

Improving traffic safety is a major concern for traffic engineers, the public and elected officials. Traffic collisions cause fatalities, injuries, property damage and highway congestion. In order to improve traffic safety, identification of highly hazardous locations or collision-prone spots and evaluation of the effectiveness of safety improvements are essential.

Among all the elements of a transportation network, intersections are found to be relatively collision-prone spots from a safety point of view due to the complicated conflicts between road users occurring within an intersection. There are a number of treatments implemented at intersections to ensure the safe and efficient operation of motor vehicles. Signalizing intersections are a common treatment used by road authorities to address the safety and operation issues.

The current signal collision justification (Justification 5 – Section 4.8) for determining traffic signal installation at existing stop controlled intersections is that an intersection has to have at least five correctable collisions per year averaged over the past three years. There are, however, significant limitations to this approach as it does not take into consideration the effect of traffic volume variations in collisions. As shown in Figure 23, the number of correctable collisions that justify signal installation remains the same regardless of the traffic volume (AADT).

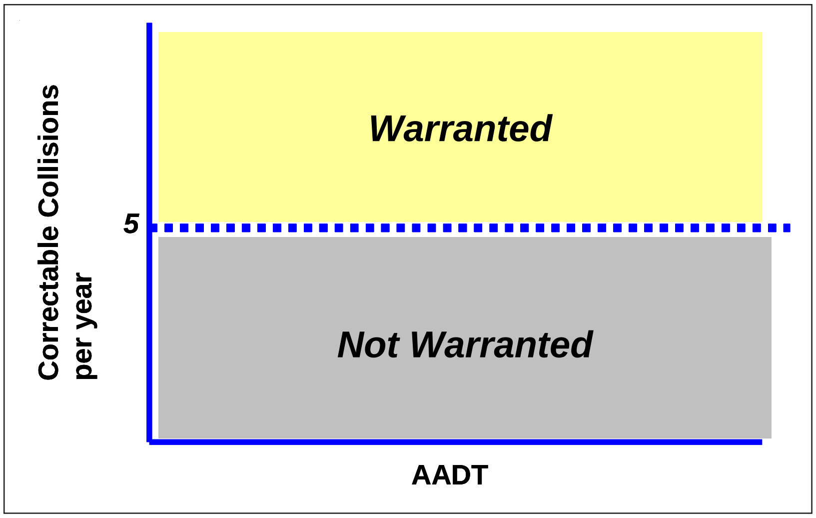


Figure 23 – Current Signal Collision Justification (Justification 5 –Section 4.8)

More critically, the approach focuses only on correctable, or reducible, collisions, those anticipated to be prevented following signal installation. The process ignores the non-correctable, non-reducible collisions that might increase following the installation of traffic signals. In summary, the current collision warrant does not provide a means to measure changes in safety at an intersection after installation of traffic signals. Therefore, a new collision justification procedure has been developed to address these 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, we are seeking 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 24.

Figure 24 – General Consideration of Safety Changes

The following section describes a detailed approach for estimating the safety impacts of signal Installations that can be used as an alternate methodology to examine the justification of signalization based on collision experience.

Purpose

The objective of this section is to develop a safety analysis and evaluation tool for estimating the expected safety of installing traffic signals in order to help the traffic engineer to determine the likely impact on safety from installing a traffic signal.

The proposed approach considers both the potential increase in some types of collisions and decrease in others. Using the Empirical Bayes (EB) statistical analysis method, combined with expected collision performance as indicated by Operation Performance Functions (OPF), the result is an estimate of the safety effects of changing an intersection from unsignalized to signalized control.

It is critically important that the expected collision performance of signalization takes into account recent collision history at the location as well as the long-term expected collision performance of traffic signals with similar characteristics for their traffic volume and intersection type.

Standard

The collision experience justification is based on concepts first introduced to Ontario in the Science of Highway Safety Manual[32]. The approach uses Operational Performance Functions (OPF) to understand how collisions at similar types of locations change in conjunction with traffic volume. It also uses Empirical Bayes (EB) statistical methods to consider the effect that recent collision history at a specific site will have towards influencing future behaviour. 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 to determine the appropriate weighting to place on each relevant factor to estimate collision outcomes for the location. The EB method determines a "smoothed" value for expected collisions and eliminates the randomness element of collisions which, if ignored, can result in regression to the mean bias.

OPFs 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 from OPFs for the type of intersection in general is used, together with the historical collision counts for the 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 type of collisions deemed to be susceptible to reduction following a signal installation. Angle and Turning Movement collisions are considered reducible collisions. On the other hand, non-reducible collisions are the types of collisions that are not likely to be reduced by a signal. These include side-swipe, rear-end and approaching collisions. Collision types are grouped in Table 20.

Table 20 – Collision Groups for Calibration of OPF

Reducible Collisions (RC)	Non-Reducible Collisions (NRC)
Angle	Side-swipe
	Rear-end
Turning-Movement	Approaching
	Other

In order 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 25 displays this concept graphically.

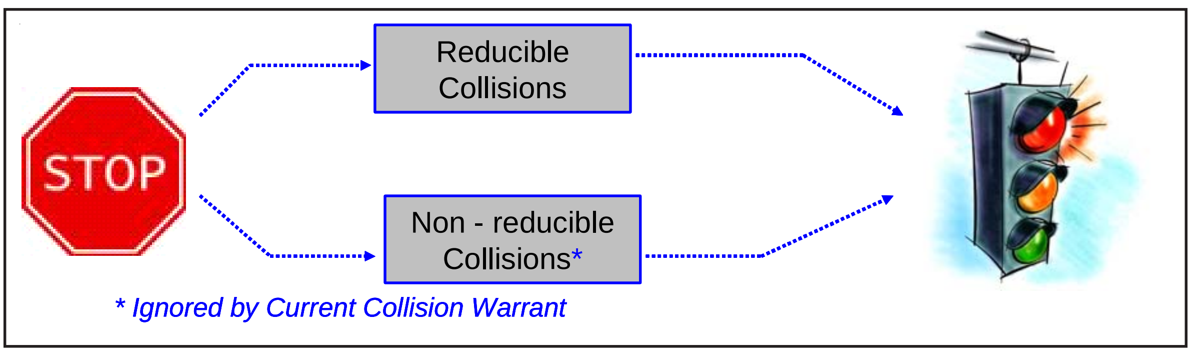


Figure 25 – Detailed Consideration of Safety Changes

For the development of the collision experience justification for each collision type, OPFs for unsignalized intersections (representing before periods) and OPFs for signalized intersections, representing after periods, for both reducible and non-reducible collisions were developed. The database used for the development of OPFs was obtained from Ontario's Ministry of Transportation (MTO). The data integrates the crash, intersection configurations, and traffic volume data from all the intersections in the MTO's Central and Southwest regions within a six-year period from 1998 to 2003.

To complete the collision experience justification, the unsignalized OPFs for reducible collisions are used to predict the expected numbers of collisions for the intersection with similar characteristics. Then, the expected number of collisions (the point on the OPF for unsignalized intersections in Figure 4h) and the observed collisions are used to determine the "smoothed" collisions for the target intersection by using the EB method.

In the next step, the signalized OPFs for reducible collisions are used to predict the expected numbers of collisions for the intersection with similar characteristics if the intersection were signalized.

Then, the expected collision for signalized intersection with "smoothed" value and the expected collision for unsignalized condition were used to determine the estimated number of target collisions if the intersection was signalized. This is shown as "Estimated Collisions, Target Intersection (Signalized)" in Figure 26.

The net change between the "smoothed" collisions in the unsignalized conditions to the estimated collisions in the signalized condition represents the safety change that is estimated to occur. Generally, the expected outcome for reducible collisions is a decrease in reducible collisions, as shown in Figure 26.

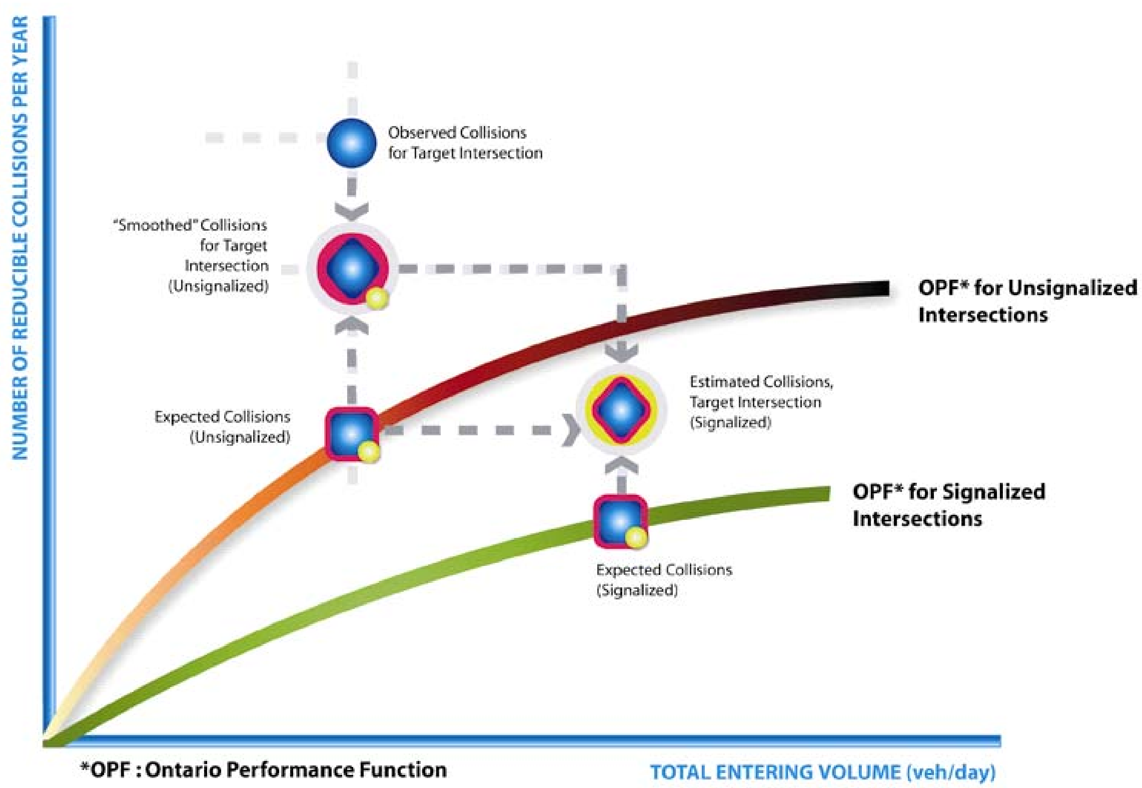


Figure 26 – Justification 5 (Alternate) – Use of Regression Relationship in the Empirical Bayes Approach for Reducible Collisions

This approach was repeated for the non-reducible collisions. As shown in Figure 27, the change from unsignalized to signalized control can be measured.

Detailed descriptions of the procedure described are explained in the research paper that has been published by the Transportation Research Board. Users of this approach are encouraged to review that documentation if they seek detailed information about the approach and the research that was carried out in its development and application for Ontario[33].

Generally, the expected outcomes of Figures 26 and 27 are a decrease in the number of reducible collisions and an increase in the number of non-reducible collisions as shown graphically in Figure 28. However, it must be stressed here that this outcome will vary because it depends directly on the recent collision history and the location characteristics.

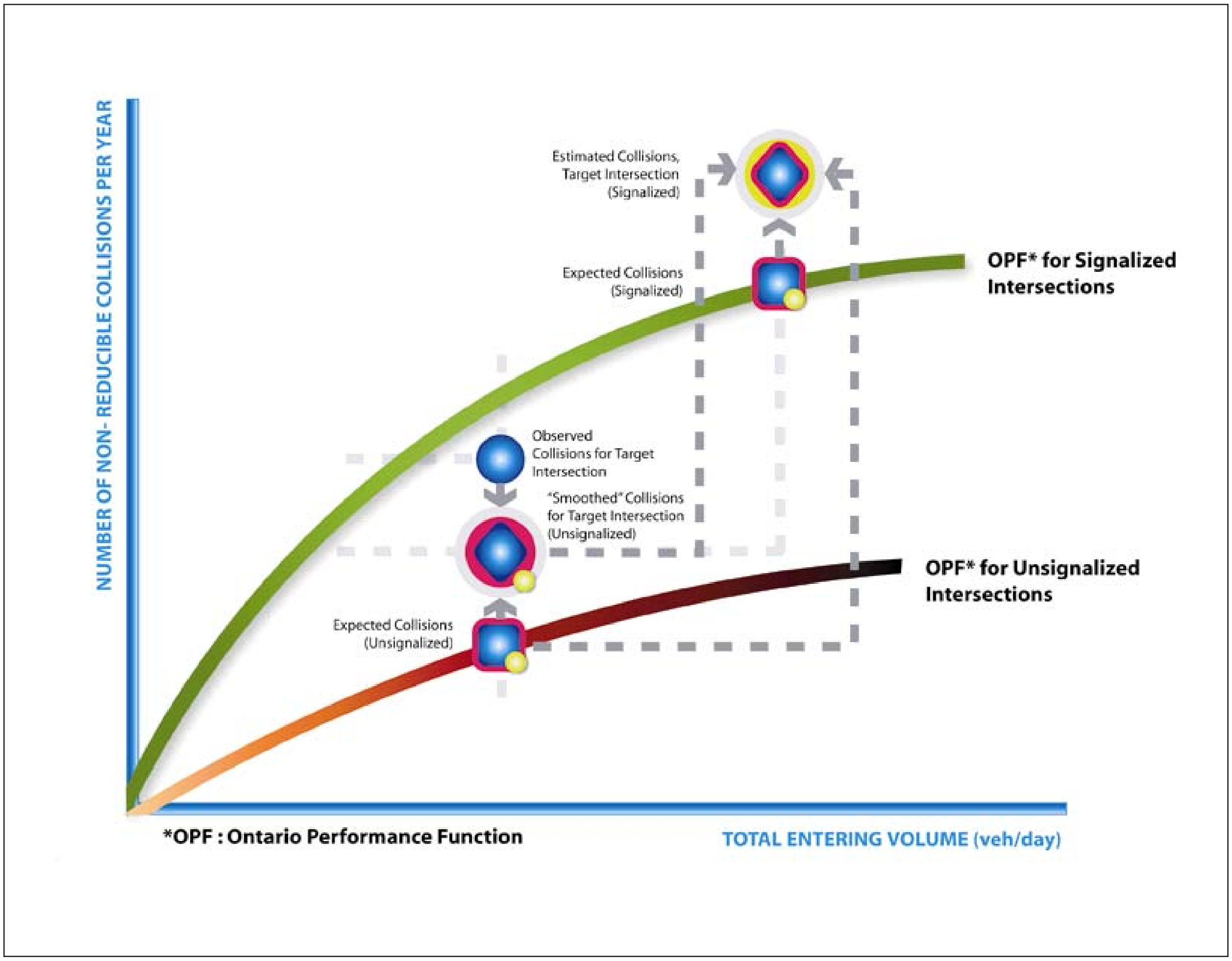


Figure 27 – Justification 5 (Alternate) – Use of Regression Relationship in the Empirical Bayes Approach for Non-Reducible Collisions

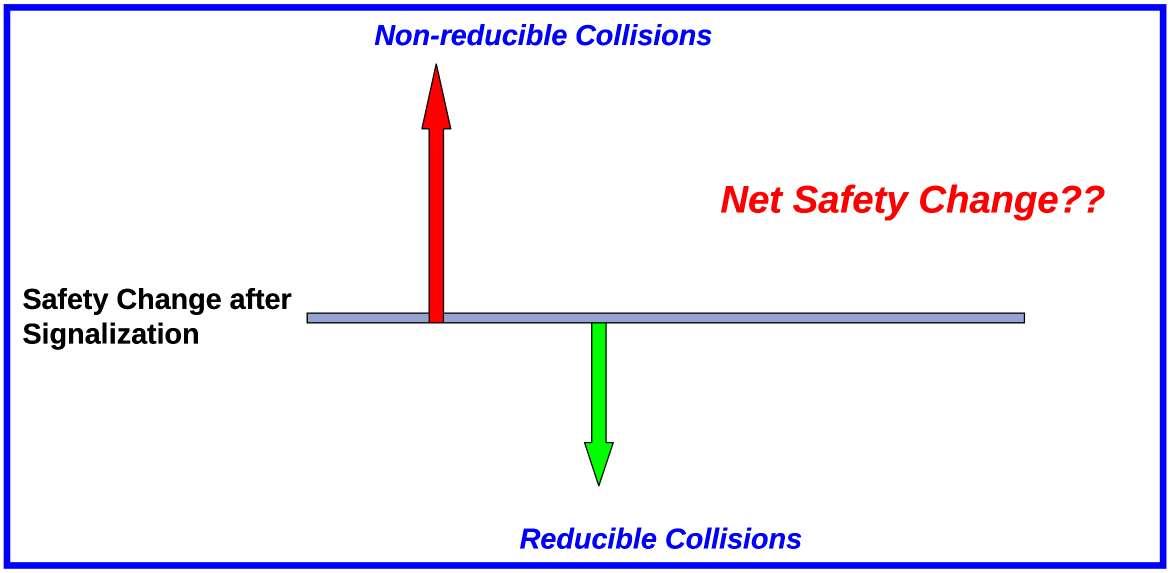


Figure 28 – Safety Changes for Reducible and Non-reducible Collisions for a Typical Case

However, the net safety change of the intersection cannot be simply calculated by straight tally of the difference between the two outcomes shown in Figure 28. Consideration needs to be given to the different consequences of reducible and non-reducible collision groups. Reducible collisions, generally, are more severe than non-reducible collisions, and this difference should be taken into account in the assessment of the net change.

In order to evaluate the association between reducible and non-reducible collisions and intersection control types (signalized or unsignalized), Collision Severity Indexes were created. These indices were used to weight the quantities of crashes so that reducible crashes are given more importance than non-reducible crashes since the reducible crashes, which include angle and turning movement crashes, are generally more severe than non-reducible crashes.

To create the indices, the database was broken down into the following 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. Then the numbers of fatal, injury, and PDO collisions as well as total exposure (traffic volume) were assigned to each of the four groups. The probability of a collision by severity type and exposure for all four categories was estimated by applying the relative risk method. The detailed descriptions of the above procedure are explained in the Transportation Research Board paper[33]. The results of safety indices based on MTO's data set are shown in Table 21.

Table 21 – Collision Severity Index based on MTO's Database

Collision Types	Collision Severity Index
Reducible Collision at Signalized Intersections	0.30
Non-reducible Collision at Signalized Intersections	0.25
Reducible Collision at Stop Controlled Intersections	0.27
Non-reducible Collision at Stop Controlled Intersections	0.18

By talking into account the safety indices for each collision estimate determined, it is possible to determine a weighted relationship between the reducible and non-reducible collisions. This result, shown in Figures 29 and 30, can then be examined to determine the net safety change (NSC). As shown in the figure, the **positive** value of NSC indicates it is likely that installing a signal will result in safety **deterioration** for the particular intersection as shown in Figure 27.

On the other hand, the **negative** value of NSC indicates it is likely that a net safety **benefit** can be achieved by installing a traffic signal (see Figure 30).

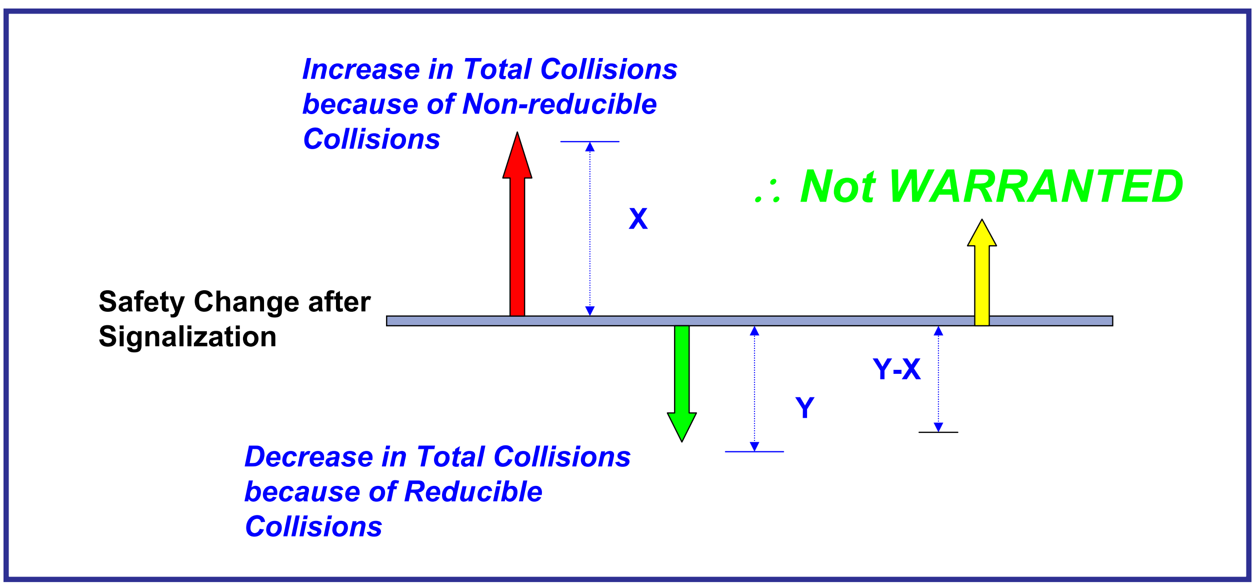


Figure 29 – Safety Deterioration Resulted from Converting an Unsignalized Intersection to a Signalized Intersection

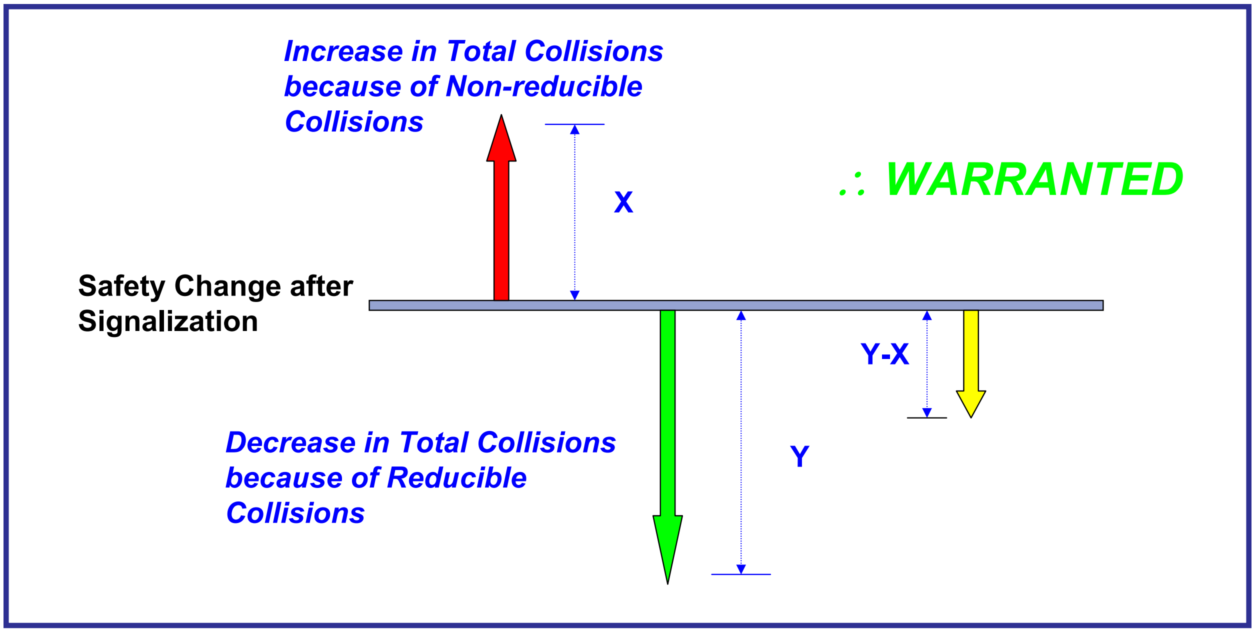


Figure 30 – Net Safety Benefit Resulted from Converting an Unsignalized Intersection to a Signalized Intersection

To facilitate completion of the collision experience justification calculations, a Microsoft® Excel™ spreadsheet has been developed. The tool allows users to carry out detailed engineering study for estimating safety impacts of signal installations only requiring the input of fundamental traffic data for the location.

The spreadsheet consists of three sections:

1. An "Input Data" section in which the basic information of the intersection, collision impact types and entering AADTs for each year of analysis are manually entered.
2. The "Analysis" section shows all the details of the analysis for both reducible and non-reducible collisions. This section displays the calculations that have been carried out, and they cannot be modified by the user.
3. The "Results" section shows the net safety change that can be achieved by installating a traffic signal. This section cannot be modified by the user.

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 Operational Performance Functions (OPF) for signalized and unsignalized intersections were used to explore the relationship between the number of collisions and traffic flow. For each collision type, models for unsignalized intersections that represent before periods and for signalized intersections that represent after periods are used to assess the expected change in overall collision performance following signalization.

As with the existing collision justification, less restrictive measures that may be implemented prior to traffic signal installation 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, relocation of bus stops, and/or the prohibition of parking and/or turns.

When applying this justification, the analyst must also consider the quality of information that is available, particularly as relating to collisions. Where "self-reporting" collision records are collected and used, as opposed to at-the-scene reporting by police, the accuracy of the information should be closely scrutinized. Data from these reports may have the effect of introducing less accuracy into the determination of whether or not the collision was preventable by signals.

The justification provides a significant departure from the existing approach being used. By considering both the safety benefits and drawbacks of installing signals, it is hoped that users will be able to make more informed decisions. This new tool provides an assessment of the potential safety impact of installing a signal, but as with all justifications, this information must be considered in association with a full range of information and proper engineering judgment.

Appendix B – Sample Calculations for Traffic Signal Justification

Calculations for the six Justifications are carried out using an Excel™ spreadsheet. The spreadsheet consists of three sections:

1. "**Input Data**" sheet in which all the required information for calculation of justifications is manually entered.
2. "**Analysis**" sheet that shows all the detail of the analysis for all the justifications. This spreadsheet cannot be modified by the user.
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.

This section provides a numerical example for illustration purposes.

The example illustrates a 4-leg stop-controlled urban intersection being considered for traffic signal installation. The information and calculation required for traffic signal justification is provided as follows:

Input Data

Input Data Sheet

Analysis Sheet | Results Sheet | Proposed Collision

GO TO Justification:

What are the intersecting roadways? Richmond Street / Ducan Street

What is the direction of the Main Road street? North-South

Justification 1 - 4: Volume Warrants

a.- Number of lanes on the Main Road? 1

b.- Number of lanes on the Minor Road? 1

c.- How many approaches? 4

d.- What is the operating environment? Urban **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
7:30	55	221	3	9	5	7	6	530	32	9	58	4	10
8:00	33	222	1	12	12	16	4	521	37	9	35	5	10
8:30	7	330	3	12	10	5	6	318	9	4	3	8	10
9:00	9	309	4	9	8	12	8	339	15	9	9	3	10
9:30	13	544	11	13	21	22	7	296	11	3	18	9	10
10:00	13	557	14	26	22	42	8	371	8	3	9	9	10
10:30	9	522	5	31	61	80	2	386	12	4	6	5	10
Total	**172**	**2837**	**43**	**114**	**142**	**187**	**42**	**3172**	**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 susceptable to correction through the installation of traffic signal control

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		Zone 2		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			
Factored 8 hour pedestrian volume	120		15		7		0		
% Assigned to crossing rate	100%		50%						
Net 8 Hour Pedestrian Volume at Crossing									128
Net 8 Hour Vehicular Volume on Street Being Crossed									5560

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		Zone 2		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	7:30	8:00	8:30	9:00	9:30	10:00	10:30		
1A	480	720	600	900	661	939	907	715	734	968	1082	1123		
	COMPLIANCE %				92	100	100	99	100	100	100	100	791	99
1B	120	170	120	170	61	92	89	42	50	86	111	187		
	COMPLIANCE %				36	54	52	25	29	51	65	100	412	52

Restricted Flow Signal Justification 1:			
	Both 1A and 1B 100% Fullfilled each of 8 hours	Yes ☐	No ☑
	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	7:30	8:00	8:30	9:00	9:30	10:00	10:30		
2A	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 Signal Justification 2:			
	Both 2A and 2B 100% Fullfilled each of 8 hours	Yes ☐	No ☑
	Lesser of 2A or 2B at least 80% fulfilled each of 8 hours	Yes ☐	No ☑

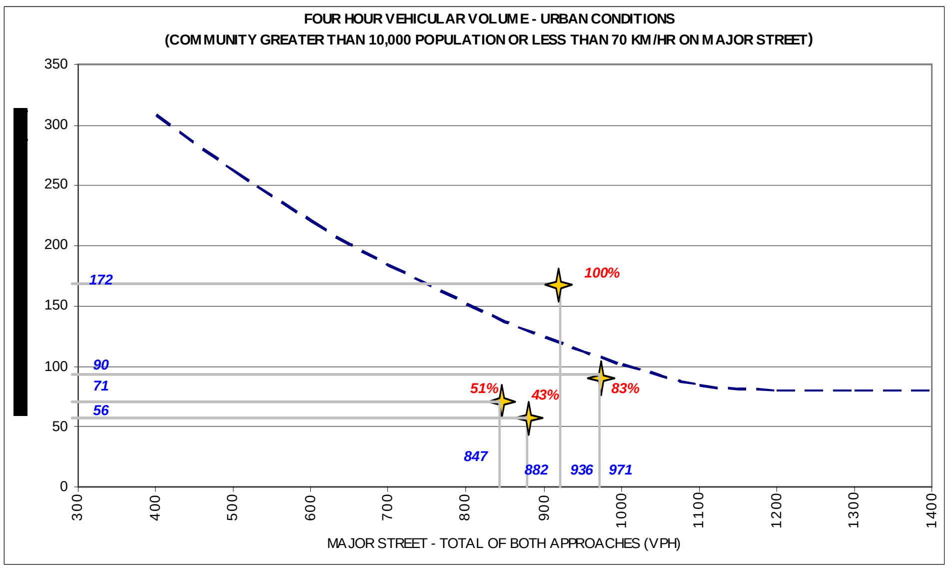
Justification 3: Combination

Combination Justification 1 and 2

Justification Satisfied 80% or More				Two Justifications Satisfied 80% or More	
Justification 1	Minimun Vehicular Volume	YES ☐	NO ☑	YES ☐	NO ☑
Justification 2	Delay Cross Traffic	YES ☐	NO ☑		NOT JUSTIFIED

Justification 4: Four Hour Volume

Justification	Time Period	Total Volume of Both Approaches (Main) X	Heaviest Minor Approach Y (actual)	Required Value Y (warrant threshold)	Average % Compliance	Overall % Compliance
Justification 4	10:00	971	90	108	83	70
	10:30	936	172	116	100	
	7:30	847	71	138	51	
	9:30	882	56	129	43	



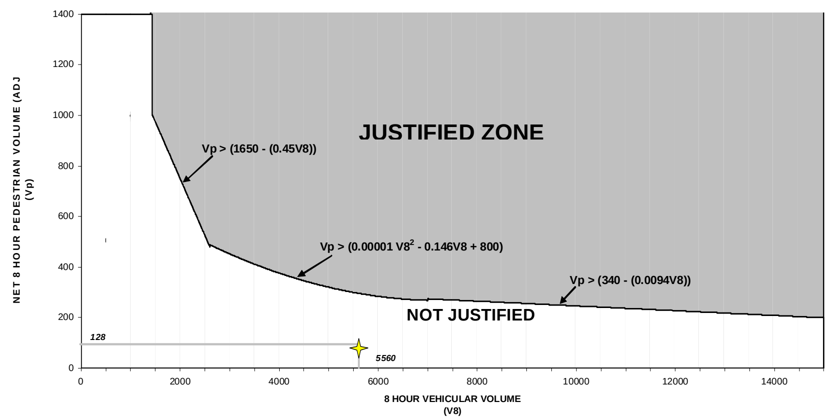
Justification 5: Collision Experience

Justification	Preceding Months	% Fulfillment	Overall % Compliance
Justification 5	1-12	80%	73%
	13-24	60%	
	25-36	80%	

Justification 6: Pedestrian Volume

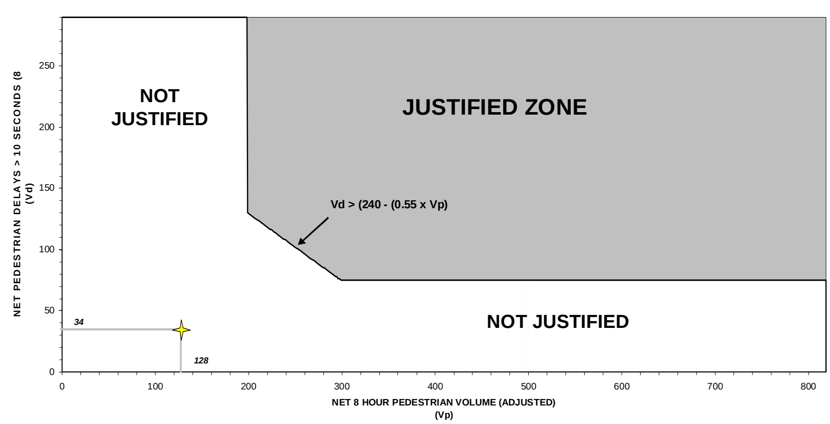
Pedestrian Volume Analysis

	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 Sheet

Summary Results

Justification			Compliance	Signal Justified? YES	Signal Justified? 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		

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.

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 people should be acquired for intersections with challenging configurations. Also, each road authority may have its own specific design requirements. Designers should refer to the authority's 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 Ministry and municipal traffic control systems
- Suggest standard practice details for use by municipalities not having standards
- Comment on some non-standard practices, conditional on the nature of the intersection and the 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, provides acceptable levels of service and delay to motorists, meets recognized standards and is practical in the following areas:

- Free of utility interference
- Meets signal head visibility requirements
- Compatible with the roadway, pavement structure and roadside works
- Uses standardized equipment
- Is readily expandable to additional phases or movements

It is acknowledged that there are sometimes limitations imposed by boulevard conditions, sidewalk locations and underground and overhead utilities that may make it unfeasible to abide by all the practices and guidelines given. In such cases, some compromise is normally necessary and sound engineering judgement must be used to arrive at designs that follow the practices and guidelines as closely as practical.

5.3 Safety Considerations

The detailed design of traffic signals should include the following safety factors:

- Adequate pole offsets from the edge of the through lanes of pavement as 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 curb is suggested in urban areas of 50 km/h or less with 0.6 m being the absolute minimum for use at posted speeds of 40 or 50 km/h.
- The use of pole types that meet the requirements of the safety clear zones as given in the Ministry's Roadside Safety Manual[22] and in municipal policy manuals.

- Adequate vertical clearance to traffic signal heads and overhead wiring such that they are electrically safe and free from vehicle 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 detailed requirements for the above may be found in the Ministry's Electrical Engineering Manual[2,3] series, municipal practice manuals and in other referenced documents.

Many other aspects of signal design, such as phasing, signal head visibility, and synchronization, affect safety with respect to accident risk. These factors are discussed in the relevant sections.

5.4 Future Considerations

The prediction of future traffic volumes within a 10 year period is based on an anticipated traffic demand. A traffic control signal Needs Report or Justification Report should be prepared that addresses not only current traffic volume and intersection capacity analysis, turning needs 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 incorporate any features required in the future into the current design.

Overbuilding of the traffic signals may be a waste of money if many features will require future reconstruction. 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, 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 will be required within five years, then the recommended practice is to construct underground provisions, in the form of ducts and electrical chambers within the current intersection upgrade. Pole footings should only be constructed where traffic at the intersection will meet the signal justification thresholds within two years.

5.5 Signal Visibility

General

Signal visibility is critical in ensuring 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.

The visibility of signal indications outside of geometric considerations 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 the lenses to appear illuminated through reflections of the sun
- The type of optical system (standard, optically programmed, LED, fibre optic)
- The size of the lenses for traffic signal control

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 due to buildings, signs, etc., adjacent to the right-of-way
- Colours of the signal heads and backboards in contrast with the colour of their background
- 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 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.
- At least one, and preferably both signal heads should be located within the motorists' 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 either side of the center line of the eye position (a cone of 10°), and adequate lateral vision up to 20° on either side. Therefore, it is desirable that the primary signal head be located within the 10° cone of vision with the secondary head located within the 40° cone of vision. Figure 31 shows this application of the horizontal cone of vision.

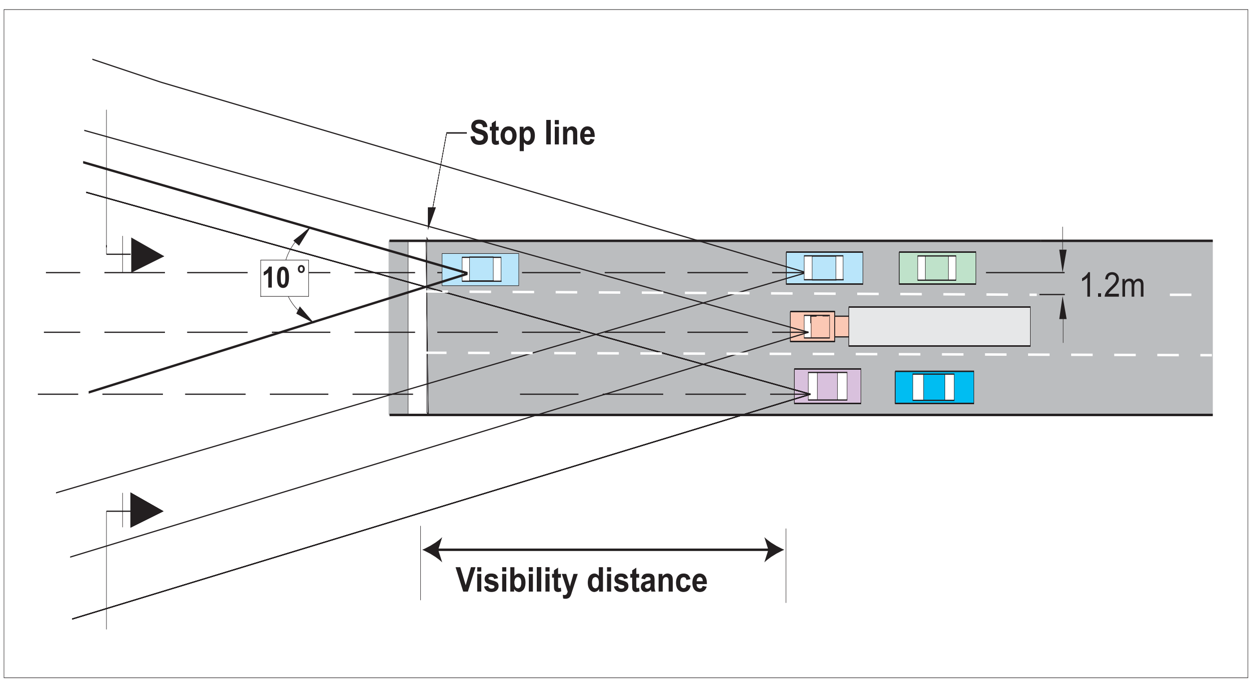


Figure 31 – Cones of Vision for Signal Visibility

The cone of vision originates at the stop line and is centred on the approach lanes, excluding any parking lane(s). Separate turn lanes should be included unless they have their own signal head. 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 22, the use of an auxiliary signal head and possibly a continuous or activated flasher / "signals ahead" sign is usually required.

Two sizes of lenses are used for traffic signal control displays: 200mm or 300mm nominal diameter. Where the speed limit is 80 km/h or greater, a 300mm lens must be used for the red ball indication. Consideration should be given to using a 300mm lens for all indications.

The 300mm lens is also recommended for the following uses:

- All arrow indications
- For signal heads located more than 30m from the stop line
- All intersection approaches where drivers may be confused when both traffic control and lane control signals are viewed simultaneously
- For 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 at 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 centered on the approach.

The secondary signal head must be located on the left of approaching through lanes. They may be placed on the median or, where there is no median, on the far left side of the intersection at least at the 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 heads (far left side) should be located at or as close to the edge of the roadway as practical. There should be a minimum of 5.0 m separation between the primary and secondary heads (see Section 5.6).

Table 22 – 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**

Median Mounted Signal Heads

Signal heads mounted on median poles may be mounted either on the front of the pole 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. Secondary heads for roadways posted at 80 km/h or more are preferred to be at the same height as the primary head for long range visibility. 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.

Obstruction by Other Signal Heads

If positioned incorrectly, the secondary signal head could possibly act as a sight line obstruction, as shown in Figure 32. The design must be checked to ensure that the near side secondary head is not blocking the front of the far side primary head and that at least one signal head is visible to the motorist at all times for at least the minimum distance given in Table 22. A field check of these requirements is required during installation.

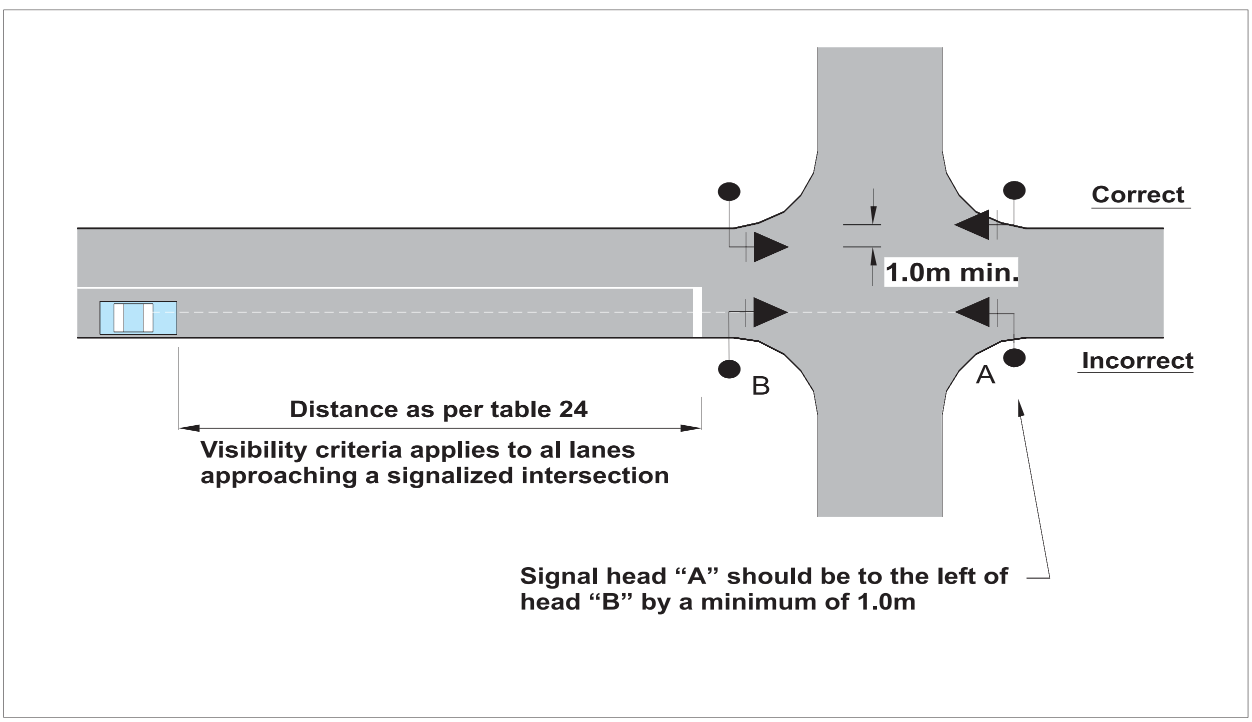


Figure 32 – Secondary Head Blocking Visibility

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 heads. Table 23 provides typical uses for signal heads and backboards.

Backboard faces must be traffic yellow in colour under most conditions. Specific conditions may exist where current policies dictate or the visibility and conspicuity of the backboard faces may be enhanced by use of a dark colour such as dark green or black.

Standard traffic yellow is used in most situations, but municipalities may prefer to apply black or grey colours to the rear surfaces 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.

Auxiliary Signal Heads and Beacons

General

Signal heads may be obstructed by bridges (where close to an intersection), by horizontal roadway curvature, by vertical roadway curvature, by other signal heads, by signs, by buildings infringing on a zone of restricted right-of-way, by large vehicles due to poor signal spacing, or other possible obstructions.

Table 23 – 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	Yes	2.75*
			Standard	Optional	
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	Yes	2.75*
			Standard	Optional	

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 of Table 24 cannot be obtained. The location of the auxiliary heads themselves must comply with the visibility distance of Table 24 or the "signals ahead" flasher signs must be used.

The designer must check each design carefully, recognize sight line limitations, and eliminate obstructions or 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 provided in Figure 33.

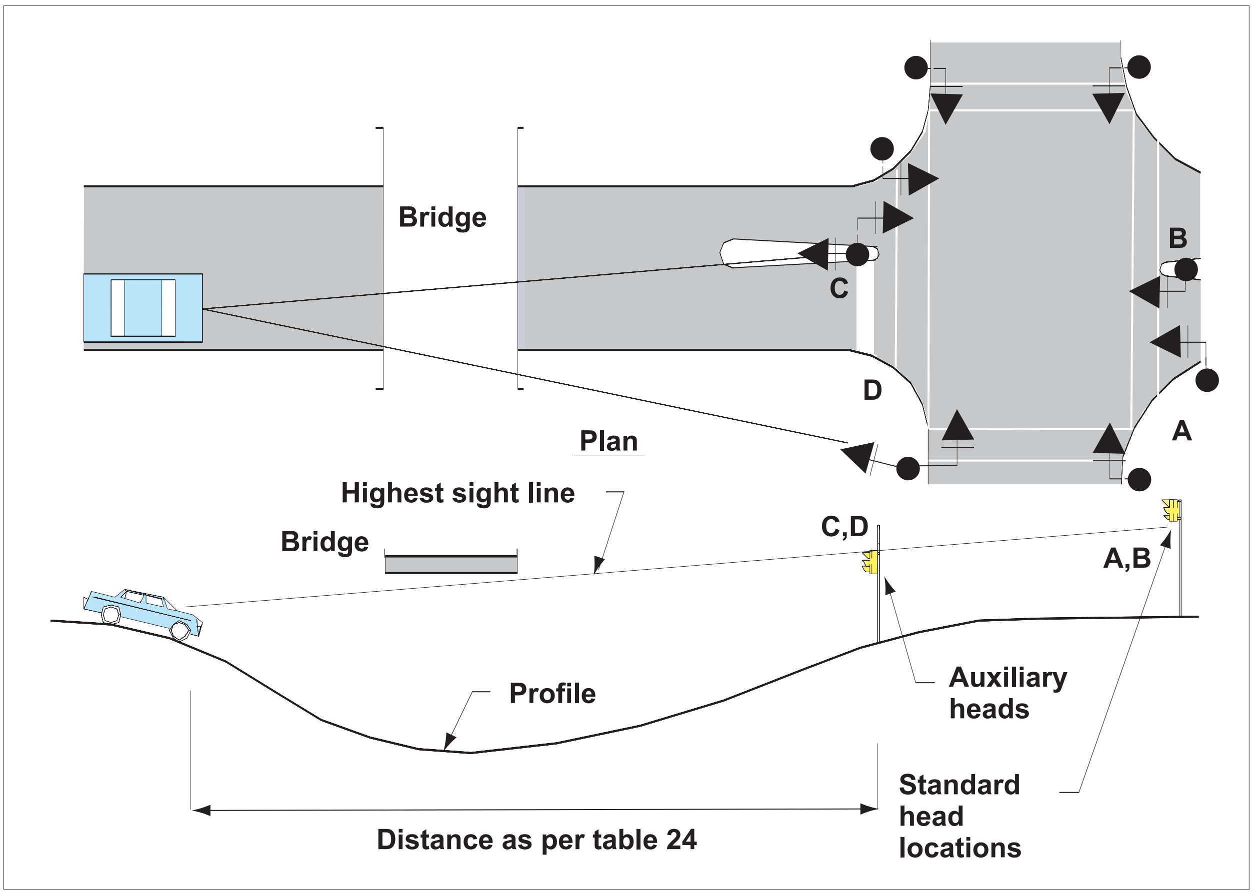


Figure 33 – Auxiliary Heads at Underpass

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 the rear of the median pole, as shown on Figure 34.

Two auxiliary heads on the outside of a curve should be avoided since the driver may align their vehicles towards the gap between them (mistaking these heads for the primary and secondary traffic signal heads 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 "Signals Ahead" sign (Wb-1102A) may be required, as shown in Figure 35.

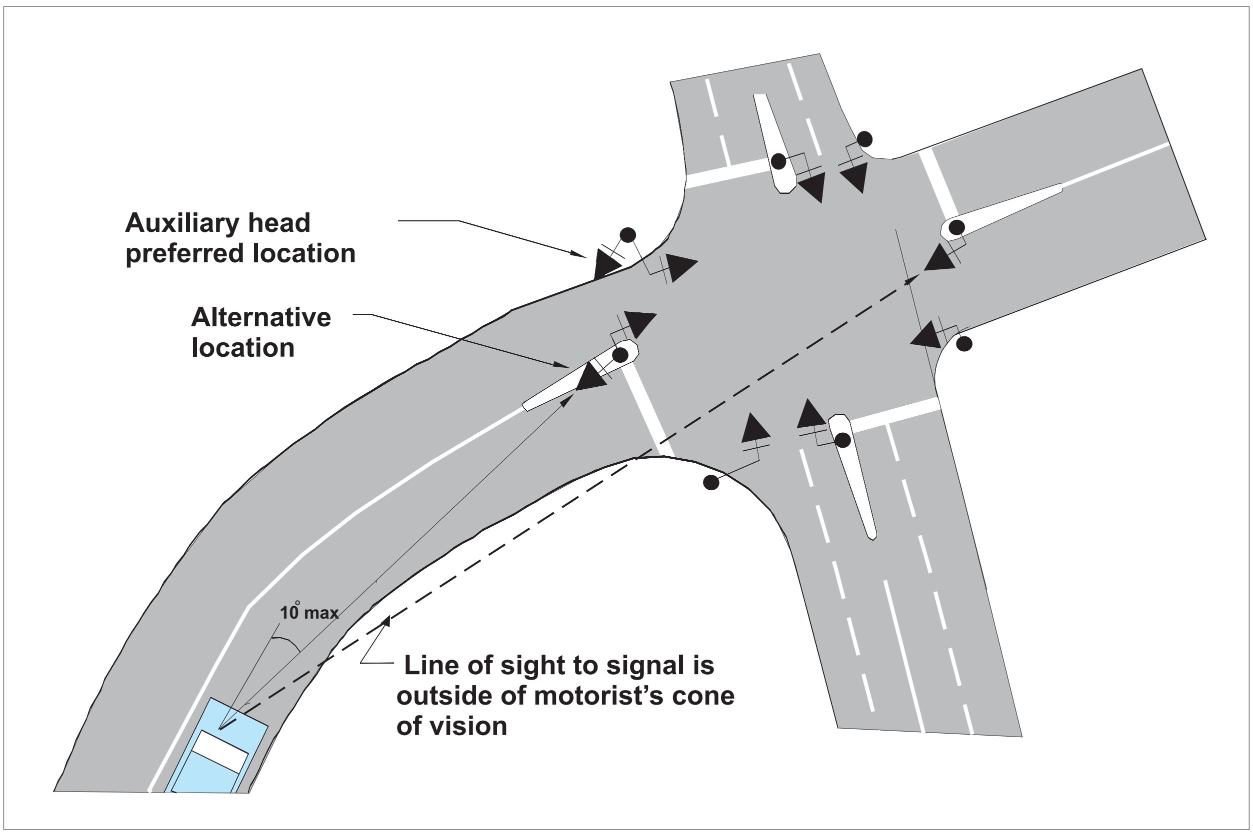


Figure 34 – Auxillary Heads at Intersection on Curve

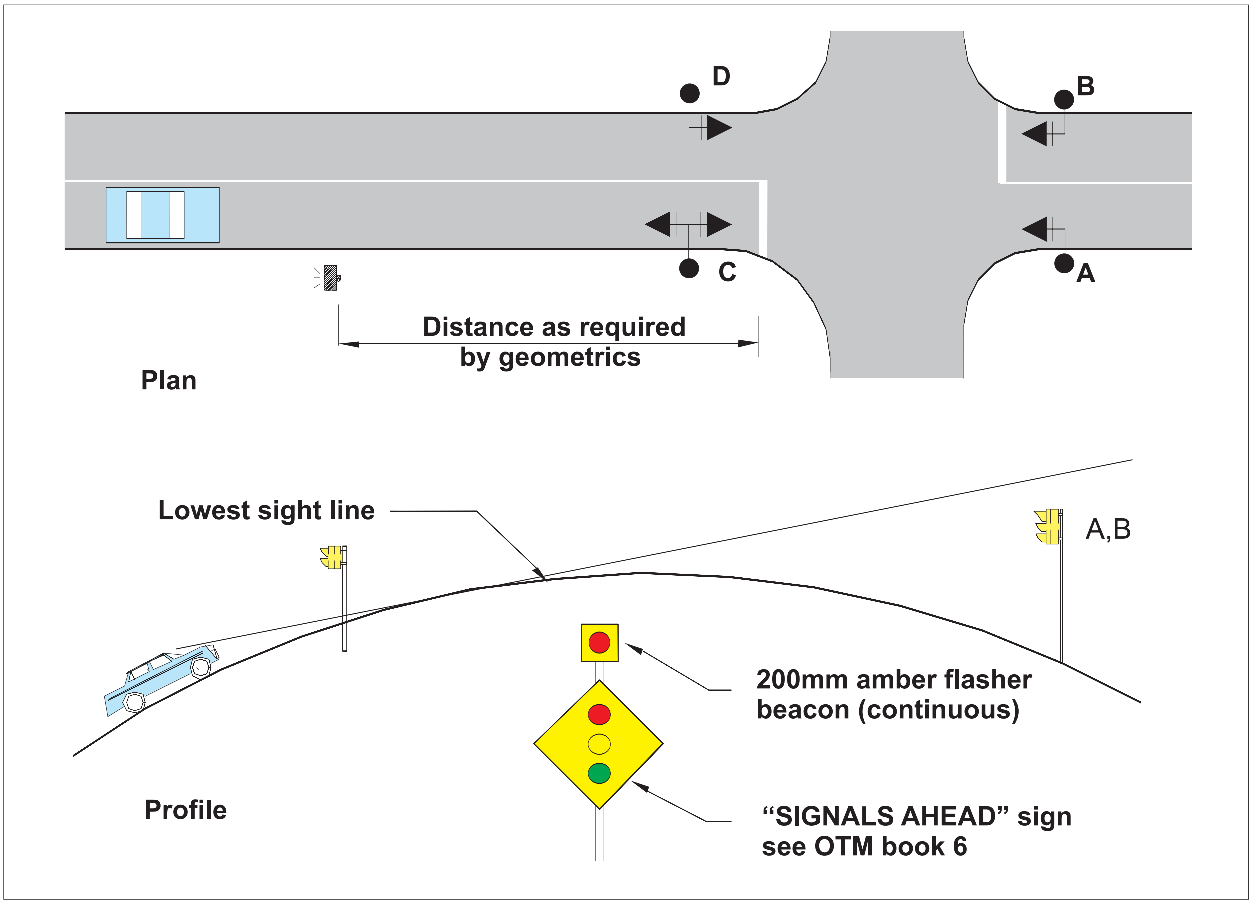


Figure 35 – Use of Continuous Flasher

The sign can be located upstream from the signalized intersection beyond the visibility distance shown in Table 22 and in general conformance with signage guidelines of OTM Book 6 – Warning Signs.

An active double flashing beacon ("bouncing ball" effect) with the oversized "Signals Ahead" sign (Wb-1102A) complete with the word tab "PREPARE TO STOP WHEN FLASHING" (Wb-102At) may be required in the following circumstances:

- Poor visibility and where location of an auxiliary head does not suit the installation
- Sight restrictions at the bottom of a hill or steep downgrade
- Signal is the first one encountered by drivers after traveling a substantial distance on a divided highway where a signal may not be expected

An example of this situation is shown in Figure 36. Note that the flashing beacon and sign should operate as described in Section 3.

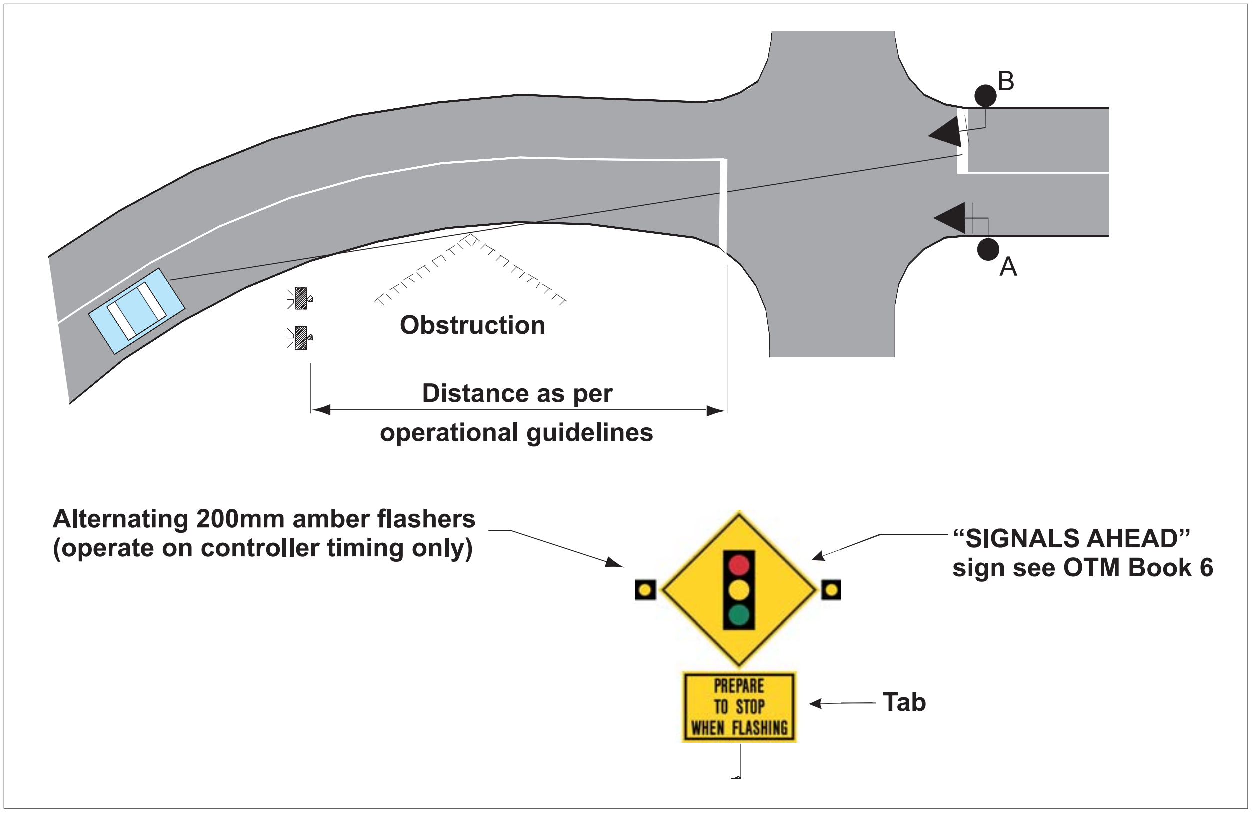


Figure 36 – Use of Active Flasher and Sign

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 minimum spacing of 5.0 m between primary and secondary heads is intended to mitigate this effect 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.

LED Signal Heads

The Institute of Transportation Engineers (ITE) has published specifications to provide the minimum performance requirements for light emitting diode (LED) 200mm and 300mm traffic signals.

Below is a summary of physical, mechanical and photometric requirements for round ball indications:

Physical & Mechanical Requirements

- Modules must fit into existing traffic signal housing built to the VTCSH Std.
- The modules must connect directly to existing electrical wiring system
- Module must replace the existing optical components

- Module lens must be hard coated or comply to SAE-J576
- Tinting is optional
- The module lens may be a replaceable part
- Environmental:
  - Module must be rated for service for a period of min of 60 months in a south facing Arizona desert installation
  - Module must operate in ambient temperature of -40° to 74° C
  - Module must be protected against dust and moisture intrusion
  - Module must not crack, craze or yellow due to UV irradiation
- Material:
  - Material used for lens and module construction must conform to ASTM spec.
  - Enclosure containing the electrical components must be made of UL94 flame retardant material

Photometric requirements

- The new extended view, which covers ranges from 12.5° above to 22.5° below horizontal plan and from 27.5° left to 27.5° right of vertical plan at 2.5° interval.
- Luminous intensity: Intensity must not exceed three times the required peak value.
- Luminous uniformity: Uniformity across the entire module must not exceed 10 to 1.

Electrical

- Input wire, two color coded, 600V, jacketed wires, minimum 20 AWG, 39 inches long.
- Input voltage range 80 – 135 Vac.
- Fluctuation over input range: ±10%.
- Low Voltage Turn OFF: There must be no visible illumination for input voltage less than 35 Vac.
- Turn ON and Turn OFF Time: Light output must reach 90% of full illumination within 75 mS, module must turn off within 75 ms.
- Transient Voltage protection: As per section 2.1.8, NEMA Std TS2-2003.
- Electronic noise: FCC, Title 47, Subpart B, Section 15.
- Power factor and AC Harmonics: PFC=0.9 min, THD=20% max.
- Off States Voltage decay: Input voltage must decay to 10 Vac RMS in less than 100 ms.
- Failed State Impedance: Module must detect catastrophic loss of LED load. Upon sensing the loss of LED load, the module must present an input impedance of 250 KΩ min.

Table 24 provides the minimum maintained luminous intensity values for the VTCSH LED Circular Signal, for the range from 12.5° above to 22.5° below the horizontal plane, and from 27.5° left to 27.5° right of the vertical plane, in 5° increments.

All LED signal locations should be checked on a yearly basis through a preventative maintenance program in order to verify proper operation and display intensity.

Optically Programmable Signal Heads

Optically Programmable Signal indications can be used as a means for precise lane control by projecting 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. Optically programmable signal heads may be used at skewed intersections with

Table 24 – Minimum Maintained Luminous Intensity Values for VTCSH LED Circular Signal

Vertical Angle	Horizontal Angle	200mm						300mm					
		ITE 2005			ITE 1998			ITE 2005			ITE 1998		
		Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green
	2.5	17	41	22				37	91	48			
12.5	7.5	13	33	17				29	73	38			
	2.5	31	78	41				69	173	90			
	7.5	25	62	32				55	137	71			
7.5	12.5	18	45	24				40	100	52			
	2.5	68	168	88				150	373	195			
	7.5	56	139	73				124	309	162			
	12.5	38	94	49				84	209	109			
	17.5	21	53	28				47	118	62			
2.5	22.5	12	29	15				26	64	33			
	2.5	162	402	211	133	617	267	358	892	466	339	1571	678
	7.5	132	328	172	97	449	194	292	728	380	251	1159	501
	12.5	91	226	118	57	262	113	201	501	261	141	655	283
	17.5	53	131	69	25	112	48	117	291	152	77	355	154
	22.5	28	70	37				62	155	81			
-2.5	27.5	15	37	19				33	82	43			
	2.5	127	316	166	101	468	202	281	701	366	226	1047	452
	7.5	106	262	138	89	411	178	234	582	304	202	935	404
	12.5	71	176	92	65	299	129	157	391	204	145	673	291
	17.5	41	103	54	41	187	81	91	228	119	89	411	178
	22.5	21	53	28	18	84	37	47	118	62	38	178	77
-7.5	27.5	12	29	15	10	47	20	26	64	33	16	75	32
	2.5	50	123	65	37	168	73	110	273	143	50	234	101
	7.5	40	98	52	32	150	65	88	218	114	48	224	97
	12.5	28	70	37	28	131	57	62	155	81	44	206	89
	17.5	17	41	22	20	94	41	37	91	48	34	159	69
	22.5	8	21	11	12	56	25	18	46	24	22	103	44
-12.5	27.5	5	12	6	9	37	16	11	27	14	16	75	32
	2.5	23	57	30	16	75	32	51	127	67	22	103	44
	7.5	18	45	24	14	65	28	40	100	52	22	103	44
	12.5	13	33	17	10	47	20	29	73	38	22	103	44
	17.5	7	16	9	9	37	16	15	36	19	22	103	44
	22.5	3	8	4	6	28	12	7	18	10	20	94	41
-17.5	27.5	N/A	N/A	N/A	4	19	9				16	75	32
	2.5	17	41	22				37	91	48			
	7.5	13	33	17				29	73	38			
	12.5	10	25	13				22	55	29			
-22.5	17.5	5	12	6				11	27	14			
	2.5	12	29	15				26	64	33			
-27.5	7.5	8	21	11				18	46	24			

non-standard turning lanes, as indicated in Figure 37, to avoid confusion to 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 38.

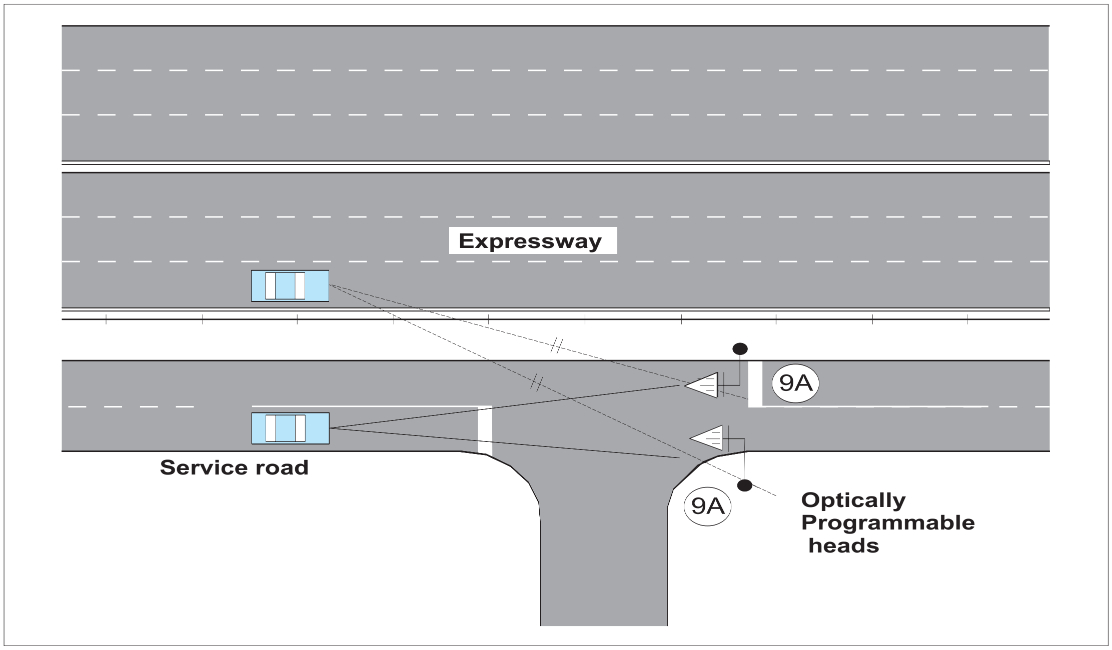


Figure 37 – Optically Programmable Heads, Example in Wide Median

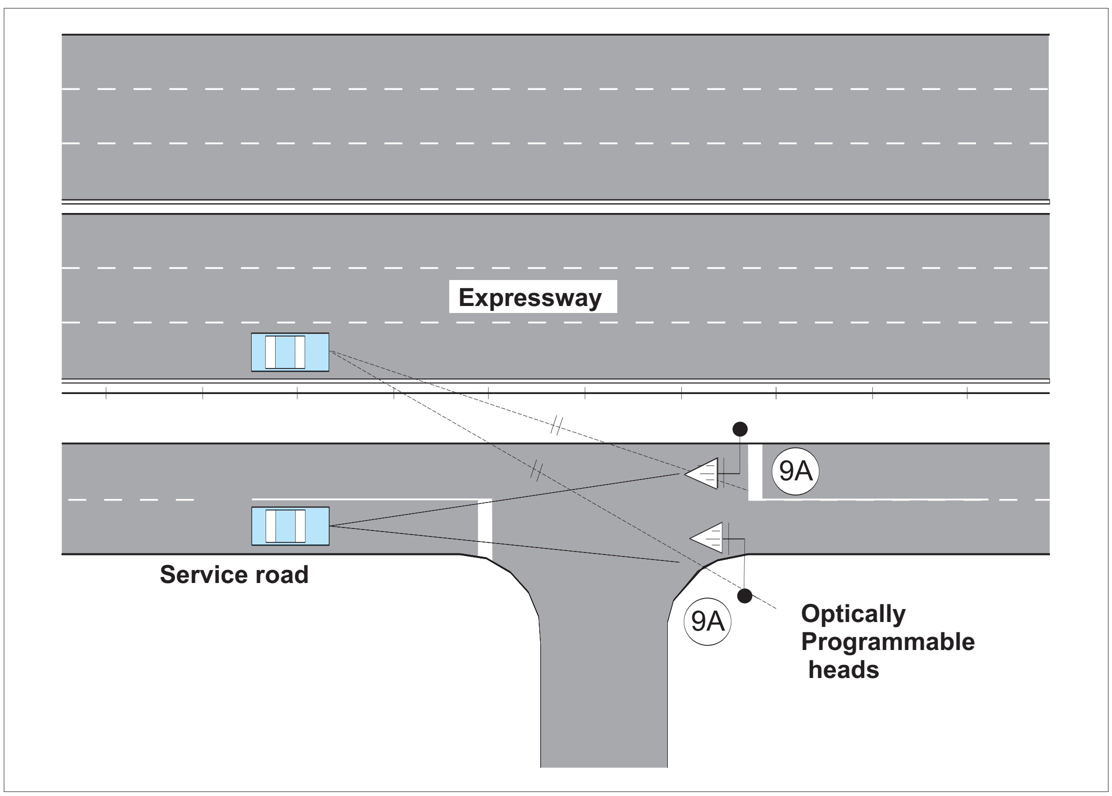


Figure 38 – Optically Programmable Heads, Example on Parallel Roads

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.

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. This guideline is shown in Figure 39.

The 15 m distance corresponds to the cut-off for visibility through a normal windshield to a signal head mounted at a 5.0 m height.

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 39.
- 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

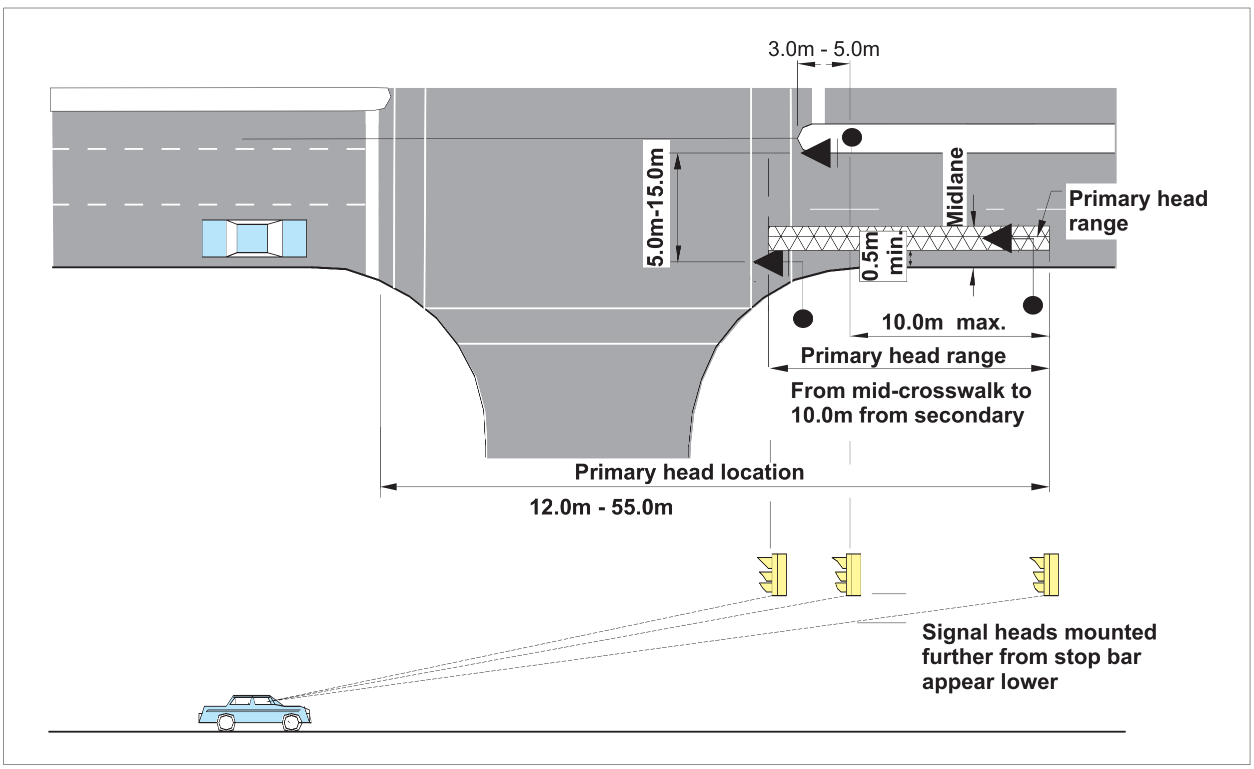


Figure 39 – Primary and Secondary Head Locations

while taking aesthetic requirements, utility clearances and mast arm length restrictions into account. 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 or 0.6 m absolute minimum in curbed areas with operating speeds of 40 or 50 km/h. Refer to Subsection 5.3 for safety guidelines.

With Median Islands

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 31 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 and an absolute maximum of 22 m. The smaller spacing allows for visibility blockage of one of the heads by larger vehicles while 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 Islands

Where median islands are not used, it is desirable to position the primary signal head between the 1/4 point and 3/4 point of the projected through edge of the approach curb lane with the head aimed on the center of the approach (as shown in Figure 40). The preferred position of the secondary head is over the edge of pavement on the left side. During the design, the location of primary poles and heads are normally placed prior to the secondary poles.

Secondary Signal Head and Pole Locations

General

Secondary heads, other than those in 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 (22 m absolute maximum distance). Since the secondary heads are normally located in the flare using 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 Islands

Where median islands are present (with two or more receiving lanes), primary and secondary signal heads should not be too close together laterally nor too far apart longitudinally such that one head appears to be much higher than the other from the approaching motorist's perspective. Figure 39 shows the range of the primary head when the secondary head location has already been set.

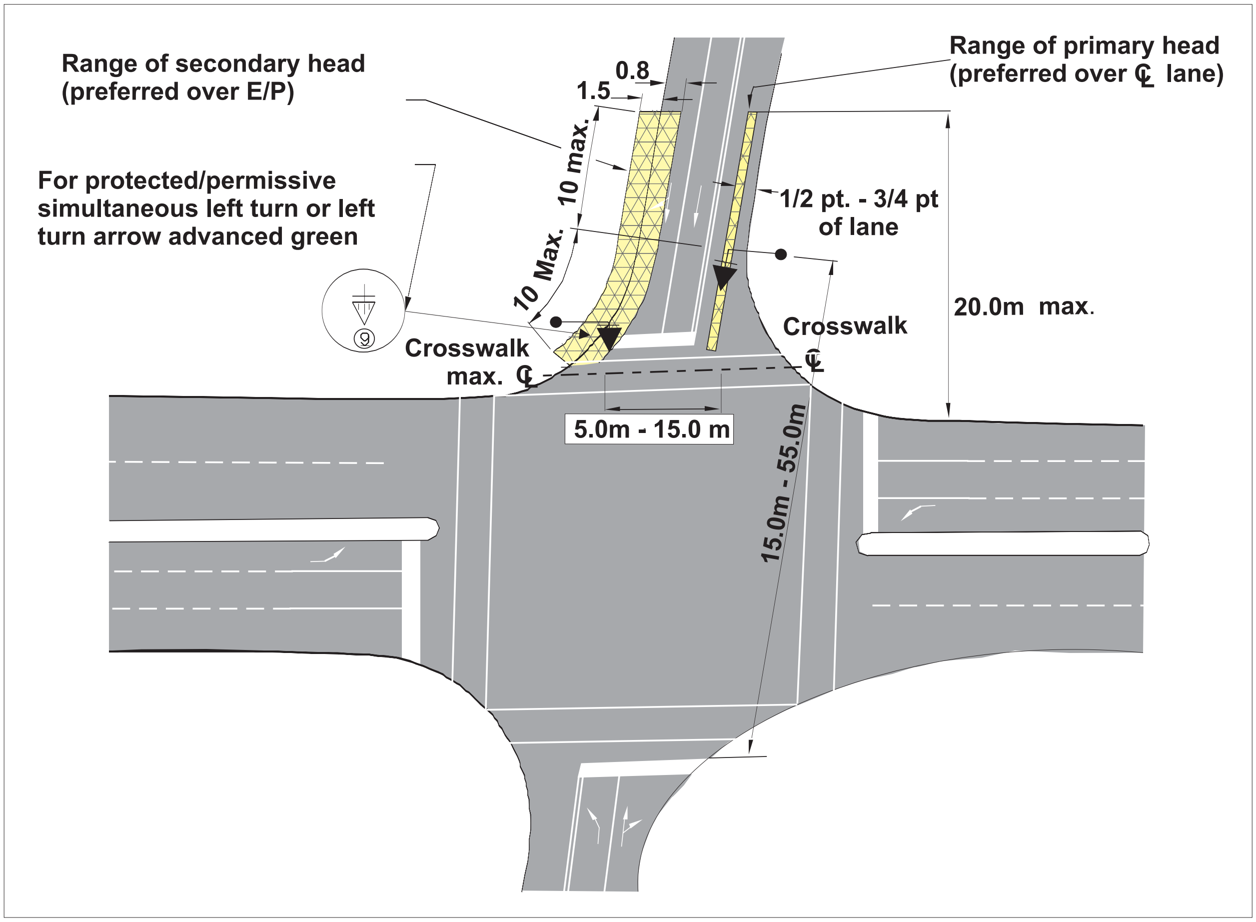


Figure 40 – Primary and Secondary Heads Without Islands

Without Median Islands

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 32. 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.

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. Note that the Ontario and Canadian standards are different from that of ITE Publication ST-217.

The symbols may be contained in a single minimum 30 x 30 cm (lens) housing or have separate housings, with the Hand Outline section mounted directly above or to the left of the Walking Pedestrian section, or in the case of a single lens, the symbols may be superimposed over each other or offset with the hand outline on the left.

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 a warning to pedestrians that the walking time is terminating.

Guidelines for Pedestrian Signal Head Installation

It is recommended practice to install pedestrian traffic control signals in most cases. Pedestrian traffic control signals are mandatory where it is necessary to control the sequence or length of pedestrian phases independent of 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 must be able to walk to any corner of an intersection. An exception to this 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. This may also apply to any intersection where it is desirable to ban particular pedestrian movements due to large left-turn volumes. Such restrictions must be supported by proper signing as shown elsewhere in the OTM.

Pedestrian signal heads should be installed in conjunction with vehicular traffic control signals under 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, 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 is less than the minimum crossing time for pedestrians and pedestrian actuation is necessary (normally by pushbutton)
- When 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, such as at "T" intersections, one-way streets or at large intersections

Guidelines for Pedestrian Pushbuttons

Pedestrian pushbuttons are required at pedestrian actuated traffic signals. Pedestrian pushbuttons should be located with the following guidelines:

- The pushbuttons should be installed on the "through sidewalk" side of the pole at a minimum height of 1.1 m.
- The pushbuttons should be in line with the crosswalk and not perpendicular to the crosswalk; location should be within 3.0 m of the edge of the crosswalk.
- It is desirable that a "push button for walk signal" or equivalent sign be installed at each pushbutton.

Mounting Height and Location

Pedestrian heads must be mounted at a minimum of 2.5 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 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 Signal

Audible or Accessible Pedestrian Signals (APS) are designed to assist visually impaired pedestrians by providing information that they can interpret to understand when they may cross. APS devices communicate information about pedestrian timing in non-visual format such as 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 sound such as a bell, buzz, tone or birdcall (typically cuckoo and chirp) during the WALK interval.

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.

A third type of APS is fully integrated into the pedestrian push button assembly. Some provide vibratory information only; others augment vibrotactile hardware with a quiet, slowly repeating, tick, click, or tone to identify the location of the push button 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.

Locations that may need APS include those with:

- Intersections with vehicular and/or pedestrian actuation
- Very wide crossings
- Major streets at intersections with minor streets having very little traffic (APS may be needed for crossing the major street)
- T- shaped intersections
- Non-rectangular or skewed crossings
- High volumes of turning vehicles
- Split phase signal timing

- Exclusive pedestrian phasing, especially where right-turn-on-red is permitted
- A leading pedestrian interval

Accessible indications are not covered by the HTA. Basic standards and pushbutton operation options are provided in the TAC MUTCDC 12. As of the date of this publication, the existing audible signal standard in the TAC MUTCDC is under review and will be updated with a more comprehensive accessible signal standard in the future. For more information, see http://www.tac-atc.ca/english/projectsandpublications/pro-progress.cfm#accessiblelink.

Pedestrian Countdown Displays

The Pedestrian Countdown Display may be added to a pedestrian signal head to show a descending numerical countdown that indicates to pedestrians the number of remaining seconds available for crossing.

The Traffic Operations & Management Standing Committee (TOMSC) of TAC investigated the feasibility of adopting guidelines for the "Optional Use of Pedestrian Countdown Displays" into the Manual on Uniform Traffic Control Devices of Canada and recommends:

- PCS be adopted as an optional device for installation at locations where pedestrian signal heads are installed.
- The "Separate Countdown Housing" configuration be used as the standard configuration. The "Overlap/Countdown Side by Side" configuration and the "Separate Countdown Housing with no Overlap" configuration may also be used in retrofit situations.
- 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.

The proposed guidelines allow for the optional use of Pedestrian Countdown Displays at the discretion of signal operating agencies. More information can be obtained at http://www.tac-atc.ca.

Recommended TAC 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 provide a certain amount of "fail-safe".
- 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 (305 mm lens height).
- Pedestrian Countdown Display must 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 that of the conventional pedestrian signal and must comply with Section B1.5.4, Section B3.4 and Figure B3-9 of the Manual of Uniform Traffic Control Devices of Canada.

5.8 Miscellaneous Traffic Control

Intersection Pedestrian Signals

Intersection Pedestrian Signals (IPS) may be installed at intersections that are characterized by very light traffic on the side road but have considerable pedestrian volumes. IPS require that a normal crosswalk be pavement 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 41.

Typical three-section signal heads are used for the main road and 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 the example, or independently.

One example of an IPS orientation is shown in Figure 41. It is 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 may be found in the TAC MUTCD.

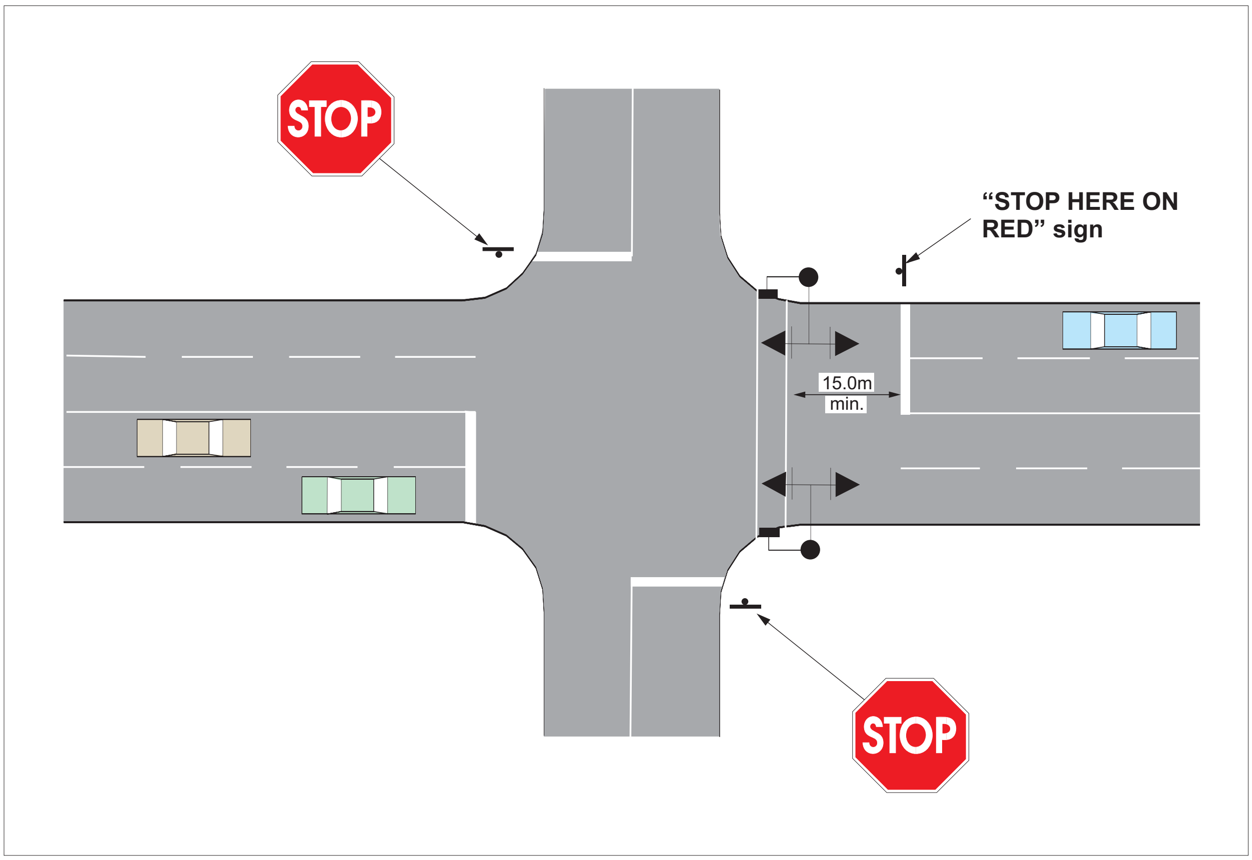


Figure 41 – Intersection Pedestrian Signals

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. All pavement marking features are similar to normal signalized intersections with the vehicle stop lines set back a minimum of 12 m from crosswalk edges (15 m recommended practice). At mid-block locations, conspicuity of the pedestrian signals for drivers is paramount. The usual cue of the presence of a cross-road, which leads the driver 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.

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 very heavy afternoon PHV in the other direction.

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 crossing the roadway 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 so as 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 (downwards), as shown in Figure 15. 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 at a minimum of the limits of 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.

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 actually 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 MUTCD.

Where the railway crossings are in such close proximity 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 pre-emption of the vehicle signals. Pre-emptive signals may also be used to activate other devices (such as blank-out signs for turn prohibitions) during train crossings.

Where the railway crossings are within 150 m of the proposed signal installations, an evaluation of probable back-ups from the signal systems must be carried out by the road authority and submitted to the appropriate railway owner for approval, coordination and costing. This evaluation must estimate the times of day and probable duration of any back-ups likely to obstruct the crossings.

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 signal indications (TPSI) may be used to assign right-of-way to public transit vehicles over all other vehicular and pedestrian traffic movements within an intersection. Transit priority signals may be operated exclusively during protected transit movements or concurrently with other non-conflicting vehicular movements.

Transit priority signal indications are specified in HTA Regulation 626 (2), and are mounted directly above the red indications as shown. TPSIs consists of "lunar white" vertical bars on opaque backgrounds. They may have 20 or 30 mm lenses and be mounted on any type of signal heads. TPSIs are generally used at intersections where there are dedicated transit lanes or where their use would improve the efficiency of the transit routes.

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.

Consideration of 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 normally has to 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 provides storage to park 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 time period while a portable traffic control signal is a temporary traffic control signal that is designed so that it can be transported and reused at different locations. There are currently four different electrical/electronic traffic control devices that can be used to control traffic under temporary conditions. The devices and the restrictions on their use are identified as follows:

Remote Control Device

The Remote Control Device is not identified in the HTA, only OTM Book 7 as an electro-mechanical device that is remotely controlled and performs the function of a traffic control person in a two-way, one lane traffic operation. It is considered a supplement to or replacement for a traffic control person and is not a Traffic Signal or a Portable Lane Control Signal.

The remote control device does not use a traditional traffic signal head with a red, amber and green lens but rather uses only a red and an amber lens in conjunction with control arm to control traffic. Communications between the signals at each end must be provided in order to prevent conflicting displays. Legal approval for installation is not required as it is not covered under the HTA; however approval of the road authority is required.

The remote control device may only be used to control one lane two way operations during construction activities that are considered under OTM Book 7 as **"Very Short Duration Work (VSD)"** or **"Short Duration Work (SD)"** during hours of daylight. Very Short Duration work is defined as work that occupies a fixed location for up to 30 minutes including set up and take down time. Short duration work occupies a fixed location for more than 30 minutes but less than a 24 hour period. Should the contractor leave the site, this 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 Lane Control Signal (PLCS)

Portable Lane Control Signal systems consist of single "standard" vehicle traffic signal heads, normally mounted on movable poles at a minimum height of 2.75 m from the roadway surface to the bottom of the heads. Use of portable signals is an alternative to continuous flagging by flag persons, and is not to be confused with temporary traffic signals.

These signals may only be used to control one lane, two way traffic flow during construction activities and only for durations that are considered under OTM Book 7 as "Very Short Duration Work" (occupies a fixed location for up to 30 minutes including set up and take down time) or "Short Duration Work" (occupies a fixed location for more than 30 minutes but less than 24 hour period in duration). 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 flag-persons working in conjunction with the equipment. This equipment must be removed and two way flow of traffic resumed when the contractor leaves the site.

Portable Lane Control Signals must be installed in accordance with the requirements of Regulation 606 of the HTA, which covers the physical and signage requirements for these devices. Driver action is prescribed by HTA Section 146. **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.

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 and where full illumination exists if the closure continues at night. PLCS may not be used at an intersection or pedestrian crossover. It is recommended 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.

Portable Temporary Traffic Signals

Portable Temporary Traffic Signals consist of typical traffic signal heads mounted on movable trailers at a minimum height of 2.75 m from the roadway surface to the bottom of the heads. The trailers are typically positioned at intersections to emulate traffic control signals. **Approval of the road authority responsible for the roadway must be obtained prior to use**.

These signals may be used to control one lane, two way traffic flow during construction activities that are considered under OTM Book 7 as **"Very Short Duration Work"** or **"Short Duration Work"** during hours of daylight. If these devices are to be used during night-time activities, proper illumination must be provided. This equipment must be removed and two way flow of traffic resumed when the contractor leaves the site.

Portable Temporary Traffic Signals must be installed in accordance with the requirements of Regulation 606 of the HTA, which covers the physical and signage requirements. Driver action is prescribed by HTA Section 146. A legal approval drawing is not required for Portable Temporary Traffic Signals.

Portable Temporary Traffic Signals may also be used to control one lane two way operations during construction activities that are considered under OTM Book 7 as "**Long Duration"** work and 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 show that it is more cost effective to use solar powered portable temporary traffic signals as opposed to regular temporary traffic signals (note in most cases full temporary traffic signals on span wire are more cost effective after four months of use). If time of day functions are required due to known variances in traffic patterns (i.e., different max green due to long weekend traffic patterns), a conventional temporary traffic signal is required. Portable Temporary Traffic Signals may not be used if a side street or access point is within the one lane section (temporary signals with multiple phasing must then be used). Legal approval is required prior to use.

The following are the material and operational requirements for 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
  - Sight distance requirements as per Table 24
  - Cone of vision from the stop bar and from the stopping site distance
- Each trailer must be capable of operating as a master or slave unit and must be interconnected to each other by either hardwire, licensed radio or spread spectrum radio communications.
- Trailer units must be solar powered with battery backup capable of sustaining full operation for at least 14 days without recharging.

- Trailer units must be capable of being operated by generator as a backup power source.

Operational Requirements

- The system must provide conflict monitoring in the following way:
  - Master and slave controller watchdog of the controller software
  - Master and slave absence of indication (burnt out lamp)
  - Master and slave conflicting display on the same signal head or heads
  - Master and slave 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 have a cellular or satellite paging system to alert the contractor to the fact it has entered fault mode.
- 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.
- 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. User must be able to select this mode through software input on a construction site.
- The user must be able to manually enter a minimum green time, a maximum green time and an extension time for actuated operations.

Portable Temporary Traffic Signals may be used for night-time activities but only with proper illumination, which includes:

- 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 meters 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 and are 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 PTTS are to be used in the winter months they 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 to control traffic during construction activities. Temporary Traffic Signals should be considered for applications that under OTM Book 7 are defined as "**Long Duration"** work, meaning it requires a separate work space for longer than 24 hours. Temporary traffic control signals have a constant power supply, closely resemble a normal signal installation and may be used at an intersection or pedestrian crossover.

Temporary Traffic Signal installations require the approval of the responsible road authority prior to installation. A legal drawing must be prepared prior to installation and turn on as per HTA 144(31). These installations must comply with all regulations pertaining to traffic signals identified in HTA Regulation 626.

Operational and timing requirements for 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

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. Under the vast majority of circumstances, standard vehicle displays are adequate to control bicycle movements through intersections. Bicycle signals should be installed when the standard vehicle displays are not adequate to control bicycle movements.

It is recommended that practitioners refer to the TAC Traffic Signal Guidelines for Bicycles dated July 2004 as a source for the justification, review and installation of bicycle signals (see http://www.tac-atc.ca/private/chiefengineers/pdfs/tac%20finalreport%20%5Fjuly%2023%2C2004a.pdf). These TAC Traffic Signal Guidelines recommend that the national standard for bicycle traffic signals to be adopted by TAC be based on the Quebec standard. The Quebec standard states that bicycle signals be mounted vertically and consist of three 200mm circular lenses containing the outlines of bicycles. Cyclists must treat the bicycle signal in the same manner that motorists treat a traffic signal display.

It is recommended practice that bicycle signal heads be installed within the field of vision of cyclists as a minimum within 30m upstream of the stop bar. It is recommended that bicycle signals be mounted in locations far enough from the roadway so as not to interfere with pedestrians or cyclists, while remaining in the field of vision of the cyclists (see TAC Traffic Signals Guideline for Bicycles at http://www.tac-atc.ca/). In addition, bicycle heads should be placed at the same height as hand/man displays at the intersection. In situations where the bicycle signal heads must be located over the traveled portion of the roadway, the signals should be placed at 4.5 m above the top of the pavement.

It is recommended practice that induction loops be used for detection of bicycles at intersections where vehicles use the same facilities. It is recommended that quadrapole or diagonal quadrapole loop detectors be used.

As of the date of this publication, some of the symbols identified in the TAC guideline are not identified in the HTA. If a road authority chooses to use them, they may need to apply for an exemption for use of the symbols.

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 while 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 that enter the detection zone. The detector remains "on" until the vehicle is no longer in the zone, at which point the output is switched "off".

Outputs from vehicle detectors can be used as inputs to a traffic controller to provide phasing and determine timing, as well as inputs to other equipment to calculate volume (vehicles per hour), average or instantaneous speed (kph), occupancy (percent usage of the roadway), density (vehicles per kilometre) and 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 and must be rigidly affixed to a pole or other structure. Detectors placed over the roadway or side fired have a defined detection zone aimed at a specific point. Detectors are subject to weather impacts, lightning and electrical discharges and vibrations. Intrusive detectors are typically embedded in the ground or road surface. Detectors placed within the roadway surface have detection zones that are defined by the actual placement of the detector element. The success and longevity of these devices depends directly on the condition of the ground / road surface, as well as the quality of the materials used to construct them. Loop assembly failure caused by electrical leakage to the ground and by loss of conductivity can most often be traced to physical damage of the loop assembly either during installation or through pavement movement.

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 by 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" loops). 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.

Other forms of detection devices include pedestrian pushbuttons for detecting the presence of a pedestrian; emergency vehicle detection – detecting a fire truck or ambulance to provide right-of-way at an intersection; bus or transit vehicle detection – detecting a high occupancy vehicle to provide priority at an intersection; and specialized detection devices – devices such as Accessible Pedestrian Signals at an intersection.

There are many brands and types of vehicle detectors to satisfy most applications. The following is a summary of the common types.

Microwave

Microwave detectors are mounted above the ground and project a cone shaped detection area. When a vehicle approaches it reflects some of the microwave energy back to the detector, providing a momentary contact closure (pulse) to indicate that a vehicle has been detected.

Infrared

There are two types of infrared detectors:

- Passive – detects the presence of vehicles by comparing the infrared energy naturally occurring in the detection zone with the change in energy caused by a vehicle; and
- Active – detects the presence of vehicles by emitting a low energy beam at the roadway and measuring the reflected signal's return to the device.

Acoustic

Pulses of ultrasonic sound are directed at the roadway and total travel time of the reflected sound is measure and compared to the previous measurement. A shorter time measurement indicates a vehicle is present.

Acoustic detectors use a microphone array to listen to traffic. The device detects vehicles by comparing the sound to a library of known sounds.

Video

Video detection is accomplished through an image processor. It 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.

Pressure Detectors

Pressure detectors are activated by the weight of a vehicle on a pneumatic tube placed across the roadway or 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 their use is now very limited due to high installation costs and resulting adverse pavement conditions.

Magnetic Detectors

There are four types of magnetic detectors:

- Standard
- Directional (no longer available)
- Magnetometer
- Self powered vehicle detector (SPVD)

The standard magnetic detector cannot sense vehicles moving less that 5 mph; therefore, cannot provide presence detection.

Loop Detectors

Loop detectors consist of an amplifier located in the controller cabinet and coiled wires in the pavement, which create an electro-magnetic field that changes when a vehicle is in the loop area. It is the most widely used type of vehicle detection because of its flexibility of design. Loop detectors can be used to sense vehicle presence, passage, lane occupancy, speed and volume.

The current practice of many authorities is to use loops installed in the pavement together with detector amplifier/sensor units installed in the controller cabinets as detection devices. Other types of detection are available and are continually being developed. For the purposes of this section, detector design will be described using loops, recognizing that if alternate forms of detectors are used, the road authority should ensure that the operational features are similar to loops for the application.

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. This includes parked vehicles, manhole covers, transit stops, service stations or other facilities with busy entrances, etc.

System loops may be square or diamond shaped loops installed in each lane. For a central computer system, loops 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 loops 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 loops 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.

Presence Loop Detectors

Presence loops are used to detect the presence, or continued occupancy, of vehicles, provide calls to the controllers or extend green times for vehicles. They can be installed at or near the stop lines at intersection approaches or as "setback" loops in turning lanes to detect if there are two or more vehicles waiting to turn.

Presence loops may be of rectangular or irregular shapes, they may be lane selective (installed as separate loops in each lane) or all inclusive (installed as one loop across several lanes), and they may be used with a user settable time delay (1 to 15 seconds) feature to allow vehicles to stop, pause and continue without registering a call (as in right-turn lanes).

The recommended placement of presence loops 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 42.

Long Distance Loop Detectors

Long distance detection is used to provide an extra level of safety for motorists at high speed signalized intersections by providing dilemma zone protection. Long Distance Detection uses inductive loops located upstream from an intersection to sense approaching vehicles. When a vehicle passes over the loop, the signal controller extends the green time to allow the vehicle to pass through the dilemma zone prior to the on-set of the amber signal indication.

Long distance passage loops are normally used at intersections to provide either actuation of signal phases or to provide extended green times for vehicles passing through the dilemma zone. When used in the former case, they are sometimes referred to as "trip loops". When used in the latter case, they are sometimes referred to as "extension loops".

Long distance detection generally consists of a single "simple loop" centred in each through lane of the mainline approach that is located at the outside edge (upstream edge) of the dilemma zone. With respect to actuated signal timing, both approaches receive a minimum green interval, vehicle extension period, and a maximum green interval. The vehicle extension period is intended to carry a vehicle from

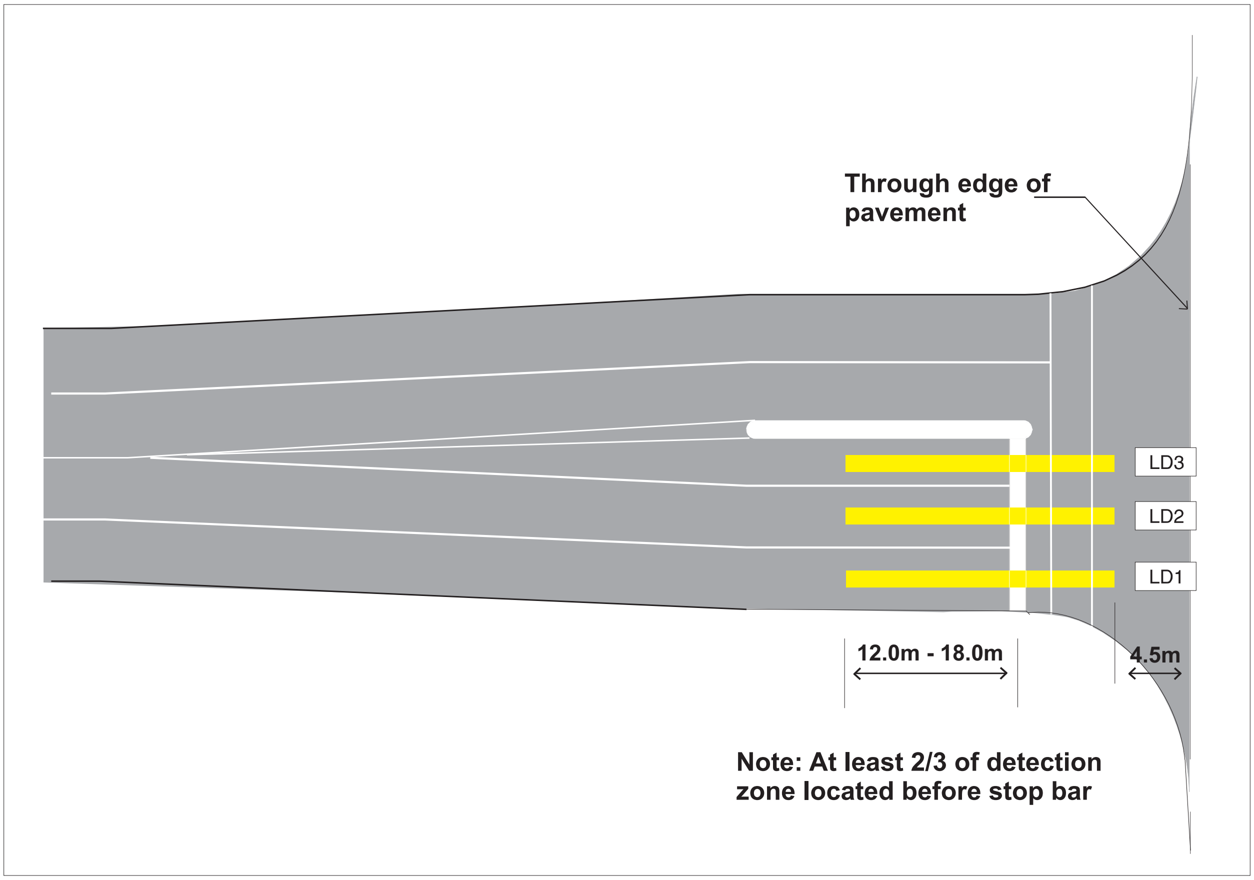


Figure 42 – Presence Loops

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 at the time vehicles are approaching the signal. A maximum green time should be established according to the prevailing traffic conditions (on all approaches). Consideration can be given to using Time of Day Functions to alter the maximum green if traffic demands change throughout the day.

Long distance detection should be implemented at intersections on roadways that meet all of the following criteria:

- Operating speed is greater than 60 kilometres per hour
- Traffic signals are fully actuated
- The intersection is isolated, non-interconnected, or interconnected with off peak free modes operation

The key elements related to the successful operation of long distance detection are the placement of the long distance loop on the mainline approach and the vehicle extension time that is provided for each loop activation. If the loop is placed too close to the intersection, vehicles may enter the dilemma zone prior to activating the loop. If the loop is placed too far from the intersection, providing short vehicle extension periods may result in motorists being in the dilemma zone at the on-set of amber. Providing excessive vehicle extension periods can increase vehicular delay as well as the probability of max-out during high volume situations.

As a recommended practice, long distance loops should be used as extension loops to extend green time on the main road for roadways of posted speed of 80 km/h or more, although they may also be beneficial to signal operations at lesser speeds. The loops are normally installed per lane and are of 1.8 x 1.8 m square configuration or the equivalent diamond shaped loops (preferred) as shown in Figure 43. The distance from the stop line to the extension loops is based on the time of entry of the dilemma zone, as shown in Table 25.

The design of loop details with the various types of loops such as simple, duplex (quadrapole TM), powerhead, preformed, etc., and with alternate detection devices is beyond the scope of this manual. Reference for further details should be made to the Ministry's Electrical Engineering Manual[2].

In order to promote efficient and safe intersection operation, the loop detector placement and vehicle extension timing parameters summarized in Table 26 should be used.

The distances for loop detector placement identified in Table 26 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.

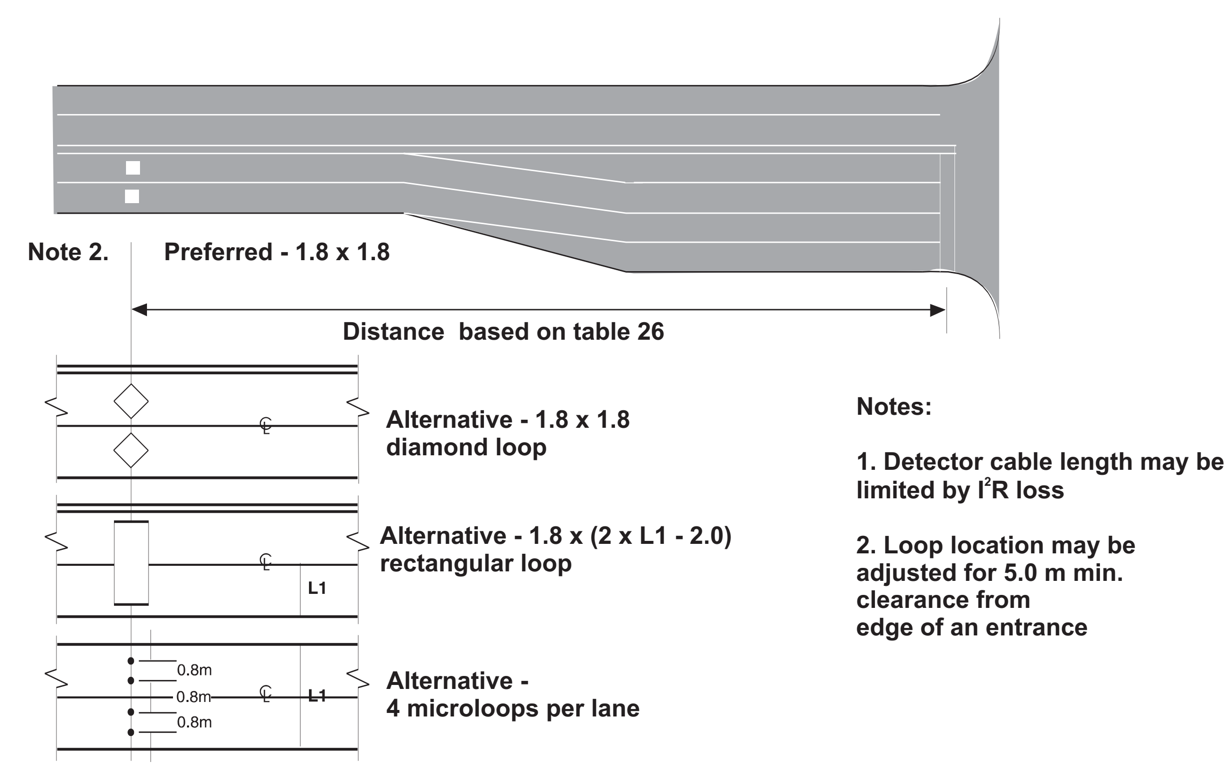


Figure 43 – Extension Loops

Table 25 – Distance from Stop Line for Long Distance Loops

Operating Speed (85th percentile)	*Distance from Stop Line (m) (based on edge of dilemma zone)*	*Distance from Stop Line (m) (based on five second line)*
60	**70**	**85**
70	**90**	**100**
80	**110**	**115**
90	**125**	**125**
100	**140**	**140**

Table 26 – Long Distance Detection Operating Parameters

OPERATING SPEED (km/h)	**LOOP PLACEMENT (DL1)** (metres 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	4.1
100	175	4.1
105	190	4.1
110	205	4.1
115	228	4.1
120	244	4.1

For operating speeds greater than 95 km/h, the loop detector location is based on the ITE stopping distance formula using a perception reaction time of 1.8 seconds. The ITE formula uses an average deceleration rate of 3 m/s^2 to calculate braking distance. The 1.8 second perception reaction time and the average deceleration rate of 3 m/s^2 are consistent with the methodology for calculating the amber signal interval.

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 prior to the installation of Long Distance Detection. Figure 44 illustrates the recommended installation for Long Distance Detection.

Double Long Distance Detection

Double Long Distance Detection is best used where high speed vehicles (above the operating speed of the roadway) are creating a safety concern. Double Long Distance Detection uses information collected from two loops 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 loops, a green extension is provided to allow the vehicle to pass through the dilemma zone prior to the onset of amber. However, if a vehicle is travelling below the threshold speed between the two loops, 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 "simple loops" centred in each lane of the mainline approach. The loop closest to the intersection (Loop 2) is located as per Table 29 for the operating speed of the roadway. The loop furthest from the intersection (Loop 1) is located a fixed distance of 50 m upstream of Loop 2.

In actuated signal timing operation, the mainline approaches receive a minimum green interval, vehicle extensions from Loop 1 and Loop 2, and a maximum green interval. Loop 1 applies an

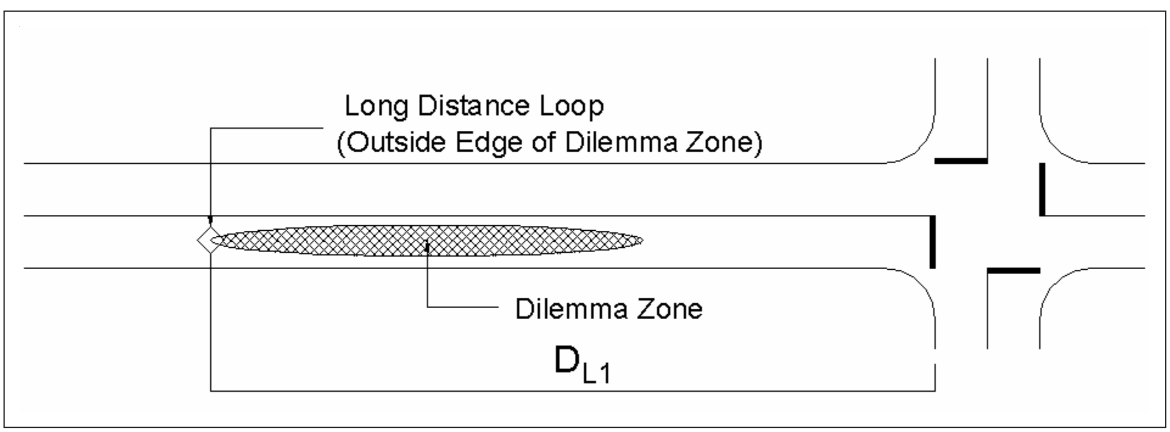


Figure 44 – Long Distance Detection – Recommended Installation

extension interval that is intended to carry a vehicle travelling at or above the threshold speed from Loop 1 to Loop 2. Loop 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 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. Prior to considering Double Long Distance Detection, the 85th percentile speed of the roadway should be determined. The existing Long Distance Detection should be reviewed to confirm that the detector placement and the vehicle extension period conform to the recommended implementation as outlined in Table 26.

It is recommended that Double Long Distance Detection be implemented at intersections on roadways that meet the following criteria:

- There is a grade approaching an intersection sufficient to require more than the normal braking effort (3% or greater).
- There are large volumes of commercial vehicles (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 kilometres per hour.
- 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.
- Isolated, rural, or non-interconnected intersections.

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 prior to or after the installation of the device, Double Long Distance Detection should be turned off during these periods (where signal controller capabilities permit). Turning the Double Long Distance Detector (Loop 1) off will result in a higher gap-out (rather than max-out) rate for the intersection during these periods.

The key elements related to the successful operation of this device are the placement of the loops on the mainline approach and the vehicle extension intervals that are provided for each loop activation. If Loop 2 is placed too close to the intersection, or too far from it, vehicles may enter the dilemma zone prior to activating the loop or be in the dilemma zone once the vehicle extension period has terminated. If Loop 1 is not correctly placed, the signal controller may falsely infer that a vehicle is travelling above (too close) or below (too far) the pre-determined threshold speed. In addition, providing excessive vehicle extension periods for both loops wastes valuable cycle time and increases the probability of max-out.

In order to promote efficient and safe intersection operation, the loop placement and associated vehicle extension intervals summarized in Table 27 are recommended. Figure 45 illustrates the recommended installation for Double Long Distance Detection.

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 10km/h above the posted speed.

Table 27 – Double Long Distance Detection Operating Parameters

OPERATING SPEED	PLACEMENT OF LOOP (metres from stop bar) (Based on operating speed)		MINIMUM VEHICLE EXTENSION PERIOD (seconds)	
	LOOP 2 DL2	LOOP 1 DL1	LOOP 2 (ext. + carry) (operating speed)	LOOP 1 (ext.) (threshold speed)
80	110	160	4.0	2.0
85	120	170	4.0	1.9
90	125	175	4.0	1.8
95	165	215	4.1	1.7
100	175	225	4.1	1.6
105	190	240	4.1	1.6
110	205	255	4.1	1.5
115	228	278	4.1	1.4
120	244	294	4.1	1.4

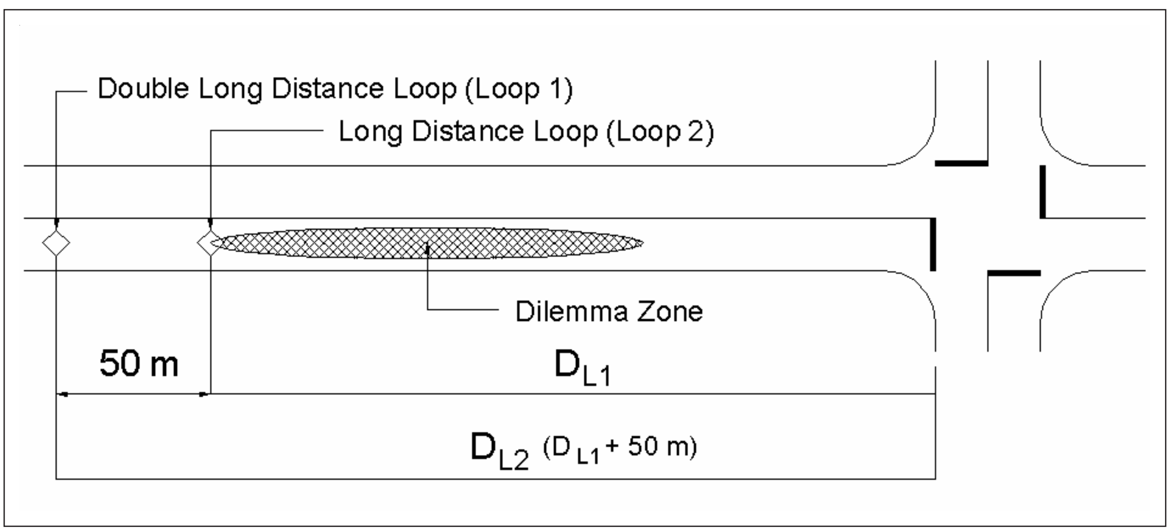


Figure 45 – Double Long Distance Detection – Recommended Installation

Where existing Double Long Distance Detection is in place and the loop placement differs from those outlined above, the following formula must be used to determine the proper vehicle extension interval:

$$\mathbf{I = D/V_T}$$

Where: I = Vehicle extension interval (seconds)
D = Distance between loops 1 and loop 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 uses several example intersections to illustrate the various requirements.

Crosswalks and Sidewalks

General

This section 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. 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 since 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 46.

Some basic guidelines to the layout of crosswalks and sidewalks are given here since the layout design of pedestrian signals and pushbuttons must be integrated with the other signal elements.

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 47 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 allow greater two-way pedestrian volumes.
- The outer edge of the crosswalk is normally 1.0 m from the edge of the stop line. The stop line location can vary if necessary from the standard location (which starts at the end of the island).

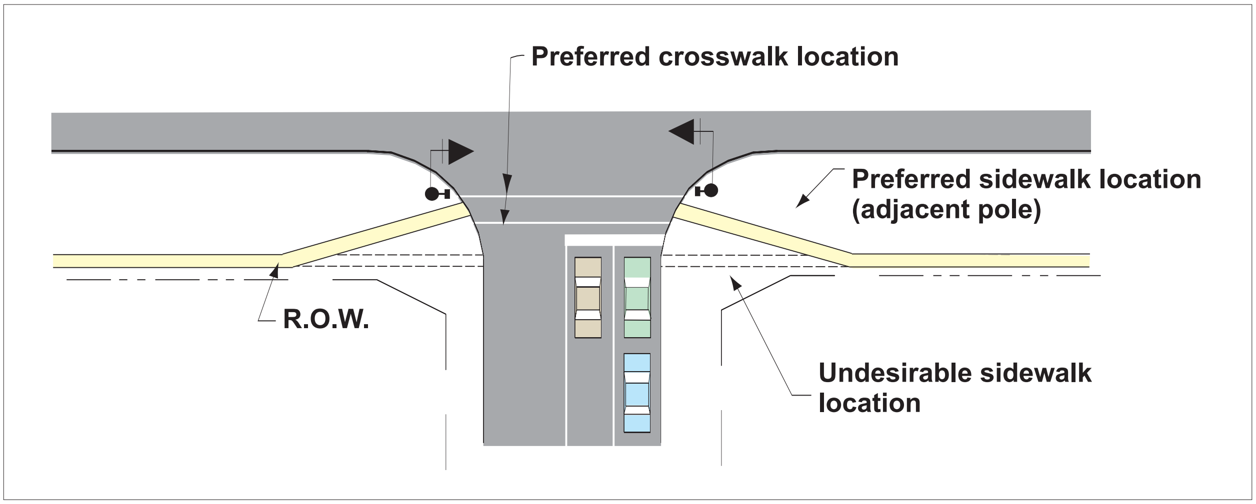


Figure 46 – Crosswalk and Sidewalk Locations

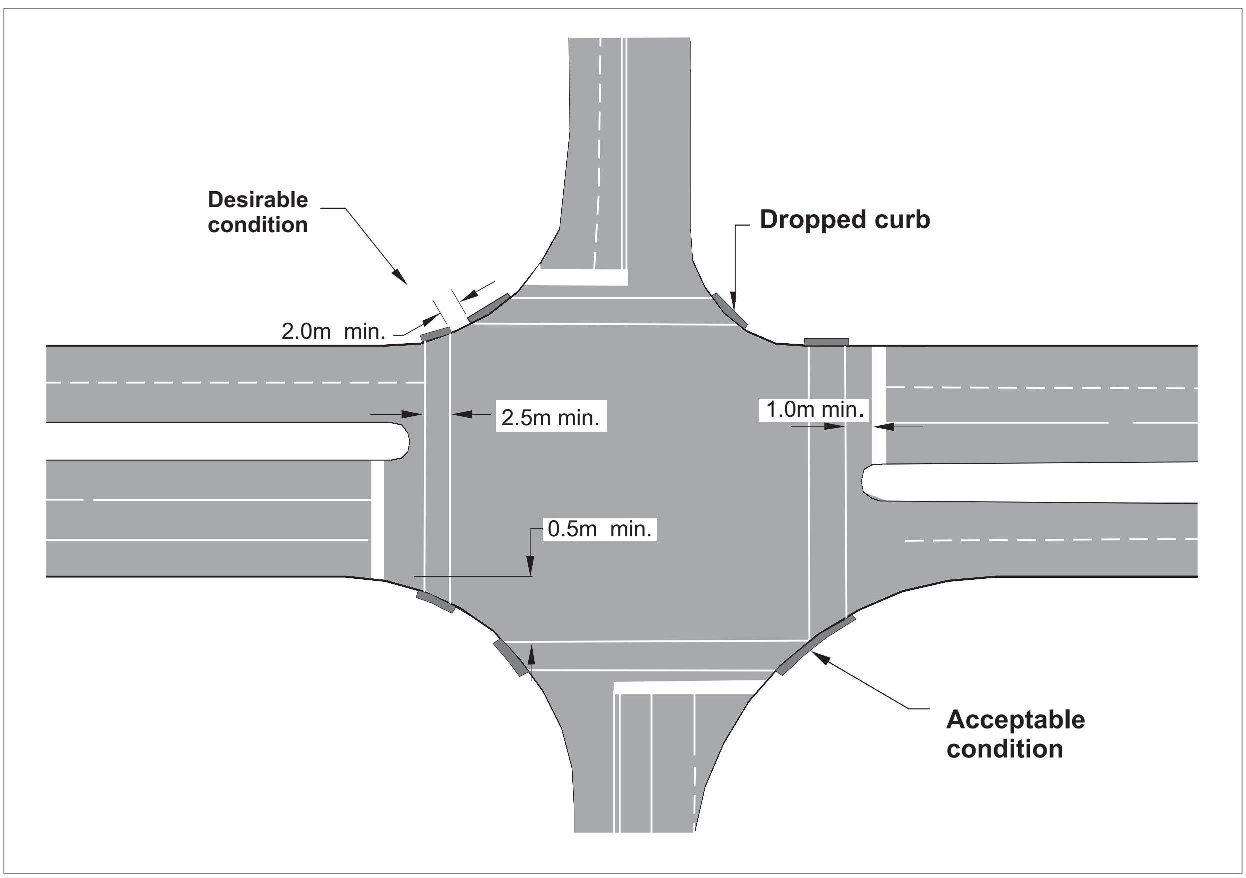


Figure 47 – Crosswalk Design

- The inner edge of the crosswalk should be a minimum of 0.5 m from the through edge of 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 preferred to have each crosswalk reach the far curb without intersecting with the other crosswalk across the other roadway. This 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.
- Crosswalks should not cross over the centre median island on roadways with posted speeds of 80 km/h and more and should not cross over any median not equipped with wheelchair ramps or at-grade depressions.
- Consideration should be given to snow-covered roadways where crosswalk lines may not be visible. Wherever possible, the 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. <u>Sidewalks</u>

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. <u>Integrated Design</u>

Care in the placement of the crosswalk markings during the design can improve the appearance and operation of the intersection. Note that 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 47, or should be brought together with the inner lines meeting to eliminate the curb “bump”. It should be noted that the “bump” does serve the functions of providing guidance for visually impaired pedestrians and deters motorists from mounting the curb.

The final markings must be coordinated with the road designers to suit pedestrian pushbutton and pedestrian head locations. Note that 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 the pedestrian walk time. The possibilities of installing a channelization island as shown in Figure 48 should be investigated and discussed with the road designers.

The island removes the turning traffic from the intersection and offers a pedestrian refuge area as well as a place to install a traffic signal pole. There are safety concerns associated with designing islands. Pedestrians crossing to the island should yield right of way to motorists (unless signed otherwise). For channelized right turn lanes, crosswalk markings should not be applied 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 less than 80 km/h, the minimum island size should be restricted to 3.7 m on any one side and 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 still preferred if attainable). From an operational perspective for roadways posted at 80 km/h or greater, a full right-turn channelized lane with adequate storage to remove all right-turning vehicles from the signal operation is preferred as well as a full acceleration lane for proper and safe merging on the crossing road.

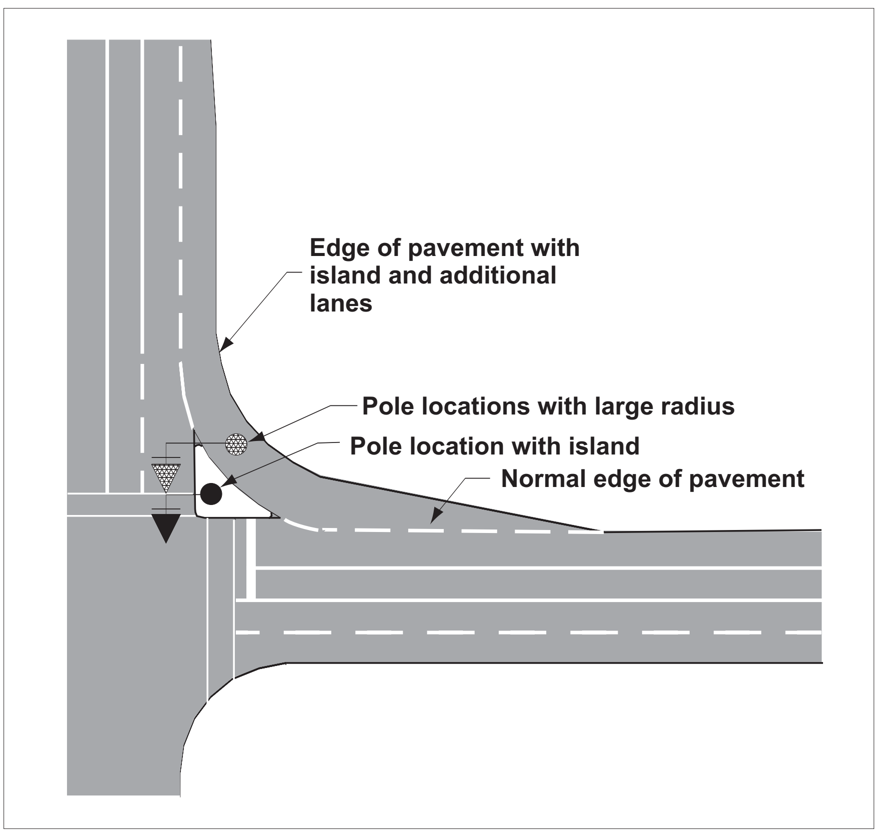


Figure 48 – Use of Right-Turn Island

5.11 Utilities

General

The designer must capture the temporary and final location of utilities that will be on site during the traffic signal construction. The final locations may include existing utility locations (where relocations are not required for roadway purposes), relocated utilities or combinations of both (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. Note that most intersection reconstruction projects widen the pavement and hence 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 can be found that are satisfactory to both the utility and the road authority and in many of these instances the signal design must be adapted from the standard to a compromise design.

Guidelines

The designer should be aware that some underground utility plans can not be relied upon. Many utility plans are provided which 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 may choose one of the following methods in designing equipment locations:

- Arrange for spot excavations and a survey of the exposed utility that can be plotted on a plan. This 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 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. I M. Note that these regulations are enforced in law 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 come 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) prior to energizing the electrical equipment. The Traffic Signal Practitioner 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 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 crossarm construction exists or is planned, the clearance should be increased accordingly 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, however this approach is somewhat idealistic and difficult to achieve in practice within congested right-of-ways.
- Where lighting is required, efforts should be made to 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 and 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 and get the neutral and any low voltage cables raised locally from the normal 8.0 m above grade to 9.5m above grade (one pole length increment of 1.5 m) such that the neutral and low voltage cable locations are well above the tops of 7.5 m signal poles and such 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 to either telephone or cable television lines. Efforts must be made however, to arrange to have these utilities raised if the cables will visually obstruct the traffic signal heads.

5.12 Layout Practice

General

In the drawings, the "Standard" layout indicated is for an approach with Highway type heads and possibly advanced green arrow heads.

Guidelines by Example

The following figures are shown:

Figure 49	"T" Intersection Approach
Figure 50	Approach Without Median Island (Standard or Advanced Green)
Figure 51	Approach Without Median Island (Fully Protected Left Turns)
Figure 52	Approach With Median Island (Standard, Advanced Green or Simultaneous Protected/Permissive Lefts)
Figure 53	Approach With Median Island (Fully Protected Left Turns)
Figure 54	Approach With Wide Median (Fully Protected Left Turns)
Figure 55	Approach With Double Lane LTL (Fully Protected Left Turns)
Figure 56	Ramp Terminal Opposite Free-flow Ramp
Figure 57	Short Offset Intersection
Figure 58	Long Offset Intersection
Figure 59	Pedestrian Signal Poles

"T" Intersection Approach

A typical "T" intersection with two-way traffic on the side road is shown in Figure 49. Note the following:

- Standard Highway heads may be used.
- The primary and secondary poles should preferably be located clear of the edge of the projected through lane for safety reasons, using 3.0 m clearance as a desirable setback for roadways posted at 80 km/h and over and using 1.5 m minimum for roadways posted at under 80 km/h.
- Double left or right turn lanes should not occur simultaneously with conflicting pedestrian crossings.
- Where pedestrians are allowed, recommended practice is that only one crosswalk should be used. The crosswalk should be located on the approach where there will be no interference with pedestrians from left-turning traffic.

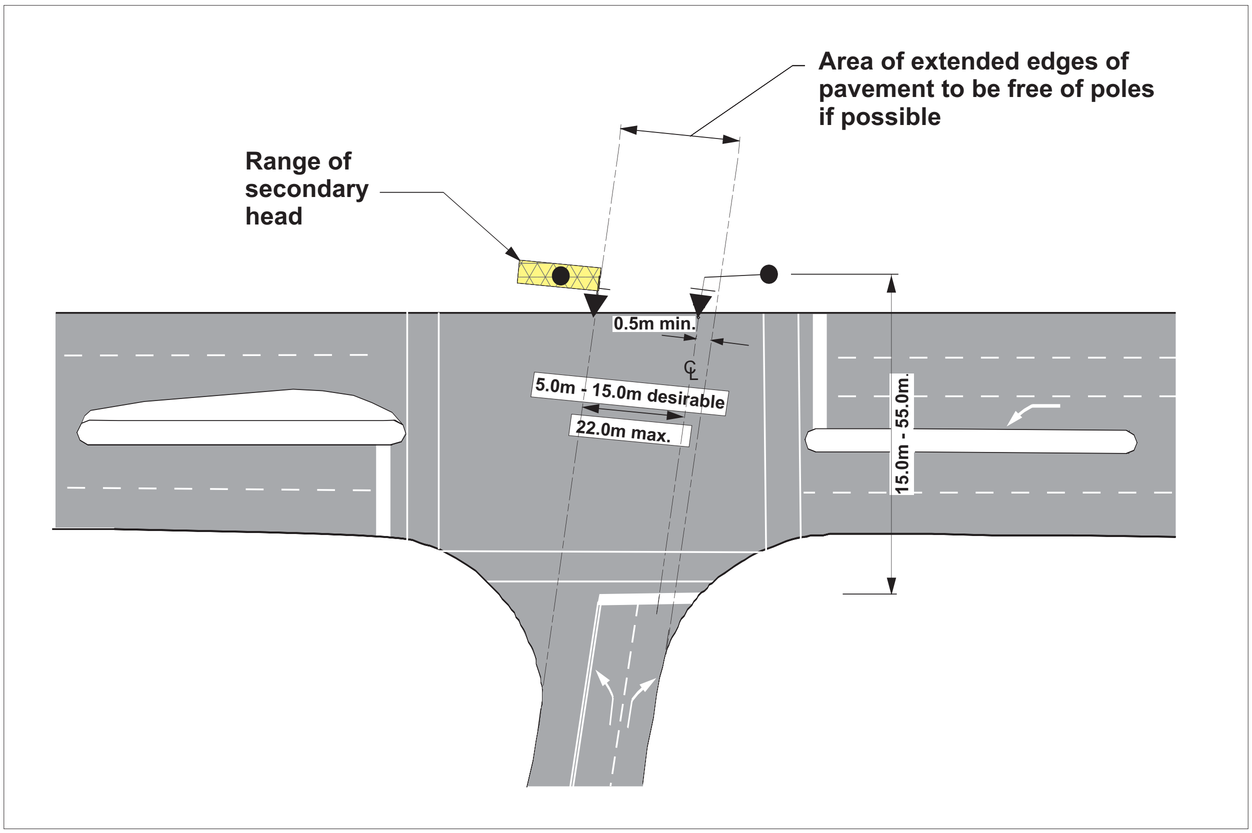


Figure 49 – "T" Intersection Approach

Approach without Median Island (Standard or Advanced Green)

A typical simple approach, without a median island and with normal or advanced green indications, is shown in Figure 50. Note the following:

- There is no median pole and therefore the primary head should be at or close to the centre of the lane.
- If mast arm lengths allow, the poles should be within 3.0 m of the crosswalk to enable pushbutton and pedestrian head installation on the same poles.

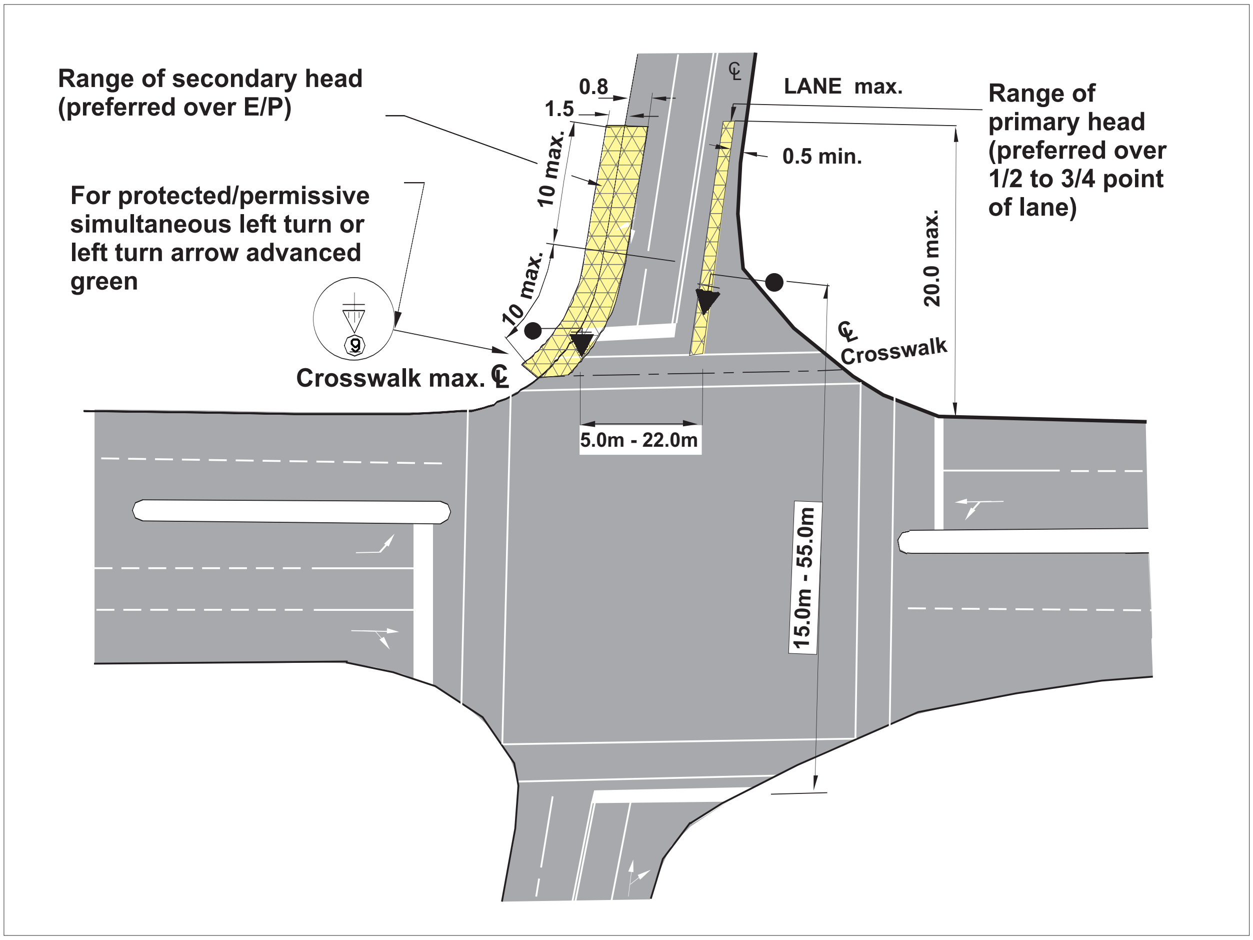


Figure 50 – Layout at Approach Without Median Island

Approach without Median Island (Fully Protected Left Turns)

A single lane left-turn approach, without a median island and with fully protected left-turn indications, is shown in Figure 51. Note the following:

- 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.
- This application is normally used only as an interim measure until the intersection can be reconstructed with islands.

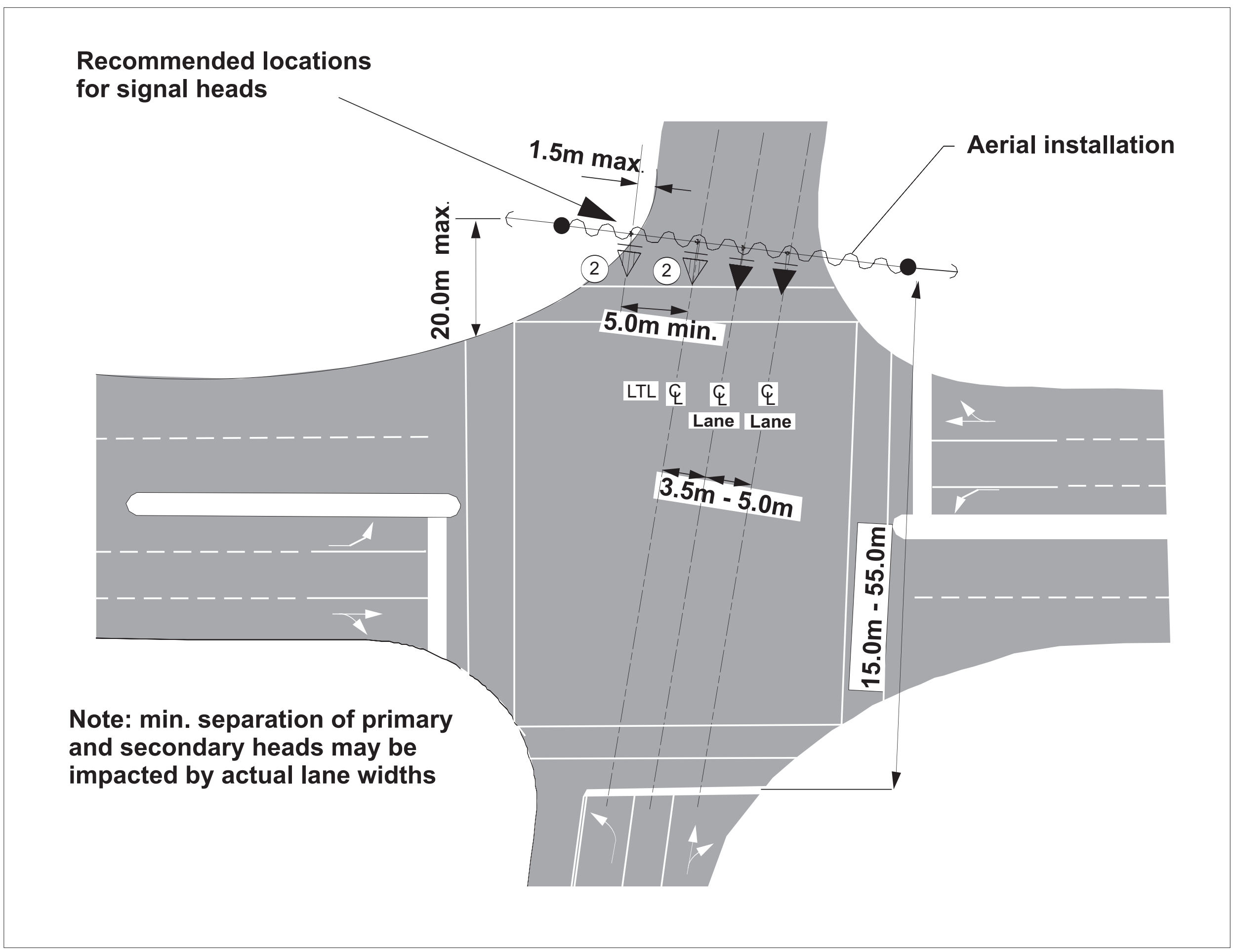


Figure 51 – Approach with Fully Protected Left Turn Heads and Without Median Island

Approach with Median Island (Standard, Advanced Green or Simultaneous Protected/ Permissive Lefts)

Two approaches are indicated on Figure 52; one approach has typical Highway heads and 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 through pavement. Standard mast arms 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.

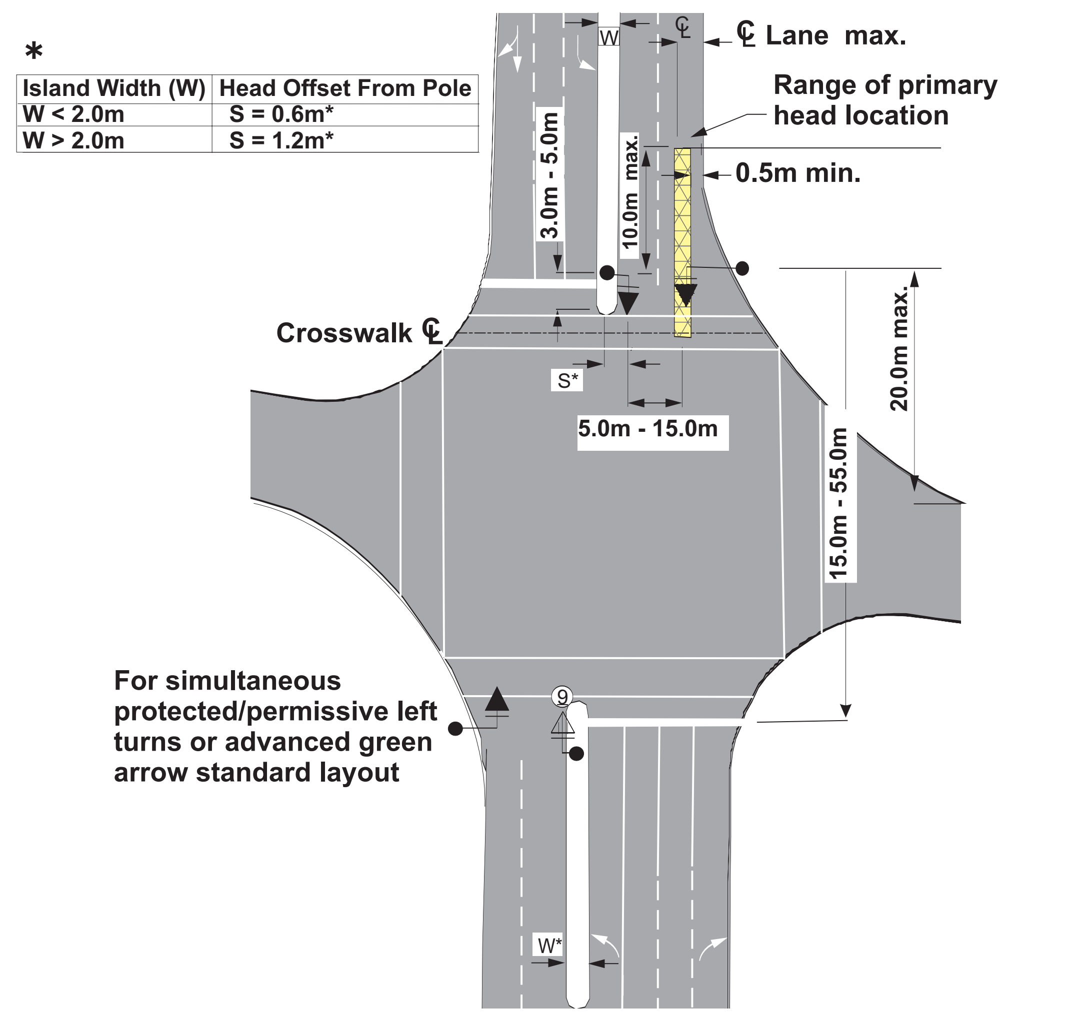


Figure 52 – Standard or Protected Permissive Layout

Approach with Median Island (Fully Protected Left Turns)

A single lane left-turn approach, with a median island and with fully protected left turn indications is shown in Figure 53. Note the following:

- The left-turn primary head is to be located only within the projected edges of the left-turn lane.
- 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.

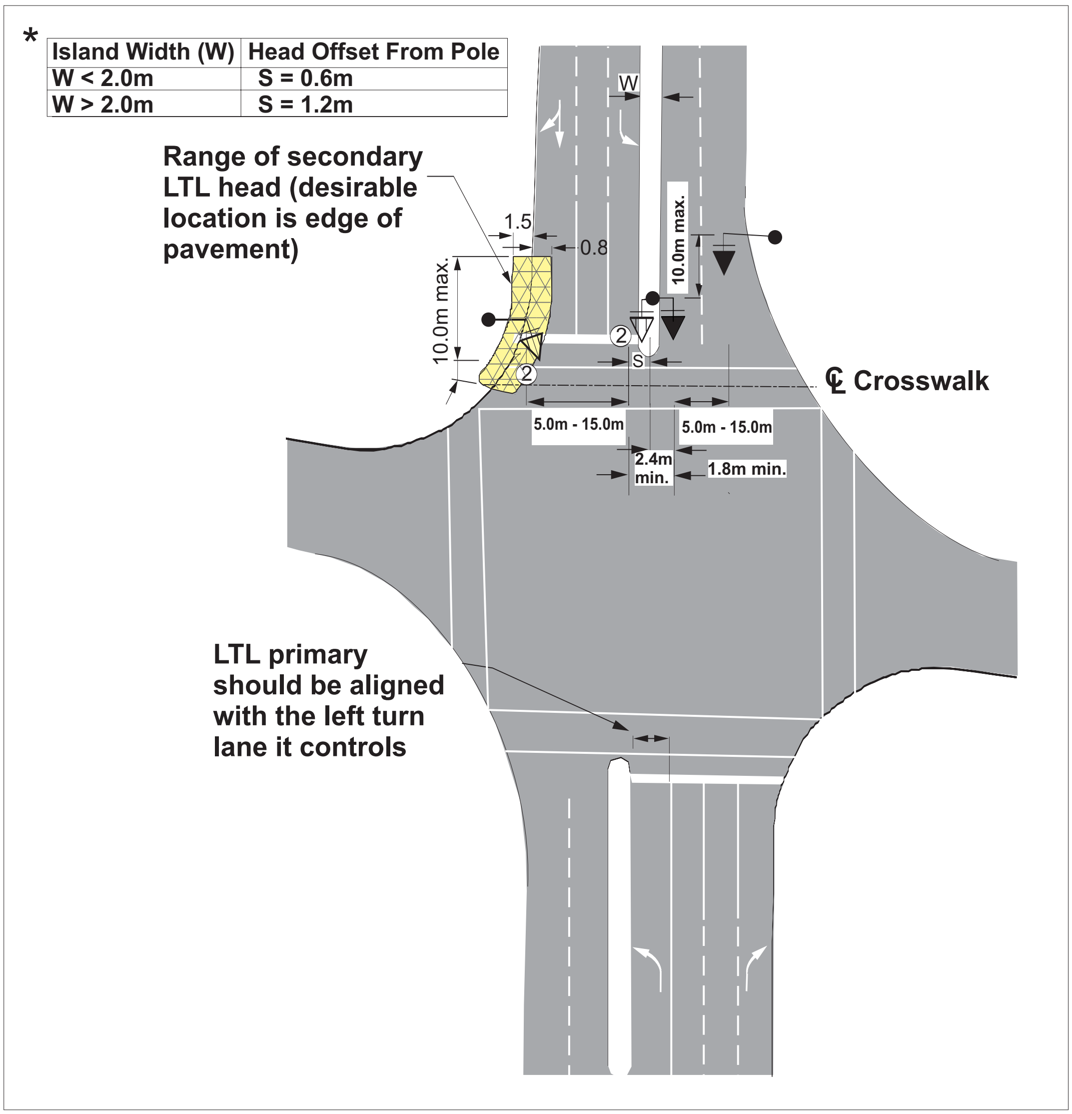


Figure 53 – Fully Protected Left Turn Approach

Approach with Wide Median (Fully Protected Left Turns)

Figure 54 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 slightly upstream.
- **Where the median width exceeds 15 m, two sets of separate signals are required in accordance with Section 144 (2) of the HTA**.

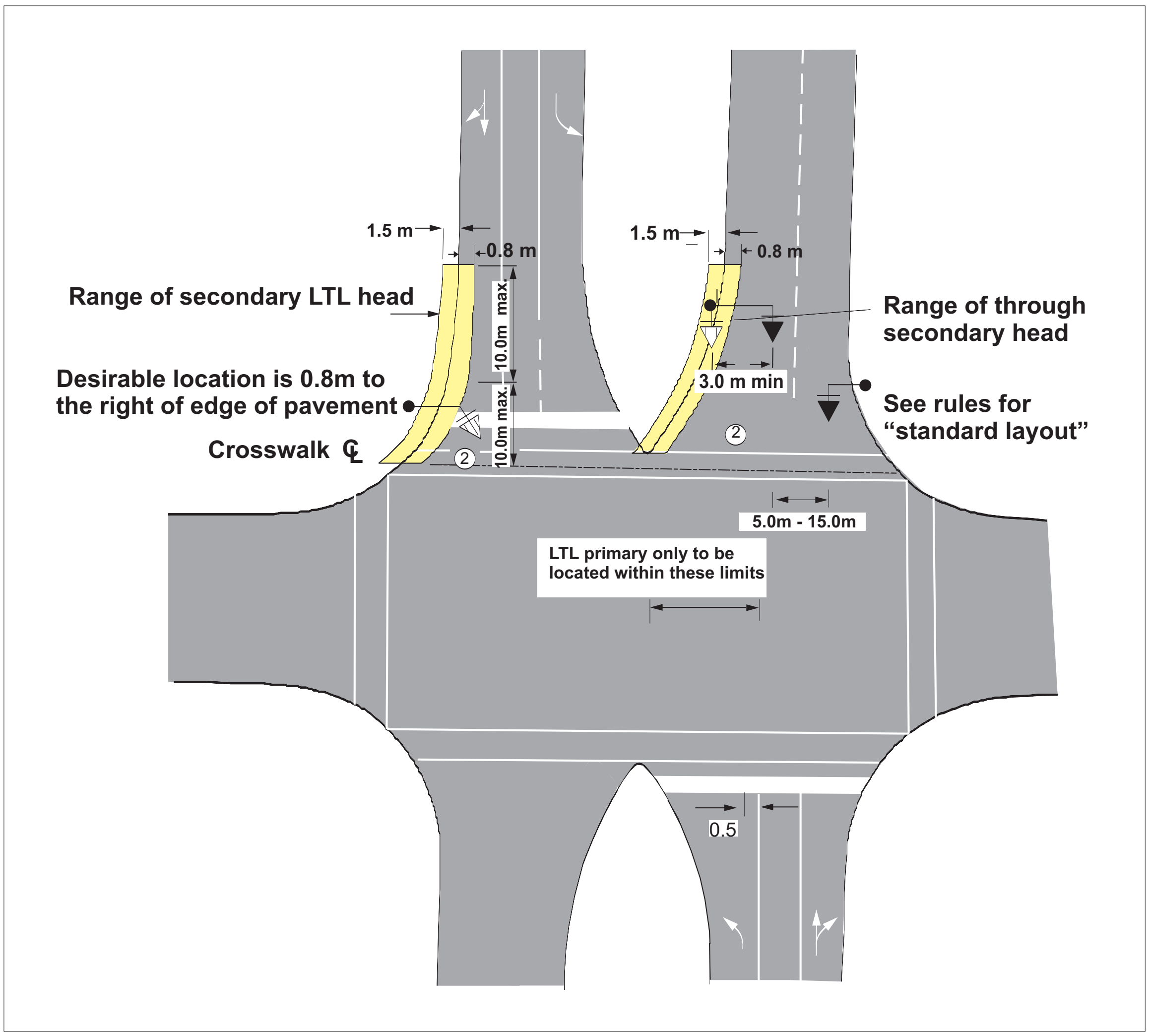


Figure 54 – Fully Protected Left Turn at Wide Median Approach

Approach with Double Left Lane (Fully Protected Left Turns)

Figure 55 shows a fully protected left-turn approach for a dual left-turn lane. 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 slightly upstream.
- The dual left-turn lane shall require pavement marked "tracking" lanes for guidance of turning vehicles. Where a dual left-turn lane 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 for safety purposes.

Island Width (W)	Head Offset From
Pole	
	S = 1.8m min.
W < 2.0m	S = 0.6m
W > 2.0m	S = 1.2m

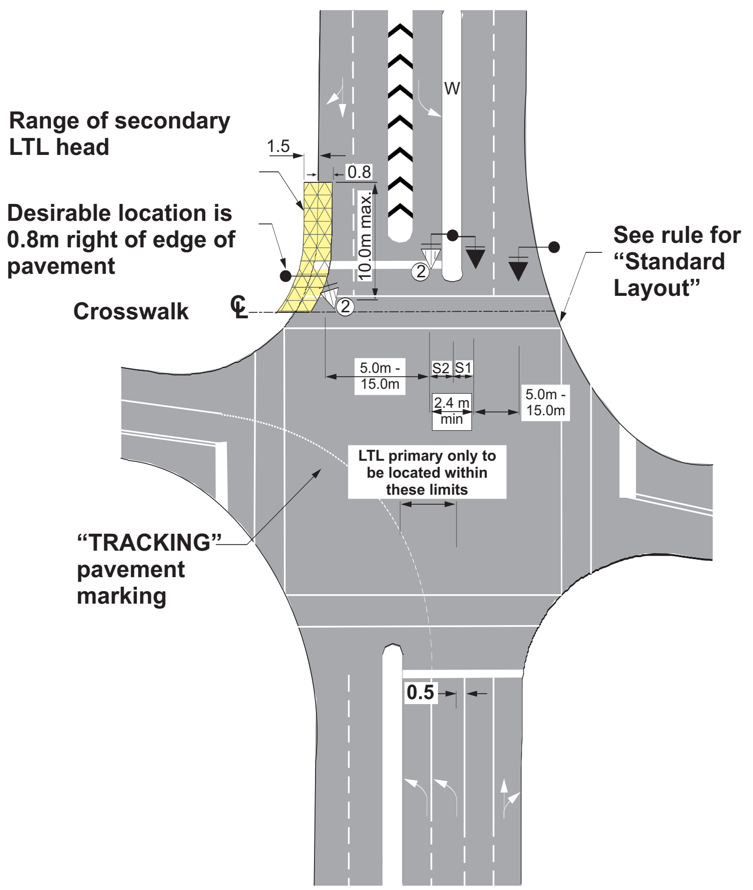


Figure 55 – Fully Protected Dual LTL Approach

Ramp Terminal

Figure 56 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 traffic turning 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, they should not occur simultaneously with conflicting pedestrian crossings.
- The through lane primary and secondary heads on the arterial should be the type to indicate 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 since the islands are in direct alignment and near median poles may obscure front mounted heads.

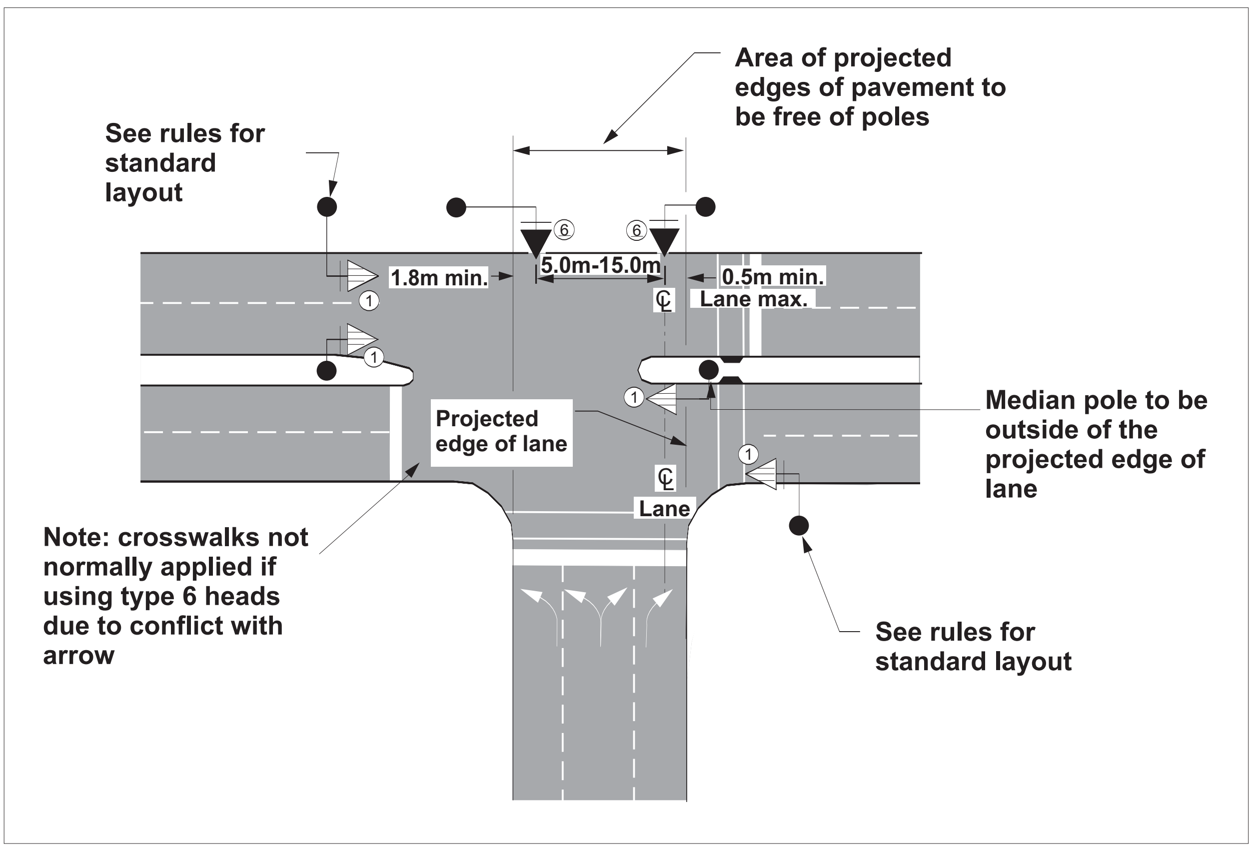


Figure 56 – Ramp Terminal Intersection Approach

Short Offset Intersection

Figure 57 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 since 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, between the side roads, are not desirable (with normal phasing). The side road approaches are typically served on separate phases, allowing pedestrian crossings in the middle during one of these phases. If pedestrian crossings are then 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 stop lines to a primary head is limited to a maximum 55 m; if 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 each side road, those motorists are 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; however, the designer is directed to Metropolitan Toronto's paper "Traffic Signal Control at Offset Intersections"[23] for a more thorough treatment of the subject.

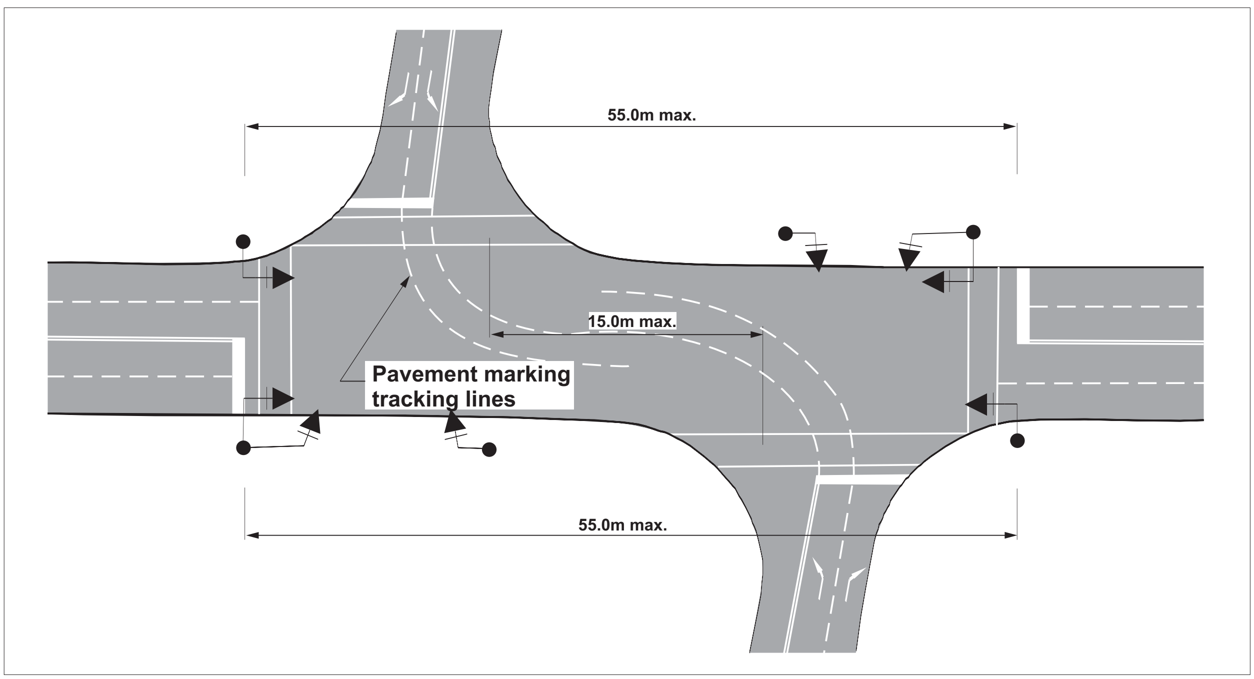


Figure 57 – Short Offset Intersection

Long Offset Intersection

Figure 58 shows a typical layout for a "long offset intersection" where one side road is offset from the other, but not so much as to visually delineate 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 since two sets of signals face motorists. Note the following:

- Pedestrian crossings in the middle, between the side roads, are not desirable unless phasing times permit the holding of turning traffic while pedestrians cross.
- The maximum viewing distance of 55 m for the primary head from the stop line cannot be obtained and therefore 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 the timing, detection could be added in the lanes between intersections to extend the green or let the next phase activate.
- Solutions to driver confusion due to two sets of closely spaced signals may include the use of optically programmable signal heads on the far set of heads to attempt to hide them from the view of approaching drivers, combined with signal timing that provides the amber indication for the upstream traffic prior to the amber for the traffic between the offset legs at the intersection.
- A subtle solution to mitigate motorist confusion may consist of painting the far set of signal head housings a different colour than those of the near side; black faces on the far set and yellow faces on the near set.
- Where "D" is less than approximately 200 m, it is difficult to have the intersections operating independently or on a system without some coordination in timing, phasing and efficiency. Refer to Metropolitan Toronto's paper "Traffic Signal Control at Offset Intersections"[23] for a thorough discussion of problems and solutions.

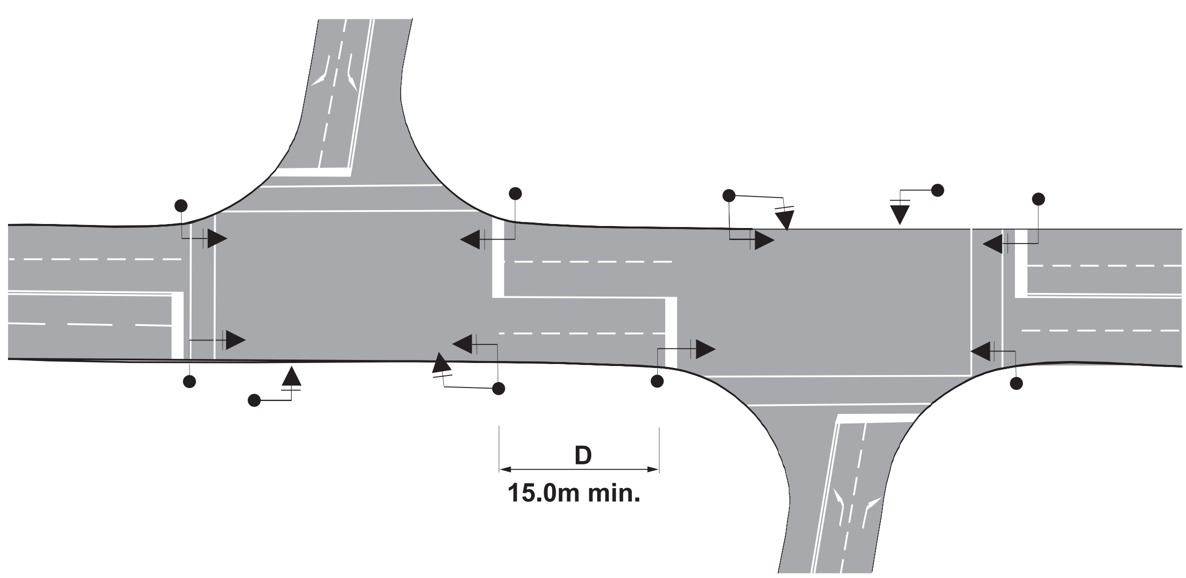


Figure 58 – Long Offset Intersection

Layout of Pedestrian Heads and Poles

General

In order 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, they must be accessible and convenient to the crosswalk being served. Consideration should be given to placing all hardware in convenient locations that are accessible but out of the travelled portion of sidewalk.

Poles with Pushbuttons

Poles with pedestrian pushbuttons should be located in accordance with the following guidelines:

- If possible, poles with pushbuttons should be within the extended crosswalk lines or 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.

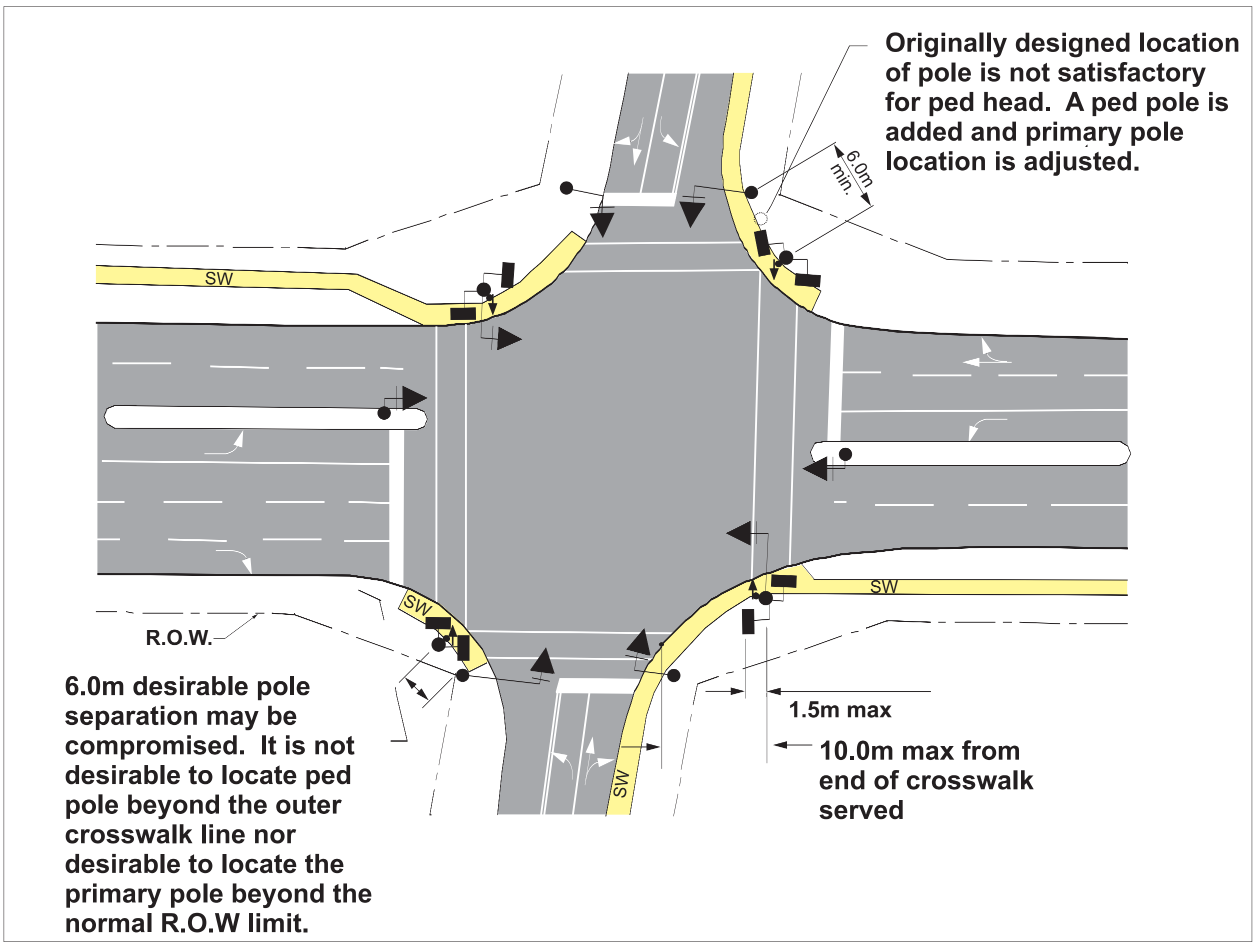


Figure 59 – Layout of Poles With Pushbuttons

- The poles must be accessible and user friendly, not located beyond reach behind barriers or in grass (mud) areas or areas where snow windrows will occur. Some additional sidewalk or paved shoulder may be required.
- Where possible, it is desirable that pedestrian pushbuttons be mounted on traffic signal poles. Where a separate pole is required, it should be installed near the intersection of the centrelines of the crosswalks and should include the pedestrian heads to avoid visual clutter. In lieu of this treatment, a short pole with 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 for aesthetic reasons. Figure 59 illustrates these principles.

Poles with Pedestrian Heads

Poles carrying pedestrian heads should be located in accordance with the following principles:

- Pedestrian heads should ideally be located within the extension of the crosswalk lines or at a maximum of 4.5 m from these lines.
- The poles should be located so that standard 38 mm dia. x 400 mm double arm brackets can be used for pedestrian heads. The use of mast arms longer than 600 mm with hangers is discouraged (unless unavoidable) due to 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 42).
- 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).

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)[2].

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:

- Controller cabinets should be located on the "far right" corner of the main road at the intersection where possible. This gives persons standing at the controller the best view of approaching traffic from both ways along the main road.
- The head displays for 50% of the phases should ideally 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

Manual[22], 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.
- Access to controllers should be directly off the shoulder or boulevard, without crossing ditches, berms, walls, etc., if possible. 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. Refer to the Ministry's Electrical Design Manual[2] for grounding details.
- Controllers must be located at a minimum distance from overhead high voltage wires to mitigate electromagnetic field interference. Refer to the Ministry's Electrical Design Manual[2] for details.
- It is undesirable to have controllers, supply poles, and primary poles in clusters that can be hit by an errant vehicle or where sidewalks are present. 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 edge of 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 and clear of doors and store-front windows.
- 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 in order to raise the bottoms of the cabinets above ground and out of the snow (225 mm minimum suggested, more in snow belts).

5.14 Design Example

General

The design example in this section is presented in detailed format for a typical intersection. The example is intended to illustrate the principles of traffic control signal design and should not be applied to any specific intersection as each intersection has its own idiosyncrasies.

The example shows an intersection that is to be reconstructed under a roadway contract but applications of the principles are equally valid for an existing intersection to be signalized. Practitioners are reminded to review Section 2 for guidelines regarding legal approval requirements.

Preparation of Base Plan

This section emphasies 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 screened). 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. A print of the design plan should be obtained showing other road information for coordination of physical features.

- 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).
- Obtain the details of the existing signal system (where applicable) 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, if metering is required, if utility pole mounting of the power supply cabinet is allowed and if there are any special details 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 60.

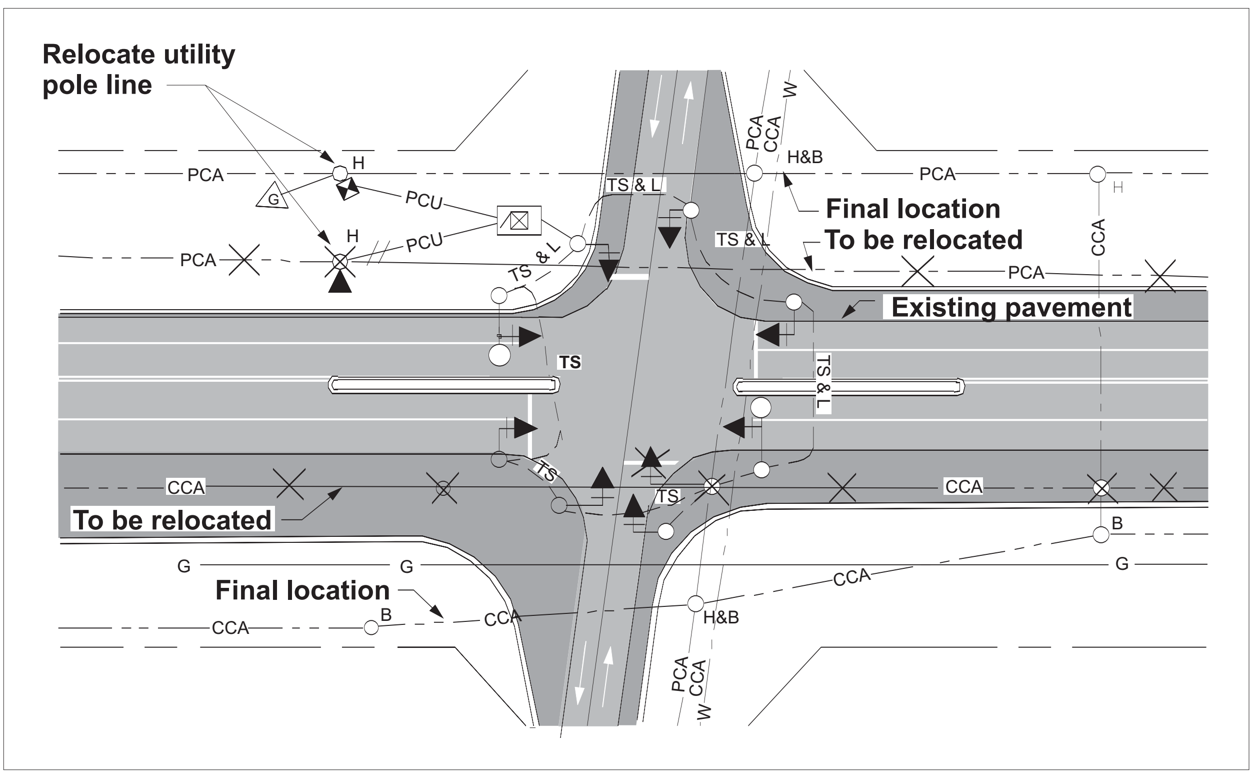


Figure 60 – Base Plan Features

Note that it is the policy of some road authorities to have utilities relocated prior to construction. This may require prior relocation of the power supply cabinet and even minor pole or mast arm relocations by the electrical maintenance staff or by the pre-construction contractor since the road/signal contractor is not usually on site when the utilities are being relocated. 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 of electrical maintenance so that appropriate arrangements can be made for the work.

In some cases, actual relocations are not required if the existing equipment is left in place as an interim measure.

Layout of Crosswalks and Sidewalks

This section uses the principles of Subsection 5.10 to layout or confirms the locations of crosswalks and confirm or suggest the location of sidewalks. This is generally the first step in the actual signal layout design.

Figure 61 shows the layouts required with some suggested modifications to 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 carried out to confirm the most desirable sidewalk layout. This should also be carried out in the case where only signal provisions are to be installed.

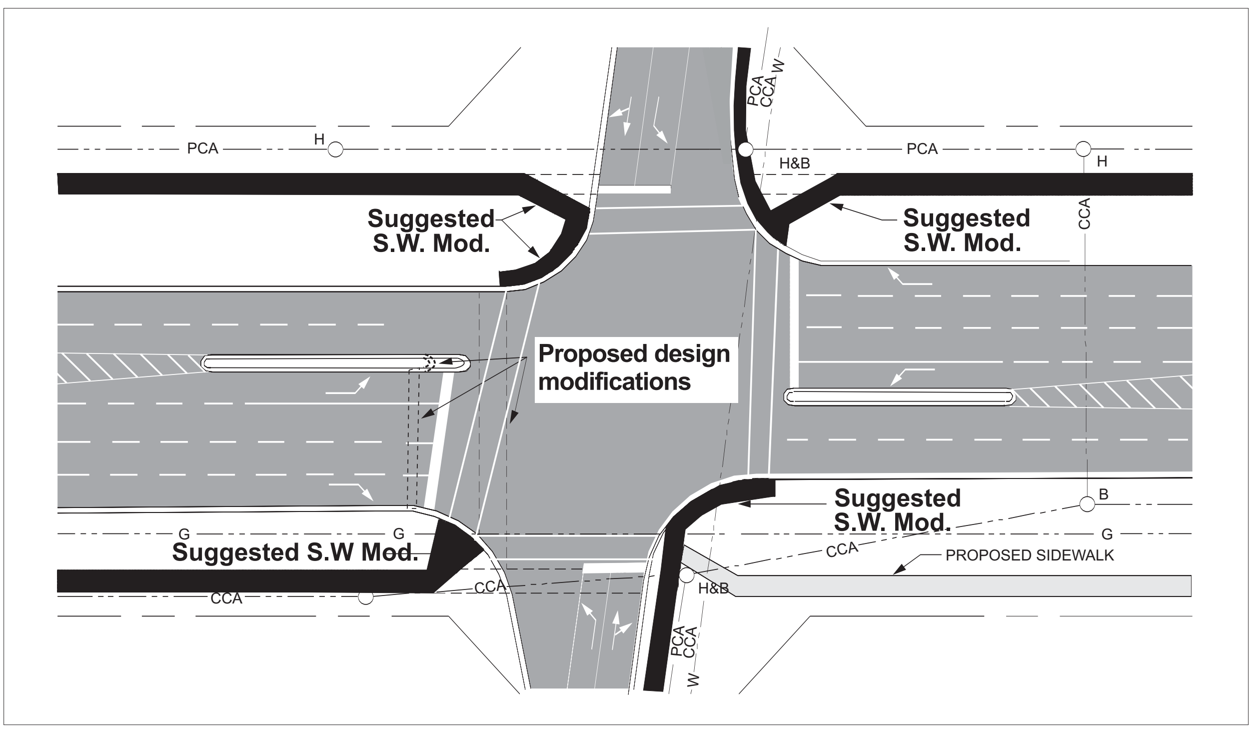


Figure 61 – Crosswalk and Sidewalk Modifications

Pole Locations

This section deals with those locations where it is impossible or impractical to install traffic signal equipment. Poles are most prone to these 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 that the designer recognize the restricted areas at all stages of the design. It is suggested that the restricted pole locations be plotted directly in the working drawing prior to beginning the layout. Note the following:

- Utility clearance rules should follow those given in Subsection 5.11.
- The range of **restricted pole areas** should follow from the information in Section 5.6.

Figure 62 shows the example working plan with utility restrictions marked.

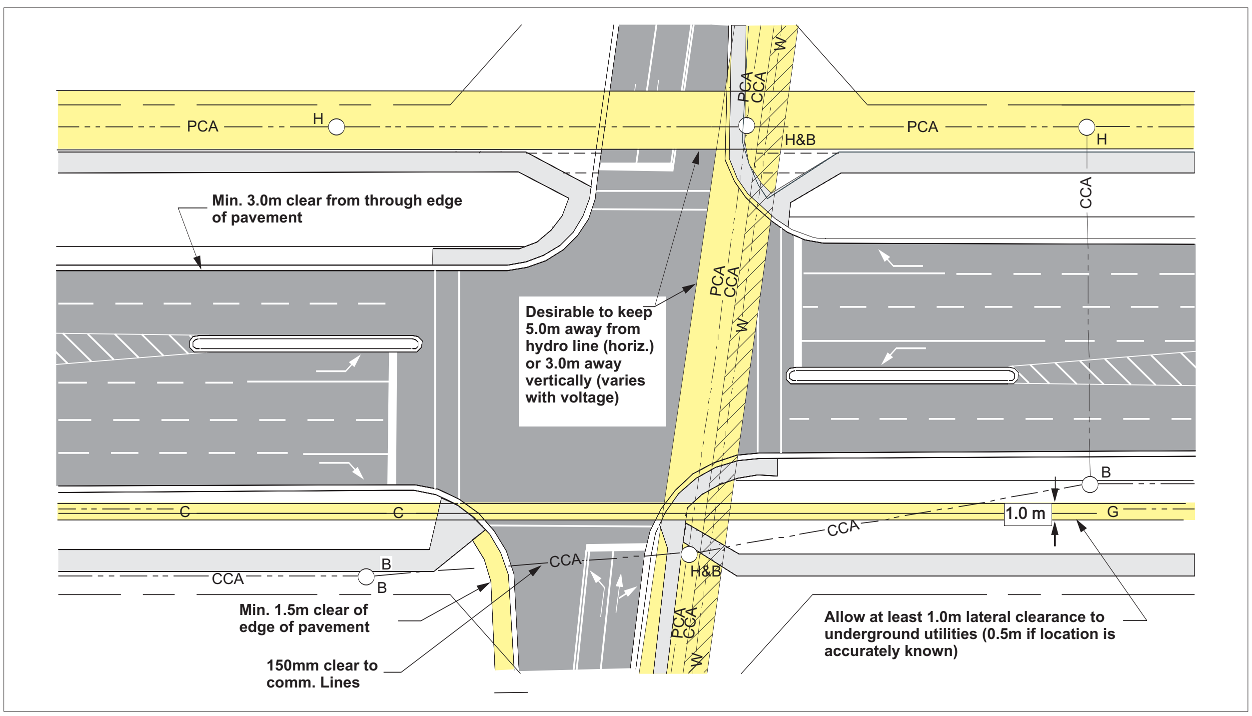


Figure 62 – Pole Areas Restricted by Utilities

Pre-set Head and Pole Locations

This section deals with signal head and pole locations that are laid out according to the guidelines in Subsection 5.3. These poles are the first to be pre-set in any design. Figure 63 shows the standard locations where signal head and median poles should be placed.

Layout of Primary and Secondary Heads

Using the principles of Subsections 5.6 and 5.12, the primary and secondary heads and poles are laid out as shown in Figures 64 and 65.

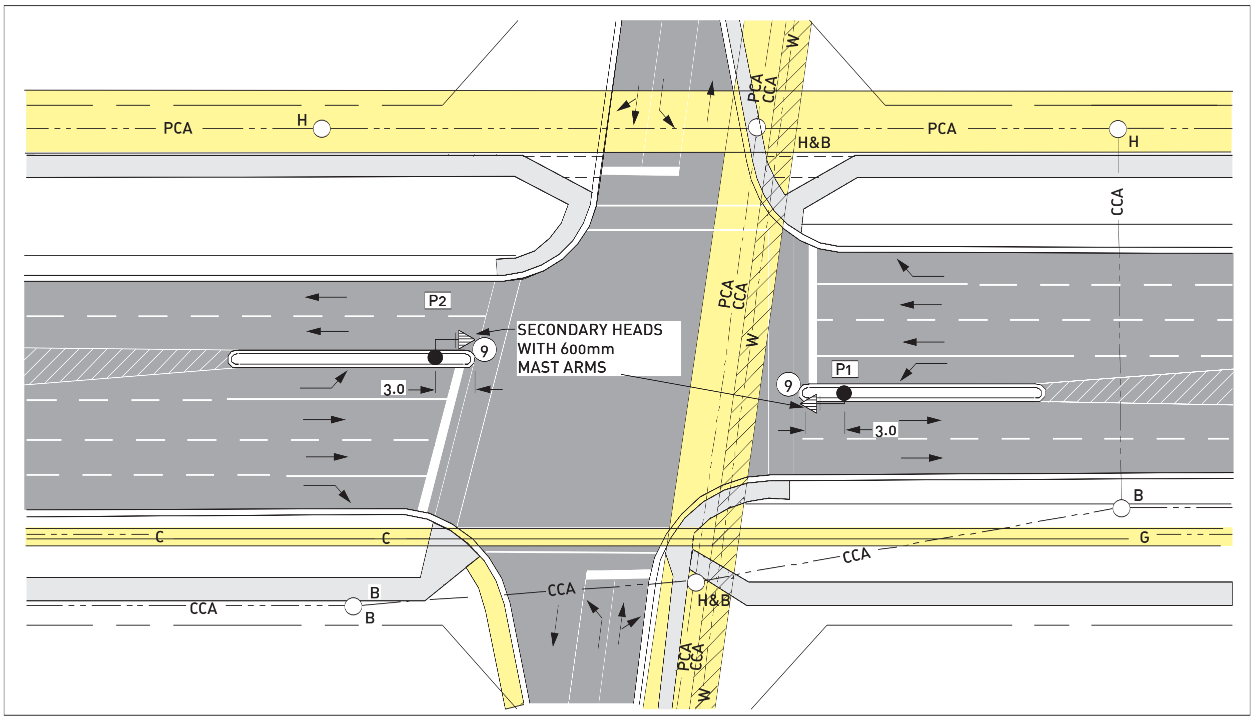


Figure 63 – Pre-set Signal Locations

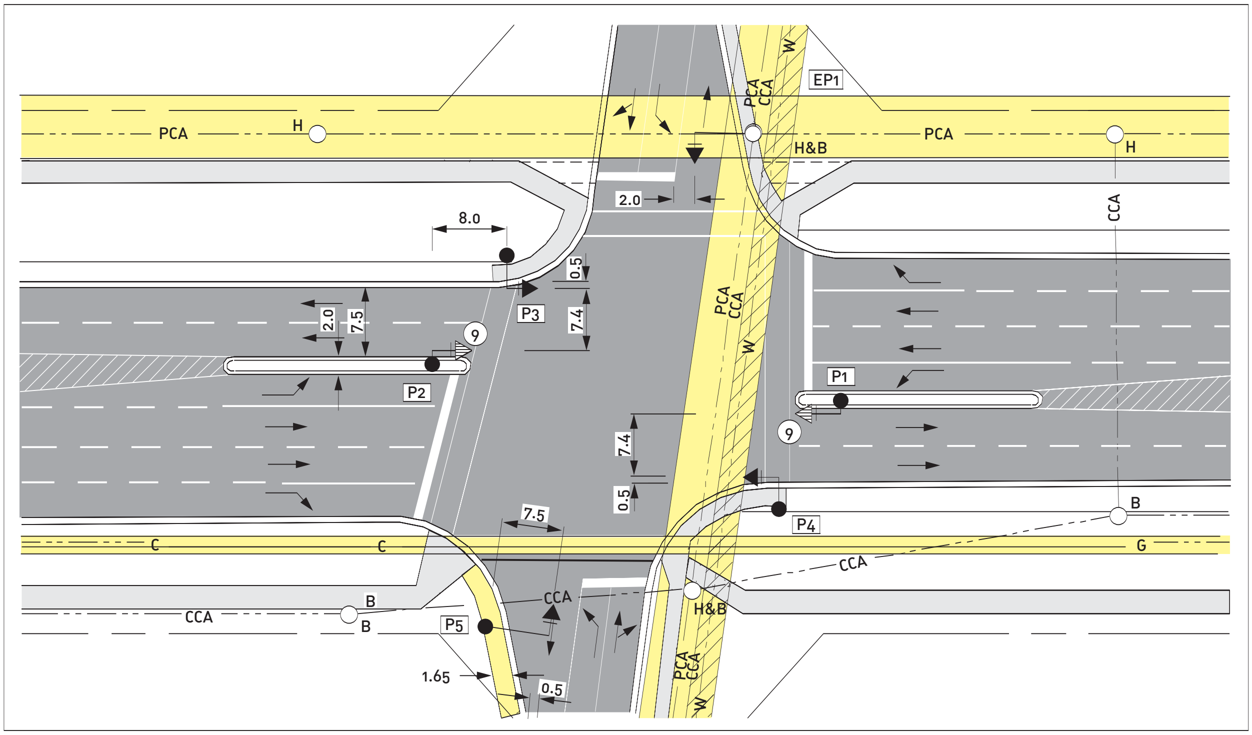


Figure 64 – Primary Head and Pole Layout

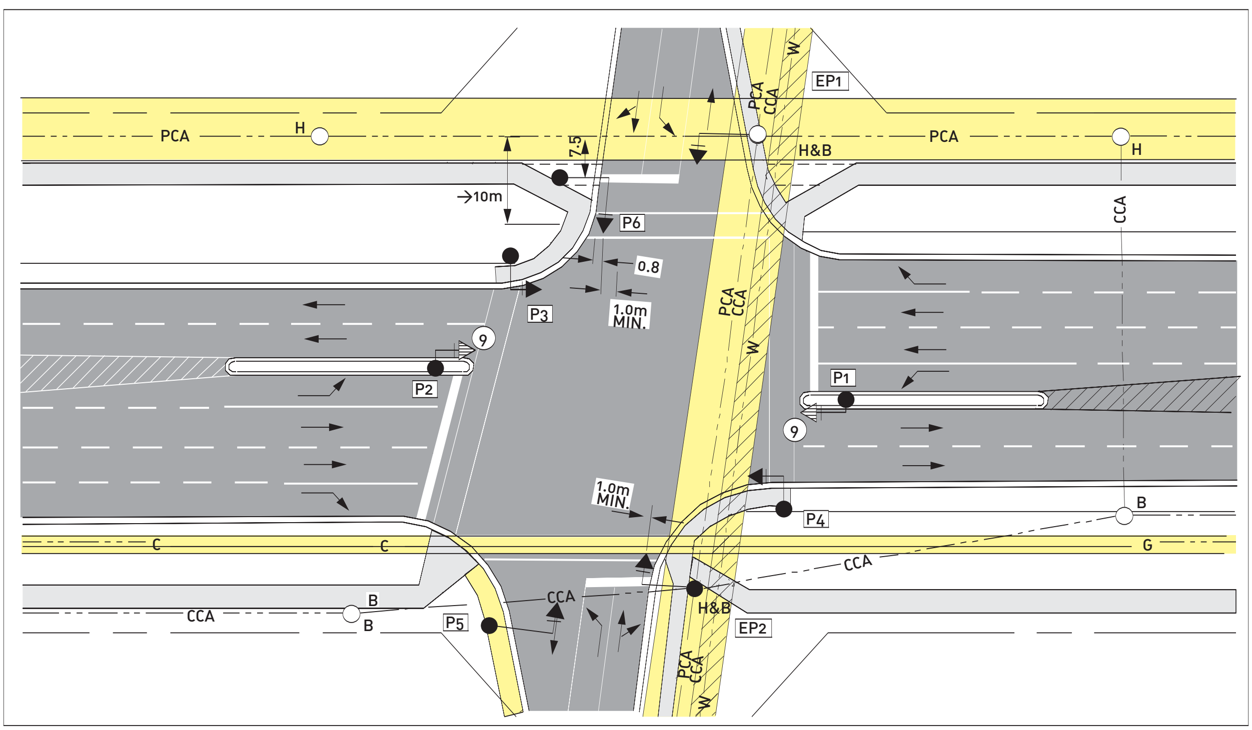


Figure 65 – Secondary Head and Pole Layout

Layout of Pedestrian Facilities

Using the principles of Subsection 5.12, the pedestrian facilities are laid out as shown in Figure 66.

Checking Layout

This section summarizes layout design checking using the principles of Subsections 5.5 and 5.12. Figure 67 shows how the cones of vision should be checked to ensure there are no blocked signal heads. The distances between heads and the pedestrian facilities should also be checked for conformance with the principles of Subsection 5.12.

A checklist is provided in Appendix C.

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 with additional details listed in the Ministry's Electrical Design Manual[2].
- 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. This location often interferes with ditches (the roadway should be visible from the controller site) and coordination with the road designer is required (see Subsection 5.13).
- Electrical maintenance and traffic staff should be consulted as to their preference of cabinet orientation. Some prefer the front door to be facing 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 68.

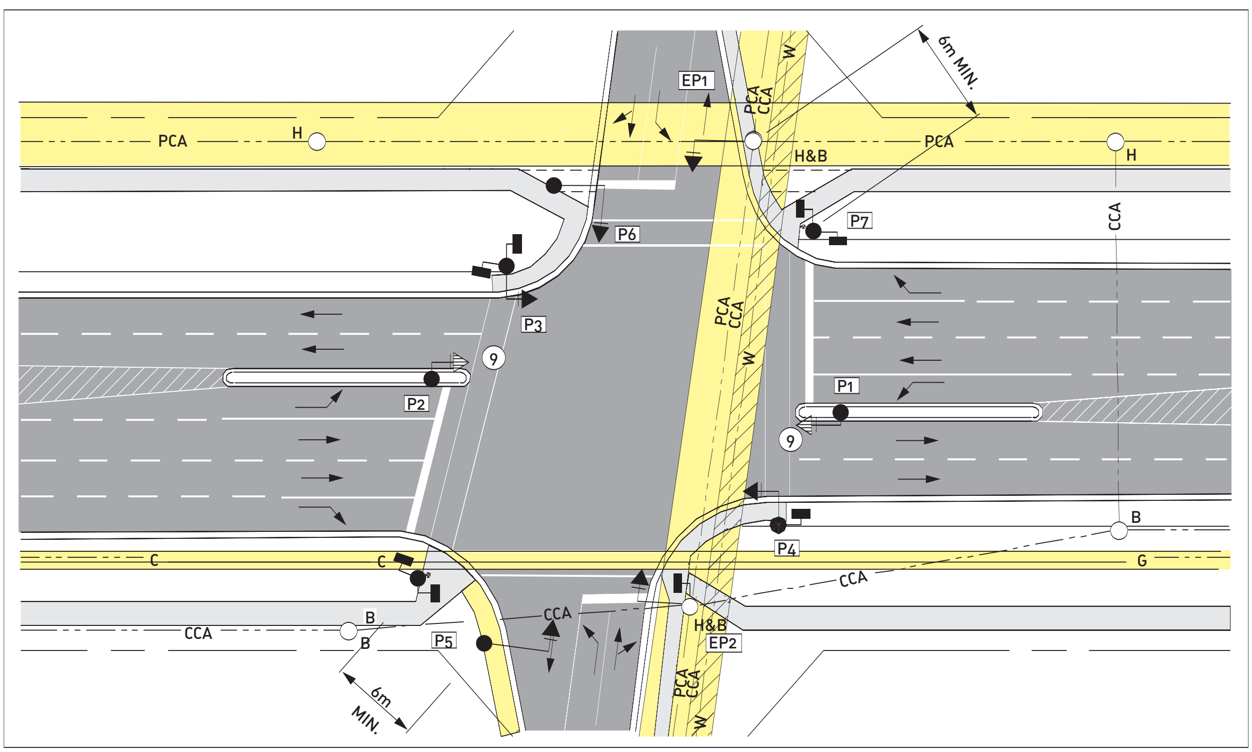


Figure 66 – Layout of Pedestrian Facilities

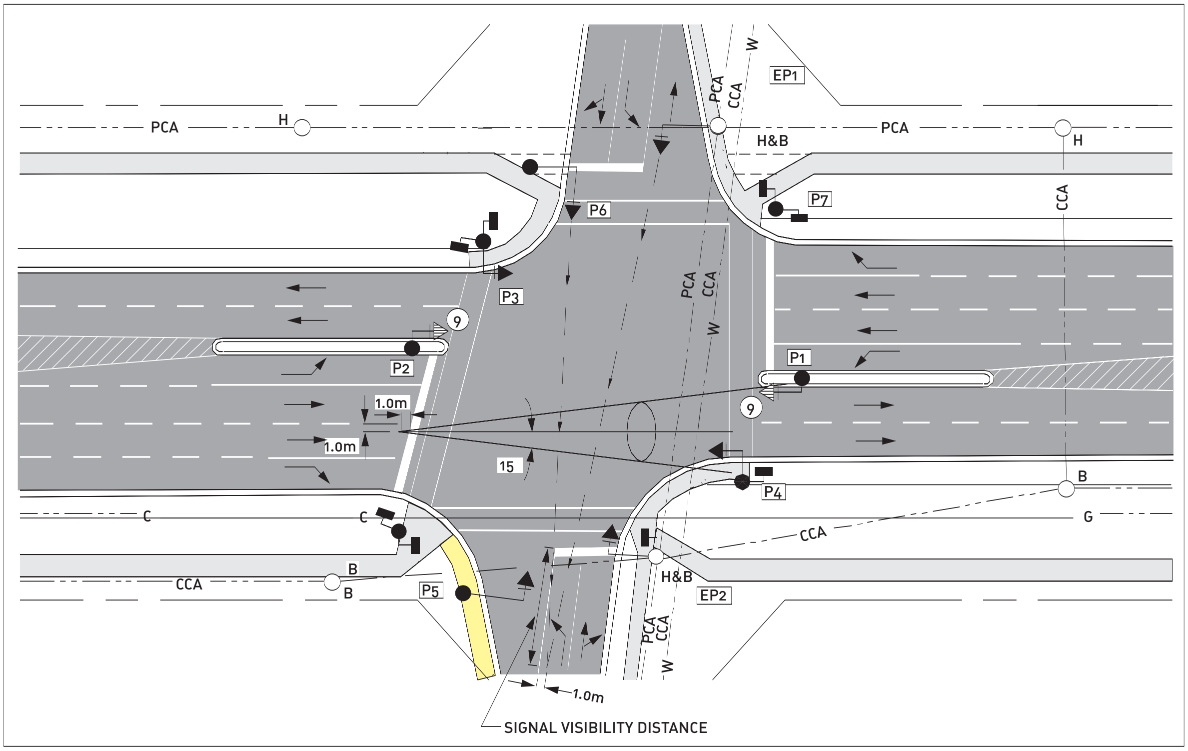


Figure 67 – Checking Signal Head Visibility and Layout

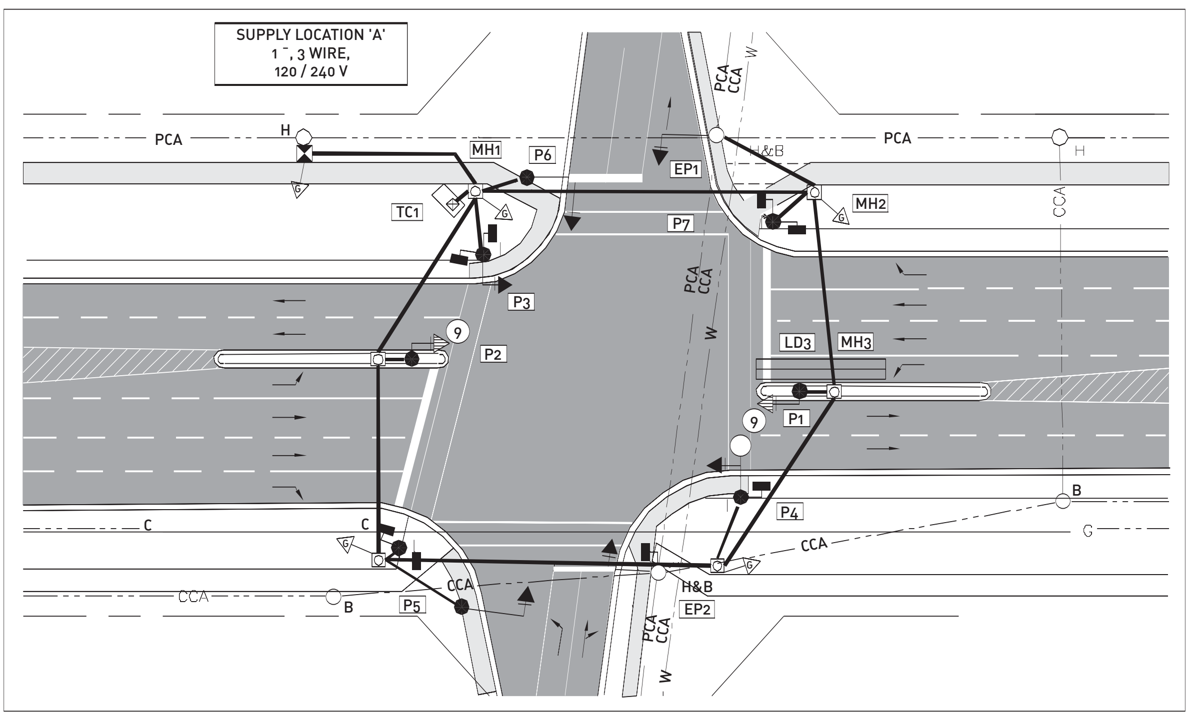


Figure 68 – Controller and Power Location

- The location of the power supply pole has some bearing on controller location; 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 to reduce the possibility of a double pole knock-down upon vehicle collision.
- 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. It should be requested that the local Supply Authority install their grounds at least one pole span away (see the Ministry's Electrical Design Manual, Part 2, Chapter 9,"Grounding"[2)].
- The power supply cabinet should be within 75 m of the controller and should be visible from both the controller and the roadway. It should also be located at least 10 m from the edge of pavement if possible.

Detector Layout

Detector loops are laid out as shown in Figure 69 for presence loops or with consideration of the dilemma zone as per Table 27 for extension loops on roadways posted at 80 km/h and over. The loops are designed using the principles of the Ministry's Electrical Design Manual, Part 2, Chapter 2, "Vehicle Detection"[2].

Figure 69 shows the detector loops laid out for the example. Note that there are two ways to number the loops. One method numbers the loops 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 loops serving a single movement common to the lanes involved.

Duct and Wiring Systems

Careful consideration must be given to the design of the underground ducts and electrical chambers due to their large cost, the possibility of prolonged traffic interference, the possibility of utility interference and possible 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 desirable to overhead wiring. The recommended practice for the design of duct systems is given in the Ministry's Electrical Design Manual, Part 2, Chapter 5, "Duct Systems"[2].

Figure 70 shows the underground system designed for the example intersection.

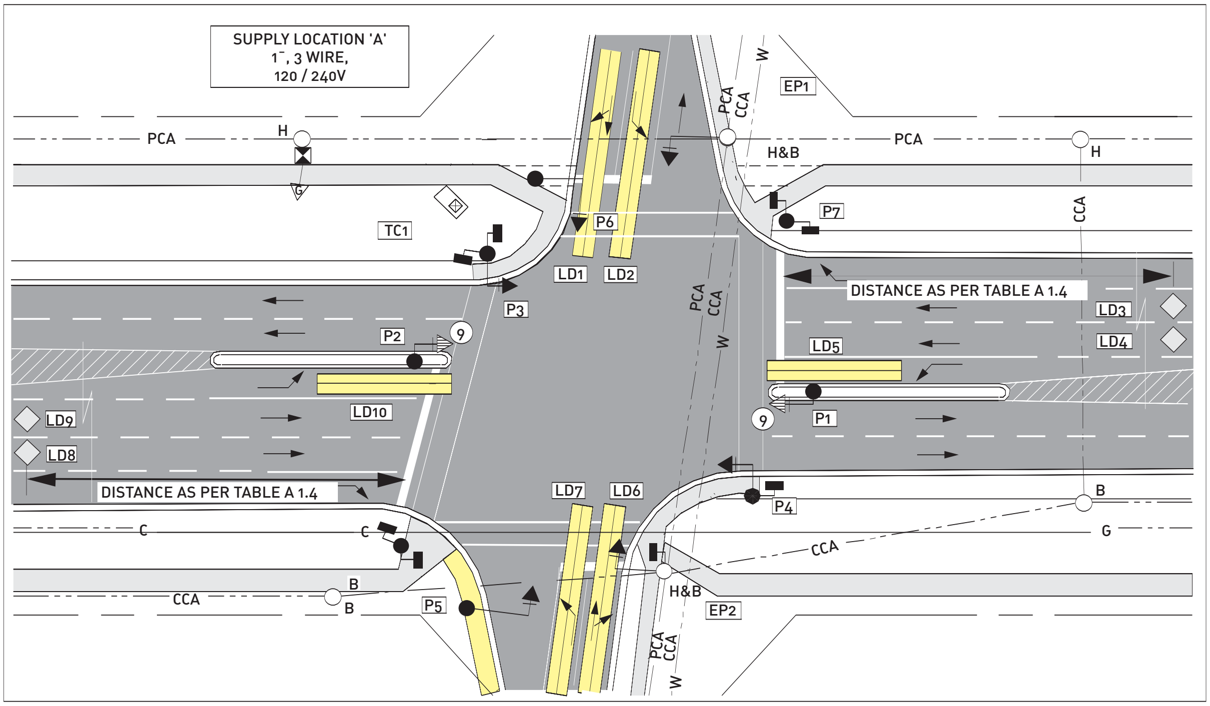


Figure 69 – Detector Loop Layout

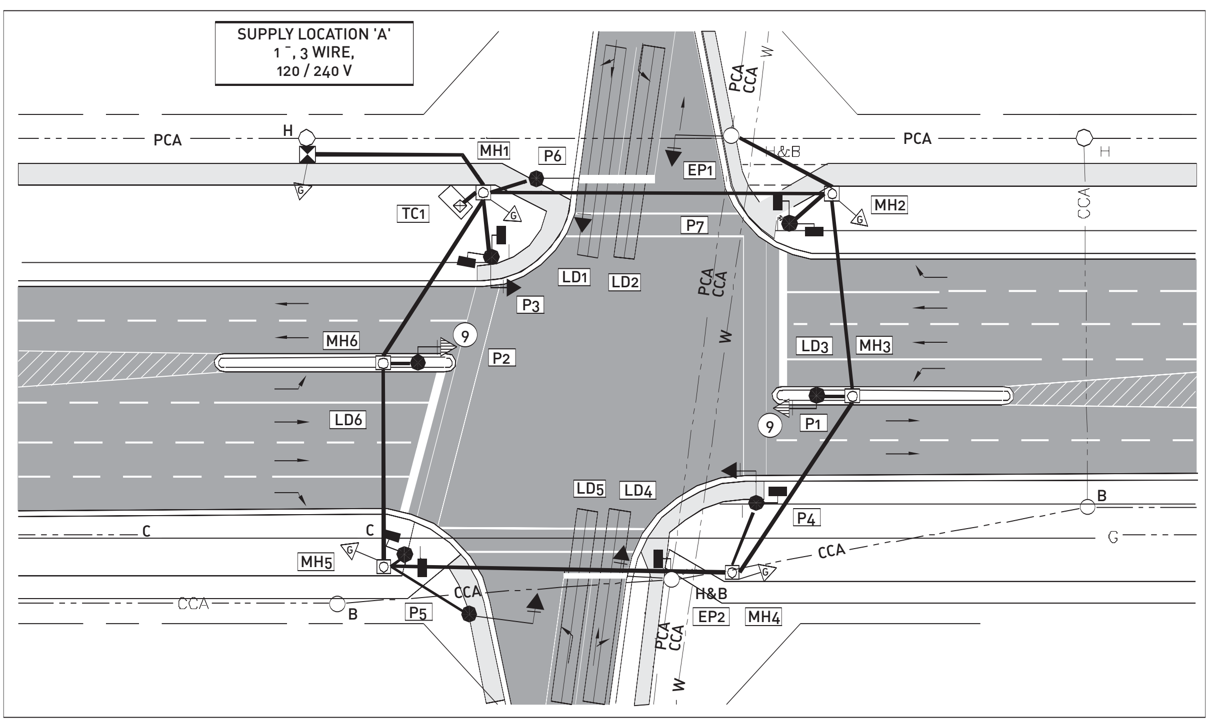


Figure 70 – Underground Duct System Layout

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. Refer to the Ministry's Electrical Design Manual, Part 2, Chapter 9, "Grounding"[2].

Figure 71 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 71. 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 as long as they are a minimum of 6 m from the signal poles and clear of utilities.

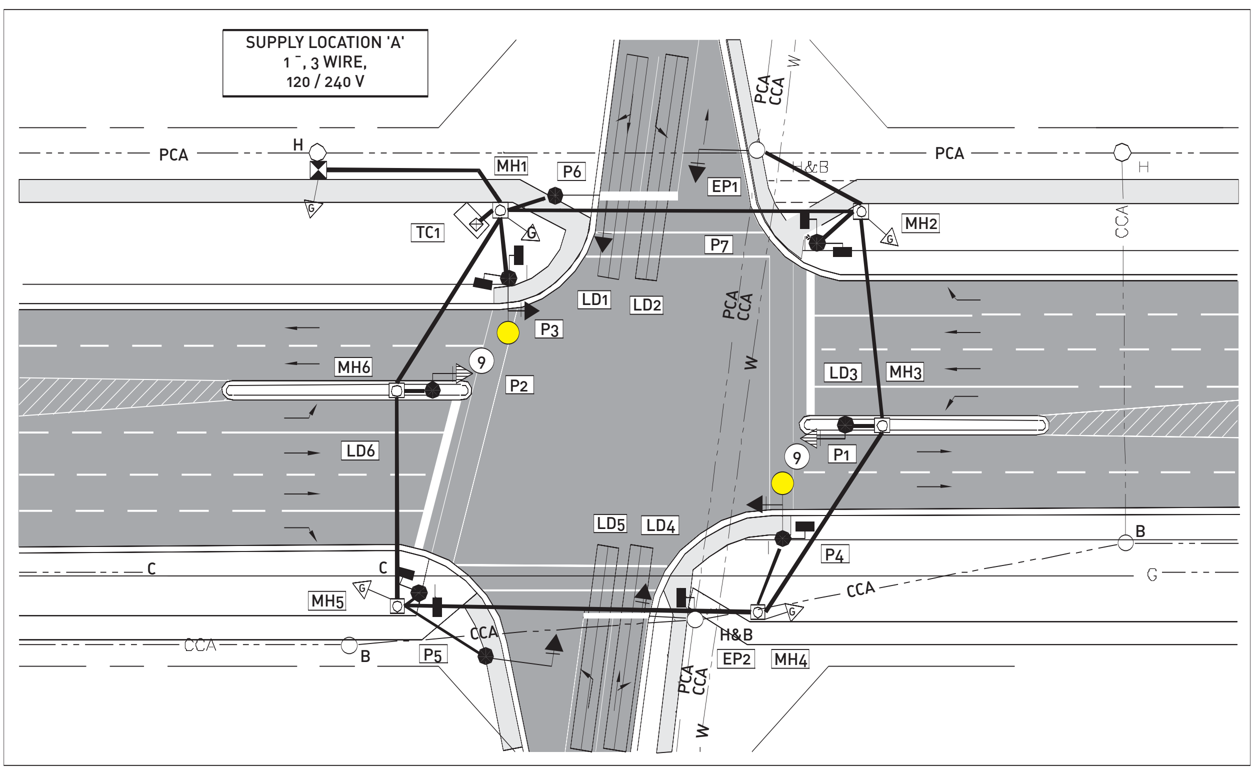


Figure 71 – Partial Lighting

6. MISCELLANEOUS

6.1 General

This part of the manual contains information on various miscellaneous aspects of traffic signal design and operation as well as some hardware information.

6.2 Standard Equipment

Maintenance staff stock standard equipment used for replacement purposes. Any variation in the selection of standard equipment as stock items should consider the compatibility with existing field equipment.

The design of signals is not an architectural competition although some municipalities make allowances for special equipment for downtown beautification schemes, prestige routes, etc. The best practice is to make each set of signals as close to standard as is practical since anything out of the ordinary may cause unfamiliarity for motorists and therefore may affect safety. The Ministry uses Ontario Provincial Standards Drawings (OPSD) for traffic signal purposes.

6.3 Other Considerations

Electrical Considerations

Traffic control signal design has traditionally been managed or approved by traffic engineers since 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 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 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 and a certain amount of local pride in their neighbourhood is natural. Since standard equipment is used in most installations, the treatment of aesthetic values consists mainly in avoidance of signal elements that are not considered to be very pleasing. Some examples are:

- Keep the number of poles to a minimum.

- The signal head displays and traffic signals are the only items we really want to consciously "see". Poles and all other equipment should be as inconspicuous as practical.
- Keep the length of single member arms to the minimum required to satisfy the criteria.
- Locations of corner poles with pushbuttons are the source of local complaints if the poles are not installed to be compatible with sidewalks, are behind barriers, have the pushbuttons on the wrong side or are sited to leave a few steps in the mud in order to reach the pushbutton.
- Where buildings are adjacent to the sidewalk, the poles should be sited such that no interference occurs with doors, windows and commercial signs. Spaces between poles and buildings should be a minimum of 1.5 m to allow space for sidewalk snowplows or 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 about 1.5 m beyond overhanging tree branches so that future tree trimming can be controlled without excessive trimming of large branches.
- Controller pads should be kept 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 so as to provide a minimum 1.5 m sidewalk space.
- Excessive equipment on poles, particularly 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 keeps these installations neater. This should be discussed with the power supply authority as to need and who should do the work.

6.4 Lamps, Lenses and Visors

Lamps

The lamps used for traffic signal indications should be chosen for compliance with ITE specifications for luminous output and for ruggedness and relative longevity. More information can be obtained from the ITE website (http://www.ite.org/standards/).

Lenses

Predominantly, lenses for incandescent displays should be standard prismatic plastic refractors meeting the chromaticity requirements of ITE Specification *Vehicle Traffic Control Signal Heads* contained in ITE Publication No. ST-017.

Exceptions to the standard lenses include optically programmable lenses, fibre optic lenses and light emitting diode lenses. Optically programmable lenses include lens assemblies that can be set to produce a narrow cone of light such that the lenses do not appear to be illuminated from traffic lanes other than those served. These lenses are used where multiple approaches may cause motorist confusion, such as at the second intersection of a very close set of intersections, on signalized service roads close to a freeway and for left turns in a wide median where the through traffic is not signalized.

Signal indications using light emitting diodes are being used in some jurisdictions in order to save energy and energy costs. The Institute of

Transportation Engineers (ITE) published an Interim Specification [*Vehicle Traffic Control Signal Heads (VTCSH) Part 2: Light Emitting Diode Vehicle Signal Modules -Interim*] in December 1995, which was officially adopted on July 1998. It covered 8" and 12" traffic signal modules only.

The interim VTCSH spec did not include the performance specification for arrow and pedestrian indication. Since than the following three specifications have been released specifically for LED traffic signals.

1. *Vehicle Traffic Control Signal Heads - Part 3: Light Emitting Diode (LED) Vehicle Arrow Traffic Signal Modules*, adopted March 2004.
2. *Pedestrian Traffic Control Signal Indications - Part 2: Light Emitting Diode (LED) Pedestrian Traffic Signal Modules*, adopted March 2004.
3. *Vehicle Traffic Control Signal Heads (VTCSH) - Light Emitting Diode (LED) Circular Signal Supplement*, released June 2005.

Copies of these specifications and more information can be obtained or purchased at the ITE website (http://www.ite.org). Ontario Practitioners should be aware that the shapes used for pedestrian signals throughout Ontario differ from those listed in the ITE specifications.

Visors

Visors must be used on all signal display assemblies to minimize the return of outside light through the lenses, which can cause the optical assemblies to appear illuminated. Normally, standard cowl visors with a shaped top and open bottom will suffice but where the sun strikes the lenses, particularly at low glancing angles, the phenomenon known as "sun phantom" may cause the optical assemblies to appear illuminated. In such cases, long cowl visors or tunnel visors should be employed.

6.5 Uninterruptible Power Supplies

Some Ontario road authorities are adopting uninterruptible power supply (UPS) systems for their traffic signals. As a battery based backup system, UPSs allow the signals to continue to operate for a short while after a power interruption. Most UPSs filter the incoming power and therefore also protect control equipment from supply voltage variations or surges.

Those road authorities that are implementing UPS backup systems generally can do so only at a limited number of intersections at a time. As a result, the process of identifying selected sites requires some form of prioritization.

The following are possible criteria to consider when establishing priority locations for UPS control. These criteria are not intended to be inclusive or complete and road authorities should amend, reduce or substitute this list to address the needs and priorities of their signals, policies and programs.

Possible candidates for UPS system installation may include traffic signals that

- Execute railroad pre-emption plans
- Reside near fire halls or hospitals
- Operate along emergency detour routes, border crossings or designated truck routes
- Involve high speed approaches and/or limited sight distances
- Reside in rural locations with no other illumination
- Operate at the bottom of a downhill grade
- Have a history of maintenance activity due to poor power quality
- Exhibit high traffic volumes
- Are located within bottleneck areas
- Experience collision patterns that can be reduced using signals

APPENDIX A
GLOSSARY

ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
AC	Alternating current
AC+	120 V a.c., 60 Hz power bus
AC-	The 120 V a.c., 60 Hz neutral bus grounded at the power source
ASTM	American Society for Testing and Materials
AWG	American Wire Gauge
CCG	Canadian Capacity Guide for Signalized (Urban) Intersections
CMOS	Complimentary metal oxide semiconductor
CPU	Central processing unit
CTS	Clear to send
DCE	Data communications equipment
DCP	Data channel port
DDE	Data distribution equipment
DHV	Design hourly volume
DTE	Data terminal equipment
EEPROM	Electrically erasable programmable read-only memory
EPROM	Erasable programmable read-only memory
FHWA	Federal Highway Administration (U.S.A.)
HCM	Highway Capacity Manual
HOV	High occupancy vehicle
IPS	Intersection pedestrian signals
ITE	Institute of Transportation Engineers
LED	Light emitting diode
LOS	Level of service
LTL	Left turn lane
MIST	Management Information System for Traffic
MODEM	Modulate/demodulate communications interface unit
MOS	Metal oxide semiconductor
MOV	Metal oxide varistor
MPU	Microprocessor unit
MTO	Ministry of Transportation, Ontario
MTTR	Mean time to repair
MUTCD	Manual of Uniform Traffic Control Devices
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 to provide 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, it 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 slave 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:
That part of the green interval in an actuated phase following the initial portion which may be exceeded by traffic actuations to the 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 utilize 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 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; 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.

Loadswitch:

A device used to switch 120 volt power to the traffic control signal heads. Loadswitches are normally semi-conductor devices that are switched by a low voltage signal from the controller unit.

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 alternate available modes of operation or accomplishing other supervisory functions. A Master Controller which controls one or more slave 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 (such as with an advanced green arrow and a circular green display). In some cases, a movement is called a faze since it 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 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 Time. (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 may be traffic responsive as determined by detector actuation.

Poll:
An enquiry message sent from a master to a slave on a regularly timed basis to solicit the status of the slave.

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.

Pre-emption:
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.

Pre-emptor:
A device or program/routine which provides pre-emption.

Presence Detection:
The ability of a vehicle detector to sense that a vehicle, whether moving or stopped, has appeared in its 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 prior to 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.

Slave Controller:
A slave 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.

Split:
For an actuated controller unit, 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 given

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 slave controllers or on a grid of roadways using either a master controller or a central computer. A system may use interconnection methods or telephone or able television networks or any combination thereof for communications transmission of data commands to the local slave 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 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.

APPENDIX B
REFERENCES

REFERENCES

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APPENDIX C
SIGN DESIGN CHECKLIST

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. Include any signing that is critical to the traffic signal operation, i.e., 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.

Review

1. Geometrics

- Should be acceptable for signal head placement.
- Drop curbs, etc., are identified, appropriate curb radius shown.
- Offset side roads are shown if part of signal.
- Private entrances are shown if part of signal. Heads must be used.
- Residential entrances shown. Note: these do not require signal heads but if they are used for commercial purposes or rezoned to commercial use or are for public use, heads must be provided.
- A split entrance, two entrances each allowing an in and out movement on each side on the same approach are not allowed to operate within the lateral curb lines of a signalized intersection or intersection to be signalized.
- Adequate pavement widths.
- 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

- Must be safe, may not create restricted or conflicting movements.
- Should be legible.
- Temporary drawings may be exempted from zone painting scheme if not feasible to show paint during staging.
- Stop lines and pedestrian crosswalks should be indicated.

3. Equipment

- All signal heads and equipment under HTA; primary head is always recommended to be a highway head with backboard.
- Secondary head may be a standard head with no backboard but preference is 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 correct number indicated as per special arrow chart. If no chart, a key must be drawn showing the lens display and lens sizes used.
- If used, pedestrian heads must be indicated.
- Push buttons are shown if pedestrian actuation is required. Arrows indicating direction of pedestrian pushbutton actuation are usually shown on the drawing.

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 loops are used on the highway if needed to extend the amber display (safe passage).
- Microwave, infrared and video detectors are used by various municipalities but presence loops are preferred by most and are the recommended choice.
- Microwave detectors can be useful for private driveways and temporary signals where permanent routes may not be possible or pavement is too poor to cut loops.
- Emergency vehicle preemption detectors are shown facing the direction of travel in which they are utilized.
- Railway preemption may be required if a railway crosses or is in close proximity to a proposed signalized intersection.

5. Phasing

- Phasing appropriate to the design may be utilized.
- Phasing should not create conflicting traffic movements.
- Phasing may never compromise the safety of pedestrians.

APPENDIX D
LEGEND

ABBREVIATIONS

AFG	Above Finish Grade
AC	Alternating Current
AWG	American Wire Gauge
AMB	Amber
BFG	Below Finish Grade
BGRD	Bare Ground
BLK	Black
BLU	Blue
CCT	Circuit
CE CODE	Canadian Electrical Code
CMS	Changeable Message Sign
CCTV	Closed Circuit Television
COMM	Communication
C/W	Complete With
COND	Conductor
CONT	Control
CDT	Conduit
CSA	Canadian Standards Association
CTMS	Corridor Traffic Management System
DB	Direct Buried
DC	Direct Current
EC	Electrical Chamber
EMI	Electromagnetic Interference
EQPT	Equipment
ELV	Extra Low Voltage
FO	Fibre Optic
FTMS	Freeway Traffic Management System
GRN	Green
GRD	Ground
HH	Electrical Handhole
HV	High Voltage
HEC	Hydro Electric Commission
IGRD	Insulated Ground (green)
IMPD	Impedance
IND	Inductance
ITS	Intelligent Transportation Systems
JB	Junction Box
LCS	Lane Control Sign
LV	Low Voltage
MH	Electrical Maintenance Hole
NEUT	Neutral
NIC	Not Included In Contract
OESC	Ontario Electrical Safety Code
PCS	Permanent Counting Station
PUC	Public Utilities Commission
PXO	Pedestrian Crossover
RF	Radio Frequency
RFI	Radio Frequency Interference
RMS	Ramp Metering Station
TS	Traffic Signal
XFMR	Transformer
UPC	Underpavement Crossing
VDS	Vehicle Detector Station
WHT	White
YEL	Yellow

SYMBOLS

Al	Aluminum
A	Ampere
Cu	Copper
F	Farad
H	Henry
Hz	Hertz
Ω	Ohm
PVC	Polyvinyl Chloride
V	Volt
VA	Volt Ampere
W	Watt
Wh	Watt Hour

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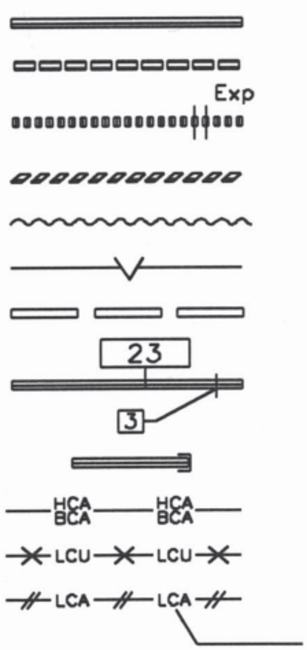
ELECTRICAL ABBREVIATIONS AND SYMBOLS

Date ______

OPSD – 2000.010

DUCTS AND CABLES



- Ducts and/or Cables, Underground
- Ducts and/or Cables, Surface Mounted
- Ducts and/or Cables Embedded. "Exp" Indicates Expansion Joint
- Cables, Installed in Existing Ducts
- Cables, Aerial
- Cables, in Pavement Slot
- Ducts and/or Cables, Future by Others
- Underpavement Crossing Identification Code, Note 1
- Reference Point with Identification Code, Note 1
- Duct Stub with Plug, Note 1
- Existing Cables and/or Ducts to Remain in Place
- Existing Cables and/or Ducts to be Removed
- Existing Cables and/or Ducts to be Abandoned
- Identification Codes For Existing Duct or Cable Usage:

IDENTIFICATION CODES, Note 2

BCU	Bell Cable, Underground
CCA	Communications Cable, Aerial
DC	Extra Low Voltage Detector Cable
GC	Guy Cable
HC	Hydro Cable
LC	Lighting Cable
PC	Power Cable
TS	Traffic Signal Cable
TV	Television Cable

NOTES:
1 The duct symbol shown is for illustration only, other duct and/or cable symbols may be used.
2 Add suffix U for Underground or suffix A for Aerial.

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MANHOLES, JUNCTION BOXES

MH32	Electrical Maintenance hole with Identification Code
JB36	Junction Box, Embedded or Surface Mounted with Identification Code
HH21	Electrical Handhole, Underground with Identification Code

PADS AND FOOTINGS

CP33	Concrete Pad with Identification Code
F43	Footing in Earth or Rock with Identification Code
F44	Footing on Structure with Identification Code
SF3	Sign Footing with Identification Code

POLES

P24	Pole with Identification Code
EP32	Existing Pole to Remain with Identification Code

LS

Identification Codes for Existing Pole Usage:

A	Authority Owned Pole
B	Bell Pole
C	Communications Pole
GP	Guy Pole
H	Hydro Pole
HM	High Mast Lighting Pole
LS	Lighting Pole
TS	Traffic Signal Pole
TV	Television Pole

LS

R33	Existing Pole to be Removed with Identification Code

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ELECTRICAL LEGEND II

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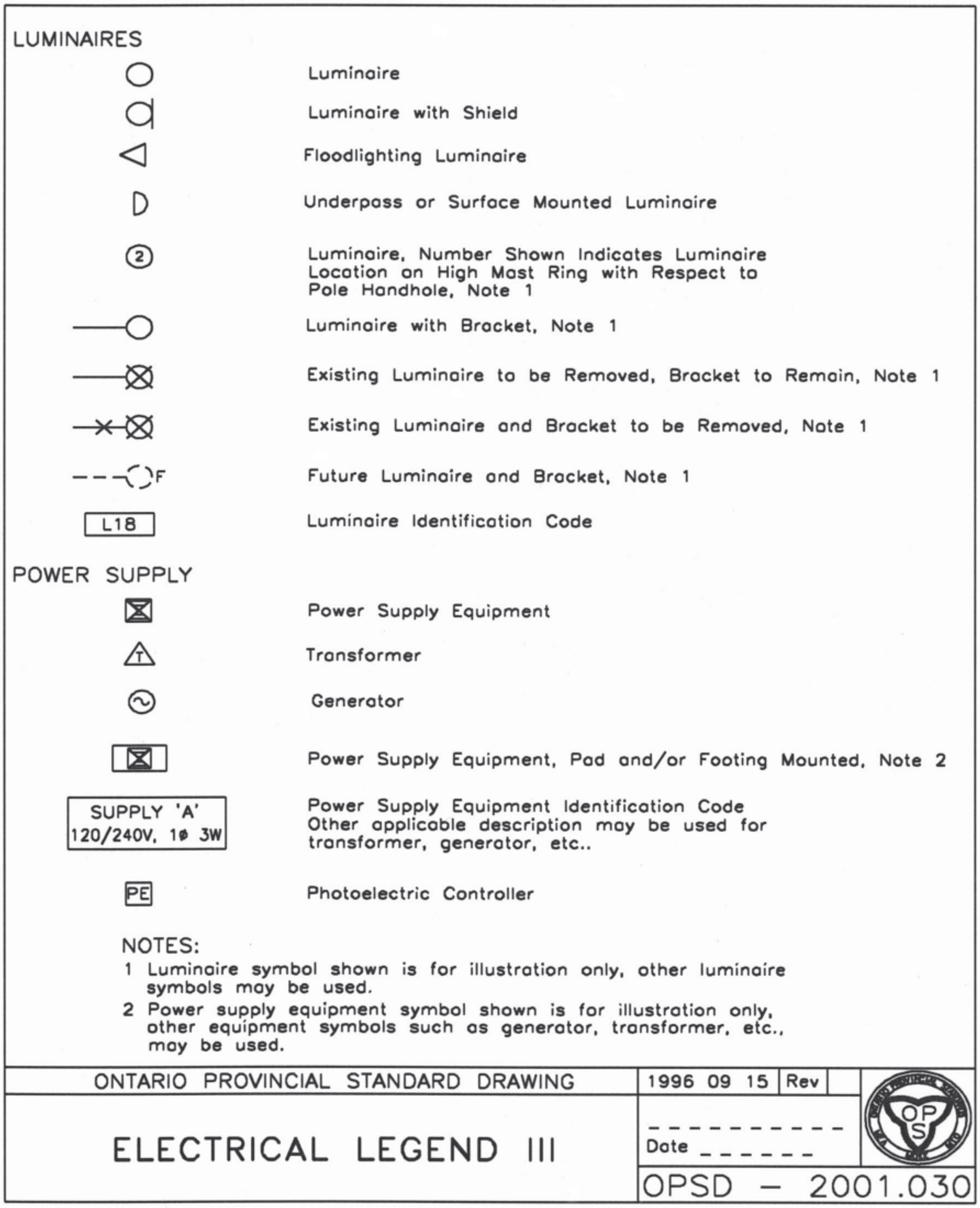
LUMINAIRES
Luminaire
Luminaire with Shield
Floodlighting Luminaire
Underpass or Surface Mounted Luminaire
2
Luminaire, Number Shown Indicates Luminaire Location on High Mast Ring with Respect to Pole Handhole, Note 1
Luminaire with Bracket, Note 1
Existing Luminaire to be Removed, Bracket to Remain, Note 1
Existing Luminaire and Bracket to be Removed, Note 1
F
Future Luminaire and Bracket, Note 1
L18
Luminaire Identification Code
POWER SUPPLY
Power Supply Equipment
T
Transformer
Generator
Power Supply Equipment, Pad and/or Footing Mounted, Note 2
SUPPLY 'A'
120/240V, 1ø 3W
Power Supply Equipment Identification Code
Other applicable description may be used for transformer, generator, etc..
PE
Photoelectric Controller
NOTES:
1 Luminaire symbol shown is for illustration only, other luminaire symbols may be used.
2 Power supply equipment symbol shown is for illustration only, other equipment symbols such as generator, transformer, etc., may be used.
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ELECTRICAL LEGEND III
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GUYING

	Single Guy with Single Anchor
	Double Guy with Single Anchor
	Double Guy with Double Anchor
	Single Guy with Sidewalk Strut and Single Anchor

CONTROL EQUIPMENT

	Controller Cabinet, Front Door Opens on Side Indicated
	Controller Cabinet with Adjacent Power Supply Cabinet on Side as Indicated. Front Door Opens on Side Indicated
	Controller Cabinet with Attached External Communications Interface Box on Side as Indicated. Front Door Opens on Side Indicated
	Controller Cabinet, Pad and/or Footing Mounted, Note 1
	Two Controller Cabinets, Pad and/or Footing Mounted, Side by Side Type, Note 1
	Two Controller Cabinets, Pad and/or Footing Mounted, In-Line Type, Note 1
TC2	Identification Code for Traffic Signal Controller Cabinet

NOTE:

1 Controller cabinet symbol shown is for illustration only, other controller cabinet symbols may be used.

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ELECTRICAL LEGEND IV

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DETECTORS

Code	Description
LD2	Simple Loop Detector with Identification Code
LD3	Duplex Loop Detector with Identification Code
LD4	Powerhead Loop Detector with Identification Code
LD5	Diamond Loop Detector with Identification Code
(2) (4)	Numbers Shown Within Loops Indicate Loop Numbers in a Set
PD3	Probe Vehicle Detector with Identification Code
OD2	Microwave, Lightwave, or Sonic Vehicle Detector with Identification Code
PB1	Pedestrian Pushbutton and Direction Arrow
	Video Detector

TRAFFIC CONTROL DEVICES

Code	Description
TS4	Illuminated Traffic Sign, Single Side with Identification Code
TS5	Illuminated Traffic Sign, Double Side with Identification Code
FB3	Illuminated Traffic Sign, with Flashing Beacon(s), with Identification Code
FB4	Flashing Beacon, with Identification Code
FB5	Flashing Beacons, 4-Way, with Identification Code, AMB-Amber RED-Red
FM2	Flasher Mechanism with Identification Code
PXO3	Pedestrian Crossover with Identification Code

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ELECTRICAL LEGEND V

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TRAFFIC CONTROL DEVICES

TS8	Traffic Sign, Overhead Sign Support with Static Sign and Identification Code
TS9	Traffic Sign, Overhead Sign Support with Changeable Message Sign and Identification Code
TS10	Traffic Sign, Overhead Sign Support with Lane Control Signs and Identification Code; May be used in combination with static or changeable message sign

CCTV

- T.V. Camera with Pan and Tilt Unit
- T.V. Camera, Fixed Location, Aiming Direction Indicated by Arrow
- Video Camera

COMMUNICATIONS

P22	Communications Pedestal with Identification Code
PS3	Coaxial Cable Power Supply with Identification Code
A12	Coaxial Cable Amplifier, Automatic Gain Control with Identification Code
A13	Coaxial Cable Amplifier, Manual Gain Control with Identification Code
A14	Coaxial Cable Amplifier, Automatic Gain Control in One Direction; Manual Gain Control in Opposite Direction with Identification Code
DC6	Coaxial Cable Directional Coupler with Identification Code

COAXIAL COMMUNICATIONS SCHEMATIC

- Standby Power Supply and Power Inserter
- Two Way Splitter
- Multi-Tap (4-way)
- 75 Ω Cable Termination
- 19mm — Coaxial Cable, Size as Shown

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ELECTRICAL LEGEND VI

Date

OPSD – 2001.060

TRAFFIC SIGNALS

Highway Signal Head, 300mm Red, 200mm Amber and Green Lenses, with Backboard

Highway Signal Head, All 300mm Lenses, with Backboard

Standard Signal Head, All 200mm Lenses

Standard Signal Head, All 200mm Lenses with Backboard

Special Signal Head with Backboard, Lens Sizes as per Table 1; Number Indicates Type of Signal Head as per Table 1

Pedestrian Signal Head, Two Section Type


FO

Pedestrian Signal Head, Single Section Fibre Optic Type

Signal Head with Backboard, Span Wire Mounting, Note 1

Signal Head with Backboard and Mast Arm, Note 1

Signal Head with Backboard and Double Arm Bracket, Note 1

NOTE:

1 Highway signal head symbol shown is for illustration only, other signal head symbols may be used.

TABLE 1 – SPECIAL SIGNAL HEAD CONFIGURATIONS

Type	No. of Sections	Lens Size in mm and Arrow Indication					
		Red	Amber	Green	Arrow	Arrow	Arrow
1	3	300	300	-	300 ↑ GRN	-	-
2	3	300	300	-	300 ← GRN	-	-
3	3	300	300	-	300 → GRN	-	-
4	4	300	300	-	300 ↑ GRN	300 ← GRN	-
5	4	300	300	-	300 ↑ GRN	300 → GRN	-
6	4	300	300	-	300 ← GRN	300 → GRN	-
7	5	300	300	-	300 ↑ GRN	300 ← GRN	300 → GRN
8	5	300	200	200	300 ← AMB	300 ← GRN	-
8A	5	300	300	300	300 ← AMB	300 ← GRN	-
9	4	300	200	200	300 ← AMB/GRN	-	-
9A	4	300	300	300	300 ← AMB/GRN	-	-
10	4	300	200	200	300 ← GRN	-	
10A	4	300	300	300	300 ← GRN	-	-
11	4	300	200	200	300 → GRN	-	-
11A	4	300	300	300	300 → GRN	-	-

AMB–Amber
GRN–Green
AMB/GRN–Amber and Green

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ELECTRICAL LEGEND VII

Date _ _ _ _ _ _

OPSD – 2001.070

MISCELLANEOUS

Symbol	Description
	Ground Electrode(s)
	Cable Protection Bricks, Concrete Cap, or Marker Tape in Trench
R12	Identification Code for Removal Equipment

WIRING DIAGRAMS

Symbol	Description
	Conductors, Single or Multiple, Identified by Note
	Indicates Cables to be Installed in the Same Duct
	Indicates Spare Duct for Future Use

2-19/C #14 TS-75mm — Wiring Identification Note

- 75mm — Duct Size, Aerial, or Direct Buried
- TS — Type of Cable:
  - TS – Traffic Signal
  - HV – High Voltage
  - LV – Low Voltage
  - ELV – Extra Low Voltage
  - CONT – Control
  - BGRD – Bare Ground
  - IGRD – Insulated Ground (Green)
  - CSA designations, may also be used
- #14 — AWG Size of Conductor
- 19/C — Number of Conductors in Cable; Not Required for Single Conductor
- 2 — Number of Cables

Symbol	Description
4	In-Line Cable Splice; Number Denotes Number of Cables
3	Tap Cable Splice; Number Denotes Number of Cables
OR	Wiring Enclosure, Manhole, Junction Box, etc., Identification Code Matches Layout Drawings
OR	Equipment Item; Identification Code Matches Layout Drawings

ONTARIO PROVINCIAL STANDARD DRAWING

ELECTRICAL LEGEND VIII

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