

Traffic Signals

Traffic Signals

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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1 General Information

1.1 Introduction

Book 12 of the Ontario Traffic Manual (OTM) replaces the Manual of Uniform Traffic Control Devices (MUTCD), Chapter on Traffic Signals.

This is a user manual intended to provide some elementary instruction 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; that all required information cannot be given in a manual; and that extensive knowledge and experience are required to be proficient in the field.

The material has been extensively revised from that previously given in the MUTCD and has been updated to reflect the following:

- the introduction of additional types of traffic signals including Intersection Pedestrian Signals (IPS), Transit Priority Signals (TPS) and Bicycle Control Signals (BCS);
- traffic signal needs and justifications incorporating changes due to recent developments;
- deletion of the requirement for Ministry approval of municipal signal designs from the Highway Traffic Act⁷ (HTA) and the consequent need to include more details on formation of design guidelines and procedures;

- the desire to emphasize the need for standardization of signal displays across the province. This includes the need to provide as much information to Ontario road authorities as is practical and the need to be compatible, where possible, with the Canadian national standard (TAC MUTCD¹²) and the U.S. standard¹¹.

1.2 Sections of this book

- **Section 1, General Information**, gives general information and basic signal concepts;
- **Section 2, Legal Requirements**, gives the legal requirements pertaining to application of the Highway Traffic Act;
- **Section 3, Operational Practice**, gives guidelines and recommended practice for operational features;
- **Section 4, Planning and Justification**, gives guidelines and recommended practice for justifying the need for traffic signals;
- **Section 5, Design Practice**, gives guidelines and recommended practice for design concepts, philosophy and details;
- **Section 6, Miscellaneous Information**, gives recommended practices and guidelines for miscellaneous aspects.

This book 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). A reference section is provided in the book.

The manual uses acronyms and, of necessity, some industry jargon. A Glossary is provided in the manual.

Where symbols appear for layout drawings, the symbols legend may be found in Ontario Provincial Standard Drawings¹⁵, Volume 4, Electrical Drawings, Division 2000. An abbreviated version of this legend may be found in Appendix D.

1.3 Use of This Book

In this publication, the meaning of identifying terms 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 Act⁷ (HTA) and its Regulations. The requirement is typically described by the use of "shall" or "must".

"Interpretation" means the interpretations and emphasis of the legal requirements. The interpretations are not necessarily precise wording interpretations of the HTA⁷ and Regulations. Many small items of application do not warrant a full description under the legal documents and further interpretation is required in the interests of safety, standardization throughout Ontario or other requirements. The interpretations are given in lay language and may include some jargon of the industry. The requirement is typically described by the use of "shall".

"Recommended Practice" means the best manner in which the legal requirements and interpretations are applied using the typical procedures and equipment in use in Ontario. The recommended practices are not necessarily the only practices available based on the interpretation of the legal requirements or the selection of equipment or methods of operation. The recommendation is typically described by the use of "should".

"Guideline" means a suggested method of practical application of the legal requirements and interpretations using the typical procedures and equipment and methods of operation in use in Ontario. The guidelines are meant to provide guidance to those in the traffic signal industry who may be unsure of the methods of application. A guideline has no legal connotation and several alternate methods of achieving the same result, consistent with standardization, may be available to the user. A guideline is typically described by the use of "may".

1.4 Classification

Traffic signals include electrically operated traffic control devices (except signs and pavement markings) which are recognized in the HTA⁷ and by which traffic is warned or is directed to take some specific action.

Traffic signals may be classified as follows:

1. Traffic Control Signals are defined as those which alternate vehicular and/or pedestrian right-of-way and include the following:

- Full Intersection Traffic Control Signals;
- Intersection Pedestrian Signals (IPS);
- Midblock Pedestrian Signals;
- Bicycle Control Signals;
- Moveable Span Bridge Traffic Signals;
- Transit Priority Signals;
- Ramp Metering Signals;
- Portable Lane Control Signals;
- Train Approach Signals; and
- Lane Direction Signals.

2. Flashing Beacons:

- At Intersections; and
- Warning Of Other Special Hazards.

1.5 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 efficiency and safety. Maximum efficiency implies the minimum delay to traffic. Safety requires that the traffic control signals operate at the minimum hazard to vehicles and pedestrians. Traffic control signals, as the name implies, are primarily control devices rather than safety devices.

Traffic control signals can seldom be justified as safety measures alone since their installation does not necessarily guarantee a reduction in collision experience. 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 lower overall delay without a signal than would occur waiting for a signal change at an unjustified traffic control signal.

Unnecessary 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 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 although some signals can be justified on a safety basis only.

Traffic control signals are to be used for the safe control and regulation of the movements of goods and people. 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 for use of a specific route.

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

1.6 Signal Indications

General

This Section describes the general usage of signal indications including some design and some operational features.

The meaning and position of the various traffic control signal indications described herein have been interpreted as standardized for use in Ontario and should not be varied. The meaning of the indications may be clarified or qualified, where appropriate, by a sign as identified in the Ontario Traffic Manual - Book 5 - Regulatory Signs.

Different operations and displays will depend on the need to produce a given level of service at the maximum level of safety for traffic movements as discussed in Section 4.

Continuity Of Operation

Once a set of traffic control signals has been installed, it should always display some indication under normal conditions. It should never intentionally be turned off unless control is provided by a police officer or an alternate method.

When the traffic signal is to be taken out of service for an extended period of time, the signal heads should be either removed or the lenses covered in such a manner that they are no longer visible to motorists and/or pedestrians. The absence of any signal indication will help to warn motorists that the traffic signal is malfunctioning. When signals are removed, some alternative form of control shall be introduced for that period.

If due to a collision or reconstruction, some or all of the existing traffic signal heads have to be replaced or relocated, 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 constable on site) the interim installation should be considered as being required. The temporary signal heads must conform to the requirements for traffic control signals.

Recommended Practice For Standardized Displays

In Ontario, standardization of the signal design for a basic two phase intersection has been achieved through the application and interpretation of the principles of the HTA⁷ and the previously published MUTCD¹⁰. The use of at least two vertically mounted signal heads located on the far side of the intersection from which traffic is approaching is a standard which has been used in Ontario for many years.

Traffic control signal lenses for vehicular traffic must be circular with a diameter of not less than 20 cm. At least the red indications of the primary signal head shall be 30 cm diameter. For roadways posted at 80 km/h and over, it is recommended practice that both primary and secondary red indications be of 30 cm diameter. All arrow indications shall be 30 cm diameter.

The standardized traffic control signal indications shall be shown by means of lenses not having visible lettering nor insignia of any kind on their surface, excepting special signal lenses used for pedestrian signal heads, arrow indications and transit priority signals.

The lenses shall be illuminated and shall produce a visual display conforming to ITE Standard ST -017²⁷ for chromaticity and luminance of the red, amber ("yellow" in ITE publications) and green displays and shall be clearly distinguishable under all normal conditions of visibility.

The standard indications used in Ontario are shown in Section 2, Figure 1.

2. Legal Requirements

2.1 General

Section 2 gives an interpretation of Subsection 144 (31) and Regulation 626 of the Highway Traffic Act⁷ (HTA) together with recommended practice guidelines and comments. The April, 1996 edition of Regulation 626 is used.

2.2 Approval Of Signal Designs

HTA Statute 144 (31) - Approvals

1. General

A revision to The Highway Traffic Act (HTA), Subsection 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 Municipalities are responsible for designating a person to approve traffic signal designs and installations on their own roadways;
- ii The Ministry will still approve traffic signal designs and installations for connecting links;
- iii For highways and ramp terminal intersections under Ministry jurisdiction, the Ministry will continue to follow the practice of preparing form PHM-125 for each signal and these will be reviewed and approved internally; and
- iv 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 form PHM-125 and submitting it to the Ministry for approval.

4. Recommended Practice

- i It is a recommended practice that municipalities should follow a similar procedure, within their own organizations of preparing, approving and updating traffic control signal drawings to ensure that a competent person reviews the design and in order to assist in the protection of the municipality should a traffic collision or other mishap occur. A continuing program of proactive risk management including the approval procedure is strongly recommended.
- 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 qualified persons 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 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 which directly affects the signal operation (usually 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; and
 - detection devices and their location.
- 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;
 - electrical details such as underground ducts, electrical chambers and controller and power supply locations;
 - property lines, street lines, building outlines, parking meters and parking control;
 - bus bays and bus stops;
 - lane dimensions; and
 - information/guidance signs.
- v It is recommended practice that if signal heads are relocated or, if additional signal heads are installed, then re-approval of the entire installation is required by the designated approval person.
- vi It is recommended practice that approval plans should be prepared for both temporary and permanent signals.

2.3 Regulation 626

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

1. Legal Requirements

Sub-section 1(1) states: *“Every traffic control signal shall consist of one circular amber and one circular red indication in combination with,*

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

2. Interpretation

- i Every traffic control signal must have a mandatory circular red and circular amber indication;
- ii Every traffic control signal head must have a mandatory green indication.
- iii The green indication may be composed of a single circular green or a maximum of three green arrows, indicating only right, left and through traffic movements, or
- iv Where a circular green indication is used (indicating that all traffic movements are allowed; a “permissive” display), only one additional green arrow indication may be used in the same signal head, indicating that either left or right turns, specifically in one direction only, are “protected” from interference from a conflicting traffic movement;

- v Where the green indication consists of either left, right or through arrows or any proper combination thereof, with a circular green (for example, with type 10 or 10A heads as per Figure 1), then the arrows indicate single protected movements which 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 lens indications should be combined** in one signal head;
- ii Every green indication (circular or arrow) must have an amber (circular or arrow) indication to indicate that the green interval has ended;
- 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 and an amber arrow is recommended to act in conjunction with the green arrow to indicate that the protected 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 fibre optic or LED arrow which 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) as would be used with the flashing green arrow in this type of operation;

- iv **The standard indications shown in Figure 1 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 which is not shown in Figure 1. 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; and
- 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 1. 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	Note 2 below
Straight Through Green Arrow	Note 3 below
Left Turn Green Arrow	Note 3 below
Right Turn Green Arrow	Note 3 below

Notes:

1. The circular green indication may be replaced by a straight through, left turn or right turn green arrow where indicated.
2. The amber arrow direction must be the same as that of the green arrow 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 1 shows the **only types of traffic signal head configurations which shall be used due to the need to maintain uniformity** in Ontario (with the exception of

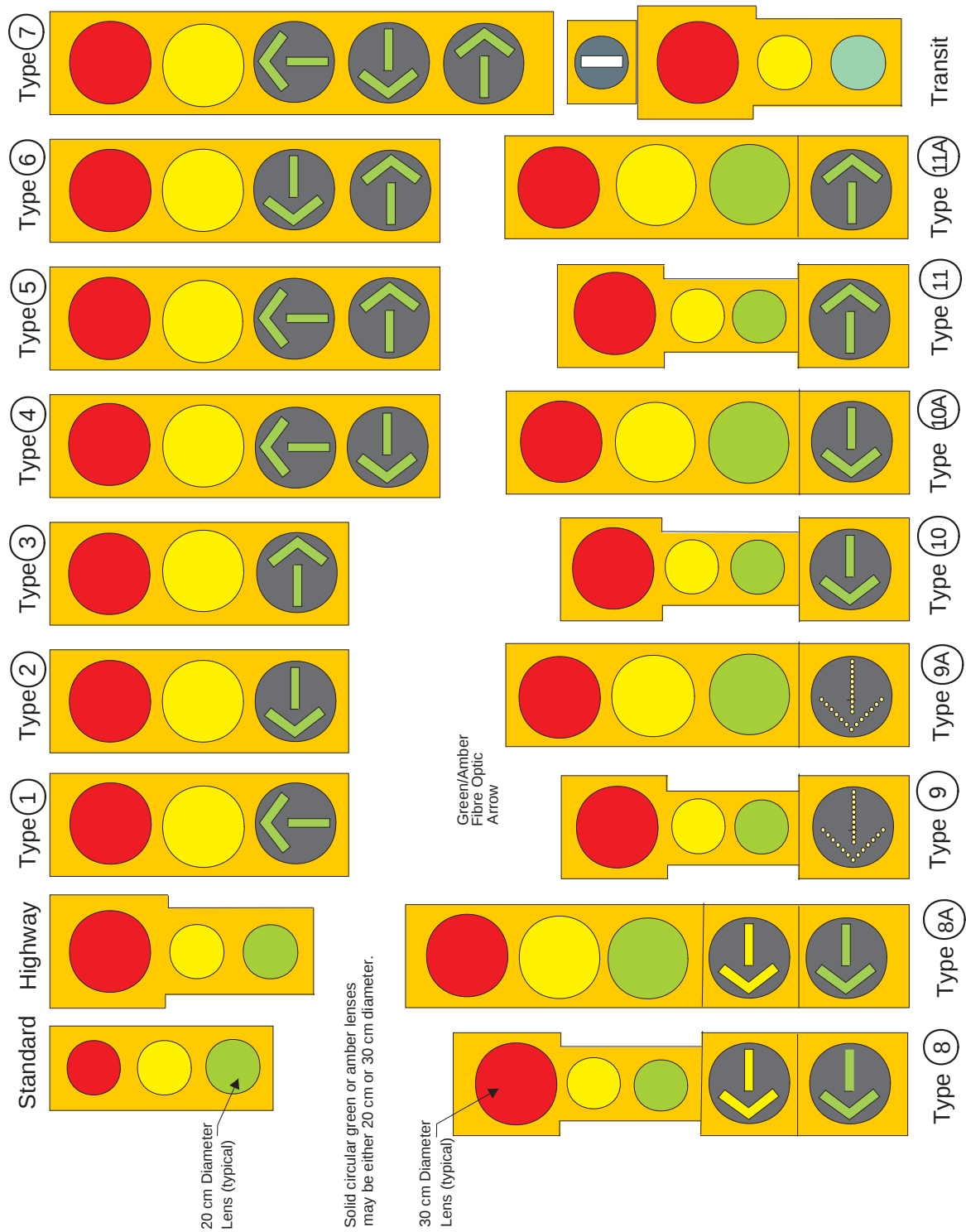


Figure 1 - Traffic Control Signal Heads
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lens size which may be either 20 cm or 30 cm for circular lenses). Exceptions to the types of heads shown should only be used where authorized by a senior and experienced traffic engineer/analyst and with the approval of the road authority; and

- 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; and
- ii A red indication is not allowed to be displayed at the same time as a circular amber or 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 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 1, 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 which 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 Any fully protected phase, such as a left turn operation facing type 2 signal heads, a bicycle phase and so on, shall use a layout with two separate signal heads. In the case of the fully protected left turn operation, the type 2 head on the traffic island is the primary signal and the type 2 signal head on the far left side of the intersection fulfills the need for the secondary signal head;
- iii 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.
- 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, schools, churches, community centres, etc. which front onto an intersection should be signalized normally.
- v For **private driveways** which front onto an intersection, it may be desirable to provide the driveways with traffic control signals.
- 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** (a maximum of three heads is permitted). This distinction is made so that there will be no confusion with the fully protected type of operation. 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 which permits traffic to either proceed through the intersection, to 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 Signals¹

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) where PXOs may not be appropriate because of pedestrian volumes, pedestrian types (young and seniors), the Authority's policy 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 MUTCD¹² indicates use of crosswalks on both sides of the side road and this type of IPS is used in some parts of Canada.)
- 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); and
- 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 overheight 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

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);

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; and

- 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

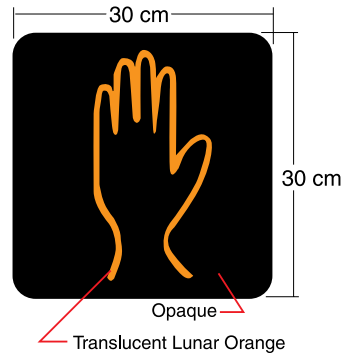
- i This subsection refers to special “ramp metering” signals used on some freeways to control the number of vehicles per hour entering the main freeway traffic. The recommended practices and guidelines for normal traffic control signals do not apply to these special signals since the approach speed 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 a opaque background as illustrated in the following Figure.”*



- iv 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;
- v 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.

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 Fibre optic, LED or incandescent sources may be used if they meet the colour requirements of ITE Publication ST-217;
- iii 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 2.75m 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".

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

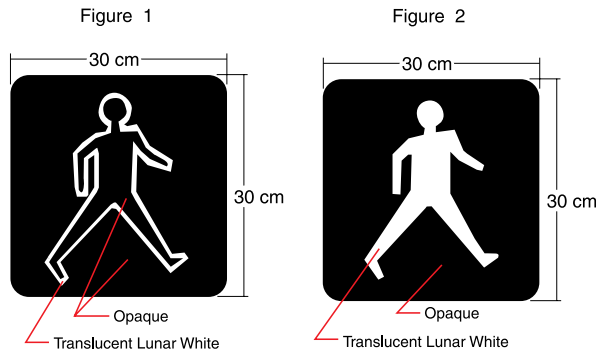
1. Legal Requirements

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 1; 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 2." O. Reg. 213/92, s. 1(1).

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 Fibre optic, LED or incandescent sources may be used if they meet the colour requirements of ITE Publication ST-217 for suitable white symbols.

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; and
 - The “walking pedestrian” symbol may also be in a separate head mounted below the hand.

3. Recommended Practice

- i Single head fibre optic or LED pedestrian heads or two-section pedestrian heads with incandescent lamps may be used in lieu of the traditional dual section head shown; and

- 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.



good reasons; and 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; and

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

- 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 where present in front of the activity that is taking place.**

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

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 which 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 protected/permissive movements during a left turn, and where these are on phases occurring simultaneously, the circular amber indication operates in conjunction with the circular green indication and **an amber arrow is required to follow a green or flashing green arrow**. The left turn amber arrow shall consist of either a fibre optic or LED arrow which changes from green to amber, or a separate amber arrow may be mounted above the green arrow.
- iii Refer to Section 3 for explanation of the terms “permissive” and “protected”

3. Recommended Practice

- i Signal headtypes 8, 8A, 9 or 9A of Figure 1 should be used for the protected/permissive indications;
- ii Flashing green and amber arrows are allowed but caution should be used in their application as discussed in Section 3.5.

3. Operational Practice

3.1 Introduction

General

This part of the manual gives an overview of traffic signal operational practice. It is required to use industry jargon to describe various pieces of hardware and signal operations terms and the traffic engineer / analyst is referred to the Glossary to obtain an understanding of any unfamiliar terms which are not explained here.

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).

Standardization

Standardization of many of the aspects of traffic control signal operations throughout Ontario is important from the viewpoint of motorists' expectations and hence safety.

Signal operations range from the simplest two-phase operation to complicated eight-phase operation at the intersections of major arterials. The local operation may be complicated by single or dual simultaneous left turn phases and right turn overlaps.

Modes of operations range from night flash to simple single plan pretimed mode to the complex multi-plan with changing cycle lengths and differing phase and interval sequencing and timing. In all modes, the operations shall be consistent with the established practices for safety reasons.

Standardization is achieved through the application of:

- consistent determination of the need for 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 determination of the need and type of phasing;
- determination of the need for coordination, the need for interconnection or the need for a central system.

Complex items which require some standardization in the method of solution provincially and locally are:

- the operational design of phasing requirements and phase and interval timing;
- timing of clearance intervals;
- determination of phase time-of-day omissions or additions; and
- determination of the need for advanced pedestrian and advanced amber displays where intersections are close together, and for sequences required for optimization of traffic flow.

Signal Operations Report

A Traffic Signal Operations Study should be undertaken at intersections with operational problems 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;
- confirmation of through volumes of traffic;
- percentage of heavy trucks and buses;
- proximity to other intersections;
- the need to operate independently or on a system;

The benefit/cost ratio of the proposed improvements or new signals may also be considered.

the required phases for the intersection;

- the computer board sends commands via a 24 Volt line to an electronic loadswitch which allows 120 Volts to pass through or be cut off from the incoming line to the signal head indication lamps;
- various peripherals monitor the controller circuits; “watchdog” circuits monitor voltages and currents and alert the “conflict monitor” to shut down the signals and revert to “all flash” mode.

It is at the discretion of the roadway authority to select the type and brand of available 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 hardware specification where the input/output specifications are all laid out for any manufacturers to follow. Operational software must be purchased separately for a number of functions.

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 widely used by municipalities, they are not discussed in this manual.

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

- the Central Processing Unit (CPU) (or Remote Processing Unit (RPU) if the controller is in a system) of the controller is programmed using appropriate software to set all timed and actuated intervals and variables and to allow

Many municipalities use the NEMA specification ^{24,26} controllers of either TS1 or TS2 (Type 1 or Type 2). NEMA is a functional standard where controller functions that all manufacturers must follow are laid out. The NEMA controller is supplied complete with the manufacturers’ operational software which meets or exceeds the functional specifications.

All modern controllers have connections available for conflict monitors. Conflict monitors detect the interruption of electronic circuits due to lightning and power surges and detect signal conflicts on green, amber and walk signals as well as the absence of voltage and the absence of a red signal on all of the signal indications. Controllers shall not be operated without conflict monitors.

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 following:

- the variation between peak and average hourly traffic volumes on the main road;
- the variation between morning and afternoon average hourly volumes on the main road;
- the variation between morning and afternoon average hourly volumes on the side road;
- the percentage of the total average hourly volume using the intersection which enters from the side road;
- the percentage of large vehicles;
- special usage such as bicycles and transit buses;
- 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.

For any intersection, it is desirable to optimize 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 ends the ITE's "Canadian Capacity Guide for Signalized Intersections¹" (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, and so on¹.

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. Maximum efficiency and safety are derived from traffic control signals only where the lengths of the various intervals are set in accordance with traffic demand 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 reach, methods for which are all defined in the CCG.

4. *Evaluation:*

This includes the evaluation of any changes made to the traffic control signals for capacity related criteria, queuing related criteria and other criteria.

To achieve these ends, and 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, clearance intervals;

- timing design for cycle times composed of times for green intervals, walk intervals and clearance intervals; and
- analysis of the assigned parameters to specific criteria that is related to 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)" which is primarily for urban conditions but may be used for any intersection.

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, season;
- volume percentage of total traffic volume through the intersection as generated by the side road;
- 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 which operates within a fixed cycle length using preset intervals and no detection. A pretimed signal is a traffic control signal which 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 and do not vary significantly. 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 acceptable than traffic-actuated control in areas where large and fairly consistent pedestrian volumes are present, and 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.

Pretimed control tends to be most applicable at intersections which are part of a signal system in an urban area and where variations in volume are predictable and control timing can be pre-set to accommodate variations throughout the day.

Actuated Mode

An actuated signal is a traffic control signal which services movements based on demand. Actuated signals make use of detection to respond to vehicle calls 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 which 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. A background cycle time may be superimposed upon the operation to effect coordination with nearby signals. This operation is normally sluggish due to the requirement to fit into the coordination window;
- traffic-actuated control may minimize delay during periods of light traffic because no green time is provided to phases where no traffic demand exists;
- semi-actuated control tends to 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 to an intersection of a heavy-volume traffic arterial with a relatively lightly travelled side road. The signal is normally green on the main road, changing to the side road only as a result of a vehicle or pedestrian actuation thereon or on continued actuation of the main road left turn detector (indicating that turning gaps are not available).

In some types of controllers, the sideroad green intervals are of fixed duration, which may be undesirable. In the more flexible types of controllers, the duration of the side road green interval varies according to the traffic demand thereon, with provision for a maximum limit beyond which the green display cannot be retained on the side road even when traffic demand on it is heavy. Upon the expiration of the required or maximum 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, and therefore may frequently assign the right-of-way to the side road at the most inopportune time for main road traffic. Hence the effective use of semi-actuated control is limited to intersections with very lightly travelled side roads and to 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 during a fixed cycle which best accommodates main street progression.

In a semiactuated controller, signal indications are not 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 intervals may be omitted when there is no actuation or demand from waiting vehicles or pedestrians. In semi-actuated operation, the main road may have the “mainroad ped recall” feature activated. In this mode, the walk signals along the main road are on as well as the main road greens and pedestrian movements on the main road are therefore facilitated. A common variation is the rest mode for the main road green/walk with the minimum walk timed out and delay represented by the flashing Don’t Walk (FDW). Side road actuation calls will send the controller unit into the FDW pedestrian clearance interval. For coordinated systems use, the main road pedestrian signals may rest in “Don’t Walk”.

Fully-actuated Mode

This type of control requires detection on all approaches of both the main road and the side road. Fully-actuated control should be selected for intersections where failure to take all traffic demands into account will materially impair the efficiency of traffic control. 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 movements are heavy only during specific periods and light the rest of the time;
- high speed locations where there is a need to avoid “dilemma zone” problems.

Where, in rural situations, 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 or recalls to main road green. The operation may be used in coordinated systems with a background cycle superimposed upon the operation to effect coordination with nearby signals.

A variation is used on roadways posted at 80 km/h or greater where the sideroad is actuated but the main road rests in green, and has extension loops set back from the stop line. The long distance or “passage” loops are located at an upstream distance as given in Section 4. The purpose of the passage or “extension” loops is to add to the main road green time to allow the higher speed main road traffic to enter the intersection one second before the amber signal is displayed. This aids in decisions within the “dilemma zone” and allows motorists to continue through the intersection without hesitation. If the traffic on the main road is heavy, the extension loops will be registering calls regularly and extending the main road green time, until a maximum programmed time limit is reached. At that time, main road green is said to have “maxed out” and the side road phases are initiated regardless of the main road traffic.

System Operation

General

A system can vary from two or more interconnected controllers to large centralized computers controlling thousands of intersection controllers. Two or more 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.

Signal systems, except for systems using traffic adaptive software such as SCOOT (Split Cycle Offset Optimization Technique), use a common cycle length and have a definite offset relationship between their main road greens (or advanced or delayed greens) for each major section of road. Any system which accommodates traffic progression offers the following advantages over isolated/ independent operation:

- traffic normally moves in tight groups or platoons, with clear gaps between platoons, which may be utilized for vehicle or pedestrian crossing times at sideroads or at secondary intersections or entrances between signalized intersections;
- stops and startup delays 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 headways and startup delays;
- reduced collision rates 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;
- systems with central communications offer 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

Systems are normally initially started for intersections in the Central Business District (CBD) but inevitably expand outwards to major arterials in outlying areas. The problems of both types of areas are different and are sometimes treated differently with respect to the controlling software used and the number of plans per day that are required. As well, CBD systems are normally based on grid networks and systems in outlying areas may be local arterial coordination systems.

Where an arterial has multiple sets of signals but the signalized section is itself isolated from other sections of signalized roadway, a coordinated interconnected system should be considered for local 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.

In such 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.

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 the new cycle length and offset required to accommodate the progression of the platoons.

Pretimed control is normally used for simple interconnected systems and on minor centralized systems. Pretimed operation can promote the formation of tight platoons of traffic where good progression is possible. This is because vehicles entering the coordinated route will usually be released from the first intersection with a high probability of getting a green signal at all downstream intersections on the route. However, actuated control may reduce system delays if a significant proportion of vehicles

join the route from side roads or accesses along the route, and arrive randomly at intersections within the route. Actuated control will simulate pretimed control when vehicle volumes are high enough on the side street that continuous vehicle actuation causes the side road to go to the maximum green time allowed.

Actuated control has some advantage for use on interconnected intersections which are not being continually actuated at the side roads. In these cases, some progressions, which are less than optimal due to the distance between intersections, can be made through the intersections except during times when actual transfer of right-of-way is required. Controllers operating in actuated mode may be fitted with a coordination unit to interconnect with pretimed controllers.

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 to each intersection for the beginning of main road green. Normally preference is given to the direction with higher traffic demands when determining offsets. The extent to which two-way progression can be achieved 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

Table 2 (page 26) may be used as a guide for the selection of the type of controller operation at any isolated intersection subject to variation in the local conditions. In Table 2, the 20% volume variation is taken as the critical value since with average volumes, this variation would require a change in cycle length which cannot be accommodated with single plan pretimed operations. Actuated control may be used

to advantage at complex intersections where simplification is not possible and where a minor movement must be accommodated since it can be arranged for one or more phases to be omitted when not required.

3.5 Phase Determination

General

The number of phases required for efficient operation will depend on the physical characteristics of the intersection, the equivalent through volumes and the equivalent volumes of turning movements taking place. The least 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” (CCG¹).

Factor	Pretimed Single Plan	Pretimed Multi-Plan	Semi-Actuated	Fully-Actuated
a) Main Road variation between average and peak hourly volumes	Less than 10%	Any value	Less than 20%	More than 20%
b) Main Road variation between morning and afternoon average hourly volumes	Less than 20%	More than 20%	Less than 20%	More than 20%
c) Side Road variation between morning and afternoon average hourly volumes	Less than 20%	More than 20%	More than 20%	More than 20%
d) Side Road volume percent of total volume through intersections	Less than 30%	More than 25%	Any value	Any value
e) Seasonal traffic volume variation	Not recommended	Satisfactory if adjusted	Preferred	Satisfactory

Table 2 - Controller Operations Types for Isolated Operation

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 such a case.

The number and type of phases required will be largely dependent on the left turn volumes-and-intersection geometrics. An analysis of the left turning volumes and intersection geometrics will determine what phases are required. The number of phases and their sequence will constitute the cycle structure.

Standard Movements

General

It is recommended that the standard traffic movements, as identified by number, be used for the type of controller to be utilized.

The type 170 controller¹⁶ and the NEMA type controller^{24,26} use similar but different methods of movement identification.

Traffic Movements for Type 170 Controllers

Type 170 controllers identify traffic movements as shown in Figure 2. The “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 clockwise around the intersection;
- 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 location and progressing clockwise around the intersection;
- faze 2 always opposes faze 1. Odd number fazes are always left turn movements and even numbered fazes are always through movements.

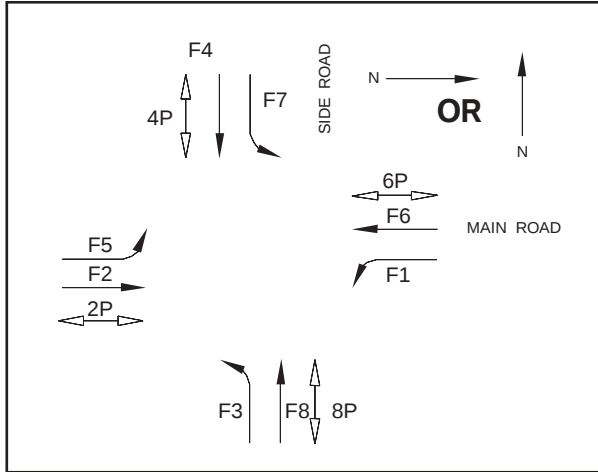


Figure 2 - Type 170 Fazes

Traffic Movements for NEMA Type Controllers

NEMA type controllers identify movements as indicated in Figure 3. The "P" designates a pedestrian movement number. The following convention is used:

- the through movements are even numbers starting with movement 2 (always on the main road) in either the northbound or eastbound location and progressing counter-clockwise around the intersection;

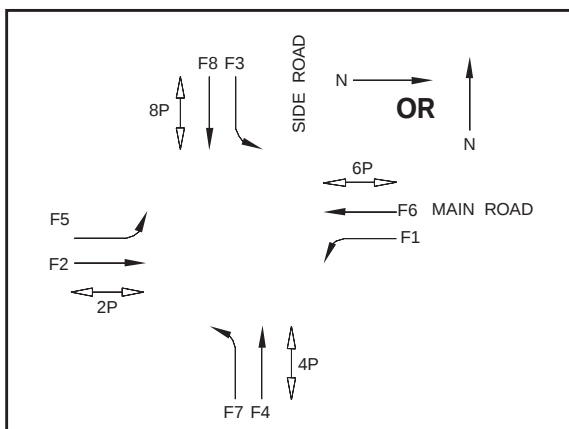


Figure 3 - NEMA Movements

- the left turn movements are odd numbers, starting with movement 1 (always on the main road) in the southbound to eastbound or the westbound to southbound location and also progressing counter-clockwise around the intersection;
- movement 2 always opposes movement 1. Odd number movements are always left turn movements and even numbered movements are always through movements.

Interval Sequence

The interval sequence occurs in a predetermined order, within any phase.

A phase is composed of two or more intervals consisting of specific displays of green, green arrow, amber, amber arrow and all red indications which may provide timing for one or more subordinate or split phases. For example, if there are no separate left turn displays provided, the operation is a simple "two phase" one (abbreviated as "2Ø") and through greens proceed concurrently (they are "tied together") followed by ambers, all red clearance interval and then the side road through movements concurrently. The traditional normal sequence of phases with left turn indications, as may be used at isolated intersections, is indicated in the following phase "diagrams". Opposing movements may be considered interchangeable depending on actuation or intervals may be skipped or tied together.

Phase Diagrams

It is essential that phase diagrams on the approved signal plan show the following information in order to avoid any confusion or misunderstanding at a later date:

- each lane should be shown;
- the signalled 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;

Typically, in the following sections, all phase diagrams are specific to the application and must be individually devised for each intersection. The examples shown use “permissive” and “protected” 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, no conflicting traffic is permitted to proceed during a protected left-turn movement. The left-turning motorist is given a signal display which provides right-of-way for the left-turning vehicle over conflicting traffic. Pedestrians 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 with an accompanying sign or by a flashing circular green or a solid or flashing left green arrow.

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 one to another within the same intersection.

In some cases, simultaneous left turns are used where left turns 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. Because it is common to apply detection to both 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

A simple two phase operation is satisfactory for many intersections. In this operation, the controller simply alternates between main road and side road greens under any mode of operation. Figure 4 shows the phase diagram.

Three Phase Operation

With the addition of a left-turn signal on any approach, the operation becomes a 3 phase one as shown in Figure 5 in which movement 5 is the advance green (any of the other three can be selected, in proper sequence). Note that this operation would be classed as “protected permissive” as the left-turn green signal display would be a left-turn arrow type 8, 8A, 9 or 9A, a flashing circular green or a flashing green arrow for the protected left-turn movement. Left turns would also be permitted after the left-turn display has stopped.

Multiple Phase Operation

The number of phases may be increased to provide up to 8 phases where analysis indicates that they are required to serve the equivalent traffic volumes.

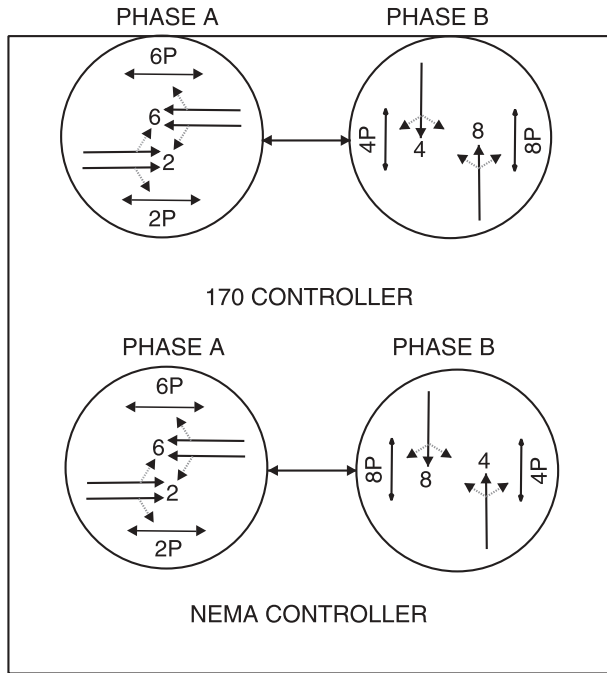


Figure 4 - 2-Phase Diagram

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, six phase diagrams 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 6. The following should be noted:

- for clarity, stopped traffic is not shown;
- the operation shown will operate with a maximum of six phases 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.

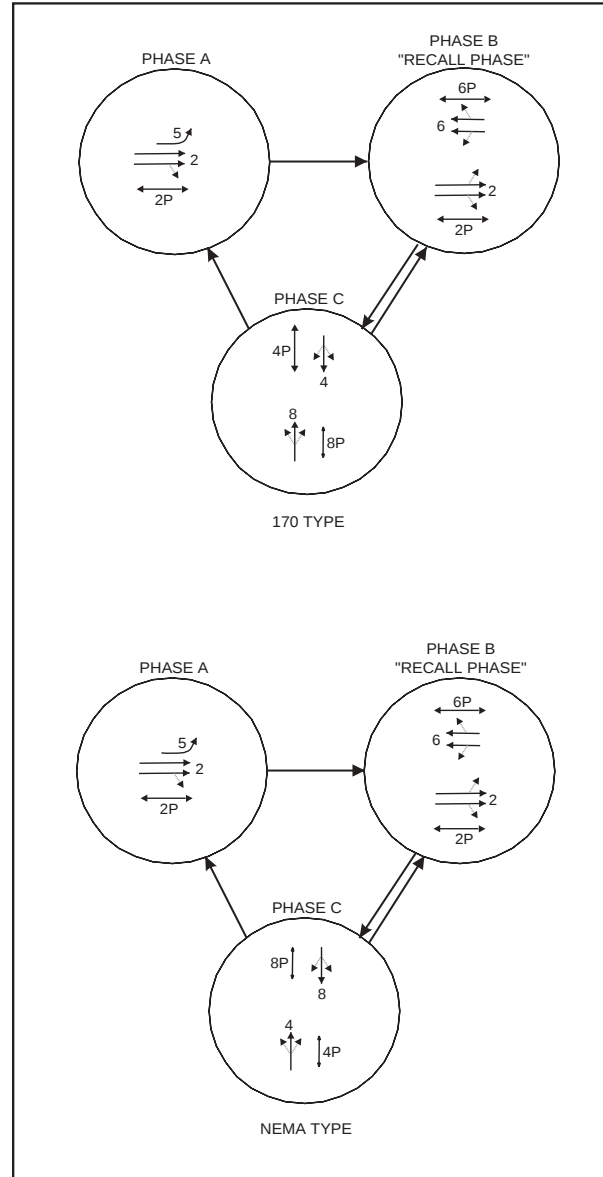


Figure 5 - Three Phase Diagram

Pedestrian Phases

General

In normal applications, the pedestrian timing interval requirements will sometimes exceed the green times required for vehicular movements and will override the vehicle timing. Pedestrian signal indications should follow the following sequence:

- Steady Hand Outline (“Don’t Walk”) shall be displayed with the corresponding through phase reds and with any conflicting protected turning movements. This indication may also be displayed during the amber display;
- Walking Pedestrian (“Walk”) shall be displayed only when the corresponding through movement green indications are displayed. The Walking Pedestrian indication does not necessarily have to be displayed with the green

at actuated intersections (where a pushbutton actuation is required) as this allows for the use of less vehicular green time during cycles when no pedestrians are waiting to cross; and

- 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. It is permissible to continue the FDW through the amber and all-red clearance intervals as this allows more time for pedestrians; however, it may not allow sufficient vehicle intersection clearance opportunity.

Exclusive Pedestrian Phases

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 which parallel the (vehicle) signal head operations. Should volumes of

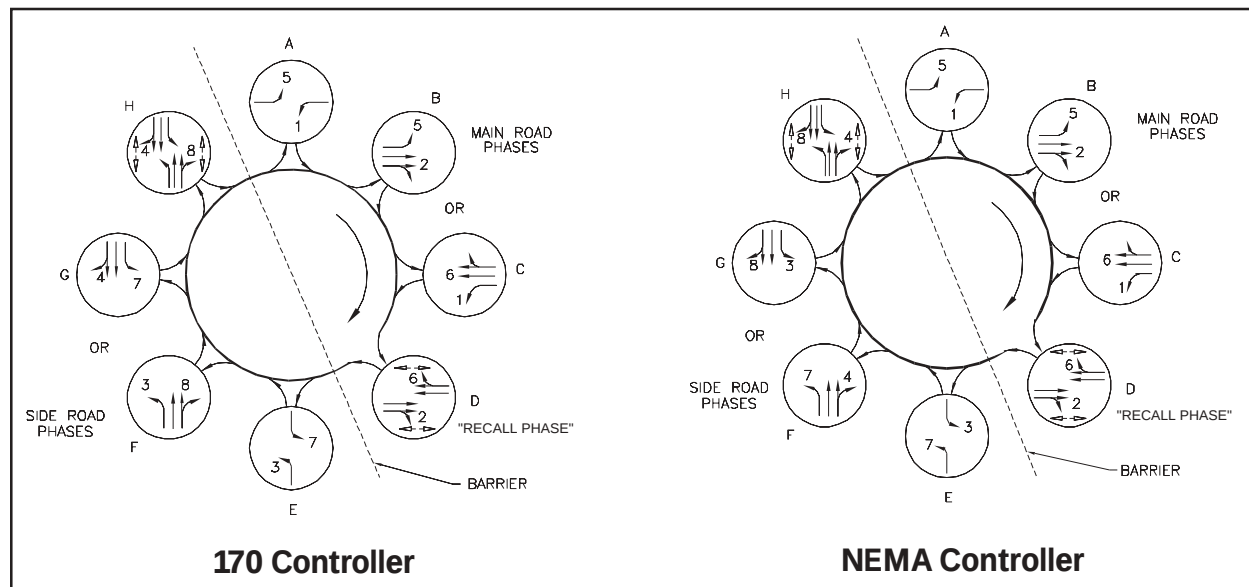


Figure 6 - Multi Phase Diagrams With Fully Protected Operation on the Main Road and Protected/Permissive Operation on the Side Road

pedestrians become severe, an "all-cross" phase can be applied where only pedestrian Walk signals are displayed in all directions (including "corner to corner" diagonally across the intersection) and all vehicular traffic indications are on red. This method is normally only used on downtown streets of the "street mall" nature where traffic avoids the areas due to the congestion in any event. Exclusive pedestrian phases offer advantages as follows:

- eliminates friction between pedestrians and right-turning vehicles;
- potentially reduces delays to motorists in curb lanes.

Disadvantages are:

- increases delay for all pedestrians;
- increases potential for pedestrians to disobey signals;
- increases delay for vehicles in the intersection which are not the first vehicle in the curb lane (for right turn on red) because time must be allowed to clear the full intersection of pedestrians;
- disruptive to signal coordination because longer cycle lengths and shorter green times are normally required;
- increases queue lengths for all intersection approaches and turning lanes, potentially causing queue spillover;
- potentially exceeds storage space available for pedestrians waiting on the sidewalks;
- no right hand turns on red.

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 shall not start to cross the roadway in the direction of 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 in the direction of the indication.

Left-Turn Phase Justification

General

Left-turning movements are affected by turning cars, 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 fully 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 in their lane unless a separate left-turn lane is provided with adequate storage to handle the number of arriving vehicles less the number of turning vehicles per cycle.

The contents of this subsection assume that an adequate left-turn lane can be provided. Where the left-turning movement is combined in a lane with the straight through traffic movement, shifts of the straight through traffic from this lane to the other through lanes must be taken into account. This case is treated in the TCSTCA²⁵.

Approximation

A simplified method using traffic volumes 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 and volume exceeds at least two vehicles per cycle not turning and the Level Of Service at the intersection will not be jeopardized; or
- ii If the left-turning volume plus the opposing volume > 720 vph; or
- iii If a field check shows that vehicles consistently require more than two cycles in the queue in order to turn left.

Methods of Analysis

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

1. Capacity Analysis Method

This method is given in the TCSTCA²⁵ and is abbreviated and paraphrased here. The method is useful for planning of new signals.

When separate turning lanes are used, the equivalent vehicle volume of the turning lane should be compared to the equivalent vehicle volume of the other lanes to determine the critical lane volume which justifies a separate left-turn phase.

The threshold capacity of a left-turn lane can be stated²⁵ as $[1400 G/C - V_o]$ taking into account V_o , the opposing volume of traffic. Left-turn volumes greater than the threshold capacity require 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 if they have a separate phase), 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 3. The opposing volume, V_o , should be modified by the (f) factor according to the number of opposing lanes

Table 3-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 per cycle turning on the amber interval, clearing the intersection.

The capacity of the left-turn lane during the *permissive* stage (no separate left-turn phase) is given by:

$$c_{L_t} = 1400 G/C - (f) V_o + L_{t_a}$$

where:

c_{L_t} = 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 4);

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 2 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 by the heavy traffic percentages. The TCSTCA²⁵ provides nomographs for the solution of the problem.

2. Left-Turn Delay Method

This method is one developed by Metro Transportation in their "Left-Turn Phase Criteria" study⁹. The method is useful for existing intersections and consists of the following basic steps:

A. Needs Criteria:

- a. If potential intersection benefits with no delay study needed -go directly to Impacts section ;
- b. Average ≥ 2 LT per cycle in an hour within the study period;
- c. $\geq 10\%$ of LT have one or more cycle delays in an hour within the study period;
- d. ≥ 5 vehicles per hour have one or more cycle delays in an hour within the study period;
- e. Any of:
 - e1: LT study period collisions total 6 or more over the past 5 years or;
 - e2: LT 24 hour study period collisions total 20 or more over the past 5 years or;
 - e3: LT study period collisions total 2 or more in the most recent single year or;
 - e4: LT 24 hour study period collisions total 5 or more in the most recent single year or;

e5: > 2 evasive actions per hour observed in an hour within the study period.

- f. > 2.5 LT sneakers per cycle on average over an hour within the study period (impacts next phase);
- g. LT queue blocks through lane $> 30\%$ of cycles for multiple through lanes, (busiest hour) or LT queue blocks through lane $> 10\%$ of cycles for single through lane, within an hour in the period;
- h. More than 2 in-service transit vehicles per hour in the LT traffic in an hour within the study period;
- i. There was a previous request regarding the same LT movement within the last 18 months.

Consider Left-turn phasing if a. or (b.& c.) or (b.& e.) or (b.& d.) and any one of f., g., h. or i. is/are true.

B. Impacts

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

- a. Green time is not available or cycle length increase is not acceptable;
- b. If LT 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;
- c. There is a policy reason why LT phase is not desirable (e.g. LT phase will encourage left-turn traffic through a neighbourhood protection scheme, or from streetcar tracks);
- d. Quality of signal progression is greatly decreased.

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 there is no requirement for an opposing left-turn phase, during the plan under consideration, and if the capacity analysis indicates that a single left-turn lane will suffice, the protected/permissive type of operation should be considered as it is the simplest and most economical to implement;
2. If a geometric or visibility problem exists at the intersection, consideration should be given to a fully protected left-turn phase. This type of operation may also be considered where the left-turn movement is predominant and the green interval for straight through traffic is governed by the opposing traffic flow;
3. 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 as left-turning vehicles have a completely separate phase;

4. Simultaneous left-turn operations should be considered wherever both opposing left-turn lanes require separate phases. The left-turn phases may be operated in the protected/permissive mode or the fully protected mode with the latter being preferred where dual left-turn lanes are used or where high volumes may cause motorist distraction such as at an intersection with requirements for four way left-turn phases.

Recommended practice for simultaneous protected/permissive left-turn operation, with single left-turn lanes, uses type 8, 8A, 9 or 9A signal heads. Recommended practice provides for a fully-protected left-turn operation to use separate left-turn signal heads. A sign showing "Left-Turn Signal" is a recommended part of a fully protected left-turn operation and 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.
5. Delayed green or permissive/protected operation should be considered only where there is no opposing left-turn movement which would create an unsafe trap situation. These operations are required to fit smooth traffic flow into a coordinated system.

Types of Left-Turn Phasing

The figures shown in this section are sufficient only to show the left-turn parameters. A more complete treatment of display diagrams may be found in the TAC MUTCD¹². Additional amber, clearance and other traffic movement phases beyond those shown are normally required. The material presented here is recommended practice for the conditions given.

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 opposing traffic stopped. The associated through and right-turning vehicles are also allowed to proceed during the protected left-turn phase. After the protected movement terminates with

a clearance interval, the opposing traffic is released with a normal circular green ball display. The left-turning vehicles are still permitted to turn; however they must yield 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. Alternatively, the use of the circular flashing advanced green and arrow flashing advanced green is allowed under Section 144 (13) the HTA.

This type of phasing is shown in Figure 7.

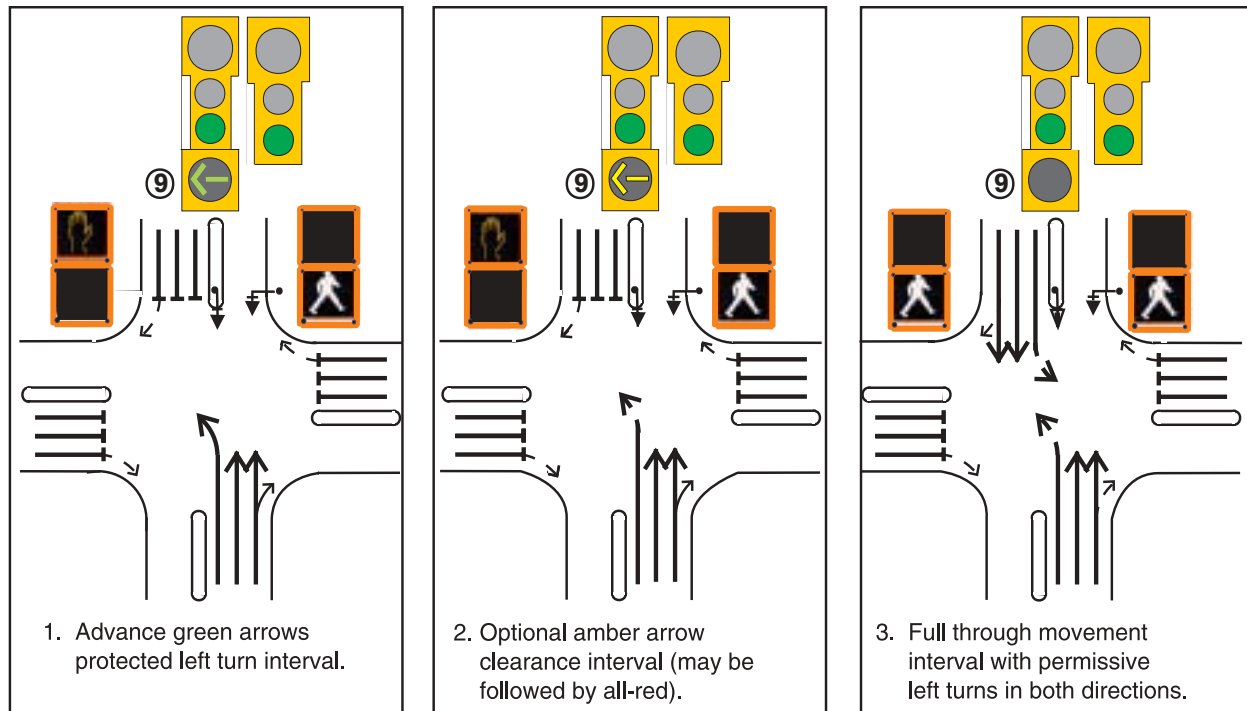


Figure 7 - Protected / Permissive Intervals

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 if adequate gaps are available.

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

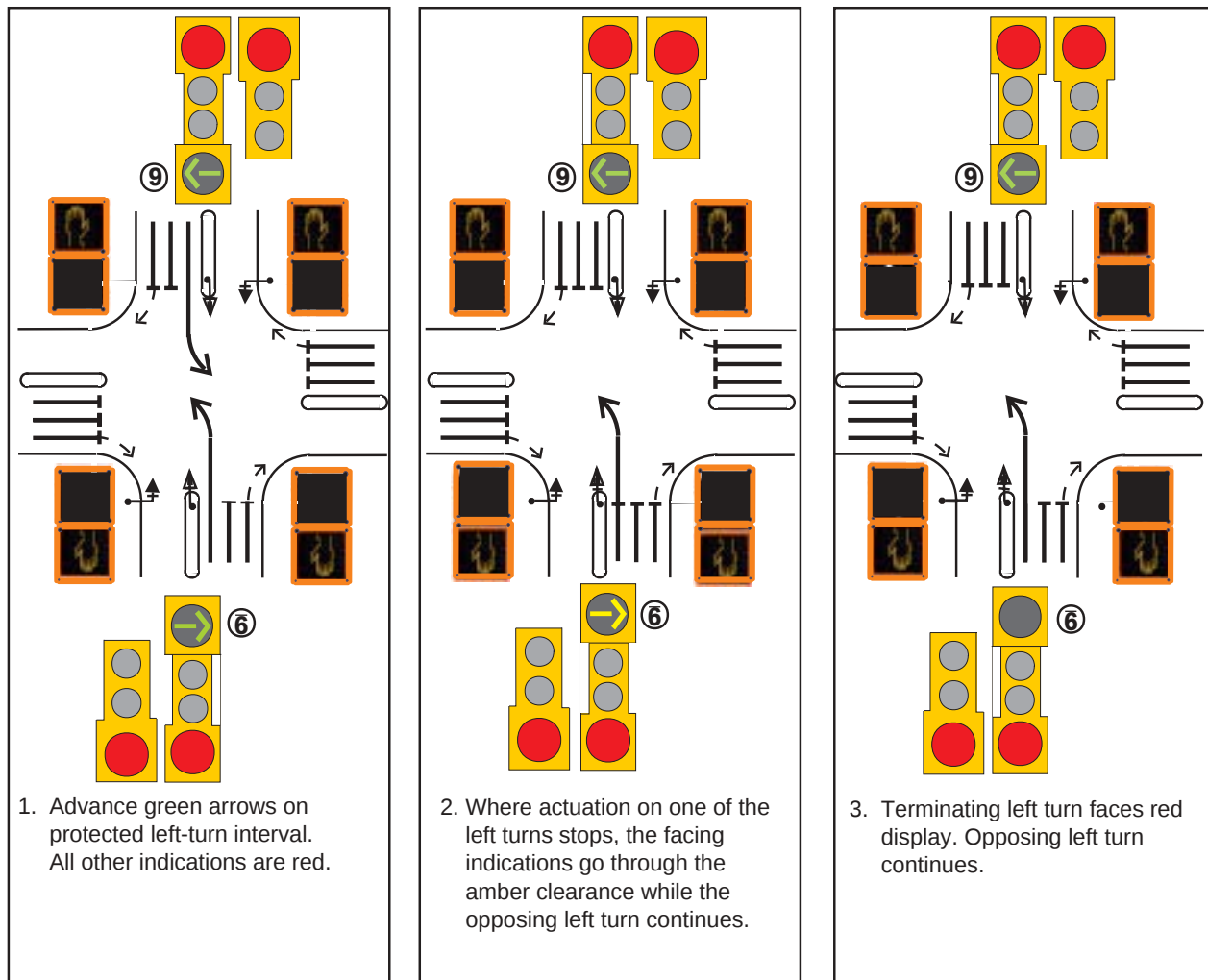


Figure 8a - Protected / Permissive Simultaneous Left-Turn Operation

opposing protected left-turn phase can be skipped and the operation during that cycle will be similar to an advanced green. Figures 8a, 8b and 8c show 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 should be placed adjacent to these heads. This type of operation is used where the visibility of vehicles

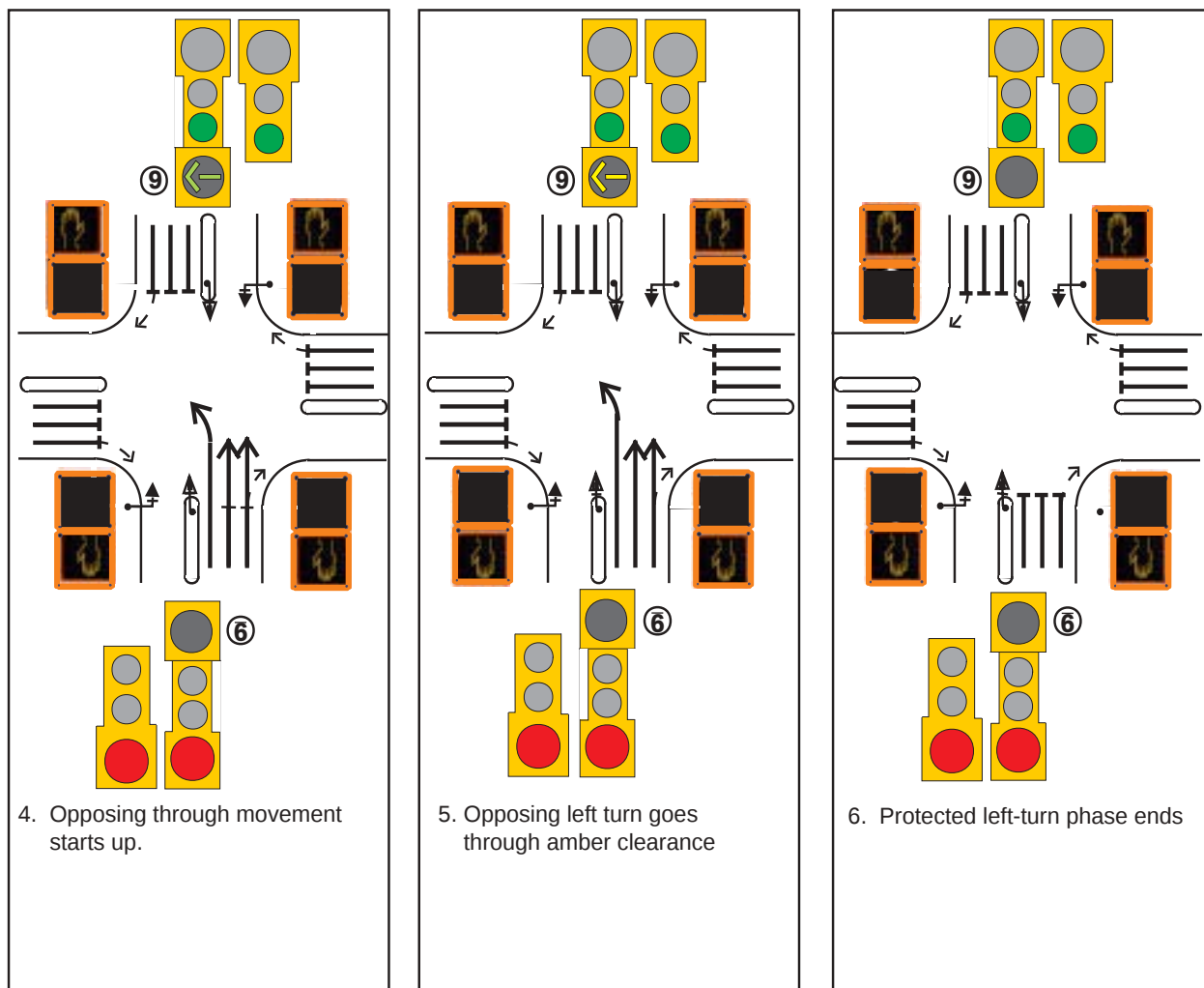


Figure 8b - Protected / Permissive Simultaneous Left Turn Operation... Continued

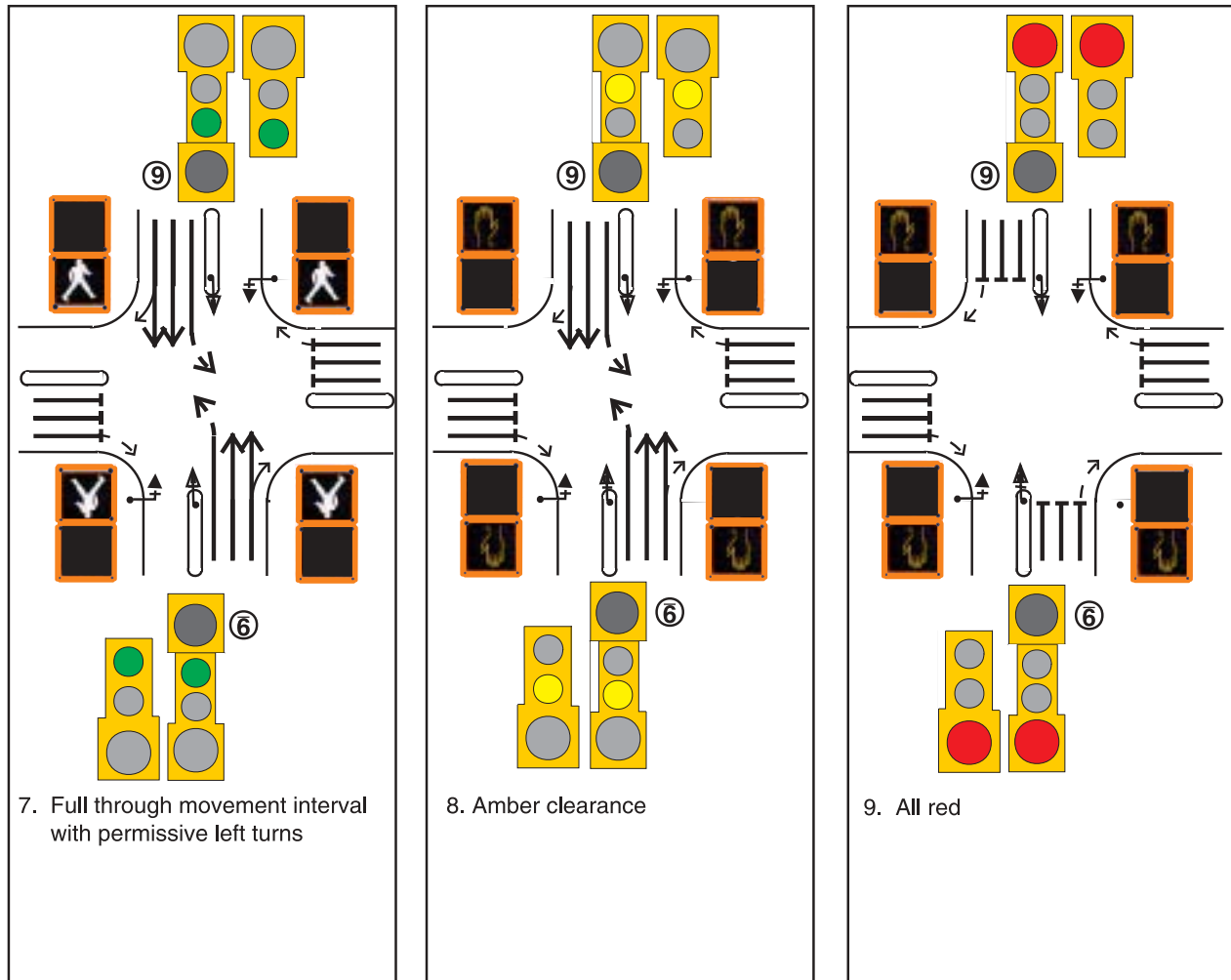


Figure 8c - Protected / Permissive Simultaneous Left Turn Operation ... Continued

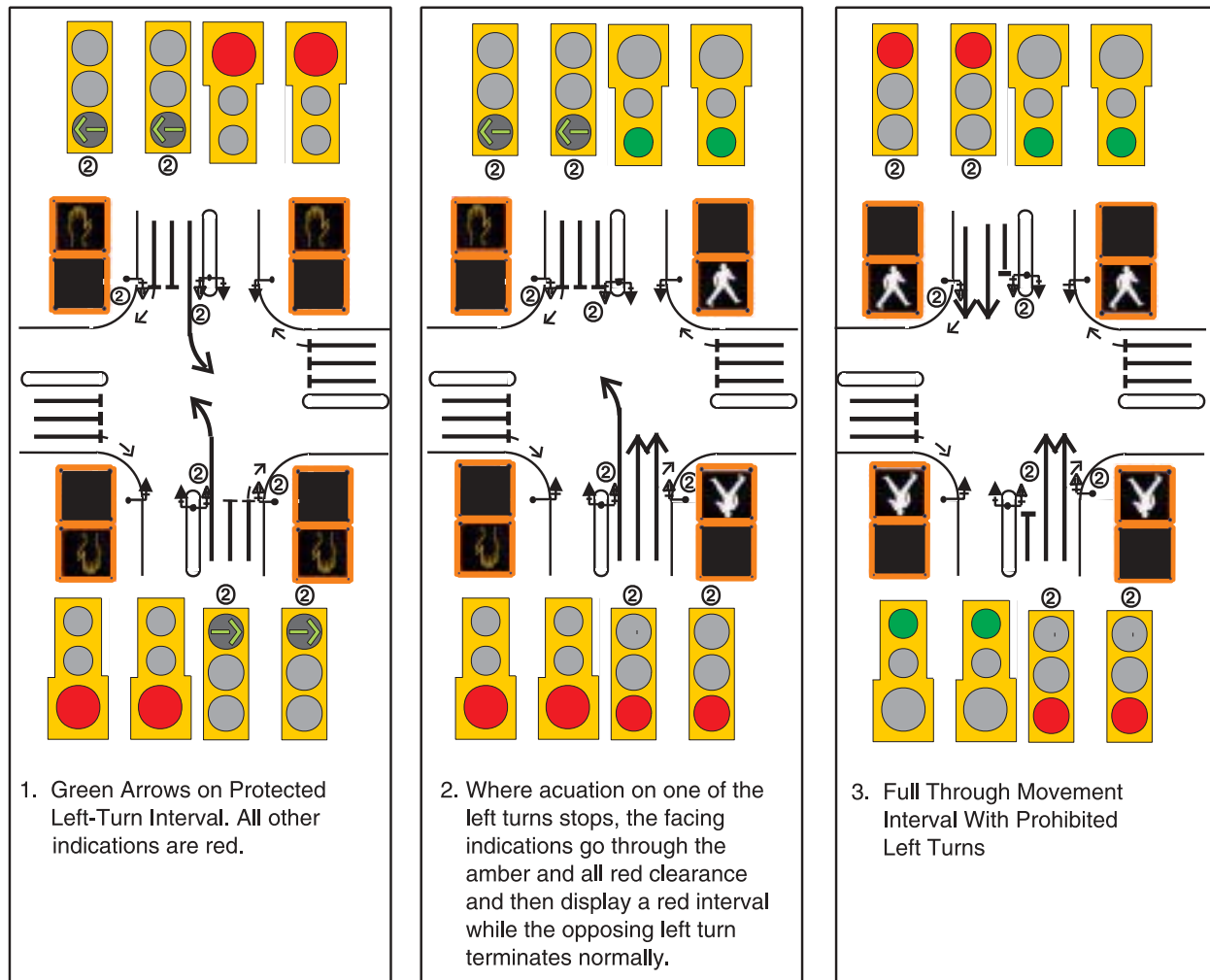


Figure 9 - Fully Protected Left-Turn Operation
(Note: Not all intervals shown)

making left turns to the opposing traffic, or vice versa, 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 where visibility problems due to geometry or collision problems exist. Double left-turn lanes may require this type of phasing. Figure 9 shows the basic intervals.

4. Extended Green, 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 can only be used at locations where there is no opposing left-turn movement,**

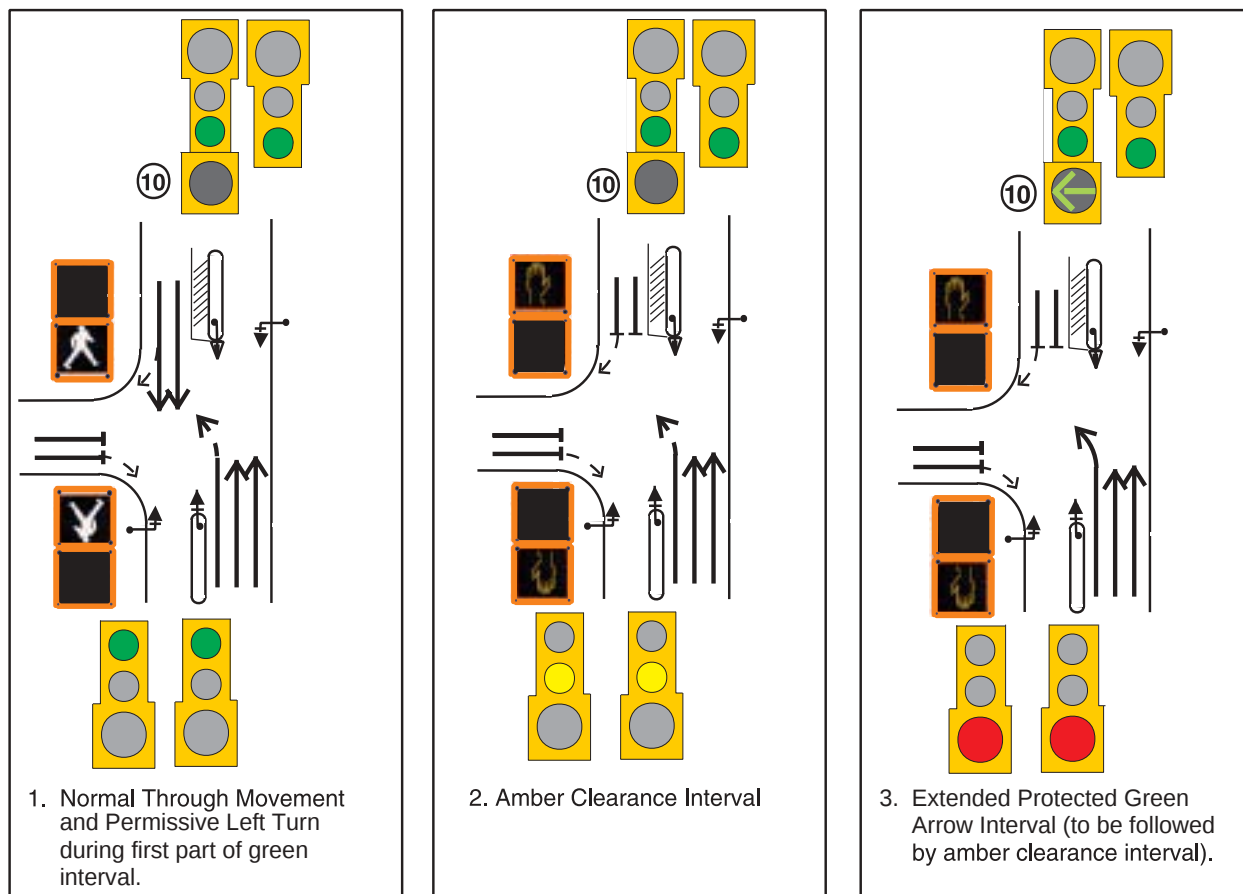


Figure 10 - Extended Green Intervals
(Note: Not all intervals shown)

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 he expects opposing traffic to receive an amber display when he does. Figure 10 shows the basic intervals.

This method which is typically used with either/or shared lanes is generally inefficient but offers a very effective way to eliminate collisions involving left turns with opposing through traffic.

Figures 11a and 11b illustrate the basic intervals for this type of operation.

5. Separate (Exclusive) 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.

6. Lagging Fully Protected Simultaneous Left Turn

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

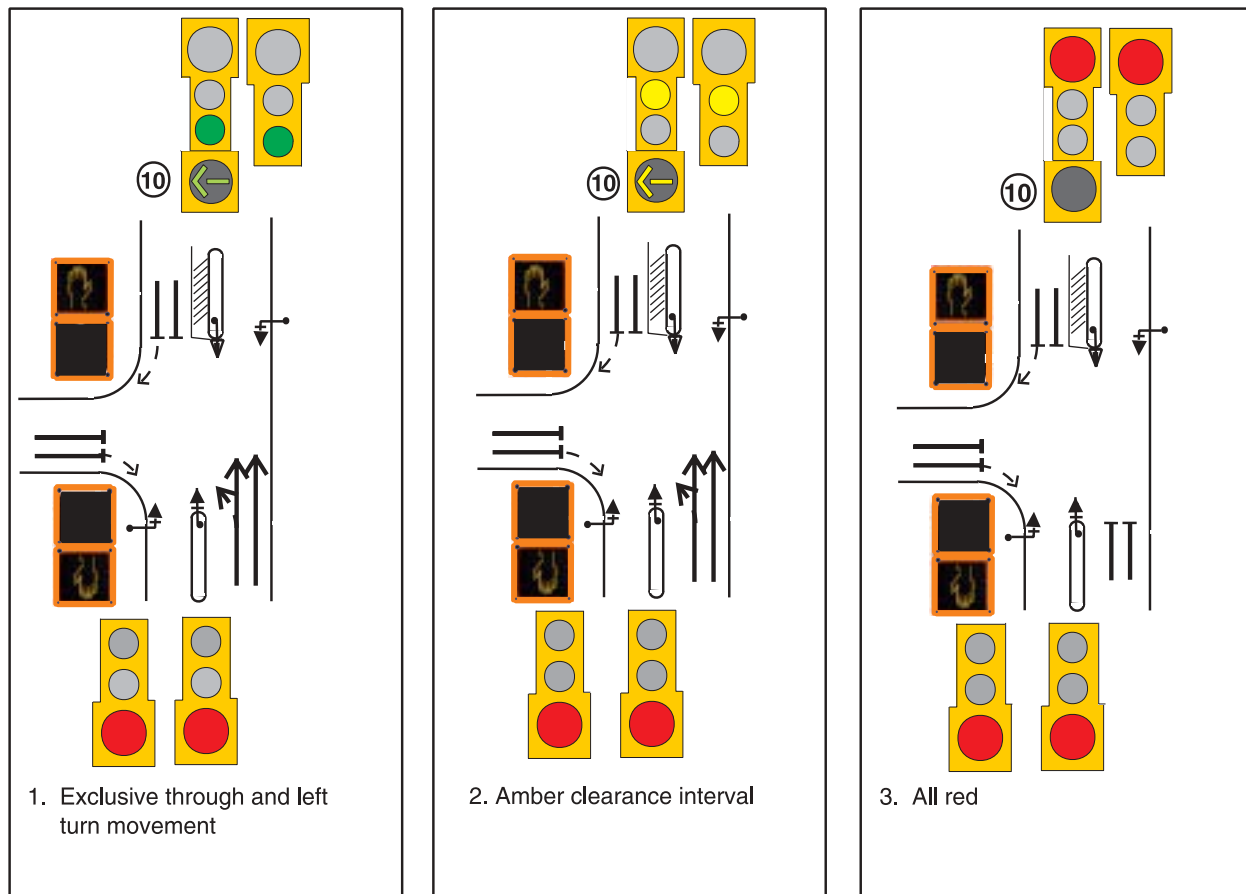


Figure 11a - Separate (Exclusive) Phasing

If there is periodically insufficient left-turn storage space for the subject movements, through movements can be blocked during the solid green phase by left-turn queue spillover. Operating the left-turn phase before the through phase would be preferable in this case because any queue spillover could be cleared prior to the through green, and additional motorists could enter the left-turn lane.

requires the operation because of the proximity of other signalized intersections. This operation can also be used with fully actuated operation and fully actuated left-turn phases if there is no actuation on the side road and actuation occurs for the left-turn movement.

However, this method is seldom used since left-turning displays are normally brought on before the through traffic indications. It is recommended practice that the use of this type of operation be restricted to that required to minimize delays to large volumes of turning traffic in a system where good progression

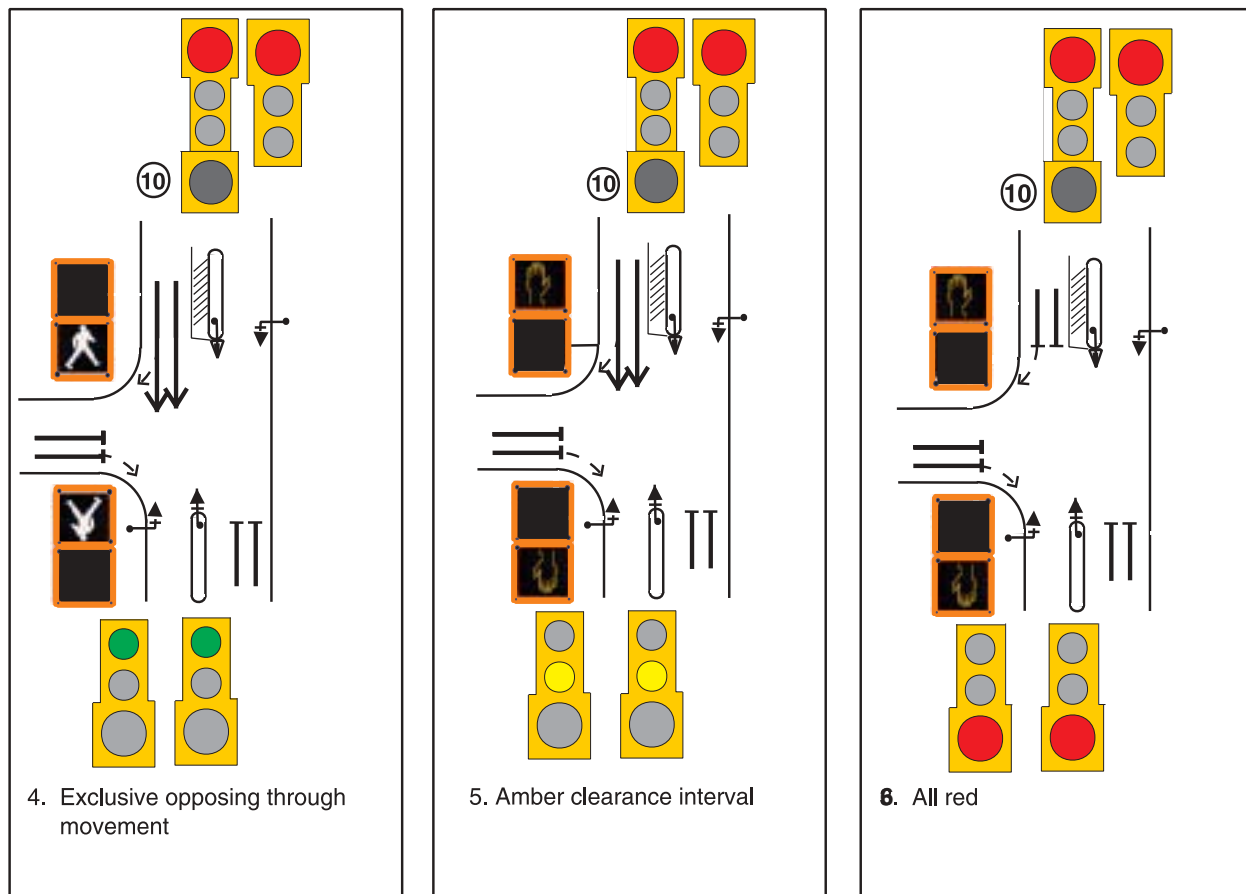


Figure 11b - Separate (Exclusive) Phasing

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 as stated in Subsection 3. Traffic demand analysis will determine the optimum interval timing to achieve safety and maximize traffic flow efficiency.

Guidelines are primarily found in the Ministry's "Traffic Control Signal Timing and Capacity Analysis at Signalized Intersections" (TCSTCA²⁵) and ITE Canada's "Canadian Capacity Guide for Signalized Intersections" (CCG¹).

During the determination of equivalent traffic volumes in accordance with the principles of the CCG1 or the TCSTCA²⁵, 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. The flow ratios are related to capacity and delay and lost time per cycle.

The analysis of the interval and cycle timings are more convenient to carry out when a rough idea of the timing is calculated first.

Minimum Interval Timing

Motorists do not expect an immediate termination of a signal display that has just started.¹ Table 4 shows guidelines for minimum interval timing values:

Calculation of Clearance Interval Timing

Table 4 - Minimum Timing Intervals

Interval	Desirable Minimum (s)	Acceptable Minimum (s)
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
Flashing 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 a minimum of 2.7 seconds.

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 while in the dilemma zone. 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}

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

Amber + All-Red

Where:

y	=	the amber interval clearance(s);
r	=	the all-red interval clearance (s);
t	=	1.8 seconds perception and reaction time (s) for posted speeds of 80 km/h or greater and 1.0 seconds for posted speed < 80 km/h;
V	=	approach operating speed (km/h);
70.6	=	factor of 2 x 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 that the right-of-way is about to be changed and provides 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 timing, at level approach grades, is given in Table 5 for 1.0 and 1.8 seconds perception plus reaction time. The 1.0 second value is used by many municipalities and the 1.8 seconds is used on rural roads, King's Highways or higher speed roads.

Clearance for Left-Turn Signals

Where the protected/permissive mode of operation in a left-turn lane is used, it is not required to provide a Level of Service (LOS) greater than LOS E * regardless of the LOS on the through lanes. Queuing is normal and two vehicles are considered to be able to clear the intersection on the amber. Since the speeds are lower for the left-turning vehicles and the time across half the intersection is also lower, engineering/analyst judgement should be used to ensure safety. A green clearance or an amber arrow clearance 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.

Level of Service

General

Various methods may be used to define the Level of Service (LOS) at an intersection. 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. *See tables, page 46.

Table 5 - 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
Amber clearance for 1.8 seconds perception + reaction time (s)	3.6	4.1	4.5	5.0	5.4	5.9	6.3	6.8

Table 6 - 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	2.7s	2.3	2.0	1.8	1.6	1.5

Notes:

- Table does not apply to left turn clearances.
- 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 $g = \% \text{ grade} / 100$ and $70.6 = \text{factor } 2 \times \text{acceleration of gravity } (2 \times 3.6 \times 9.81) \text{ in km/h/s}$.
- Perception + Reaction time = 1.8 seconds for posted speeds of 80km/h and over and 1.0 seconds for <80 km/h.
- 3.0 seconds is the recommended minimum for the amber clearance time; 1.0 seconds is the recommended minimum for All-Red.
- If operating speed deviates significantly from posted speed, the operating speed may be used in the calculation.
- If posted speeds are less than 40 km/h, use 3.0 second amber and 1.0 second all-red.

The following are the most commonly used:

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 HCM⁸. Table 7 gives LOS for signalized intersections.

Table 7 - 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	> 40.0 and < = 60.0
F	>60.0

LOS Based on Probability of Clearing the Arrivals

In this (more commonly used) 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 and the actual arrivals could be different. The percentage of time that this is achieved defines the LOS as given in Table 8.

Table 8 - LOS Based on Clearing Arrivals

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

Source: Highway Capacity Manual ⁸

LOS Based on Volume/Capacity (V/C) Ratio

This simple method is based on the calculation of a critical intersection volume. This volume is then compared to a benchmark intersection capacity for determination of LOS. This method does not take into account the signal timing or phasing. Table 9 gives the capacity ranges of an intersection for each level of service.

Table 9 - LOS Based on Volume/Capacity

Level of service	Range of capacity (VPH)	
	Low	High
A	0	900
B	901	1050
C	1051	1200
D	1201	1350
E	1351	1500

Determination of Green Interval Timing

General

The highest rate of traffic flow begins after approximately two to three vehicles per lane have started through the green signal because the initial headway of the vehicles is significantly longer than those experienced under saturated traffic flow. The result of this is that the first several seconds of the green interval accommodates significantly fewer vehicles in terms of vehicles per second than the latter portion of the interval.

The analysis of the traffic flow to determine green interval times may be accomplished by several methods. Three of the commonly used 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 (TCSTCA²⁵) manual.

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

This 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 the average arrivals during the first green interval after arrival at the intersection.

If the total number of vehicles per hour arriving at the intersection is divided by the number of signal cycles per hour, the average arrival rate (m) is determined. 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.

The Traffic Control Signal Timing and Capacity Analysis at Signalized Intersections Manual and software ("MTOPT") based upon this method is available from the Ministry Of Transportation of Ontario, Traffic Office.

Canadian Capacity Guide Methodology

The Canadian Capacity Guide for Signalized Intersections, 2nd Edition, (CCG¹) 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 during the green interval. 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. The critical lane is identified by the highest flow ratio in 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, that is the duration of individual phases, within the cycle time 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.

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. This edition of 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[®]) 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 which 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 into account operational objectives, 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 whose duration varies in response to traffic on that phase. The green interval time maybe extended up to a set maximum value (“Max1”). The minimum time for the green interval is the fixed initial portion plus one unit extension of the extendible portion, and is the time required to clear stopped vehicles between the detection and stop line. 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 travel time from the stopline. In some systems, the unit extension time should be based on holding the phase green while demand for the conflicting flow is present and loop placement distance is based on gap timing.

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 timing. This will extend the green interval as long as vehicle actuations are spaced closer than the time set on the extension detector 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 which stop at the detection device but which are turning when a gap is available in conflicting traffic. The delay time is normally set from 5 to 12 seconds and if the detection device is not cleared by the vehicle, the controller activates the phase change to allow the vehicles to proceed.

Calculation Of Pedestrian Timing

General

Where pedestrians are present at signalized intersections, the minimum safe crossing needs should be accommodated in the pedestrian interval (walk) and pedestrian clearance interval (flashing don’t walk) times. The total time of these two intervals shall be sufficient time for pedestrians to clear the conflict zone prior to the release of a conflicting traffic movement. 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), may include the vehicular amber and all-red clearance intervals. The advantage of including the clearance interval times is in giving the pedestrians reassurance that they still have the right to be in the intersection because the method allows the change from FDW to solid Don’t Walk to be delayed as long as possible. A disadvantage to this approach is the potential conflicts between pedestrians still in the crosswalk and turning vehicles which are trying to clear the intersection. The FDW should not be less than 5 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 green interval 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 1.25 m/s is usually assumed for initial calculations although the time of 1.0 m/s can be used at crossings frequented by young children, seniors and disabled 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 other intervals and therefore the minimum cycle time.

Several methods of timing are available for use.

Method A (TCSTCA²⁵)

In this method, the pedestrian clearance interval should allow for pedestrians to at least reach the mid point of the roadway. Values of 50% of the pedestrian walking time are used for timing of the pedestrian clearance interval. The “flashing hand” pedestrian clearance interval normally terminates with the beginning of the associated through traffic amber. For a normal walking speed of W_s and a minimum starting time of 5 seconds, the total pedestrian crossing time is $(5 + W_c/W_s)$ seconds where W_c is the pedestrian crossing distance in metres.

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.

To provide a suitable pedestrian clearance time, a percentage of the total time is used. If, for example, 50% of the pedestrian walking time is assigned to the Walk interval, the flashing “Don’t Walk” interval time is also 50%. The philosophy is that pedestrians must be provided with meaningful indications by keeping the pedestrian clearance interval as short as practical while still providing proper crossing and warning times.

Method B (CCG¹)

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, to 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 $W_c / (W_s)$ in seconds which allows a pedestrian to walk the full distance during the clearance interval.

Method C (Metro Toronto ¹⁷).

This method is taken from Metro Transportation's "Pedestrian Crossing Time at Signalized Intersections¹⁷". This method relies on the termination of the FDW clearance interval at the start of vehicular amber. This allows a 5 to 7 second margin of safety for pedestrians while the vehicle amber and all-red intervals are displayed.

The total pedestrian crossing time is $W_c / 1.20$; of this time, 5/8 of the total time is allocated to the flashing Don't Walk clearance interval and the balance is allocated to the Walk interval. Minimum values of 7 seconds for Walk and 5 seconds for flashing Don't Walk are required.

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), the green vehicle time may be extended upon pedestrian actuation (normally by pushbutton) where the equipment allows this type of programming. 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 startup 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 follows²³:

- The useful range for cycle lengths is between 50 and 120 seconds ²⁵ ;
- For low speed urban roads (10 to 12 m width) and lighter traffic, a cycle length of 50 to 70 seconds is preferable;
- 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 would be required to serve minimum timing requirements;
- Where three or four phases are present, a cycle length of 90 to 120 seconds is 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 wait times 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 walk time (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 disabled 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;
- The cycle times in which the lost times for each hour are minimized are normally the best. Since these are the longest cycle lengths which are useful up to the point of decreasing intersection throughput, the traffic engineer/analyst can normally start with an assumed cycle length (90 seconds is suggested ²⁵) for further evaluation;
- 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.
- 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 up 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 which fits in with other intersections and allows a progression to be coordinated;
- 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 interval timing and different cycle lengths for the traffic fluctuations at different times;
- The establishment of protected left-turn intervals should be considered and it may not be possible to include the advance left turn plus the through green times in any progression if the opposing green time suffers.

Many worked examples may be found in the TCSTCA²⁵ and the CCG¹

3.7 Signal Spacing

Existing Intersection Analysis

Where the road authority has been forced by circumstances to install traffic signals in close proximity to each other, the operation of these intersections must be coordinated if a semblance of smooth traffic flow is to be maintained. Downtown area gridlock is a familiar phenomenon which traffic engineers/analysts have had to continually deal with. Constant adjustments are necessary in order that control systems react to a wide variety of traffic circumstances. Transit bus schedules and roadside bus stops also contribute to the problems and must be taken into account. The use of one-way streets alleviate the

Cycle Composition

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

situation somewhat as the opposing direction of traffic flow does not have to be accommodated. Left-turn lane storage lengths may be restricted and long left-turning traffic queues may interfere with through traffic lanes. Through traffic with familiar motorists will tend to move to the curb lane.

Where private and commercial entrances are present between intersections, vehicles turning into these from the roadway will cause friction or even stoppage of traffic. Vehicles entering from the side roads, where gaps allow, will partially fill the approach lanes of the next intersection. The solution of these problems is not an easy undertaking. Several suggestions for consideration are:

- restrict turning vehicles at intersections in peak traffic hours (requires a bylaw and signage);
- prohibit trucks in selected hours (requires a bylaw and signage);
- restrict use of commercial entrance deliveries in selected hours (requires a bylaw and signage);
- install reserved lanes such as High Occupancy Vehicle (HOV) lanes to enhance transit bus flow;
- analyze traffic flow supplemented by a detailed field study and produce optimum signal cycle times which may have sub-plans and which correspond to actual observed conditions;
- introduce fully traffic-responsive control systems where practical; and
- consider adjusting offsets to relieve queued vehicles prior to platoons arriving at the intersection.

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 need to exceed 85 m in length for low LOS, the minimum distance between intersections is approximately 215 m for roads posted at 60 km/h or less and up to 350 m for roads posted at 80 km/h to allow “back-to-back” left turn lanes and proper tapers but 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 but not sufficient to provide good coordination;
- intersection spacings 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 that the pattern of deceleration, decreasing headways, stopping, accelerating, adjusting to increased headways and repeating this pattern at the new intersection may produce unacceptable delays in poorer levels of service. The CCG¹ gives analysis methods for determining whether continuous queues will exist and the delays to be expected;
- the optimal distance for coordination between signalized intersections, considering a two-way arterial only and not considering network effects, is, at 50 km/h posted speed:

<u>Cycle length</u>	<u>Distance</u>
60s	416 m
70s	486 m
80s	555 m
90s	625 m

to convert the arrows to flashing advanced green arrows at a later date.

The flashing green traffic control signal indication shall be at a rate of not more than 180 or not less than 150 ON and OFF flashes per minute, with the length of each ON period approximately equal to the length of each OFF period.

3.8 Flashing Operation

Advanced Green Flashing Operation

A circular flashing green indication may be used to provide discrete time or a separate phase for an approach at the intersection when protected/permissive green is necessary in a single direction only. The permitted use of circular flashing advanced green may be terminated in the future. The use of the circular flashing advanced green is not promoted as a future standard since Ontario is one of only a few users in North America and it may cause some confusion to out-of-province motorists.

A flashing green arrow may be used when either a protected/permissive or a fully protected left-turn phase is necessary, on one or more approaches. 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 MUTCD¹², use flashing arrow signals only and do not recognize steady arrow or flashing circular displays. The use of the arrow flashing advanced green is not promoted at this time due to possible confusion of motorists with Ontario's circular flashing advanced green. 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 be undertaken

Standardized Flashing Operation

Traffic control signals (which do not use left-turn arrow heads, excluding types 8, 8A, 9 and 9A in Figure 1, Section 2), 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 or for special events.

Caution should be used in the choice of locations for planned timed flashing operation of signals. Flashing operation may be of some advantage to traffic flow, particularly with pretimed signals, when conditions of very light traffic occur such as during the night hours, on a Sunday or holiday in an industrial area. As a guideline, the red-red mode of flashing operation is preferred for safety over the red-amber mode where traffic is heavy and where hardware allows this

alternative. The amber-red mode should be used where side road traffic is very light and where higher speeds on the main road may make a red less safe than an amber. A nighttime flashing mode is not necessary at actuated signals since the signal normally rests in green on the main road and will only change if there is actuation or a pedestrian call from the side road.

It is recommended that the timed flashing mode of operation in off-peak hours should not be considered at intersections with channelizing islands, at intersections with nighttime volumes of traffic exceeding LOS B on the side road, at intersections with a proven collision history if hardware of the system will not allow red-red flash or at intersections with pedestrian crossing required.

In the flashing mode, either the red indication facing all approaches must flash (desirable for safety on busy roads) or the amber flashing indication must face the approaches on the main road and the red flashing indication must face the approaches on the side road.

The standard flashing red or flashing amber traffic control signal indication shall be at a rate of not more than 60 or 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

General

All modern controllers offer two preemption modes of operation in addition to the signal plans provided. The preemption plans available normally include the use of two railway plans, two to four emergency vehicle plans or one of each. The preemption mode

allows a limited operation where one or more phases remain on red and one or more phases remain on green during the preemption operation. The preemption may be activated by the following incidents:

- an approaching train on a level crossing which crosses one or two of the roadways near or within an intersection and sends a signal to the intersection controller upon train approach;
- an approaching emergency vehicle (fire, ambulance, police, etc.) which requires the signal on the approach to return to green as soon as possible and/or right-of-way to be held in green on the vehicle approach or on one roadway.

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.

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 MUTCD¹².

In the case of railway preemption, it is extremely important that a preemption sequence compatible with the railway crossing signals provide safety for vehicle, pedestrian and train movements. Because trains cannot stop in time to accommodate traffic at the level crossing, it is essential to ensure that the separate intersection and railway signal devices complement rather than conflict with each other¹⁸.

The following situations may require railway preemption phases and the interconnection of railway and vehicle signals will then be required:

1. Where a railway crossing is in proximity to an intersection such that vehicle back-ups in the queue approaching the intersection, after crossing the tracks, may cause an inadvertent vehicular stoppage on the level crossing, it will be necessary to provide an intersection clearing preemption phase to allow the traffic to clear the approach prior to train arrival. This situation requires analysis of the maximum traffic flow that can be expected on the approach and 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 some panic stopping from the intersection side of the crossing and lead to the plugging of the distance between the intersection and the railway tracks. Here, it is necessary to clear the approach between the intersection and the tracks for the other direction of traffic as for case 1, and also desirable to prevent the filling of the space between the intersection and the tracks such that the intersection does not become 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 the use of arrow signal heads or blank-out signs or a combination of both.

A recommended practice of the Institute of Transportation Engineers titled "Preemption of Traffic Signals At or Near Railroad Grade Crossings with Active Warning Devices"¹⁸ gives recommendations on when to preempt, design considerations and operations and should be followed when the given conditions occur.

Signals which require railway interconnection should not be constructed until the approval of the appropriate railway authority has been received.

Preemption For Emergency Vehicles

Preemption for emergency vehicles can be activated by a stroboscopic light emitting device or radio frequency device mounted on the emergency vehicles. The light signal is received by a photosensitive detector of the proper frequency mounted at the intersection in the direction facing the approach which will receive the preempt green indication.

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 the fire station entrance to remain on green until the emergency vehicles have left and to activate special preemption phases which 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 optical preemption system normally requires a study of the arterials to be covered, the types of vehicles to be fitted and coordination and agreement of cost sharing for the participating parties.

3.10 Operation Of Miscellaneous Signals

Pedestrian Signals

Traffic control systems 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.

For IPS, the side road must be provided with stop signs if not already provided.

The control of the pedestrian signals is by pedestrian actuated two phase operation with the only phase indications present being the pedestrian signals across the main roadway and the traffic control signals on both main roadway approaches.

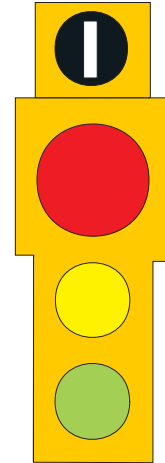
Pedestrian timing should be set as for normal intersections considering the factors of subsection 3.5. The controller should rest in main road green until a pedestrian actuation is received. The controller may operate in conjunction with the background cycle imposed by a system if required for safety or capacity reasons. Alternatively the controller should have a long minimum green interval programmed for the main road so that continual pedestrian interruptions of traffic are tolerable.

Transit Priority Signals

A transit priority signal display may be used to assign right-of-way to public transit vehicles over all other vehicular and pedestrian traffic movements within an intersection. The signal indication allows for the movement of transit vehicles through a signalized intersection. The transit priority signal is generally used at an intersection and may be operated exclusively during a protected transit movement or concurrently with other non-conflicting vehicular movements.

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 through the intersection while all other vehicles and pedestrians must stop and are not allowed to proceed.



Following 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 at only certain times of the day or on certain days or for special events and the additional phase(s) can therefore be programmed into a signal plan.

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 not change to amber less than 15 seconds before the gates are closed and the indications will not show green at any time when 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 followed

by the bridge mechanism. In cases where areas of traffic congestion such as nearby intersections or railway crossings 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 by the bridge mechanism.

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 park one or two vehicles in an emergency.

Lane Direction Signals

Lane direction signals 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 if visibility from both directions permits.



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 of the time required, it will be necessary to allow enough phase time to allow a vehicle travelling at normal speed 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.

Portable Lane Control Signal Systems

Portable Lane Control signal systems consist of a single "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 on the roadway which requires lane closure. The phasing intervals must be for a two phase operation only, with the all red clearance interval sufficiently long to clear the previous approach lane of all vehicular traffic while travelling at the desired operating speed.

Communications between the signals at each end must be provided in order to prevent conflicting displays.

Audible Indications

Audible indications consist of audible semiconductor devices which emit "peep-peep" and "cuckoo" signals when walking pedestrian symbols are operational. Actuation of the pedestrian signals is recommended to be by an oversized pushbutton. The audible signals are crosswalk specific, normally applied at least across the main road.

Audible indications are not covered by the HTA. Standards and pushbutton operation options are provided in the TAC MUTCD¹².

Tunnel Signals

“Tunnel Signals” are composed of two types:

- signals at the ends of a tunnel which 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.

Signals located near the ends of a tunnel are constructed at crossing roads, if possible, 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 from the tunnel alarm systems for fire, collision, noxious gases or heavy water leakage. The signals operate similar to those for railway preemption, with arrow control and/or blank-out signs.

Lane direction signals within a tunnel are sometimes restricted in size due to vertical clearance. The principles of visibility outlined under “Lane Direction Signals” elsewhere in this section should apply.

Ramp Metering Signals

Ramp metering signals are used on freeway or expressway entrance ramps to control the rate of vehicle entrance to 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 which 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 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 interval time is normally set to a very short one in the order of 1.0 seconds (one vehicle only per green signal) with the amber even faster and 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. In off-hours of the day, the system is not operating and in this case, the signals rest in green.

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

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 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.

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

Beacons shall 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.

Beacons should be used with considerable discretion because over-use of these devices has led 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, supplemental to advance warning signs and supplementary to regulatory signs such as STOP, YIELD and DO NOT ENTER. They are also used as visual warning on pedestrian crossovers.

Beacons with flashing amber indications may be used to emphasize the need for caution when studies indicate a problem is present at the intersection (e.g at least six collisions over the previous 36 months have occurred) and where one of the following conditions exist:

- a physical obstruction in the roadway;
- a sharp curve in the roadway;
- a major intersection is hidden by a sharp curve or severe grade.

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 the intersection signal ahead and this type of flasher is therefore seldom used. The flasher should not be used where it will be a visual distraction to a signalized intersection, midblock pedestrian signal, pedestrian crossover or where it will cause possible confusion (generally a minimum of 300 m away).

Intersection Control Beacons

General

An intersection control beacon consists of one or more head sections with 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.

Flashing beacons may be used when two major high speed roads intersect in a rural area or when an average of three reportable personal or property damage collisions per year for at least three years have occurred and were directly attributable to poor observance of the STOP sign.

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. The application is used basically to provide visual assistance to normal stop signs and require 24 hours a day operation.

These types of overhead beacons should use 30 cm red lenses and be positioned to aim along each approach of the side road. Normal stop signs are also located on the side road approaches as backup in case of beacon failure.

3-Way and 4-Way Overhead Red Flashing Beacons

These types of beacon are used where "all-way" stop conditions are in place but traffic control signals are not justified. The beacons are used in conjunction with traffic, geometric or visibility conditions that require reinforcement of the normal usage of stop signs. The beacons require 24 hours a day operation.

These types of overhead beacons should be positioned to aim along the approach of each road. Normal stop signs are always required on each road 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 traffic, geometric or visibility conditions that require reinforcement of the normal usage of stop signs and where side road traffic has some problems in finding an acceptable gap for turning or have limited visibility.

These types of overhead beacons should be positioned to aim along each approach road of the intersection with the red beacons facing the side road(s) and the amber beacons facing the main road. The beacons require 24 hours a day operation. Oversized stop signs are also 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 long flat approaches to intersections that exhibit poor visibility of the intersection due to fences, tall weeds, etc. and 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 require 24 hours a day operation.

Warning Beacons at Signalized Intersections

Continuous Advance Warning Beacons for Traffic Signals

These types of single 20 cm diameter beacons are used as a reinforcement to the "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 with horizontal roadway curvatures which are made visually abrupt by 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 from the minimum distances from the stop lines as given in Section 5. In these situations, continuous single flashing beacons with the oversized "Signals Ahead" sign (Wb-1102A) may be required. The location of the signs are not critical and can be located at any reasonable distance upstream from the signalized intersection, beyond the distances shown in Section 5, in general conformance with the requirements shown elsewhere in the Ontario Traffic Manual - Warning Signs, and in a location that prohibits view of both the beacon and the intersection.

Active Advance Warning Beacons for Traffic Signals

These types of double 20 cm diameter beacons may be used as a reinforcement to the "Signals Ahead"

symbolized warning signs where visibility of intersections with traffic control signals is restricted by geometric and physical constraints and where studies indicate that traffic speeds, visibility, volumes and collision rates or collision severity are problems. For example, these types of beacons are used at temporary signalized intersections on freeways and are of the active type because stopping is not normally required and hence the continuous type of beacon is undesirable. The beacons are normally employed to aid motorists in defining the edge of the dilemma zone and indicating that there is a good probability that stopping is required.

Visibility problems may be particularly bad where trees enter into the sight lines and opposing vehicle headlights produce high glare at night. Other uses include warning of signals at the bottom of a long steep downgrade, where an intersection is not visible to approaching traffic, where a traffic control signal is unexpected such as on a divided highway and at the end of a long length of road where no signals have been seen for a substantial length of time.

Active 20 cm amber double flashing beacons ("bouncing ball" effect) with the oversized "Signals Ahead" signs (Wb-1102A) and complete with the word tabs "PREPARE TO STOP WHEN FLASHING" (Wb-102At) may be required.

The beacons should be connected to the intersection traffic signal controllers to give advance warning of upcoming amber indications or to at least indicate the start of amber for actuated signals. The beacons begin to flash as the signal changes from green to amber, or a set time in advance of the signal changing from green to amber to provide additional warning.

The flashers can be connected as a separate phase which starts early and finishes late. Conversely, the 170 controller program #233 is equipped to handle the flasher operation as are some NEMA controllers if they are provided with an "advanced warning package".



Vehicles passing the signs when the beacons are not flashing must have sufficient green time when the beacons are activated before amber, or sufficient clearance time if the beacons are activated when the amber comes on, to clear the intersection. Site condition judgement on the part of the engineer/analyst is required to determine the correct timing of the flashers.

The beacons and signs should be accurately located such that vehicles passing the signs and beacons when they are flashing have sufficient time and distance to stop before the intersection.

If the beacons are set to come on a fixed number of seconds before amber, most controllers will give a final extension to the green after gap-out or max-out. With this operation, the signs should be placed at a distance of (operating speed (m/s) x amber time + added extension time) from the stop line. If beacons are set to come on with the amber, the sign should be placed at (operating speed (m/s) x amber time) from the stop line.

3.12 Systems

Need for a System

The need for a traffic signal control system is dependent on the levels of efficient traffic flow through the various intersections being considered. Some general guidelines to be considered are:

- spacing of intersections along an arterial or within a grid;
- the number of locations approaching LOS E which could not operate within a common background cycle length;
- two or more parallel arterials experiencing similar problems;
- impending occurrences of “gridlock” on crossing arterials;
- demographics of the signals; outlying suburban signals will operate entirely separately from those of the downtown core for example;
- the LOS expected locally; motorists in dense downtown environments of large cities may tolerate more congestion than those in smaller communities because they are used to it;
- number of signals in the municipality; up to 64 sets of signals on two or three arterials can be controlled with an interconnected system using a system master controller at the main or critical intersection;
- over approximately 75 signals requires full time traffic attention and use of a central system not only enhances the management of the signals at the intersections but allows observation and analysis from a central location.

Types of Systems

General

The types of systems to be used should bear in mind the functionality expected in the area to be served. Many municipalities have several independent systems operating and outlying areas are only brought into the central main system after the areas have been built up. The following are guidelines which may be considered in a study of the systems to be used:

Arterial Interconnected System

The arterial interconnected system or the “distributed closed loop arterial system” uses a field arterial system master controller connected to a series of slave controllers. Interconnection of up to 64 intersections may be accomplished by the use of a communications system. The methods of interconnection are based on the master controller containing the programming for the system. The local or slave controllers along the arterial, or crossing arterials, follow the command of the master for which control plan to use. The master has the ability to select a traffic plan or cycle length in each controller on the system in order to optimize traffic flow.

Input parameters may be entered locally or via telephone or other communications modes from a central PC. The master normally sends a command to synchronize the slave controllers at time zero. Each slave has a local offset for its cycle to start and to change the time-of-day plans of the controllers. Several types of interconnection are available:

- “hard wired” interconnection using older technologies such as 7-conductor traffic signal cable operating at 120 Volts or “tone control” or modem interconnection using extra-low voltage cable operating at 24 Volts;
- “wireless” systems which use modulated RF radio type emissions to transmit and receive the coordinating signals or “time based” interconnection where each controller is precision timed using a digital time clock to follow the master at predetermined times of day.

Further information should be obtained from the controller manufacturers since each method has its own advantages and associated costs.

Grid Interconnected System

Interconnection of up to 255 sets of signals may be accomplished by the use of one of the interconnection methods. Typically the critical intersection controller is set as the system master and coordination of plans and offsets is calculated to achieve optimal traffic flow along arterials in both directions. This system works best where the directions of heavy traffic during a particular time of the day are easily determined and intersection spacing is regular and fits a good cycle length.

Small Central System

A small central system or “centrally distributed” system may be operated from a PC with software supplied by the controller manufacturers. Typically, the central computer addresses a field zone master controller on a dial-up basis. The zone master then controls its own slave controllers. The slave controllers can also be accessed directly in some systems. The systems are sold on the premise that up to 5760 signals may be controlled but the practical limit appears to be much less.

In these systems, each arterial is coordinated in a preferred direction for any time-of-day or traffic responsive plan to approximate efficient traffic flow. Limits on the software application do not allow for more than 32 plans to effectively be used.

Several manufacturers offer small central systems named as Management Information Systems for Traffic. System operating software packages use databases and other software devices to enable reporting of many traffic flow functions and are a good aid to analysis where traffic problems are occurring.

The packaged programs available are normally operated on a state-of-the-art PC or miniframe, are an improvement over most of the older central distributed systems and allow the user to select the custom features to be analyzed and reported.

Large Central System

A large central system or “mainframe” system may be operated within a large city or region with customized software allowing multiple time-of-day plans or traffic responsive plans. Time of day plans are generally used but “system loops” may be installed in bellwether locations on inbound and outbound arterials and the system plan may be chosen by the software to correspond to the reported traffic density and volumes. More commonly, software plans are set to multiple time of day plans which are derived from field studies, observations and experience for various times of the year.

Traffic Adaptive System

Software programs such as the “Split Cycle Offset Optimization Technique” (SCOOT) have been installed in Metropolitan Toronto. These types of programs rely on loops in each lane installed upstream of all intersections. Detectors measure traffic density and the central computer calculates the optimal splits and offsets of the signal set ahead so that the traffic platoon will theoretically move through the next and succeeding intersections smoothly. Optimal cycle lengths are also calculated for user-defined control areas (such as major arterials) and these assist in optimizing traffic operations according to user-defined parameters. The costs of installing, calibrating and maintaining detection equipment for such a system is significant, but improvements to traffic operations and reductions to delay can be significant, particularly where traffic flow patterns change frequently.

4. Planning and Justification

4.1 General

Purpose

This section addresses the justification or needs for traffic control signals. A comprehensive study of the traffic conditions and the physical characteristics of an intersection or mid-block location should be undertaken in order to determine whether or not the installation of a traffic signal is justified.

Background/Context

In Ontario, traffic signal installations were, until the 1990s, subject to cost-sharing between the Province and the municipality within which they were located (except for signals on provincial highways, which were fully a provincial responsibility). The Province, by applying a standard set of “warrants”, ensured that only signal installations that met these warrants and the design requirements in the HTA were eligible for provincial funding subsidy. Municipalities were free to install signals at other locations at 100% municipal cost, but meeting provincial warrants became a key factor in prioritizing signal installations.

The warrants were derived from U.S. practice and standards developed during the 1920s and 1930s and updated periodically. Canadian practice was guided by the Canadian Manual of Uniform Traffic Control Devices which, until its revision in 1974, followed closely the U.S. equivalent. The revised Canadian MUTCD¹², produced by the Transportation Association of Canada, used an entirely different points-based approach and has subsequently been adopted by several provinces. Ontario has maintained its own MUTCD in the style of the U.S. warrants system.

In order to ensure that the warrants then used were up-to-date and accurate, the Ministry of Transportation of Ontario convened a Committee in 1978 comprising five municipalities and itself. The Committee recommended that the warrants be updated in four main ways:

- changing the eight hour volume warrant from being met on average to being met during each of the eight highest hours;
- the free flow/restricted flow “break point” was revised from 60 km/h to 70 km/h;
- the cross traffic definition was made more specific; and
- the warrant for “T” intersection minor street volume was increased by 50%.

After a period of provincial and municipal review, the revised warrants came into effect on January 1, 1982 and were published as part of the Ontario Manual of Uniform Traffic Control Devices.

Current Update

The update contained here (2000) follows the same approach as in 1978, with a Committee of experienced municipal and provincial practitioners being formed to review current practice and suggest improvements.

The most significant results of the 2000 update are:

- confirmation of Ontario warrants and decision to not include one hour and four hour volume justifications for signal installation at this time;
- expansion and clarification of justification used for pedestrian signals;
- revision of the supporting text to be more accessible and provide additional context; and

Table 10 - Information to be collected

Information item	Justification Application					Notes
	1. Volume	2. Delay	3. Collisions*	4. Combination**	5. Pedestrian	
1. Number of lanes on each approach	✓	✓	✓	✓		Number of lanes includes through lanes, left turn lanes, and unchannelized right turn lanes. Engineering judgement shall apply to determine whether turn lanes should be included; if a left turn lane is lightly used, it need not be considered a "lane"; similarly, only if vehicles encounter conflicts or delays in turning from a right turn lane would the lane be included.
2. Number of vehicles entering each approach on the eight highest total-volume hours of an average day, categorized as lefts, throughs and rights.	✓	✓	✓	✓		"Vehicles" includes cars, buses, trucks, motorcycles, bicycles, and all other conveyances using the roadway. Buses/trucks are normally counted separately. The Canadian Capacity Guide for Signalized Intersections ¹ (CCG) may be referred to for survey methods.
3. Total eight-hour vehicular volume during highest eight hours of pedestrian demand on street being considered for pedestrian crossing signal.					✓	
4. Day of the week and month of the year of vehicular counts	✓	✓	✓	✓	✓	Adjustment factors to convert count days to "average" days should be applied, using locally-generated figures if possible. Alternatively, MTO, HCM or TRB factors may be referred to.
5. Main road posted speed or 85th percentile operating speed on road for hours during which signal justification is being analyzed.	✓	✓	✓	✓		If either figure exceeds 70 km/h, the intersection is assumed to function under free flow conditions.
6. Total highest eight hours per day of pedestrian volume crossing a road, categorized as assisted or unassisted, and segregated into zones of crossing. (For use in justification 5; justification 2 requires total pedestrian crossing volume by hour only).		✓			✓	Pedestrian count to be done simultaneously with eight hour traffic count. Note that highest eight pedestrian hours may be different from highest eight traffic hours. "Assisted" pedestrians are those who require assistance to cross the road e.g. seniors, disabled and children under 12.
7. Delay time experienced by each pedestrian during at least two 30 min. peak periods of an average day.					✓	Full eight hour monitoring of delay is desirable, but delay counts for briefer periods can be factored up to create eight hour totals.
8. Number of reported collisions at the intersection of the type preventable by traffic control signals in each of the preceding three years.			✓			Segregate by type: fatalities, personal injury, property damage.
9. Records of field trial of collision reduction measures.			✓	✓		Satisfactory observance and enforcement is required for item to be valid. Examples include warning signs/beacons, islands, lighting improvement, bus stop relocation, parking prohibition, or turn restrictions.

* In addition to items 1, 2, 4, 5, 8, and 9, Justifications 1 and 2 must be calculated as part of Justification 4.

** Justifications 1, 2 and 3 must be calculated as part of Justification 5.

- adaptation of criteria to a computer spreadsheet format.

With respect to the last point, fitted equations have been provided for all graphics.

Although one hour and four hour warrants are included in the current U.S. MUTCD¹¹, the Committee did not support the inclusion of either concept in the Ontario Traffic Manual at this time. Also, a brief review of the basic volumes used in justifications 1, 2 and 3 did not reveal that any significant changes were needed. It is recognized, however, that further research would be useful to definitively address the issue of whether the volumes and their underlying assumptions regarding vehicle characteristics and motorist behaviour accurately reflect today's rural and urban operating conditions. In that respect, it must be continually emphasized that the justification values cited herein are only standard technical measures which do not necessarily address all situations and which must be used in conjunction with experienced engineering judgement reflective of the community needs, financial resources, network implications, traffic patterns, and physical conditions present.

4.2 Information Requirements

Basic Input Data

The information indicated in Table 10 should be collected for use in the analysis of signal justification. Note that 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 and 2 will govern). The collected information may be summarized in the form of Table 10 for ease of reference.

Supplementary Input Data

The quantitative Justifications 1 - 5 are, as noted earlier, to be applied in conjunction with engineering

judgement and within a qualitative context. 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:

1. *Vehicle Delay*

Vehicle-seconds delay determined separately for each approach.

2. *Gaps (Unsignalized Intersections Only)*

The number, length, and distribution of gaps in vehicular traffic on the main road when side road traffic experiences significant delays.

3. *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, streetlighting, utility poles and fixtures and adjacent land use / plans.

4. *Future Demand*

If significant changes in traffic volume or intersection layout are anticipated in the near term, these should be quantified. Specifically the Design Hourly Volume (DHV), Average Annual Daily Traffic (AADT), or AM or PM peak hour volume for the construction year is needed as a basis for calculating future warrants. This future volume may reflect side street traffic attracted to the new traffic signal upon a significant reduction in delay.

[illegible]

Table 11 - Basic Input Data

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 for a traffic control signal shall begin 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

Justification 2 - Delay to Cross Traffic

Justification 3 - Collision Experience

Justification 4 - Combination Justification

Justification 5 - Pedestrian Volume

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

Guidelines and Exceptions

Justifications should be used as a guide to determining the need for traffic control signals rather than as absolute criteria. The fulfilment of a traffic signal justification or justifications shall not in itself **require** the installation of a traffic control signal; the justifications must be used in combination with experience, professional judgement and economic analysis. The satisfaction of the signal installation justifications is only one criterion for determining the suitability of traffic control signals for any location.

The decision to proceed with a justified signal installation should also reflect a benefit/cost analysis in which the economic benefits are shown to outweigh the costs associated with the signal and its operation (including its effect on delay and collision rates). The Canadian Capacity Guide¹ gives some guidance on evaluation of benefits, and other sections of this Manual deal with the costs of collisions.

Even if the intersection situation meets a Justification, a traffic control signal should not be installed if it will result in operational problems which create a potential for collisions and / or significantly increase delays to all users. Potential problems include extension of vehicle queues through upstream intersections, or a break in progression in both directions for a high through volume. Operation of one-way streets presents another set of issues which require engineering judgement to be applied over and above strict reliance on the justification criteria.

Underlying all of the justification is the assumption that adequate visibility up and downstream is available from a stopped vehicle on the cross street. If visibility 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 even if Justifications 1 -5 are not met.

At intersections where transit use is a significant concern, the disproportionate person-hours of delay experienced by bus passengers may be considered by the experienced analyst into the justification.

Definitions

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 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 selected as the main road.

Average Day:

The traffic volumes used in the analysis should be representative of those likely to be experienced on an average day which reflects the problem that the signal is intended to address. Where days during which signal justifications are met occur on other than weekdays (e.g. a busy retail oriented street which is congested on Saturdays rather than during weekdays, or roads in recreational areas that experience peak traffic conditions only during summer weekends), signals may be justified on the basis of recurring congestion but their design and operation should reflect the variations in their use. They should be operated so as not to cause undue delay during the majority of the days during which the demand is reduced.

Within the day, the hours counted should reflect the volumes experienced during the hours at issue. 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.

Flow Conditions:

The justifications for traffic signals have been developed for "Restricted" and "Free Flow" conditions. This division is necessary due to the different operating characteristics which exist under each condition.

Restricted Flow (Urban) Conditions are those which are normally encountered in urban areas where the traffic volumes approach or exceed the practical working capacity of the roadway and operating speeds are generally less than 70 km/h.

Free Flow (Rural) Conditions are those which are normally encountered in rural areas and in communities of less than 10,000 population (if they are outside the commuting influence of a large urban centre). The operating speeds are generally greater than 70 km/h. The basic limitation on vehicle operation lies with the motorist. Even if the operating speed is less than 70 km/h, treatment of the situation as a free flow case recognizes that the driving characteristics in small communities are different than those in large urban areas

Roadway Type:

The minimum justification values for the volume on the main road are for a two-lane, two-way roadway. 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.

Entering Vehicles:

Only vehicles entering the intersection – whether they turn right, go straight through or turn left – should be considered. If the right turns are channelized and 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 be included in any justification calculations.

Bicycles:

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

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 control 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 vehicle-hours of delay for the intersection would be greater than if minor delays were distributed among both roadways.

Standard

The need for a traffic control signal shall 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 4, 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 potential conflicts between left turns and through moves on the minor road with the elimination of one of the approaches.

JUSTIFICATION	GUIDANCE	HOUR ENDING								No. of hours with compliance		
										≥ 100%	≥ 80%	
1A	TOTAL TRAFFIC VOLUME ENTERING INTERSECTION (vph) (2 way Total)											
	COMPLIANCE % * * $\frac{=VOL \times 100}{720}$ (1 lane approach on main road) OR $\frac{=VOL \times 100}{900}$ (2 or more lane approach on main road)											Average Compliance %
1B	CROSSING TRAFFIC VOLUME (vph) (2 way Total)											
	COMPLIANCE % * * $\frac{=VOL \times 100}{170}$ (full intersection) OR $\frac{=VOL \times 100}{255}$ (tee intersection)											Average Compliance %
(RESTRICTED FLOW) SIGNAL JUSTIFICATION 1:		BOTH 1A AND 1B 100% FULFILLED EACH OF 8 HOURS YES ☐ NO ☐ LESSER OF 1A OR 1B AT LEAST 80% FULFILLED EACH OF 8 HOURS YES ☐ NO ☐ SEE JUSTIFICATION 4										

* * Note: The compliance % figures used in Table 12 & 13 must not exceed 100%.

Table 12 - Justification 1 - Minimum Vehicle Volume for Restricted Flow (Urban) Conditions

Table 12 shall be used for Restricted Flow (Urban) Conditions, while Table 13 is applicable to the Free Flow (Rural) case (see Section 4.3.2 for definitions).

Guidelines

“Average Compliance” is calculated in Tables 12 & 13 for reference purposes, and may indicate how close an intersection is to achieving full justification. “Average Compliance” is calculated by adding all 8 hour compliance percentages and dividing that value by 8. The Compliance % figures used in Table 12 & 13 must not exceed 100%.

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 control signal shall 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 4, the Combination Justification.

Table 14 (p.72) shall be used for Restricted Flow (Urban) conditions, while Table 15 (p.73) applies to the Free Flow (Rural) case (see Section 4.3.2 for definitions).

Guidelines

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; plus
2. Total left turns from both the side road approaches; plus
3. The highest through volume from one of the side road approaches; plus

4. 50% of the heavier left-turn traffic movement from the main road when both of the following two criteria are met :

- a) The left-turn volume is greater than 120 vehicles per hour; and
- b) The total of the left-turn volumes plus the opposing volume is greater than 720 vehicles per hour.

“Average Compliance” is calculated in Tables 14 and 15 for reference purposes, and may indicate how close an intersection is to achieving full justification.

The Compliance % figures used in Tables 14 and 15 should not exceed 100%

JUSTIFICATION	GUIDANCE	HOUR ENDING								No. of hours with compliance		Average Compliance %
										≥ 100%	≥ 80%	
1A	TOTAL TRAFFIC VOLUME ENTERING INTERSECTION (vph) (2 way Total)											
	COMPLIANCE % * * $\frac{\text{VOL} \times 100}{480}$ (1 lane approach on main road) OR $\frac{\text{VOL} \times 100}{600}$ (2 or more lane approach on main road)											
1B	CROSSING TRAFFIC VOLUME (vph) (2 way Total)											
	COMPLIANCE % * * $\frac{\text{VOL} \times 100}{120}$ (full intersection) OR $\frac{\text{VOL} \times 100}{180}$ (tee intersection)											
(FREE FLOW)		BOTH 1A AND 1B 100% FULFILLED EACH OF 8 HOURS								YES ☐	NO ☐	
SIGNAL JUSTIFICATION 1:		LESSER OF 1A OR 1B AT LEAST 80% FULFILLED EACH OF 8 HOURS								YES ☐	NO ☐	
SEE JUSTIFICATION 4												

* * if calculated compliance % > 100%, show as 100% in table

Table 13 - Justification 1 - Minimum Vehicle Volume for Free Flow (Rural) Conditions

Table 14 - Justification 2 - Delay To Cross Traffic for Restricted Flow (Urban) Conditions

JUSTIFICATION	GUIDANCE	HOUR ENDING								No. of hours with compliance	
										≥ 100%	≥ 80%
2A	MAIN ROAD TRAFFIC VOLUME (vph) (2 way Total)										
	COMPLIANCE % $= \frac{VOL \times 100}{720} \text{ (1 lane approach)} \quad \text{OR} \quad = \frac{VOL \times 100}{900} \text{ (2 or more lane approach)}$										
2B	CROSSING TRAFFIC VOLUME (vph) (2 way Total)										
	COMPLIANCE % ** $= \frac{VOL \times 100}{75}$										
(RESTRICTED FLOW) SIGNAL JUSTIFICATION 2:		BOTH 2A AND 2B 100% FULFILLED EACH OF 8 HOURS LESSER OF 2A OR 2B AT LEAST 80% FULFILLED EACH OF 8 HOURS								YES ☐ NO ☐ YES ☐ NO ☐ SEE JUSTIFICATION 4	

** if calculated compliance % > 100%, show as 100% in table

4.6 Justification 3 - Collision Experience

Purpose

Where an unsignalized intersection has an unusually high collision record, signalization may be considered as one means of improving intersection safety.

Standard

While a collision situation alone seldom justifies signal control, the installation of traffic control signals may be justified when every one of the following conditions as presented in Table 16 (p.74) is satisfied:

1. Five or more reportable collisions of types preventable by traffic control signals have occurred during each of the three preceding twelve month periods, each collision involving personal injury or property damage which appears to be serious enough to be reported to

police. Preventable collisions are those involving vehicles which under signalized conditions would move on completely separate approaches.

2. Adequate trial of less restrictive remedies with satisfactory observance and enforcement have failed to reduce collision frequency.
3. There exists a volume of vehicular and pedestrian traffic not less than 80% of the requirements specified in the Minimum Vehicular Volume Justification 1, or the Delay to Cross Traffic Justification 2.

Guidelines

Less restrictive measures which 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 streetlighting, geometric or visibility improvements, shifting of bus stops, and/or the prohibition of parking and/or turns.

Table 15 - Justification 2 - Delay To Cross Traffic For Free Flow (Rural) Conditions

JUSTIFICATION	GUIDANCE	HOUR ENDING								No. of hours with compliance	
										≥ 100%	≥ 80%
2A	MAIN ROAD TRAFFIC VOLUME (vph) (2 way Total)										
	COMPLIANCE % $\frac{= VOL \times 100}{480}$ (1 lane approach) OR $\frac{= VOL \times 100}{600}$ (2 or more lane approach)										
2B	CROSSING TRAFFIC VOLUME (vph) (2 way Total)										
	COMPLIANCE % ** $\frac{= VOL \times 100}{50}$										
(RESTRICTED FLOW) SIGNAL JUSTIFICATION 2:		BOTH 2A AND 2B 100% FULFILLED EACH OF 8 HOURS YES ☐ NO ☐ LESSER OF 2A OR 2B AT LEAST 80% FULFILLED EACH OF 8 HOURS YES ☐ NO ☐ SEE JUSTIFICATION 4								Average Compliance %	

** if calculated compliance % > 100%, show as 100% in table

When applying this Justification, the analyst should consider that where self-reporting of collisions (as opposed to the once-standard documentation at the scene by police) is prevalent, it will have the effect of introducing less accuracy into the determination of whether or not the collision was preventable by signals.

The Justification is intentionally designed so that installation of traffic signals will seldom be justified on the collision justification alone. Engineering judgement 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.

4.7 Justification 4 - Combination Justification

Purpose

Signals may occasionally be justified where neither of Justifications 1, 2 nor 3 are 100% satisfied, but two or more are satisfied to the extent of 80% or more of the stated values, particularly if the other important factors are present such as:

- Sudden change from rural conditions to those of urban commercial surroundings;
- Extreme width of roadway which pedestrians must cross;
- Predominance of small children, seniors or disabled pedestrians who need to cross the roadway; and,
- Increasing traffic volumes.

Table 16 - Justification 3 - Collision Experience

A. Number of reportable collisions susceptible to prevention by a traffic signal.	Preceding Months	Number of Collisions	% Fulfillment ≥ 5 → 100% 4 → 80% ≤ 3 → 0%
	1 - 12		
	13 - 24		
	25 - 36		
			TOTAL = 3 %
B. Adequate trial of less restrictive remedies has failed to reduce collision frequency.	100% YES ☐	0% NO ☐	
C. Either Justification 1 (Minimum Vehicular Volume) or Justification 2 (Delay to Cross Traffic) satisfied to 80% or more.	100% YES ☐	0% NO ☐	
SIGNAL JUSTIFICATION 1: ALL OF A, B AND C ABOVE FULFILLED TO 100% ?	100% YES ☐	0% NO ☐	

Table 17 - Justification 4 - Combination Justification

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 ☐	☐	☐
Justification 3 -	Collision Experience	YES ☐	NO ☐	JUSTIFIED	NOT JUSTIFIED

Standard

The requirements for the Combination Justification are given in Table 17.

Guidelines

For the purposes of the Combination Justification, Justification 3 (Collision Experience) is considered to be met 80% if Justification 3A exceeds 80% and Justification 3B is met 100%.

4.8 Justification 5 - 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.

Table 18 - 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 the Road

** Factored Volume = (Unassisted) + (2 x Assisted) Volume

*** See Guideline No.1

Table 19 - 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 the Road

** Factored Volume = (Unassisted) + (2 x Assisted) Volume

*** See Guideline No.1

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 shall be considered if both the following minimum pedestrian volume and delay criteria are met:

1. The total 8-hour pedestrian volume crossing the main road at an intersection or mid-block location during the highest 8 hours of pedestrian traffic fulfils the justification requirement identified in Table 20 (p.76) ; and

Table 20 - Pedestrian Volume Justification 5A

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. > $(0.0001 V_8^2 - 0.146V_8 + 770)$

EQUATION 3: Justified **if** net 8 hour ped. vol. > $(340 - (.0094V_8))$

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

Table 21 - Pedestrian Delay Justification 5B

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 delayed peds > $(240 - (.55 \times \text{vol. of total peds}))$	Justified
> 300	Not Justified	Justified	Justified

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

Signal Justification:

Both Justification 5A (volume) and Justification 5B (delay) met?

YES ☐ = Traffic Control Justified

NO ☐ = Traffic Control Not Justified

- The total 8-hour volume of pedestrians experiencing delays of ten seconds or more in crossing the road during the highest 8 hours of pedestrian traffic fulfils the justification requirement identified in Table 21

The graphed equations used in Tables 20 and 21 are included for reference purposes as Figures 12 (p.78) and 13(p.79).

Guidelines

- 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. (See "% Assigned to Crossing Site" in Tables 18 and 19)

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 5 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 relates to the need for motorist familiarity with the crossing of running the signal or undertaking other unsafe manoeuvres. Application of a single use of one crossing type should be avoided. 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 5 being fulfilled but the crossing vehicular traffic should be so light as to not meet one of the other justifications (1 - 4).

b) *Pedestrian Crossovers (PXOs)*
Pedestrian Crossovers are intended for low to moderate volume, low speed roadways (60km/h or less posted speed) and shall 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 20 and 21, 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 Tables 19 and 20, which is set by the authority as the threshold of need.

d) *Full Intersection Signals*
Consideration should be given to implementing a full traffic control signal at an intersection in the case where pedestrian crossing protection is justified but :

- a PXO, IPS or Midblock Device is inappropriate because of the roadway physical or operating conditions as noted in (a) or (c) above; or
- an IPS is justified but is not in use 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.

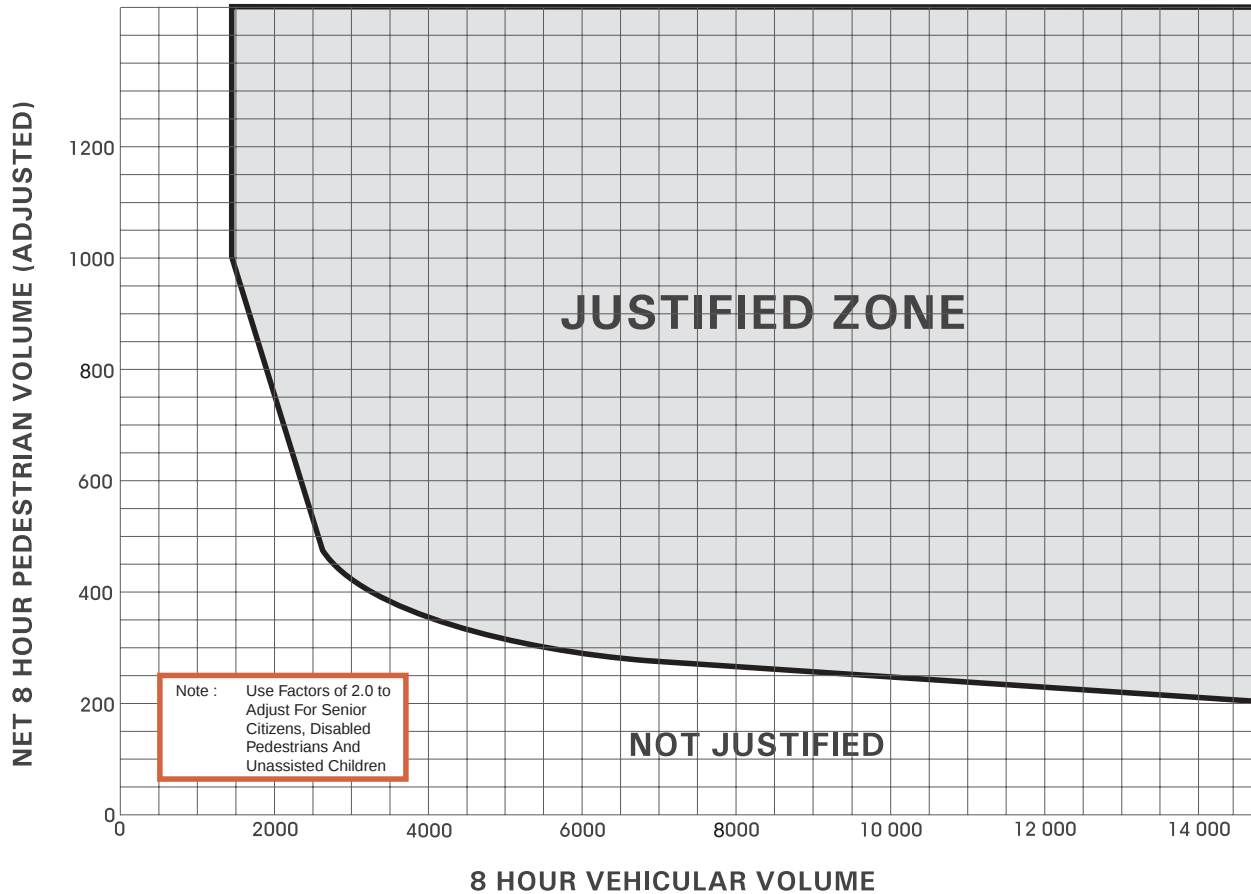


Figure 12 - Pedestrian Justification Based on Pedestrian Volumes

4.9 Signal Justifications For Future Conditions

The prediction of future traffic requirements within a 5 year period is based on knowledge of roadway usage growth, growth of local traffic generators and predicted traffic volumes .

Future hour-by-hour 8 hour volumes are difficult to predict with the necessary accuracy; therefore justifications for future conditions normally use the Design Hourly Volume (DHV) or peak hour volumes for the intersection.

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 recommended increase is 20% in the case of an existing intersection and 50% in the case of a new intersection.

As noted in Section 5, where a signal is anticipated to be justified within five years of roadway construction, recommended practice is to construct the necessary underground provisions as part of the road works.

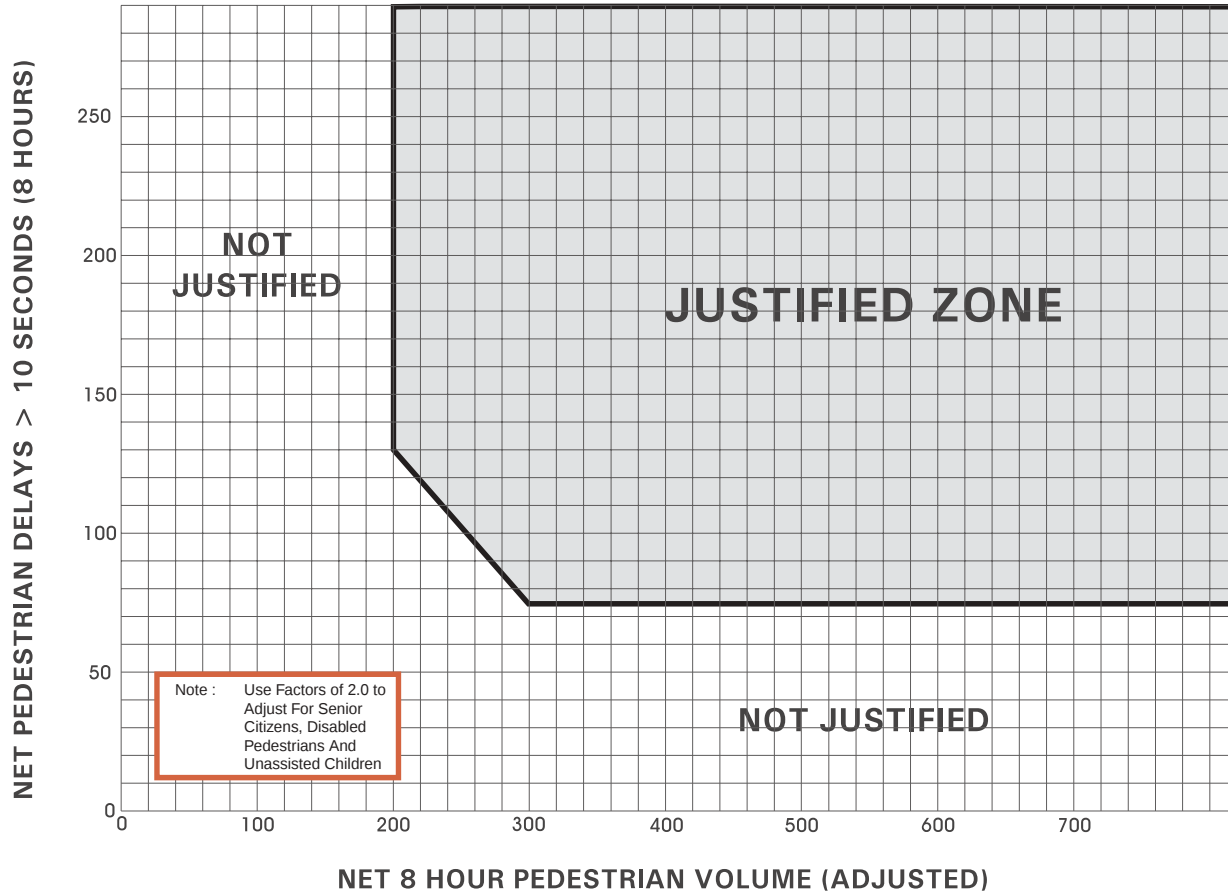


Figure 13 - Pedestrian Justification Based on Pedestrian Delay

4.10 Signal Installation Prioritization

On a network-wide scale, funding limitations or other constraints may lead to an inability to implement all signals which meet the minimum technical justification criteria. It is therefore important to understand the relative value of each candidate set of traffic control signals so that effort may be directed first to the site which 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.

The weighting placed on each of the justification components in terms of priority is the responsibility of the signal authority. There are several software packages available that will carry out prioritization. One basic manual approach is to prepare a combination justification analysis for each potential location and rank the sites by the degree to which they meet the combination justification as shown in Table 24 (p.85). This approach has the effect of ensuring collision history is integrated into the prioritization process.

Justification		Compliance	Signal Justified?		
			MET?	YES	NO
1. Minimum Vehicular Volume	A Total Volume	> 100% ____ of 8 hours			
	B Crossing Volume	> 100% ____ of 8 hours			
2. Delay to Cross Traffic	A Main Road	> 100% ____ of 8 hours			
	B Crossing Road	> 100% ____ of 8 hours			
3. Collision Experience	A Collisions	____ %			
	B Trial of Remedies	YES / NO			
	C Justification 1 or 2 Compliance	> 80% 8 of 8 hours			
4. Combination	A Minimum Volume Justification 1	> 80% 8 of 8 hours			
	B Delay Justification 2	> 80% 8 of 8 hours			
	C Collisions	3A > 80% AND 3B = YES			
5. Pedestrian	A Volume	____ %			
	B Delay	____ %			
Overall		At least one Justifications 1 - 5 met?			

4.11 Table 22 - Summary of Signal Justification

This figure may be further weighted by benefit / cost ratio, or by the capital cost of the installation relative to the average signal installation cost in the jurisdiction, or by other locally-generated factors. The ratings for each site are then tabulated and ranked from highest to lowest in terms of "Average" combined justification.

Justification 1A Compliance for Avg. Hour	_____ %
Justification 1B Compliance for Avg. Hour	_____ %
Justification 2A Compliance for Avg. Hour	_____ %
Justification 2B Compliance for Avg. Hour	_____ %
Justification 3 Condition A Fulfilment	_____ %
Justification 4A Compliance	_____ %
Justification 4B Compliance	_____ %
"Average" Combined Justification	_____ %

Table 23 - Signal Installation Prioritization

4.12 Justification for Temporary Traffic Control Signals

Temporary traffic control signals shall be justified for use in the following locations:

1. Where either road at an intersection has a posted speed of 80 km/h or greater and construction staging does not allow the existing poles to be kept at the proper clear zone, nor does it allow for protection of the poles with barrier.
2. Where either road at an intersection has a posted speed of 80 km/h or greater and the visibility of the traffic signal heads will not meet the design criteria for visibility, as given in Section 5, where traffic is moved from its normal lanes and where 24 hour flag persons, barriers and other devices are not practical to maintain; and
3. Where pedestrian visibility of pedestrian signal heads may be obscured by construction equipment and/or re-routing of pedestrian crossings and the possibility of confusion or pedestrian interference with construction activities exists (temporary pedestrian heads may be sufficient).

4.13 Justification for Bicycle Signals

This subsection may be added in future.

4.14 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 analysed using Justifications 1 - 5 on the same basis as if it were a “new” installation. If, under current conditions, the signal fails to meet any of Justifications 1 -5 then it should be considered a candidate for removal. If only Justification 5 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.

5. Design Practice

5.1 General

Use Of This Section

Each road authority may have their 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.

This section of the manual is intended to provide general design interpretation, recommended practice and guidance for the design of traffic signals. The design practices and guidelines given in this section are intended to 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 in the detail design of traffic control signal layouts.

The design guidelines in this section are based on new construction or reconstruction of intersections since that is the most common situation. The design guidelines may be easily adapted to suit existing conditions where there is no roadway work contemplated.

5.2 Practical Requirements

The responsibility of the designer is to produce a safe, effective and efficient signal design which is acceptable to the road authority, enables provision of acceptable levels of service and delay standards 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 within the foreseeable 5 year period as identified by the Needs or Justification Reports.

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

5.3 Safety Considerations

Safety considerations for the detailed design of traffic signals include the following factors:

- adequate pole offsets from the edge of the through lanes of pavement as related to the posted speed. The recommended practice uses 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 which meet the requirements of the safety clear zones as given in the Ministry's Roadside Safety Manual²² 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 fusing or circuit breaker ratings 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.

5.4 Future Considerations

The prediction of future traffic volumes within a 10 year period is based on an anticipated future traffic demand. A traffic control signal Needs Report or Justification Report should be prepared which addresses not only current traffic volume and intersection capacity analysis, turning needs and pedestrian needs, but also the five year horizon for such needs and the possibility of roadway reconstruction and/or lane reconfiguration.

If it can be confirmed that the intersection will be upgraded for roadway deficiency reasons within a five year time frame, then the designer should inquire as to future plans for the intersection since current reconstruction of signals may require basic changes to pole footings, pole types, wiring and controller equipment. If plans are reasonably firm for the future,

the traffic signal designer should request the road planner/designer to provide any features required in the future that could possibly be incorporated into the current design.

If future reconstruction of the intersection is required due to the growth of traffic or due to changes to travel patterns in the area, and this is confirmed by traffic studies, then the traffic signal designer should seek advice from knowledgeable persons such as road planners/designers. Overbuilding of the traffic signals may be a waste of money if many features will require future reconstruction in any event. Conversely, if firm plans for future intersection geometry are available, it would be advisable, where practical, to locate items such as electrical chambers and ducts in the locations required for the future reconstruction, or, in some cases, it may even be advisable to design aerial traffic signals as an interim measure.

Where traffic control signal studies indicate that traffic control signals are not required at the time of construction/reconstruction of the intersection, but 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 be grossly increased within a two year time frame due to the construction of a new shopping mall or other large traffic generator.

5.5 Signal Visibility

General

Signal visibility, for ease of comprehension, is the most important aspect of traffic control signal design. The recommended practices and guidelines given in this section should be seriously considered and followed as closely as possible.

The visibility of signal indications, outside of geometric considerations, are 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; and
- type of optical system (standard, optically programmed, LED, fibre optic).

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, especially by motorists passing through the intersection for the first time. Motorists should not be forced to search for the signals or to take their attention away from the road in order to see the signal indications.

The signal indications should be immediately and easily noticeable. The state of being noticeable, or the conspicuity of the signals, is affected by the following factors:

- at least one signal head should be within the motorists’ cone of vision extending 30° horizontally and 15° vertically from the eyes when facing straight ahead. This requirement applies from the sight distance required for visibility (Table 24 subsection 5.5). The requirement at the stop line ensures that the red signal indication is visible by the motorist through the windshield;

- Figure 14 shows application of the horizontal cone of vision. Where the horizontal and vertical geometry are not a problem, the cone of vision may be tested at the stopline. (This is the worst case since the cone encompasses more width at a greater distance);
- where horizontal or vertical geometry prohibits visibility of at least one signal head within the cones of vision from the visibility distance of Table 25, the use of an auxiliary signal head and / or a continuous or activated flasher / “signals ahead” sign may be required;
- 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;
- standardized locations so that the majority of motorists, who are residents of Ontario, will not be confused and will not have to visually search for the signal heads.

A minimum of two signal heads shall 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.

Many intersections exhibit geometric characteristics which do not lend themselves to obtaining good visibility and alternative or auxiliary methods must be explored. For good visibility of signal heads, the guidelines should be considered and followed as rigidly as possible.

Viewing Angles

The optimum viewing zone for traffic signal heads is within 15° horizontally or vertically. This gives a horizontal cone of vision of 30° and at least one signal head should be within this cone, in the area between the visibility sight distance and the stop line, as shown in Figure 14.

The secondary signal heads must be located on the left of approaching through lanes, on the median or the far left side of the intersection at least at the edge of pavement. Where intersection approaches do not align, these references may be taken 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.

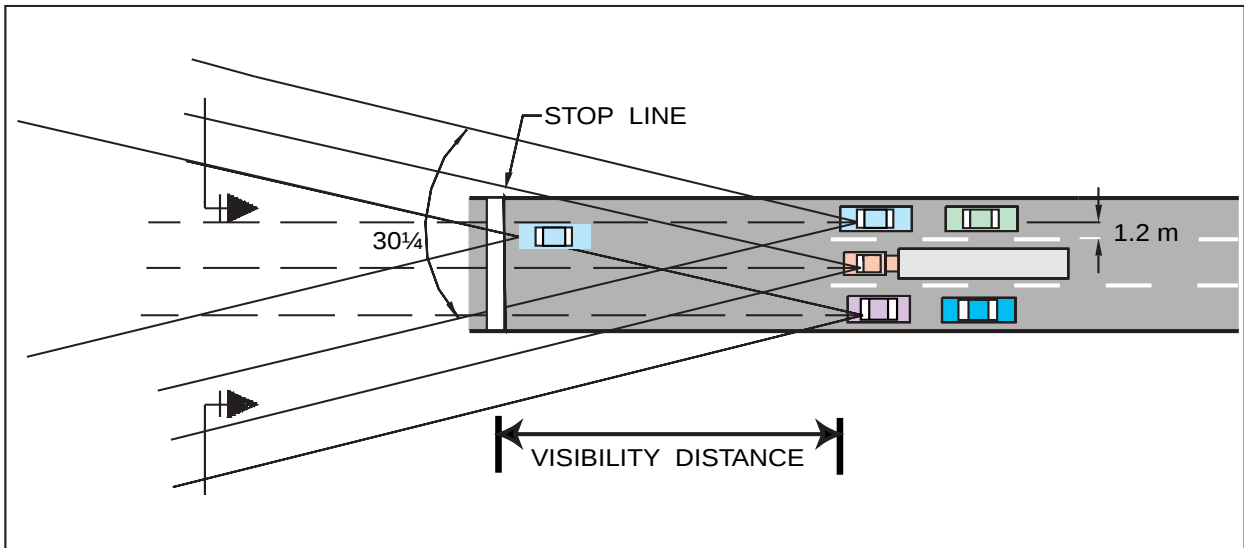


Figure 14 - Cones of Vision for Signal Visibility

Lateral Signal Head Locations

A primary signal head must be located on the far right side of the intersection facing each vehicle approach to the intersection.

The primary signal head should be located laterally at least at the edge of pavement (0.5 m over the roadway preferred), at intersections with a signal head on a median island. Where median islands do not exist, the primary signal heads should be located at the 1/2 to 3/4 point of the curb lane.

Table 24 - Signal Visibility Distances

Posted Speed (km/h)	Minimum Distance from Which Signal Must be Clearly Visible (m)
40	65
50	85
60	110
70	140
80	170
90	200
100	230

Table 25 - Typical Use of Signal Heads and Backboards

Type of Roadway	Signal Heads and Backboards				
	Posted Speed (km/h)	Signal Head	Type of Head	Backboard	Recommended Mounting Height (m)
Major Roadway (Four or more lanes)	80 and over	Primary	Highway	Yes	5
		Secondary	Highway	Yes	5
	60 to 80	Primary	Highway	Yes	5
		Secondary	Highway	Yes	5
	less than 60	Primary	Highway	Yes	5
		Secondary	Highway	Yes	2.75*
			Standard	Optional	
Minor 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	

* for signal heads not over traffic lanes

Median Mounted Signal Heads

Signal heads mounted on median poles may be mounted either on the front of the pole or side mounted to give better target value to the heads. Variations are necessary for signal heads with left-turn arrows and mast arms, multiple heads on a pole and geometric variations.

Visibility Distance

Motorists approaching a signal must be able to see the signal indications in sufficient time to react and to take any necessary actions. At least one signal head must therefore be visible from a distance as indicated in Table 24.

Backboards

Backboards are recommended for all primary heads and are preferred on all heads except secondary heads used at very low posted speeds of 50 km/h and less.

Table 25 gives typical applications for the use of various combinations of signal head and backboards without arrow control.

Backboard faces shall be traffic yellow in colour under most conditions. Specific conditions may exist where the daytime target value or visibility and conspicuity of the backboard faces may be enhanced by use of a dark colour such as dark green or black. These situations normally occur where the signal heads are at the top of a hill and have a sky background.

The rear surfaces of backboards are considered to be of little significance to the visibility of signals. Standard traffic yellow is used in most situations but municipalities may prefer to apply black or silver 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.

Mounting Height

Signal head mounting heights are legally set under the Highway Traffic Act and are given 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 reasons. 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 5.0 m clearance height.

Obstruction By Other Signal Heads

As well as trees, signs, etc., the secondary signal head facing opposing traffic could possibly act as a sight line obstruction for a considerable travel distance as shown in Figure 15. A straight edge should be used on the plan to ensure that the near side secondary head is not blocking the far side primary head and that at least one signal head is visible at all times, as seen by the motorist from the distances given in Table 24 and from all points between that distance and the intersection. A field check of these requirements is required during installation.

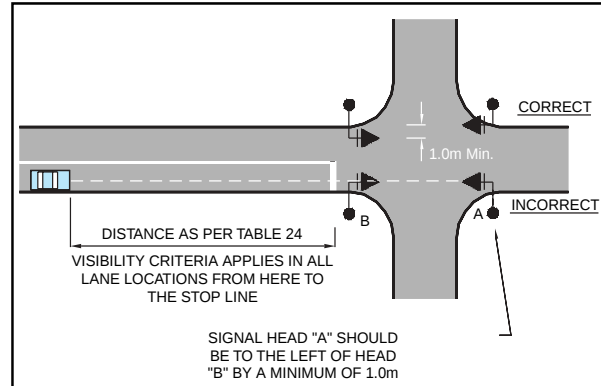


Figure 15 - Secondary Head Blocking Visibility

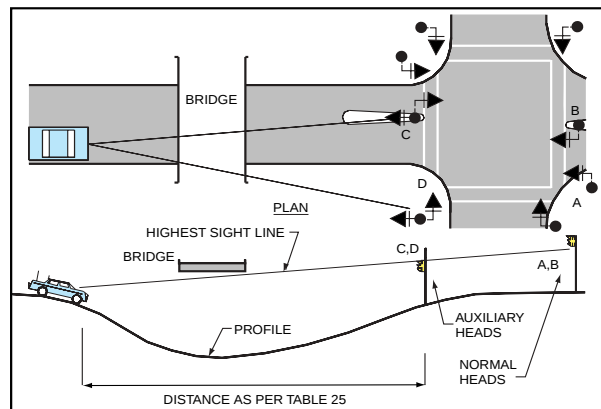


Figure 16 - Auxiliary Heads at Underpass

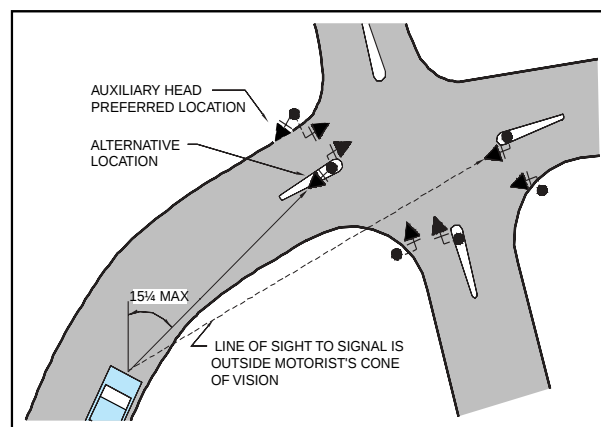


Figure 17 - Auxiliary Heads at Intersection on Curve

Auxiliary Signal Heads And Beacons

General

Signal heads may be obstructed by bridges (where a bridge is too 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 spacing of the signal heads and by combinations of many of these features.

Auxiliary signal heads are installed in addition to, and as a visual aid to 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 shall comply with the visibility distance of Table 24 or the flasher signs must be used.

The designer must be aware of the problems and check each design carefully to eliminate these problems or optimize the design to give the best possible visibility.

Auxiliary Heads at Bridge Obstructions

Bridge obstructions are typically the easiest to design for as accurate bridge details are always available. Where normal signal head visibility may be obstructed by a bridge underpass, low mounted auxiliary heads may be required as indicated in Figure 16.

Auxiliary Heads at Geometric Curve Obstructions

Special considerations should be given to signal visibility on horizontal roadway curvature where signal visibility is normally available, but the traffic signals are not conspicuous. This may be because the motorists are not looking far enough or are focusing

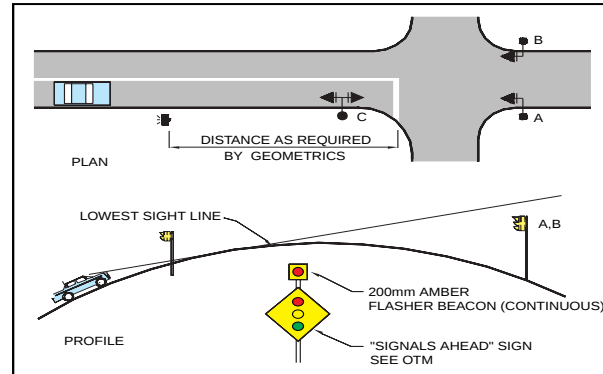


Figure 18 - Use of Continuous Flasher

on other features such as pavement marking changes, signage or off-roadway distractions. 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 of Figure 17 (page 87).

Two auxiliary heads on the outside of a curve should be avoided since the gap between them may be mistaken as the roadway during limited visibility conditions.

Care should also be taken with horizontal and vertical roadway curvature which is made visually abrupt. Visibility along horizontal curves may be hampered by buildings, rock cuts or large signs along the inside of the curve. Here, auxiliary heads at the intersection will be needed on the outside of a horizontal curve. Similarly, abrupt vertical curves which 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.

This situation is particularly bad where trees enter into the sight lines (sag curves) or opposing vehicle headlights produce high glare at night (crest curves). Also, combinations of horizontal and vertical geometry can produce rather treacherous results to designs which appear satisfactory on plan view. Only plotting of the sight lines on both plan and profile will show

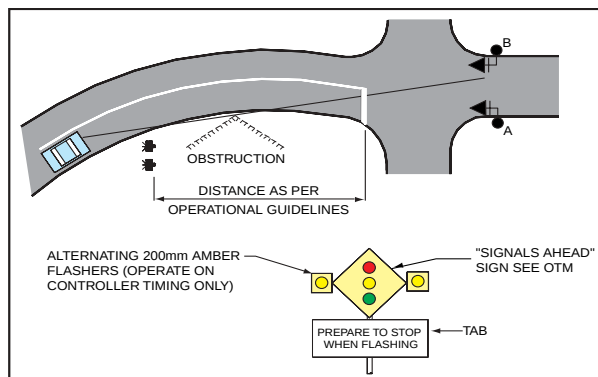


Figure 19 - Use of Active Flasher & Sign

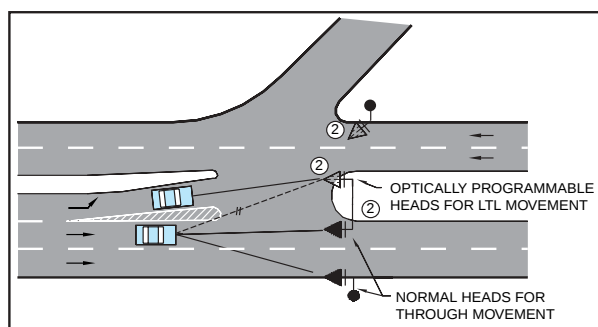


Figure 20 - Optically Programmable Heads, Example in wide Median

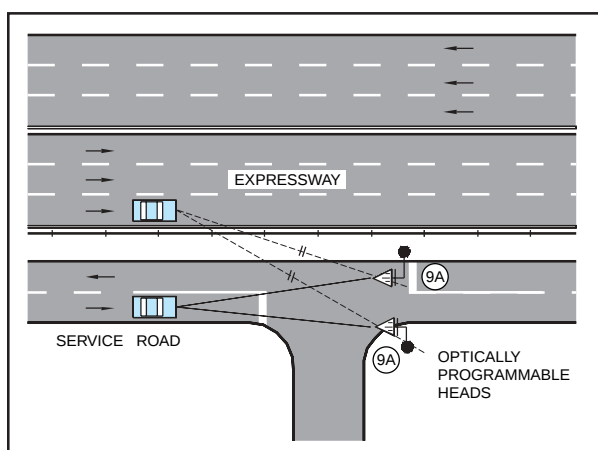


Figure 21 - Optically Programmable Heads, Example on Parallel Roads

these effects. At these locations, a continuous single flashing beacon with the oversized “Signals Ahead” sign (Wb-1102A) may be required as shown in Figure 18.

The sign can be located at any reasonable distance upstream from the signalized intersection beyond the visibility distance shown in Table 24 and in general conformance with signage guidelines of the OTM.

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 travelling a substantial distance on a divided highway where a signal may not be expected.

An example of this situation is shown in Figure 19. Note that the sign flashers should be located and would operate as described in Section 3.

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 many trucks are turning left. The minimum spacing of 5.0 m between primary and secondary heads is meant to mitigate this effect to some extent. It is not necessary to design for all circumstances as long as several basic rules of signal head spacing are followed. Where median islands exist, some municipalities install auxiliary secondary signal heads on the far left side of roads, at lower mounting heights, to mitigate the visibility impairment caused by large vehicles.

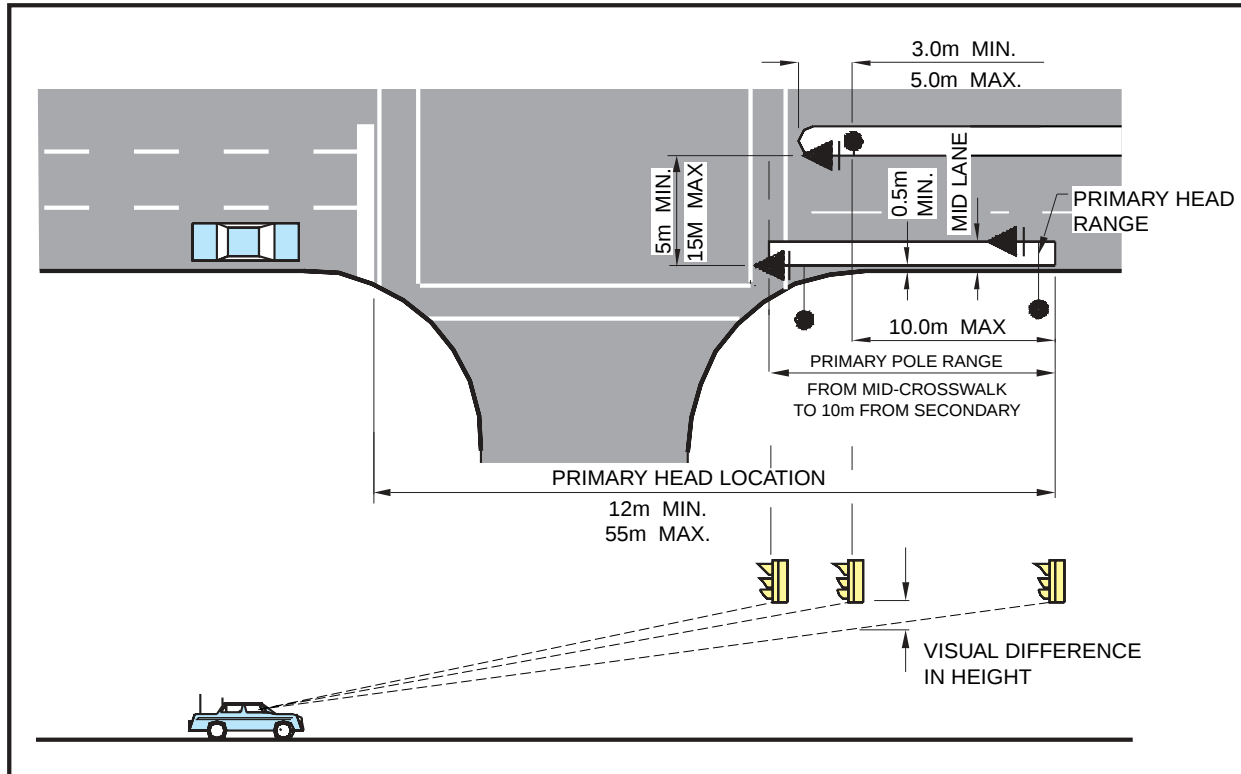


Figure 22 - Primary and Secondary Head Locations

Optically Programmable Signal Heads

Skewed intersections with non-standard turning lanes may require optically programmable signal heads to avoid confusion to motorists in adjacent lanes as indicated in Figure 20 (p.89). Similarly, signal heads between two separate parallel roadways may require focused lenses to prevent confusion on the non-controlled roadway as shown in Figure 21 (page 89).

Optically programmable signal heads may be used for displays at closely spaced intersections. Here, the motorist may focus on the furthest set of signals and miss the closest set and the optically programmable signal heads help to mitigate this problem.

5.6 Pole and Signal Head Locations

Primary Signal Head Locations

General

The primary signal heads are the most important because they are most directly in the line of sight of motorists. The primary heads shall be located at the far right corner of intersections. The primary heads should be located in accordance with the following guidelines:

- At a longitudinal distance from the approach stop line of 12 m minimum (with 15 m the preferred minimum) to 55 m maximum as shown in Figure 22.

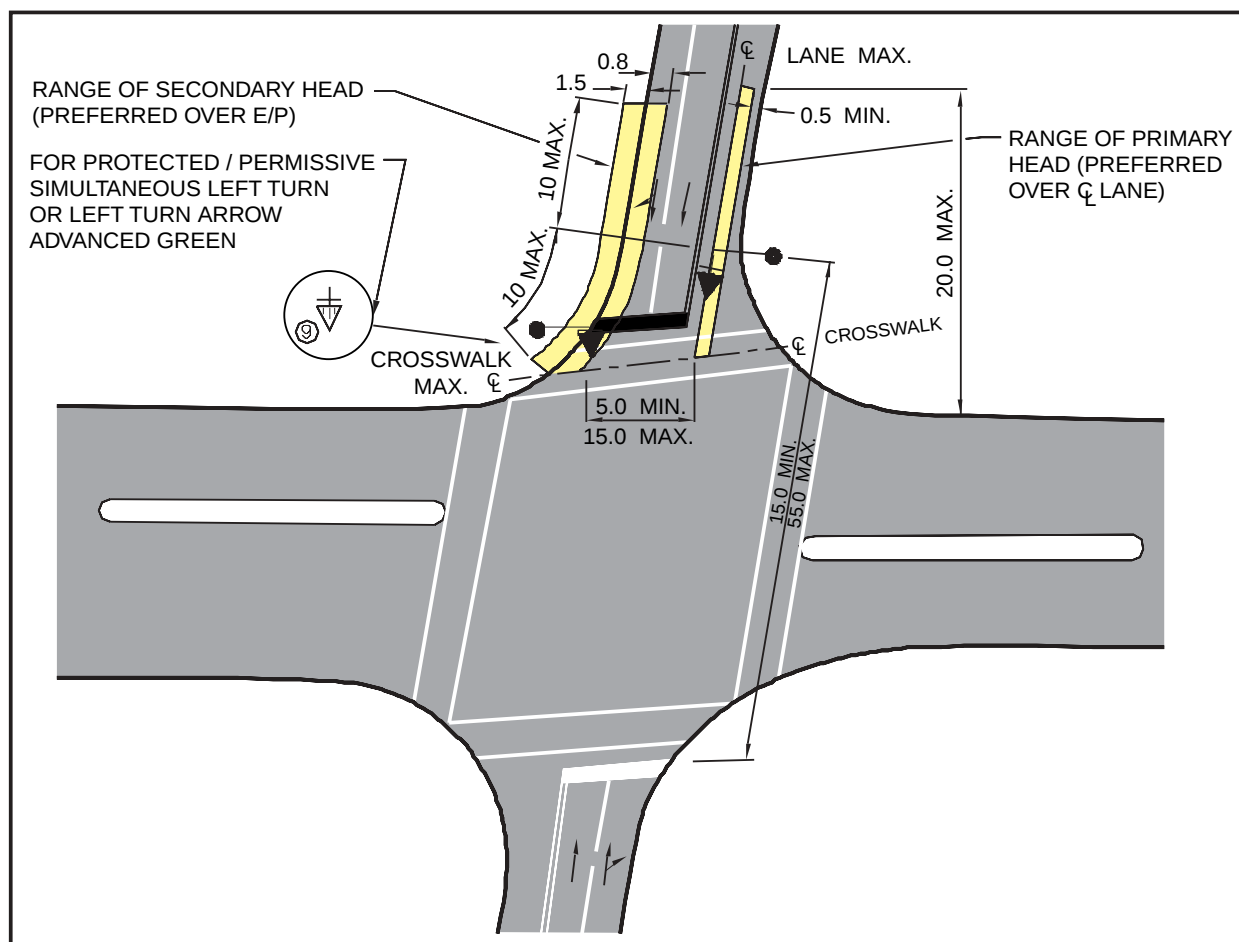


Figure 23 - Primary and Secondary Heads Without Islands

The 15 m distance corresponds to a normal windshield visibility cutoff for a signal head mounted at 5.0 m height and this distance may be reduced to 12 m minimum where tight conditions exist (with a lower mounting height used to ensure visibility if necessary):

- The 15 m distance corresponds to a normal windshield visibility cutoff for a signal head mounted at 5.0 m height and this distance may be reduced to 12 m minimum where tight conditions exist (with a lower mounting height used to ensure visibility if necessary):
- At a maximum longitudinal distance of 10 m either way from the median pole location, as measured along the centreline of the roadway, is recommended as shown in Figure 23.
 - If the above guidelines and standard mast arm lengths allow, the poles are recommended to 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 while taking aesthetic requirements, utility clearances and mast arm length restrictions into account. Iterative trials of the design are normally required.

- The standard 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.
- A minimum lateral distance of 5.0 m and a maximum (desirable) lateral distance of 15.0 m (22 m absolute maximum distance) is required between the primary and secondary heads under normal conditions. 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 obtained where possible.
- Secondary heads with left turn arrows should be located as near to the intersection as practical.

With Median Islands

For a straight 2-lane approach with a separate left-turn lane and a median island, it is normally desirable to mount the primary head at the 0.5 m minimum overhang in the curb lane in order to get as much lateral distance as practical between the primary and secondary heads.

The primary and secondary heads should be separated by a minimum of 5.0 m and a desirable maximum of 15.0 m with an absolute maximum of 22 m. The lower value allows for visibility blockage of one of the heads by larger vehicles while the upper value normally allows for at least one of the heads to remain within the 30° cone of vision at all times.

Without Median Islands

Where median islands are not used, it is desirable to position signal heads between the 1/4 point and 3/4 point of the curb lanes as shown in Figure 23. In this case, primary poles and heads are normally designed prior to the secondaries.

Secondary Signal Head And Pole Locations

General

Secondary heads, other than those in median islands, should be located using the following guidelines:

With Median Islands

Where median islands are present (with a minimum of 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 22 shows the range of the primary head when the secondary head location has already been set. The dimensions are shown between heads.

The primary head should also satisfy the cone of vision requirements shown in Figure 14 for each approach lane. During design, it is important to plot the signal heads accurately on plan (usually a point at the end of the mast arm) and desirable to produce the final drawing in a similar manner so that visibility can be checked.

Without Median Islands

Normally, opposing secondary heads are laterally outside (further from centreline) of the primary heads by a minimum of 1.0 m as shown on Figure 15. The normal 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 second choice is directly over the edge of pavement provided that range distances and visibility criteria are met. The secondary heads can also be placed up to 1.5 m from the edge of pavement if necessary to meet other criteria.

5.7 Pedestrian Signal Heads

Pedestrian Indications

Pedestrian indications shall 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 30cm (lens) housing or have separate housings provided, 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 shall 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 or pedestrian signals, for crossing the through road, on the side of the intersection which 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:

1. When a traffic signal is installed under the pedestrian justification.
2. When pedestrians and vehicles are moving during the same phase and properly adjusted pedestrian clearance intervals are needed to minimize vehicle-pedestrian conflicts.
3. When an exclusive phase is provided or made available for pedestrian movement in one or more directions, all vehicles being stopped.
4. When heavy vehicular turning movements require a semi-exclusive pedestrian phase for the protection and convenience of the pedestrian.
5. When pedestrian movement on one side of an intersection is permissible while traffic from only one approach is moving.
6. When an intersection is so large and complicated or a road so wide that vehicular signals would not adequately serve pedestrians.

7. When the minimum green intervals for vehicles at intersections with traffic-actuated controls is less than the minimum crossing time for pedestrians and equipment is provided which extends the green time upon pedestrian actuation (normally by pushbutton).
8. When complex phasing operation would tend to confuse pedestrians guided only by traffic signal indications.
9. When traffic signal heads using arrows are used.
10. When pedestrians cross only part of the road, to or from an island, during a particular phase.
11. 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

The use of pedestrian heads will require pedestrian pushbuttons at 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;
- 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" sign be installed at each pushbutton.

Mounting Height And Location

Pedestrian heads shall be mounted at a minimum of 2.75 m as measured from finished grade at the edge of pavement to the bottom of the signal housing. This dimension should be used unless unusual

circumstances require a greater height but pedestrian heads shall 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 at the stop line.

5.8 Miscellaneous Traffic Control

Intersection Pedestrian Signals

Intersection Pedestrian Signals (IPS) may be installed at intersections which 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 24.

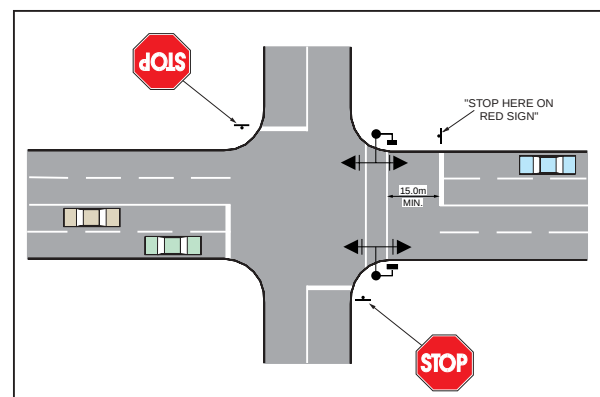


Figure 24 - Intersection Pedestrian Signals

Standard 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 IPS is shown. 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.

Mid-block Pedestrian Signals

Where justified by continual disruption of traffic flow or by conditions of collision histories and heavy pedestrian volumes and delays, vehicular and pedestrian traffic control systems may be installed at mid-block locations. All pavement marking features are similar to normal signalized intersections with the vehicle stop lines set back at a minimum of 12 m (15 m recommended practice) from the edges of the crosswalks. 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 60km/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. The normal 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. This characteristic is normally found where alternate routes, such as other bridges across a river or other routes up or down a mountain, are not available or as convenient as the roadway in question and therefore the classic tidal flow rush hour pattern evolves.

Lane direction signals shall 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 so positioned 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 5.0 m preferred.

Lane control signals must be carefully located in advance of, or beyond, an intersection controlled by normal traffic control signals so as to eliminate possible confusion by 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 here. 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 30 cm size lens is available and the size of the symbols relate to visibility up to 150 m corresponding to use with operating speeds of 60 km/h or less. Similarly, a 40 cm size lens is available which is visible up to 225 m and suitable for use up to an operating speed of 80 km/h;
- Spacing of the lane direction signals should be practically set at a minimum of the limits of visibility (approximately 150 m for 30 cm lenses and 225 m for 40 cm lenses); and
- 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 considered special for use 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 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 shall be required to provide greater protection for vehicles. Examples of this are given in the TAC MUTCD.

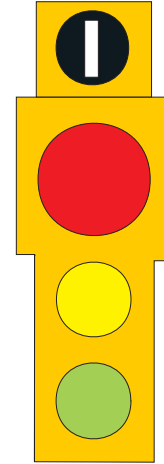
Where the railway crossings are in such close proximity to the intersections that back-ups from the vehicle signals will undoubtedly occur, the interconnection of railway and vehicle signals will be required, for the purpose of applying pre-emption to the vehicle signals, unless these back-ups can be eliminated by other means such as the use of arrow indications which permit non-conflicting movements. Pre-emptive signals may also be used to activate other devices such as blank-out signs for turn prohibition 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 shall be carried out by the road authority and submitted to the appropriate railway owner for approval, coordination and costing. This evaluation shall estimate the times of day and probable duration of any back-ups likely to obstruct the crossings.

Signals which 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. The signal indications allow for the movement of transit vehicles through signalized intersections while all other conflicting traffic faces red indications. Transit priority signals are generally used at intersections and 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, of 20 or 30 mm lenses sizes, and mounted on any type of signal heads up to 4-sections. TPSIs are generally used at intersections where there are dedicated transit lanes or where their use would improve the efficiency of the transit routes and the safety of the intersections.

Some design guidelines are as follows:

- TPSIs may be provided with bus detection;
- TPSIs may be installed on exclusive signal heads which face transit traffic within a roadway corridor;
- TPSIs may be used with caution at intersections with mixed use traffic and only when a transit vehicle is first in queue or if a priority phase which clears queued vehicles precedes the TPSI phase, otherwise there may be the potential for motorist confusion in interpretation of the transit priority signals;

- TPSI placement is flexible and they may be used on signal heads which are not directly opposite transit lanes, on transit-only left turn signal heads and so on; and
- For safety reasons, the jurisdiction should carry out an extensive public awareness and education plan prior to implementation of transit priority signals.

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.

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 normally 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 park one or two vehicles in an emergency.

Portable Lane Control Signals

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. These signals are sometimes used to reduce traffic flow to a single lane in alternate directions at very local work areas on the roadway which required lane closure. Use of portable signals are an alternative to continuous flagging by flag persons, and are not to be confused with temporary traffic signals.

It is recommended practice that the use of portable lane control signals shall only be allowed where the posted speed is 60 km/h or less, where full illumination exists if the closure continues at night,

where driveways and intersections are not included in the closure area and where the lane closure will be continually attended.

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.

Signals With Audible Indications

Audible indications may be used to assist pedestrians who are visually disabled. Audible indications are not covered in the HTA. The designer is referred to the treatments given in the TAC MUTCD.

Tunnel Signals

“Tunnel Signals” are composed of two types:

- signals at the ends of a tunnel which 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

This space is reserved for future addition of the requirements of bicycle control signals.

5.9 Detection

General

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). In areas posted at speeds of less than 80 km/h, there is greater concentration on maximizing intersection efficiency than on dilemma zone protection. Special detector types or special layouts can also be used to detect buses only for bus priority signal actuation.

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.

At critical intersections, detection zone lengths and gap settings are normally designed to terminate green when headways are greater than two to three seconds.

Pedestrian pushbuttons and pre-emption devices are also forms of detection and are discussed in Section 3.

The current practice of many authorities uses 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, and so on.

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, as indicated in Figure 25.

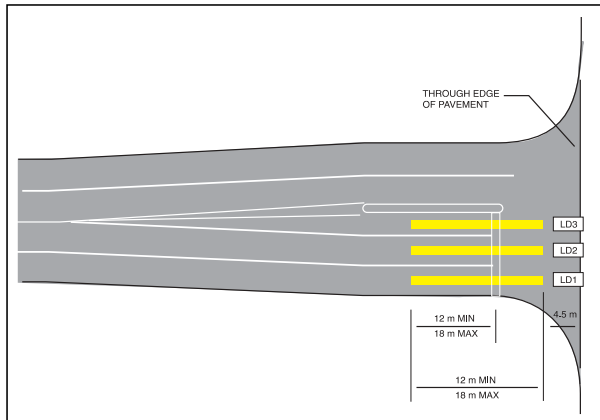


Figure 25 - Presence Loops

Long Distance Loop Detectors

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”.

As a recommended practice, these 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 and it is also good practice to use them at lesser speeds. The loops are normally installed per lane and are of 1.8 x 1.8 m square configuration or the

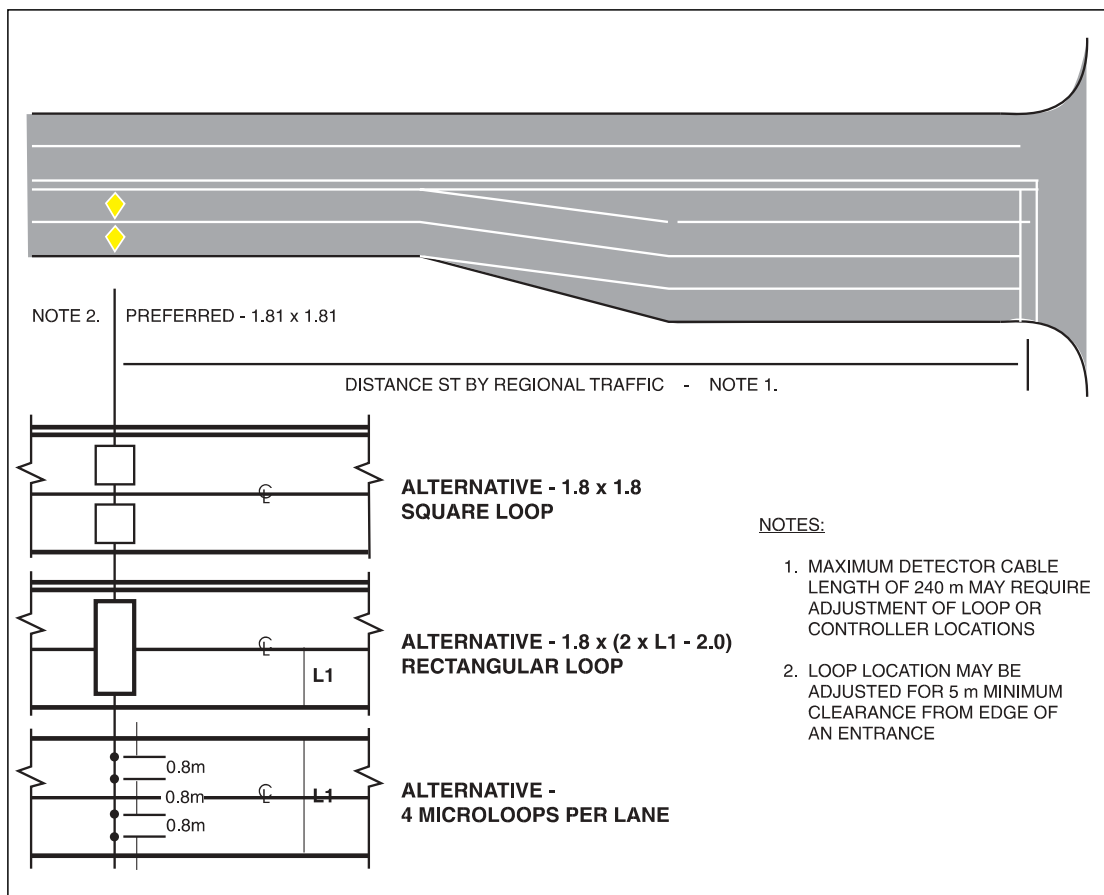


Figure 26 - Extension Loops

equivalent diamond shaped loops (preferred) as shown in Figure 26 (page 99).

The advantages of use are to serve higher speed traffic so that vehicles receive an extended green indication up to a maximum green time interval where max out occurs (LOS D & E) or gap out occurs (LOS C or better). Vehicles approaching the signal will pass over the long distance loops and extend the green time to ensure that they are able to get within a one second travel time of the stop line before the start of the amber interval. The extension of green time allows an approaching vehicle to pass through the dilemma zone. 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 26.

Passage loops may also be used as calling loops in the case of full actuation. In this case, a loop is installed in every intersection approach lane (or a single loop across multiple lanes) at a distance consistent with those shown in Table 26. Each traffic approach thereby has the ability to place a call for an approaching vehicle, with sufficient time to change

the signal indication to green before vehicles have to slow to a stop. In full actuation, another set of loops may be placed near the stop line so that vehicles arriving at the end of the maximum green time, and forced to stop, do not get trapped without any form of actuation (alternatively, recall to a minimum green time will clear the queue). This type of operation should not be used on high speed roads as it encourages local motorists to anticipate the green signal and may cause collisions with side road traffic entering on amber/all red.

The design of loop details with the various types of loops such as simple, duplex (quadrupole™), 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 Manual².

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.

Table 26 - Distances from Stop Line for Long Distance Loops

Operating Speed (85 th percentile)	Distance from Stop Line (m) (based on Edge of dilemma zone)*	Distance from Stop Line (m) (based on 5 second line)**
60	70	85
70	90	100
80	110	115
90	125	125
100	140	140

* edge of zone as determined by perception and reaction time plus braking deceleration time to within 1 second of the stop line.

** based on 5 seconds total time to within 1 second of the stop line allowing for average motorist time for perception, reaction and braking time.

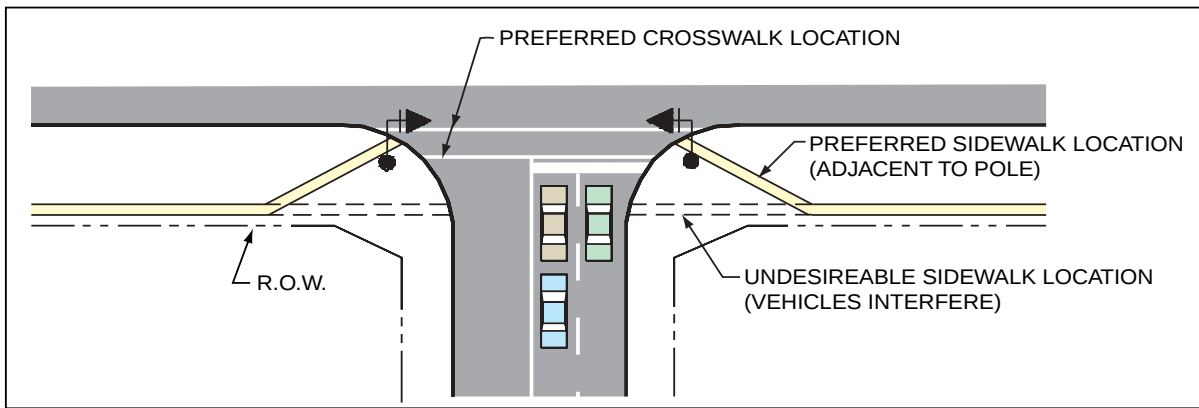


Figure 27 - Crosswalk and Sidewalk Locations

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 which are designed at the property line and leave a large boulevard between the back of 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 27.

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 these items and the signal designer must be able to discuss and support his/her case with the other offices involved.

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.

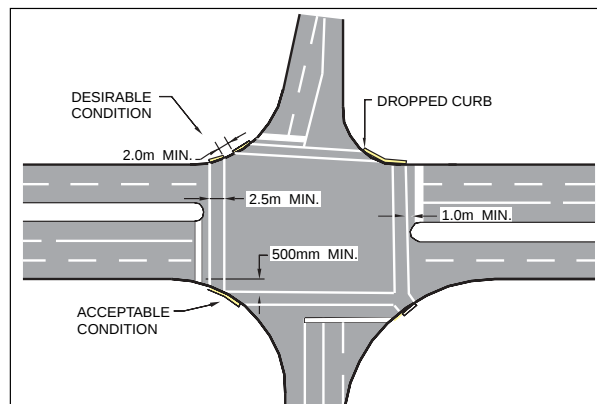


Figure 28 - Crosswalk Design

Figure 28 (page 101) shows a typical intersection on which one side is standard and the other side is modified. The crosswalks are laid out with the following guidelines in mind:

- the minimum crosswalk width is 2.5 m. The desirable minimum 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;
- the inner edge of the crosswalk should be a minimum of 500 mm 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;
- it is preferred that crosswalks be made to line up with proposed sidewalks or dropped curbs. The final design of the sidewalks and curbs should integrate with that of the crosswalks;
- 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. In these cases, and where possible, the crosswalk lines should be within the most direct route from sidewalk to sidewalk; and
- crosswalks should be as short as possible without compromising other design factors.

3. Sidewalks

The sidewalk and dropped curb designs should be coordinated with the road designer after crosswalks and all other equipment have been designed. Where the road authority allows options to sidewalk locations, a plan of the desired sidewalk locations, using the signal design plan as a base, helps to discuss the requirements. The following 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 in pushbutton locations) should be adjacent to and flush with sidewalks or hard surfaces (sidewalk extension, asphalt, etc.) should be placed between the sidewalks and the poles;
- where concrete or asphaltic concrete sidewalks are not available, a hard surface such as asphalt should be considered to be placed between the pedestrian pushbutton and other hard surfaces.

4. Integrated Design

Care in layout of the crosswalk markings can improve the appearance and operation of the intersection for pedestrians. Note that the dropped curbs and dropped sidewalk ramps for disabled persons at each crosswalk are shown on the roadway plans and must match the

final pavement marking. Where sections of dropped curbs are separate but close together, they sometimes leave a very short length of raised curb, making the sidewalk ramps abrupt and sometimes difficult to walk on. The crosswalks in this case should be separated sufficiently to allow a 2.0 m (desirable top-to-top distance) length of raised curb as shown in Figure 28 (page 101) 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.

Coordination of the final marking 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 provided that the truck turning radii are accommodated.

5. Large Radii

Very large truck turning radii leave a large area of flared pavement. This has the effect of significantly increasing the pedestrian walk time and of increasing the difficulty of signal design due to the restriction in practical single member arm lengths. The possibilities of installing a channelization island as shown in Figure 29 may be investigated and discussed with the road designers.

The island removes the turning traffic from the intersection and offers a pedestrian refuge area plus a good place to install a traffic signal. Caution should be used however because of the safety concerns about pedestrians crossing to the island as the legal responsibilities of motorists and pedestrians on the ramp are unclear as the ramp does not form part of the intersection. For channelized right turn lanes on roadways with posted speeds of 80 km/h and over, crosswalk markings must not be applied on the ramp.

For posted speeds of 80 km/h and greater, the minimum island size should be restricted to 10 m minimum 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 minimum 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 lane with adequate storage to remove all right-turning vehicles from the signal operation is required as well as a full acceleration lane for proper and safe merging on the side road.

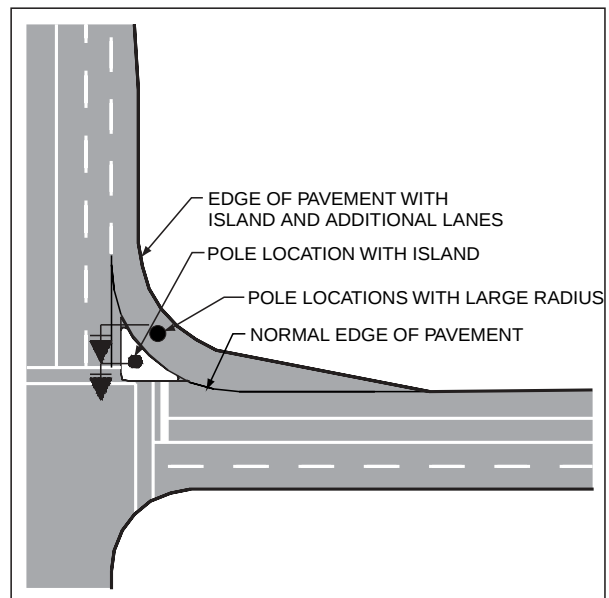


Figure 29 - Use of Right-Turn Island

5.11 Utilities

General

The designer must take great care to understand and 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). Time can be wasted if a designer assumes 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 will 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 which are 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 which 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 be less than acceptable and should not be relied upon with great accuracy. 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 $\pm$. 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 which can be plotted on plan. This would normally be 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 in accordance with the requirements of CSA Standard C22.3 No. 1 M. Note that these regulations are enforced in law under the Occupational Health and Safety Act. For transmission lines Ontario Hydro 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.

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, without exception.

The following guidelines are suggested:

- where possible, plan layout should be done 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 a desirable feature as poles hit by vehicles can “cartwheel”, sending the signal mast arm into high voltage cables and causing major damage. Good practice suggests that the traffic signal poles should be at least 5.0 m from the overhead lines (as measured horizontally) or the power lines relocation should be coordinated so as to be closer to the edge of pavement locally and the signal equipment 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. Note that these criteria are 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. The probability of a 10.5 m combination signal and lighting pole falling on the overhead lines is much higher than that of a 7.5 m signal pole.

Overhead low voltage lines, with the exception of the electrical neutral, 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 obtained.

There is no requirement to maintain other than the minimal clearance of 150 mm to either telephone or cable television lines. Efforts must be made however, to arrange to have these raised if the cables will visually obstruct the traffic signal heads.

5.12 Layout Practice

General

In the drawings, the “Normal” 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 30	“T” Intersection Approach;
Figure 31	Approach Without Median Island (Normal or Advanced Green);
Figure 32	Approach Without Median Island (Fully Protected Left Turns);
Figure 33	Approach With Median Island (Normal, Advanced Green or Simultaneous Protected / Permissive Lefts);
Figure 34	Approach With Median Island (Fully Protected Left Turns);
Figure 35	Approach With Wide Median (Fully Protected Left Turns);
Figure 36	Approach With Double Lane LTL (Fully Protected Left Turns);
Figure 37	Ramp Terminal Opposite Free-flow Ramp;
Figure 38	Short Offset Intersection;
Figure 39	Long Offset Intersection;
Figure 40	Pedestrian Signal poles.

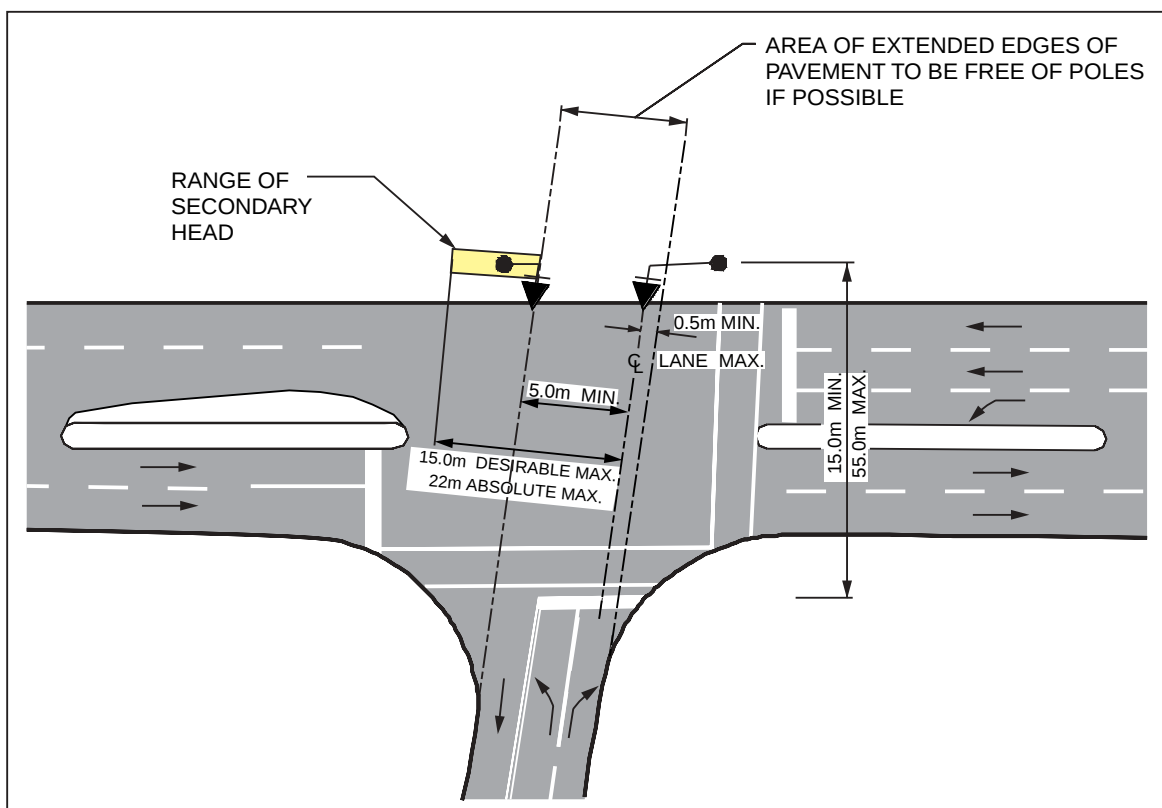


Figure 30 - "T" Intersection Approach

"T" Intersection Approach

A typical "T" intersection with two-way traffic on the side road is shown in Figure 30. Note the following:

- normal 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 purposes 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;
- where a double lane left or right turn is allowed, they should not occur simultaneously with conflicting pedestrian crossings; and
- where turning volumes and pedestrian volumes allow, 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.

Approach Without Median Island (Normal Or Advanced Green)

A typical simple approach, without a median island and with normal or advanced green indications, is shown in Figure 31. Note the following:

- there is no median pole and therefore the primary head should be at or close to the centre of the lane;

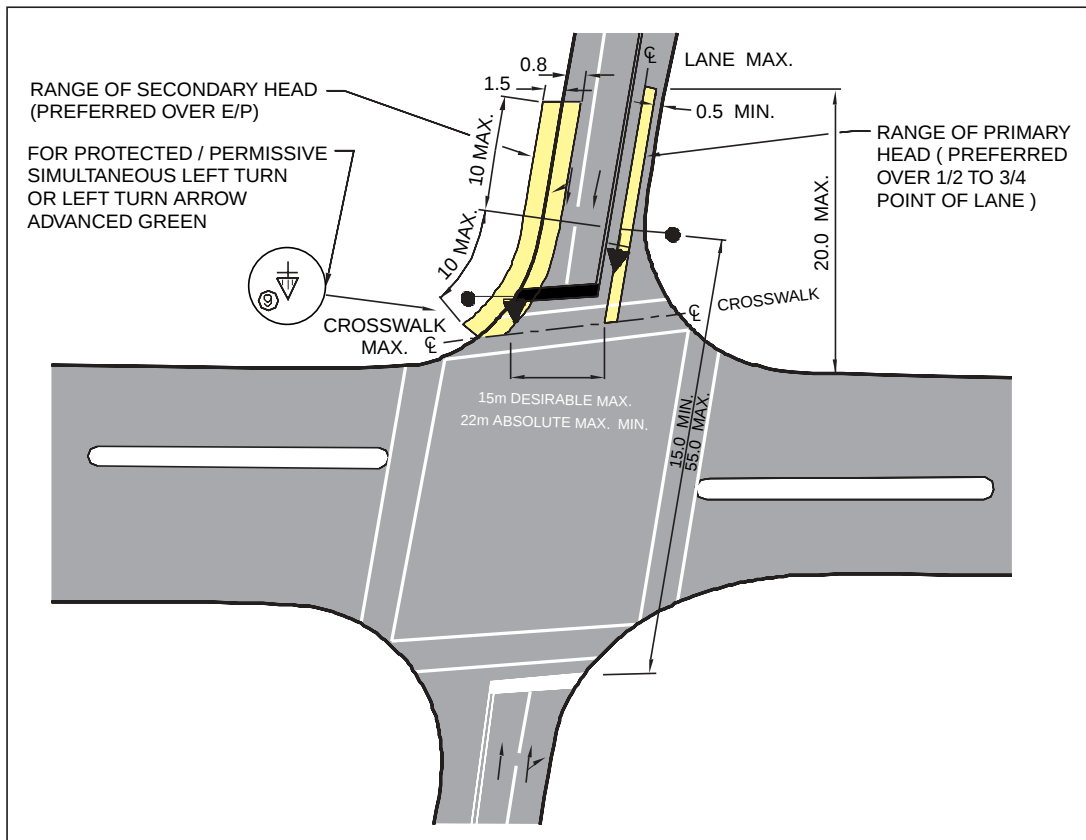


Figure 31 - Layout at Approach Without Median Island

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

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 32 (page 108). Note the following:

- this is a non-typical application using aerial installation of the left-turn (type 2) heads because of the requirements for siting the primary left-turn head within the projected left-turn lane;

Approach With Median Island (Normal, Advanced Green Or Simultaneous Protected/Permissive Lefts)

Two approaches are indicated on Figure 33 (page 109); the northbound approach is "normal" with Highway heads and the southbound approach is the often used protected/permissive one using the type 8, 8A, 9 or 9A signal head in the median. Note the following:

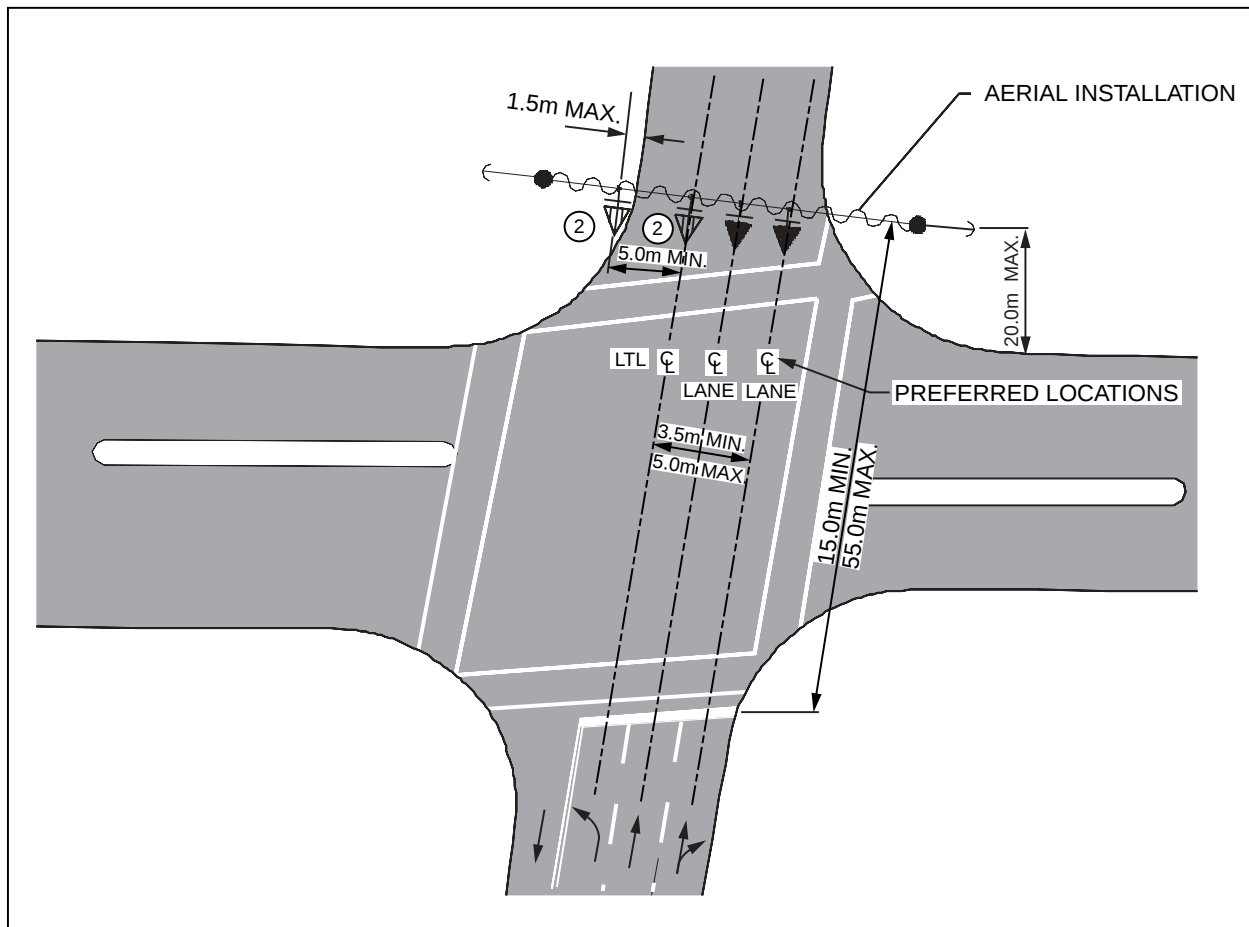


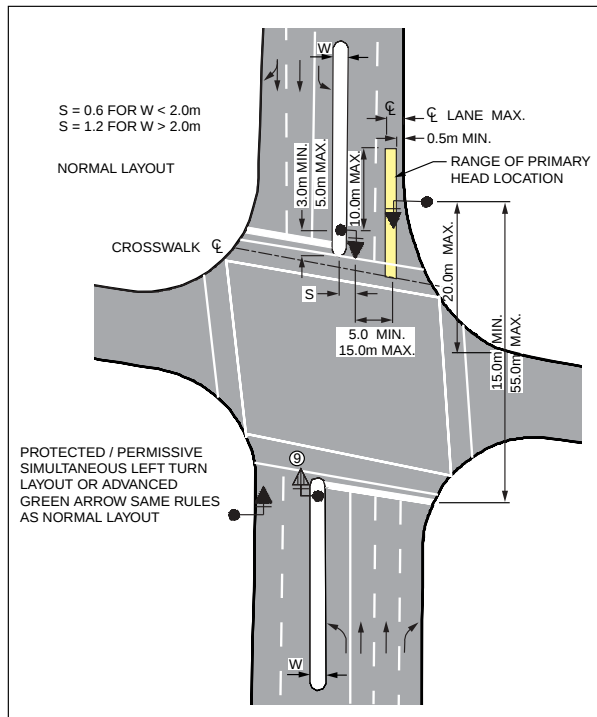
Figure 32 - Approach With Fully Protected Left Turn Heads and Without Median Island

- for recommended practice, the median (secondary) head is roughly over the edge of through pavement. Standard mast arm lengths "S" depend on the narrow median width "W";
- the combination 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.

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 34 (page 109). 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;



**Figure 33 - Normal or Protected/
Permissive Layout**

- 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 the normal rules of 5.0 m minimum and 15.0 m maximum.

Approach With Wide Median (Fully Protected Left Turns)

Figure 35 (page 110) shows a fully protected left turn layout for a wide median of between 2.0 m and 15.0 m width. 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 median island as shown;

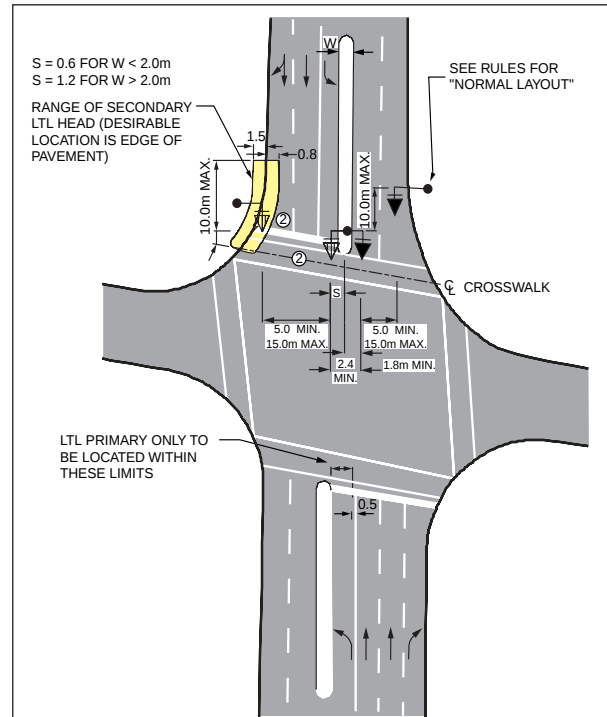


Figure 34 - Fully Protected Left Turn Approach

- 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.

Approach With Double Left Lane (Fully Protected Left Turns)

Figure 36 (page 111) shows a fully protected left-turn approach for a dual left-turn lane. Note the following:

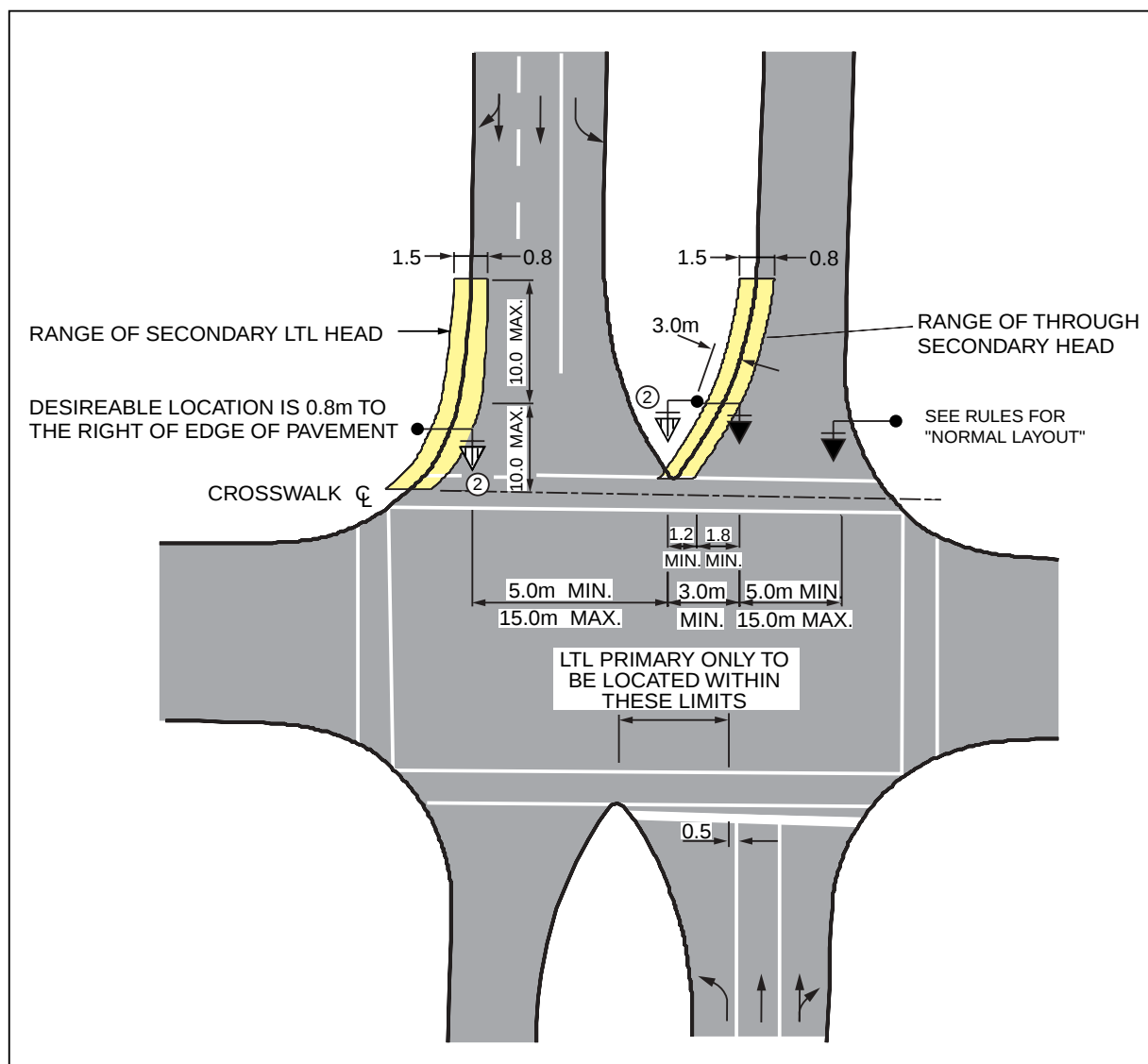


Figure 35 - Fully Protected Left Turn at Wide Median Approach

- 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 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 may 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.

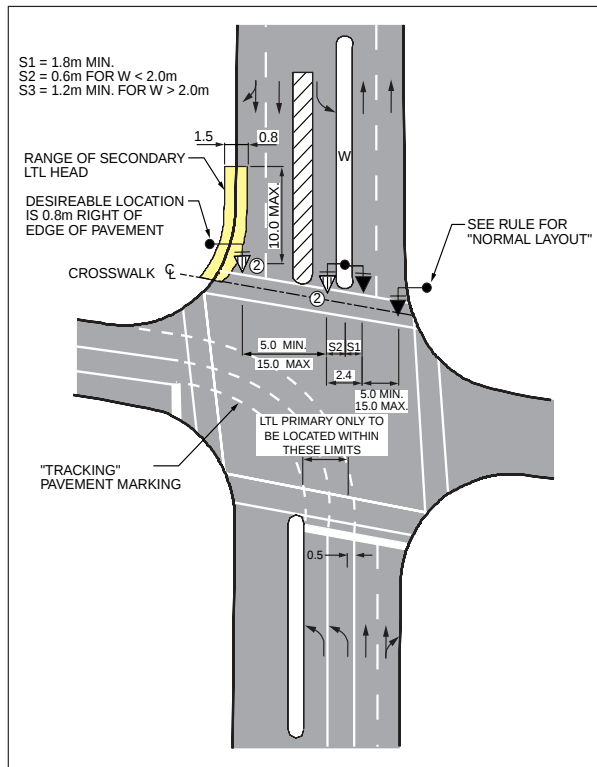


Figure 36 - Fully Protected Dual LTL Approach

Ramp Terminal

Figure 37 (page 112) shows a full layout for a freeway ramp terminal on a free-flow exit ramp to an arterial. Note the following:

- the area for the ramp primary and secondary heads should preferably be kept free of poles between the extended edges of pavement of the ramp;
- normal Highway heads may be used on the arterial provided that proper restrictive signage is also used;
- where turning volumes and pedestrian volumes allow, only one crosswalk should be used and should be designed on the approach where left-turning traffic from the ramp will not be interfered with;
- where a double lane left or right turn is allowed, they should not occur simultaneously with conflicting pedestrian crossings; and
- the through lane primary and secondary heads on the arterial should be type to indicate that no turns are to be made;
- the arterial secondary heads on median mounted 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.

Short Offset Intersection

Figure 38 (page 113) 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.

In either situation, it is difficult to improve safety, when installing traffic signals in lieu of stop signs, without severely affecting the operation of the intersection. Note the following:

- the distance between the side roads can be treated similarly to a wide median. The median width of 15 m maximum 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 served on separate phases, allowing pedestrian crossings in the middle during one of these phases and thereby providing an operation effectively the same as at a T-intersection. If pedestrian crossings are then prohibited on the other approach, the phase for “no-crossings” approach can be kept to a minimum, and the cycle length as low as possible;

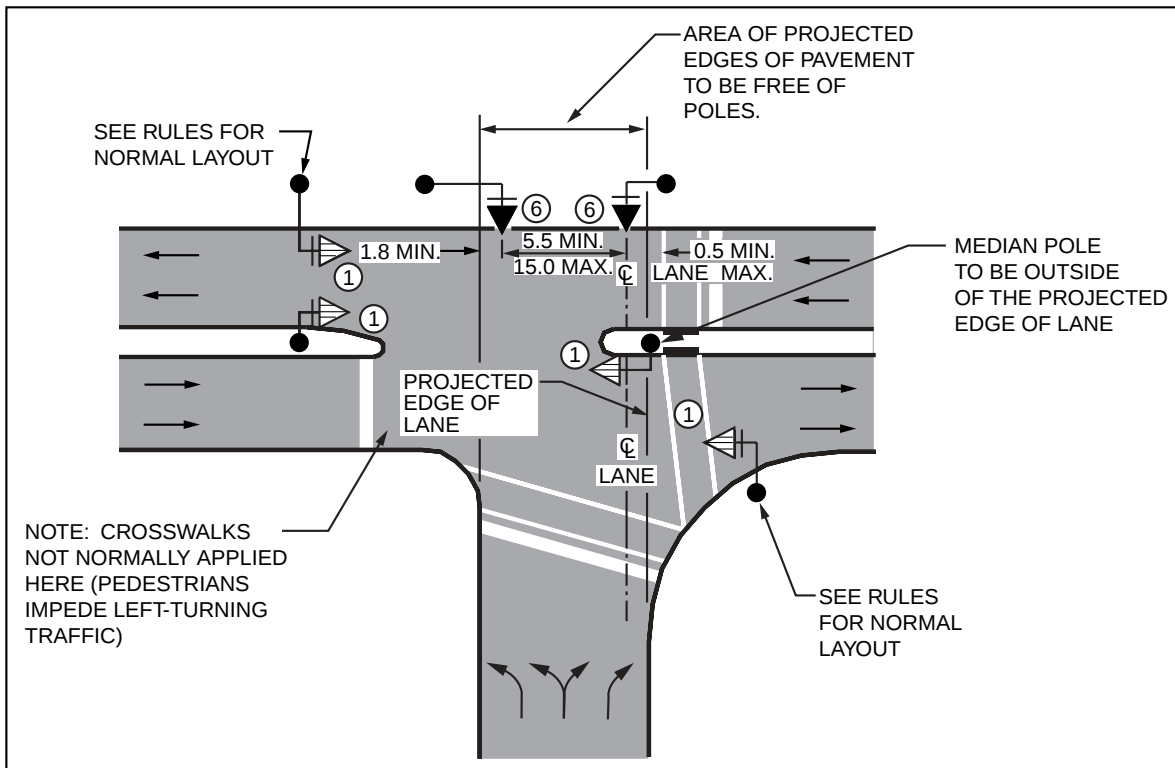


Figure 37 - Ramp Terminal Intersection Approach

- for visibility purposes, the distance from stop lines to a primary head is limited to 55 m maximum; if more, the intersection is a “long offset intersection”;
- pavement marking “tracking lines” are required to reduce motorist confusion. In these intersections, once motorists have turned left from the side road, it is difficult for them to distinguish between opposing through traffic and traffic which is turning left from the other side road; and
- when a vehicle turns left from each side road, those motorists are confronted by a red light on the arterial and confusion as to whether to stop or not will occur. Advisory signage does not appear to solve this problem.

The designer is directed to Metropolitan Toronto’s paper “Traffic Signal Control at Offset Intersections”²³ for a more thorough treatment of the subject.

Long Offset Intersection

Figure 39 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 is always a problem due to the confusion caused by two sets of nearby signals facing motorists. Note the following:

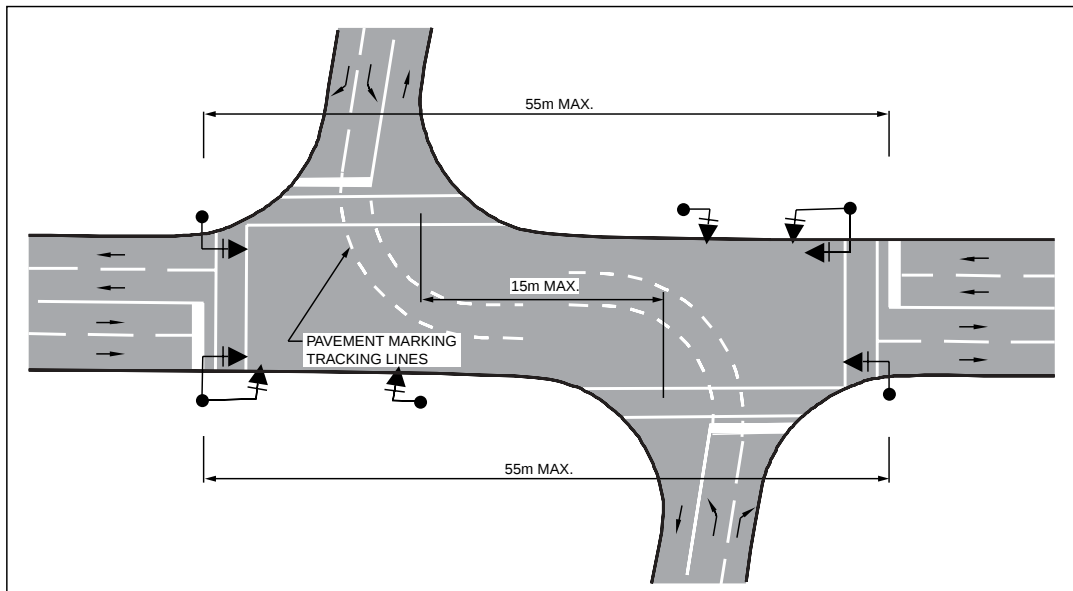


Figure 38 - Short Offset Intersection

- pedestrian crossings in the middle, between the side roads, are not desirable unless phasing times permit the holding of turning traffic while pedestrians cross;

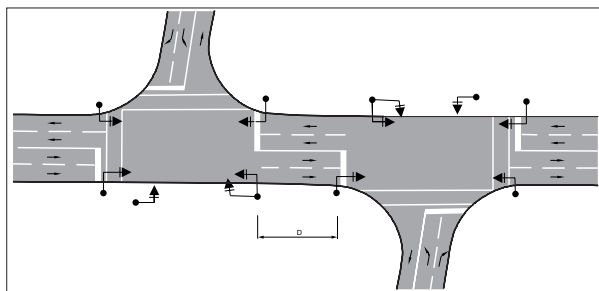


Figure 39 - Long Offset Intersection

- 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 without serious disturbance to the system, detection could be added in the lanes between intersections to either extend the green or let the next phase activate;
- past solutions to the visibility and confusion problem include the use of optically programmable signal heads on the far set of heads to attempt to hide them from view from the far intersection, 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;
- the maximum viewing distance of 55 m for the primary head from the stop line cannot be obtained as for the short offset intersection and therefore independent sets of signals are required;

- a subtle but partially effective solution to mitigate motorist confusion consists of painting the far set of signal head housings a different colour than that of the near side; black faces on the far set and yellow faces on the near set including the backs of housings and of backboards that the motorists are facing;
- where “D” is less than approximately 200 m, it is difficult to have the intersections operating independently or on a system without some sacrifices in timing, phasing and efficiency. Refer to Metropolitan Toronto’s paper “Traffic Signal Control at Offset Intersections”²³ for a more thorough discussion of problems and solutions.

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 locations with respect to pedestrian expectations and with respect to crosswalks and sidewalks. Where pushbuttons are used, they must be accessible and convenient to the crosswalk being served.

Poles With Pushbuttons

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

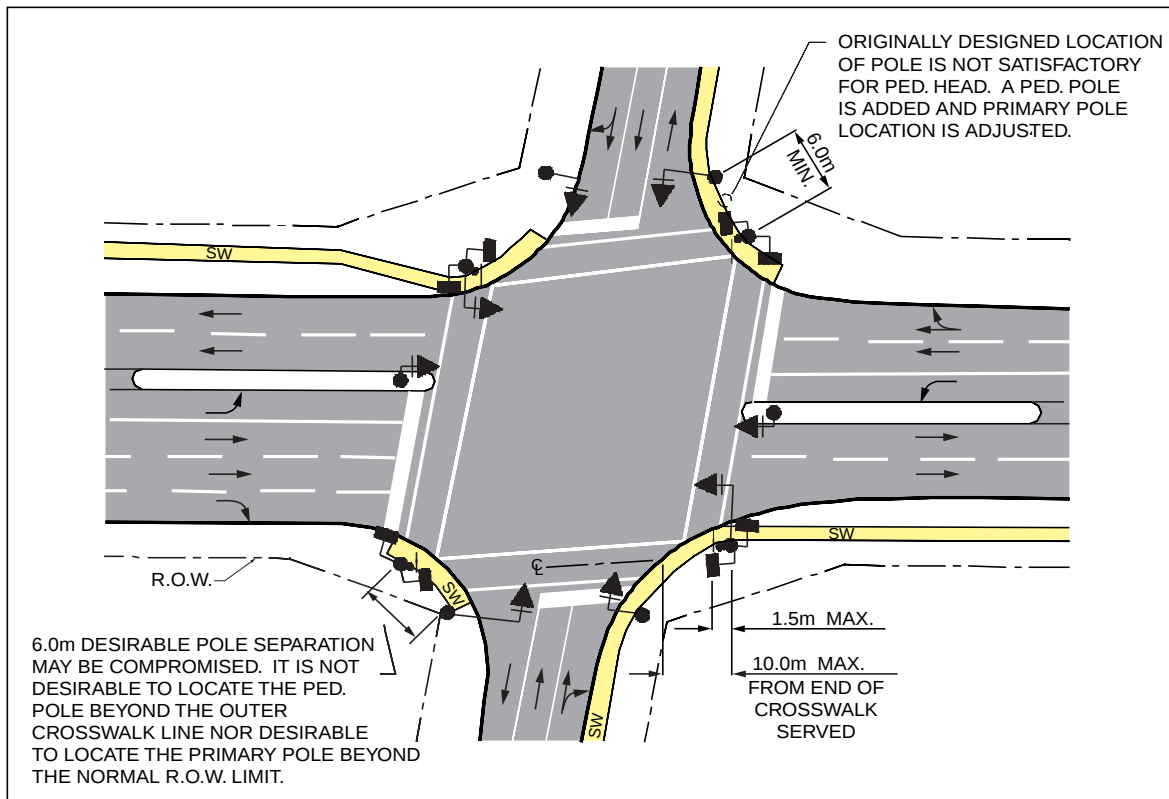


Figure 40 - Layout of Poles With Pushbuttons

- 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;
- the poles must be accessible and user friendly; not located beyond reach behind barriers or in grass (mud) areas or areas where snow windows will occur. Some additional sidewalk or paved shoulder may have to be coordinated with road designers;
- 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; and
- where a separate pole is required, consideration should be given to locating it at least 6.0 m from other poles so as to allow room for maintenance vehicles to operate and for aesthetic reasons. This may require re-adjustment of previously designed locations of primary and secondary poles. (New construction only; not rehabilitation projects). Figure 40 illustrates these principles.
- 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 40)
- ensure that the pedestrian heads will not be visually blocked by vehicles at the stop line;
- pedestrian head locations should be restricted to the rear or sides of the poles. Mounting on the front (nearest the pavement) invites damage by errant large turning vehicles, snowplows, etc. The layout drawings should indicate the proper side of the pole for double arm bracket attachment;
- the addition of pedestrian heads to poles for other uses may require re-adjustment of the previously designed locations of these poles or even minor adjustments to sidewalk and crosswalk design (new construction only; not rehabilitation projects).

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;

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 Manual².

Physical Requirements

Locations for controller cabinets must be designed with due consideration given 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 controllers;
- where barrier or guiderails are not present, it is desirable to locate the controllers at a clearance distance, equal to the clear zone in the Ministry's Roadside Safety Manual ²², from the edge, or projected edge, of through lanes. Note that it is normally required, on road construction or reconstruction projects, 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 of 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 specific minimum distance from the ground electrodes at the supply points. Refer to the Ministry's Electrical Design Manual² for grounding details;
- controllers must be located at a specific minimum distance from overhead high voltage wires to mitigate electromagnetic field interference. Refer to the Ministry's Electrical Design Manual² for treatment;
- it is undesirable to have controllers, supply poles, and primary poles in clusters which can be hit by an errant vehicle; where sidewalks are present, and in suitable locations, controllers may be sited at the proper offset distance from edge of 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 keeping 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 avoid muddy conditions for maintenance servicing; and
- 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 principals 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 which is to be reconstructed under a roadway contract but applications of the principles are equally valid for an existing intersection to be signalized.

Preparation Of Base Plan

This section emphasizes the importance of proper preparation of the base plan on which the signal design will be carried out. The steps necessary to produce the base plan are as follows:

- obtain the base plan mylar or CAD overlays 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 should be obtained 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 Supply Authority representative 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 any special details required by the local Supply Authority. Try to determine the location of future utility poles which could be used for signal arm mounting. 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 of the example will be similar to the plan shown in Figure 41 (page 118) at this point.

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 pre-construction contract since the road/signal contractor is not 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 for the work can be made.

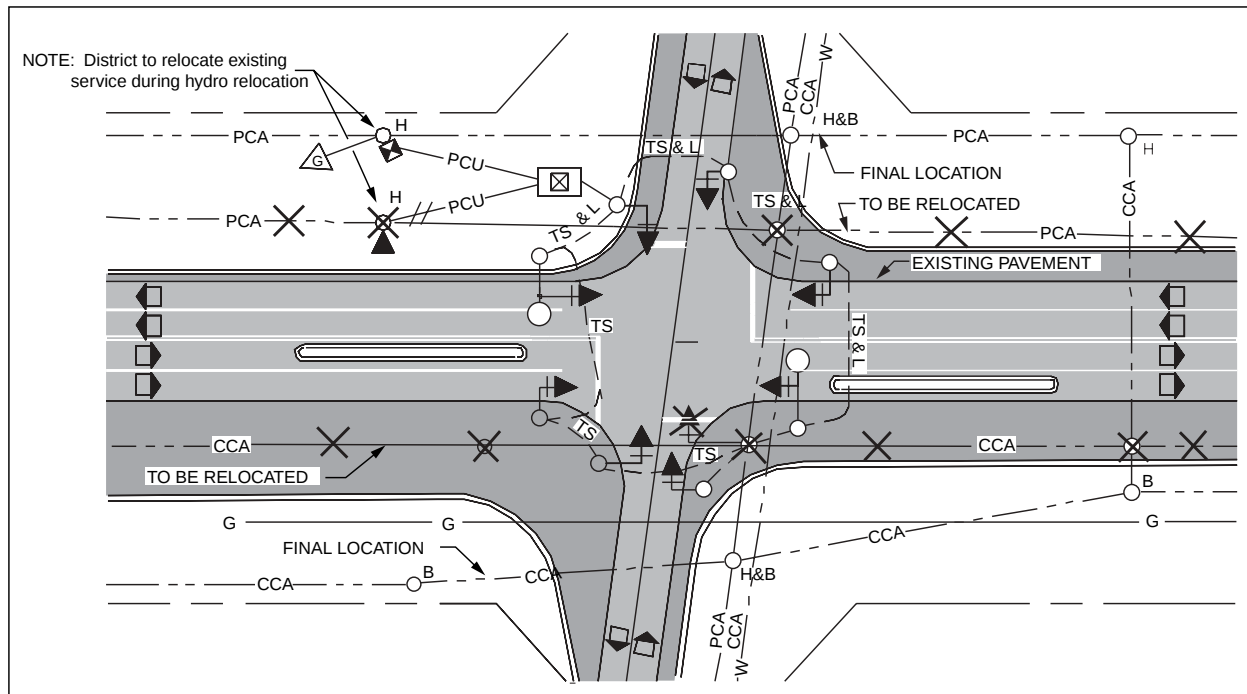


Figure 41 - Base Plan Features

In some cases, actual relocations are not required as the old utility pole is purchased and cut off, with new aerial cable feeds installed and old pole mounted equipment left in place as an interim measure.

Layout Of Crosswalks And Sidewalks

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

Figure 42 shows the layouts required with some suggested modifications to the sidewalk design. Note that the locations of the crosswalks and sidewalks at this time are preliminary and remain to be coordinated with road designers. The signal layout must first be carried out to confirm the most desirable sidewalk layout and those features which may be changed or improved towards an integrated design. This should also be carried out in the case where only signal provisions are to be installed.

Pole Locations

This section deals with the fact that there are many locations at an intersection where it is impossible or impractical to install traffic signal facilities. 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 from the beginning to the end of the design. To assist in the design, it is suggested that the restricted pole locations be plotted directly on the working plan 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**, which should not be exceeded, should be plotted from the information given in Section 5.6;

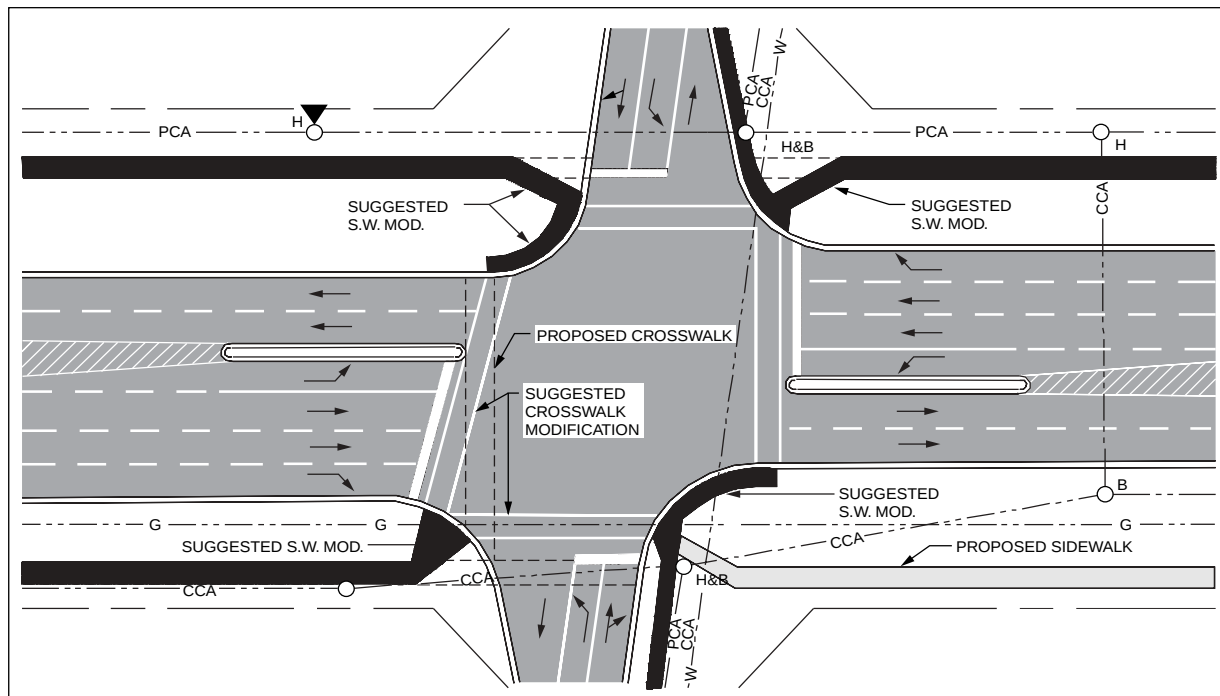


Figure 42 - Crosswalk and Sidewalk Modifications

Figure 43 (page 120) shows the working plan of the example with utility restrictions marked.

Pre-set Head and Pole Locations

This section deals with signal head and pole locations which are normally set in a standard or mandatory location by rules as outlined in Subsection 5.3. These poles are the first to be pre-set in any design. In the example, the median island poles on the main road should obviously be set in standard locations as the areas are normally free of interference from utilities (to be checked). Figure 44 (page 121) shows the standard signal head and median poles locations set in the example.

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 45 (page 122) and 46 (page 123).

Layout Of Pedestrian Facilities

Using the principles of Subsection 5.12, the pedestrian facilities are laid out as shown in Figure 47 (page 124).

Checking Layout

This section deals with the checking of the layout design using the principles of Subsections 5.5 and 5.12. Figure 48 (page 124) shows manual checking of the cones of vision and checking for blocked signal heads. The distances between heads and the pedestrian facilities should also be checked for conformance with the principles of Subsection 5.12.

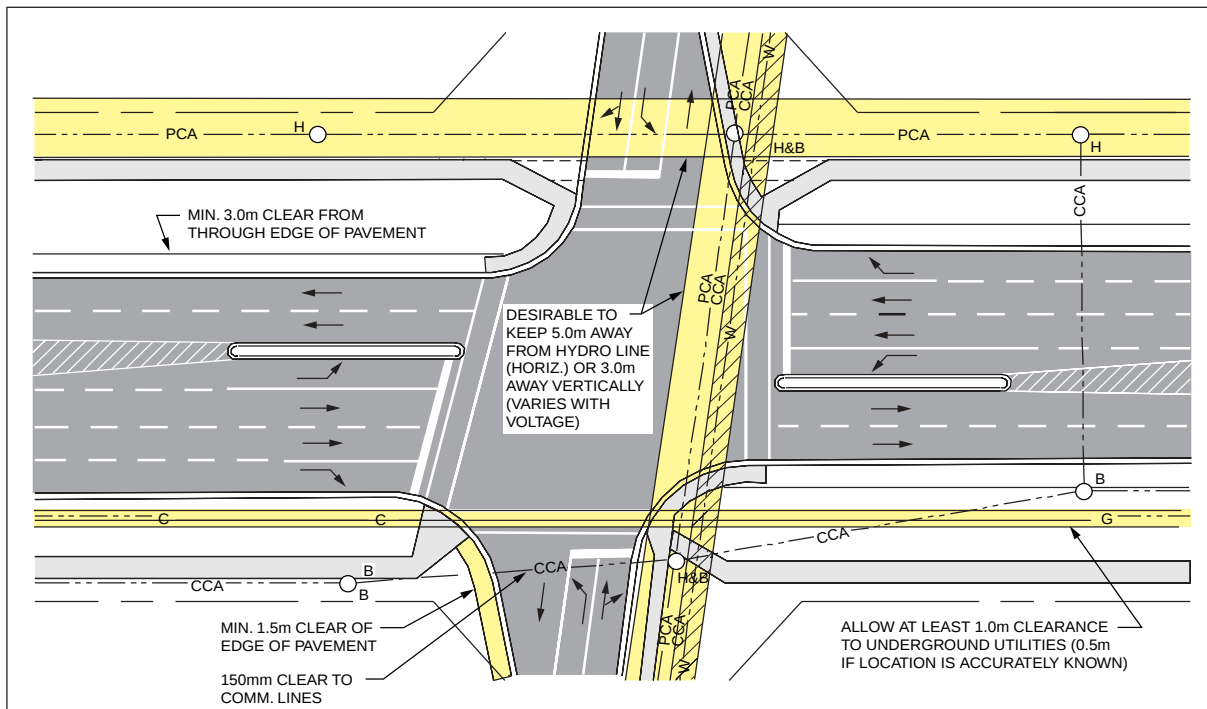


Figure 43 - Pole Areas Restricted by Utilities

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 and as elaborated on in the Ministry's Electrical Design Manual²;
- in areas of 80 km/h posted speed or greater, a controller offset of 10 m from the through edge of pavement is desirable; an offset of 6 m 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 as outlined in 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 otherwise known, the recommended location is at a 45° angle to the intersection as shown in Figure 49 (page 125);
- the location of the power supply pole has some bearing on controller location; it is desirable to have the power supply less than 75 m from the controller and it is desirable to have the controller more than 11 m from the power supply pole due to the possibility of a double pole knock-down upon vehicle collision; and
- for system use, the location of the communications connection has a bearing; separate ducts are required between the connection point and the controller.

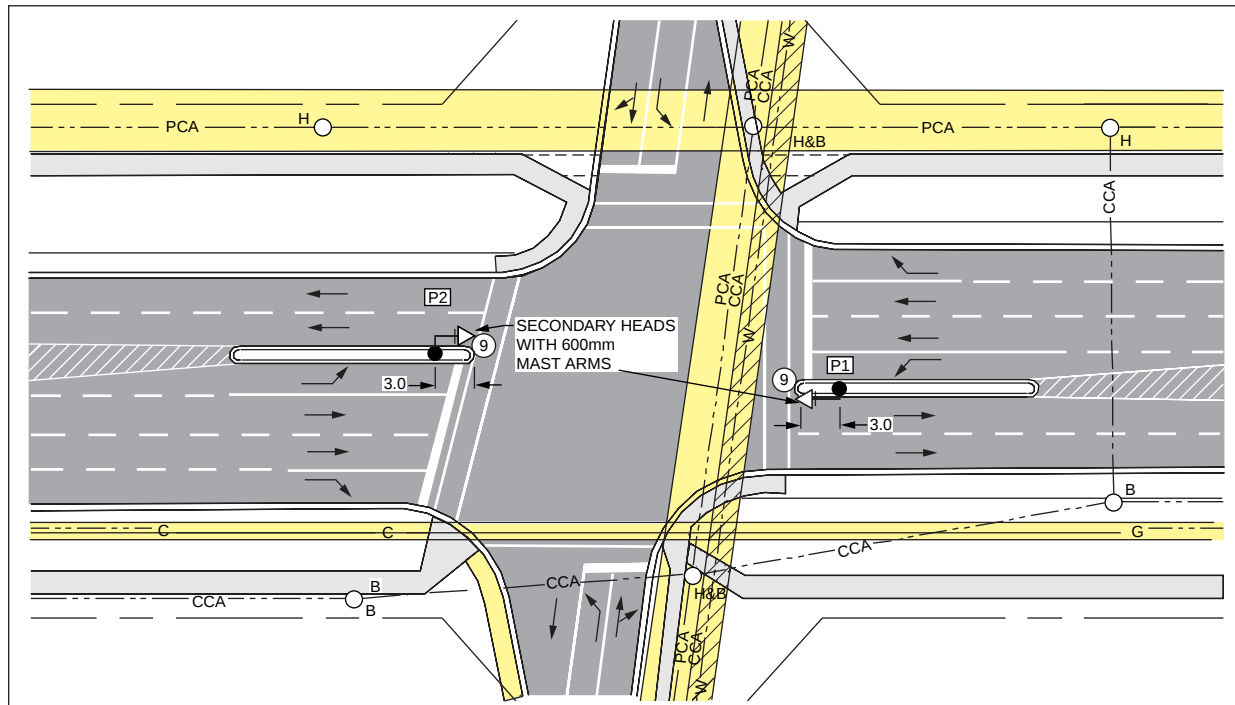


Figure 44 - Pre-set Signal Locations

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 the purpose. Common communications pedestals are not strong enough for this application;
- the cabinet may be mounted on a utility pole if the local Supply Authority permits this. It is preferred that the utility pole not have a transformer as the transformer ground can cause interference with the power supply ground. The local Supply Authority should be approached to 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 may be mounted on a separate pole suiting the purpose, may be fed aerially or underground and may have an electrical energy meter;
- 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 with consideration of the area of dilemma zone detection as per Table 27 for extension loops on roadways posted at 80 km/h and over and as shown in Figure 25 for presence loops. The loops are designed using the principles of the Ministry's Electrical Design Manual, Part 2, Chapter 2, "Vehicle Detection"².

Figure 50 (page 125) shows the detector loops laid out for the example. Note that there are two ways to number the loops; beginning at the controller, the loops are numbered clockwise (as shown). This method corresponds with that used in some asset management

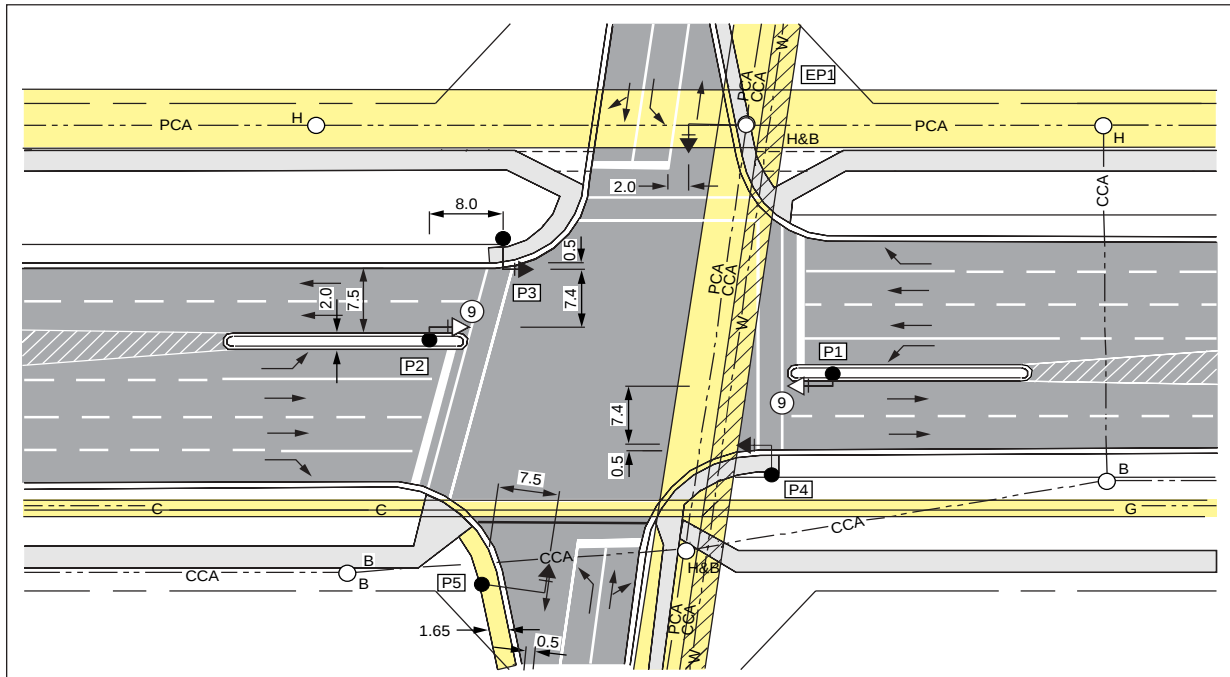


Figure 45 - Primary Head and Pole Layout

system software. An alternative method uses the numbers of the phase movements served and A, B, C.... for multiple loops serving a 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 51 (page 126) shows the underground system designed for the example intersection.

Coordination of Lighting Design

Roadway lighting shall be required at all signalized intersections. The illumination warrant may be partial or full depending on roadway and traffic conditions. While in many municipalities, most roadways already have full illumination, roadways without illumination, such as at isolated rural intersections, shall be provided with at least two lighting luminaires to provide partial illumination. The lighting system should be integrated with the signals according to the following principles:

- the lighting should be installed 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;

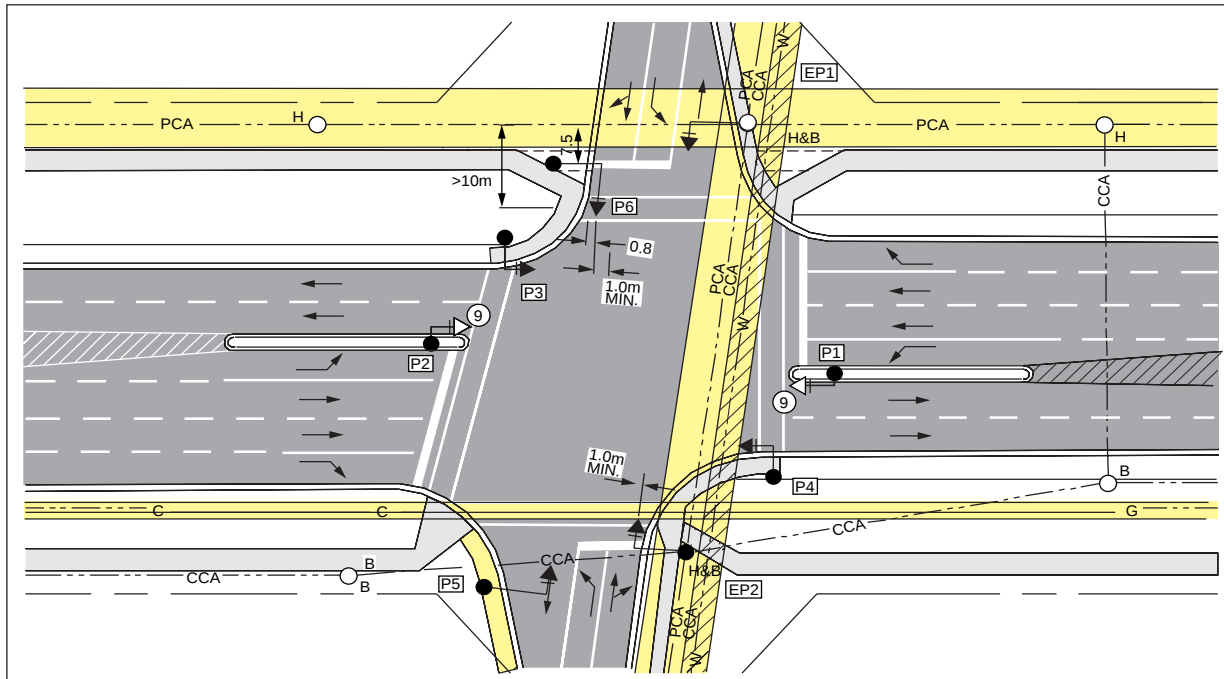


Figure 46 - Secondary Pole and Head Layout

- Different voltages and different sources of supply are not allowed by the Ontario Electrical Code unless multiple provisions are carried out;
- 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 52 (page 126) shows a typical partial lighting layout combined with the signals for the example. Partial lighting should be installed on the "far right" side of each approach of the main road. The lighting is typically integrated on a combination or joint-use pole with the signals as indicated in Figure 52. 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.

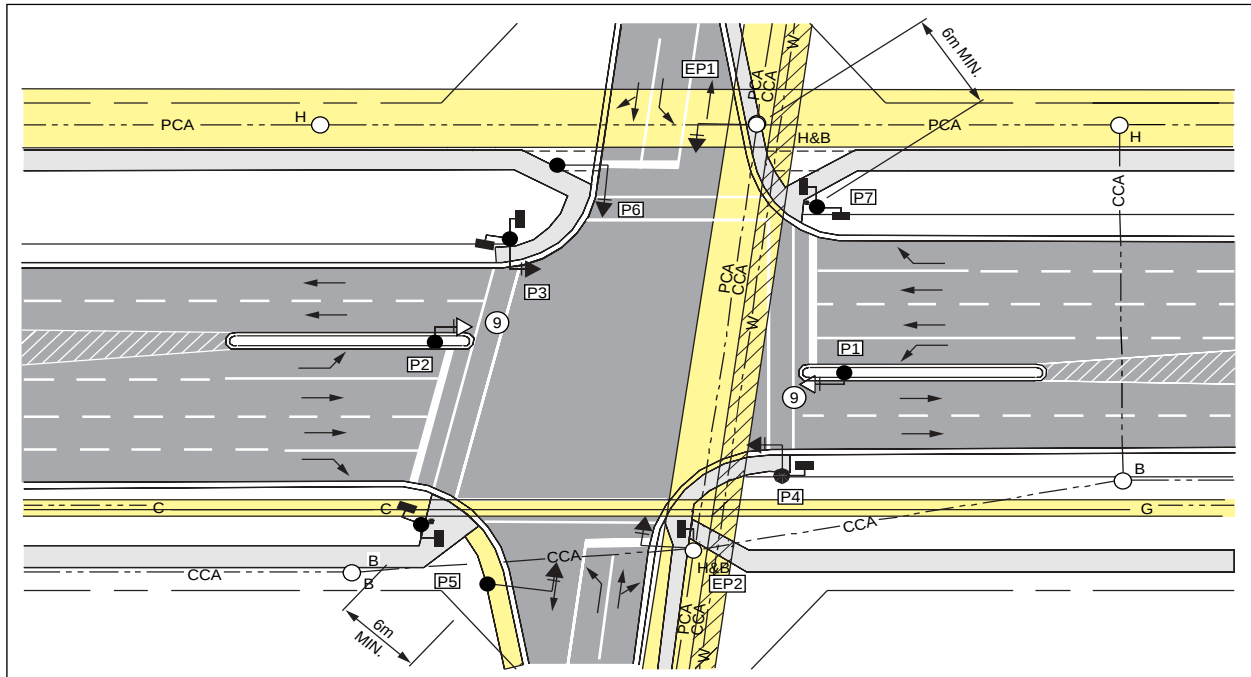


Figure 47 - Layout of Pedestrian Facilities

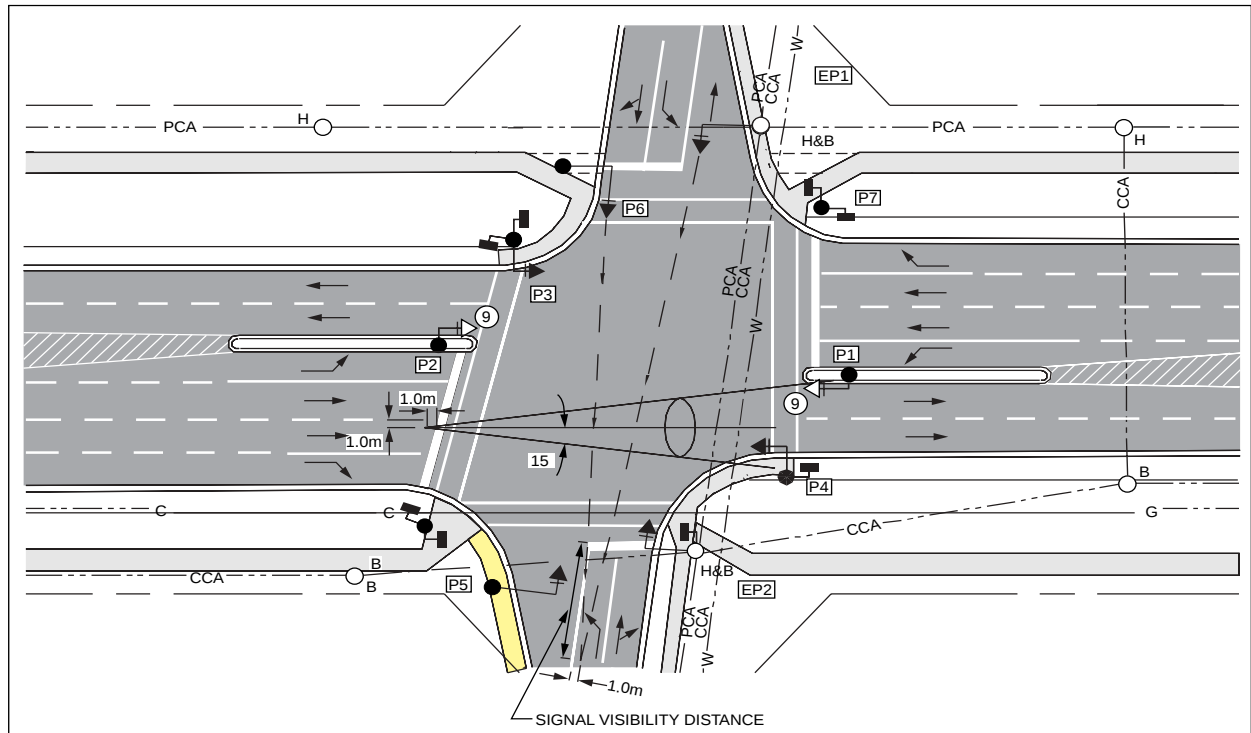


Figure 48 - Checking Signal Head Visibility and Layout

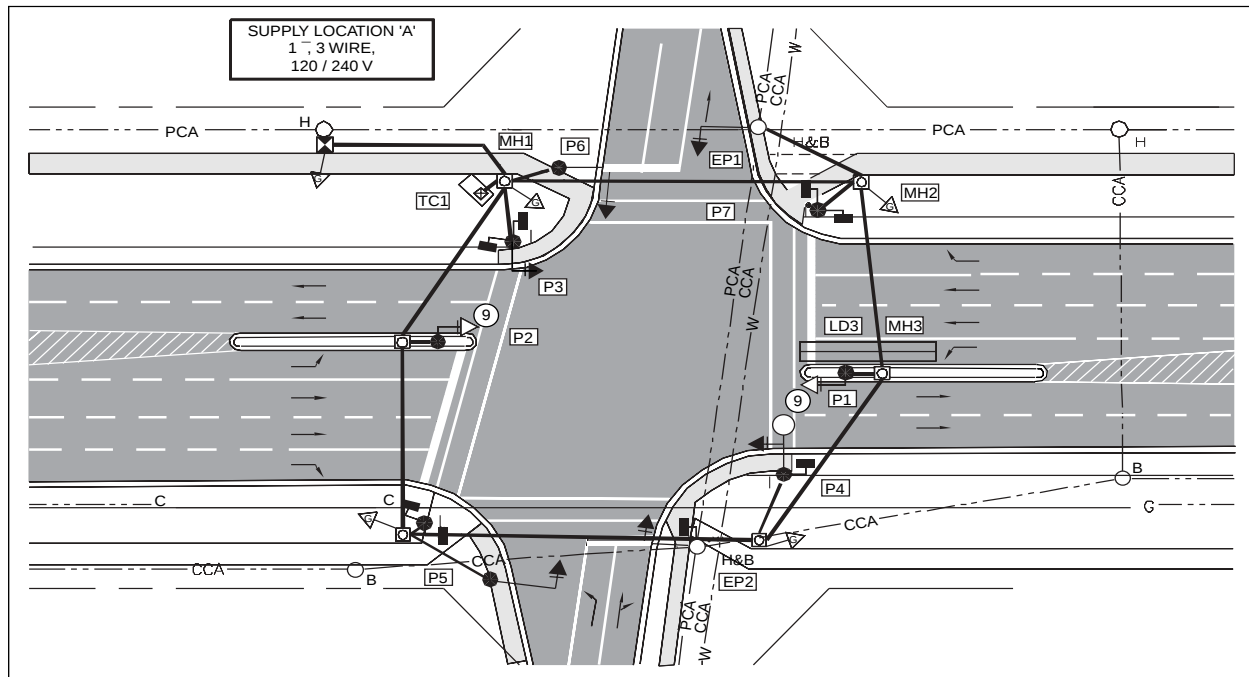


Figure 49 - Controller and Power Location

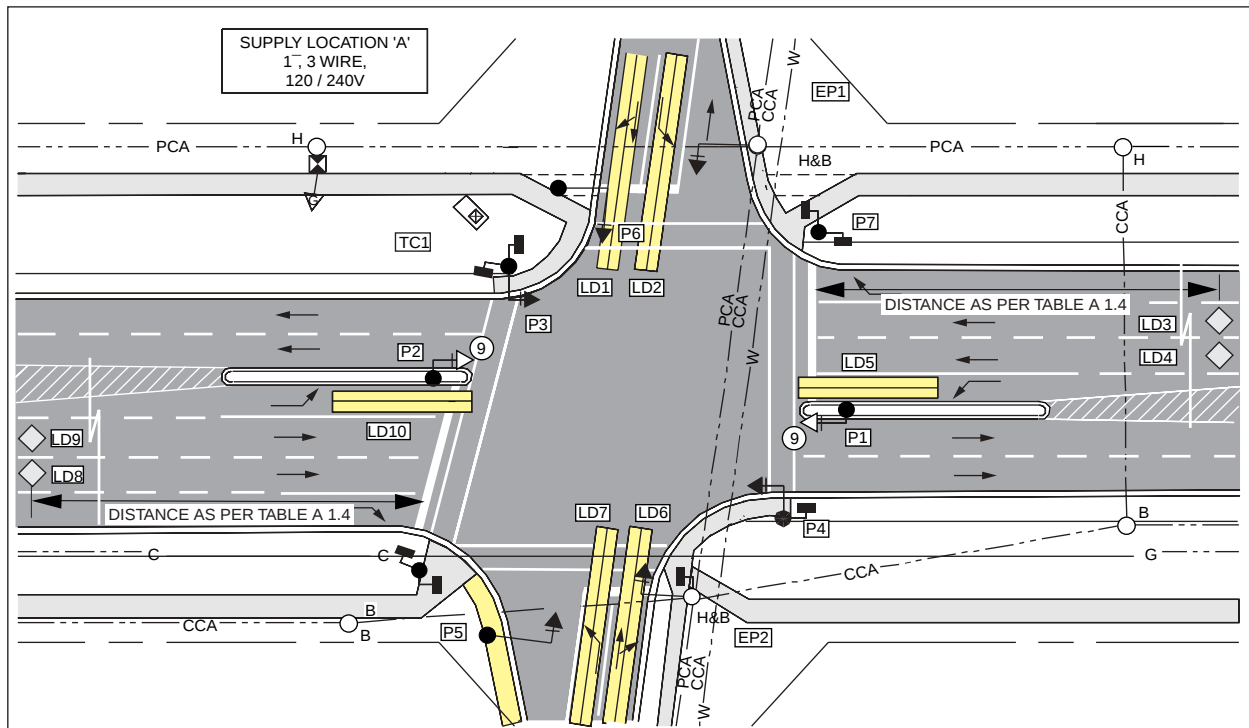


Figure 50 - Detector Loop Layout

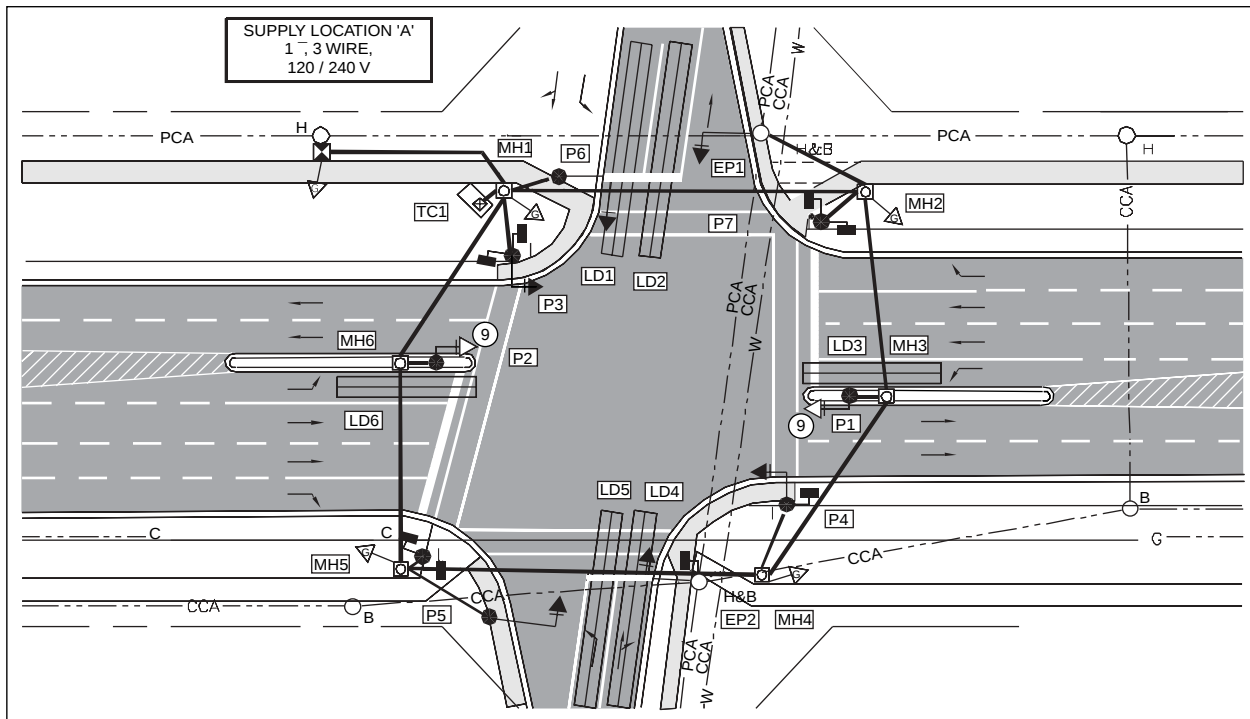


Figure 51 - Underground Duct System Layout

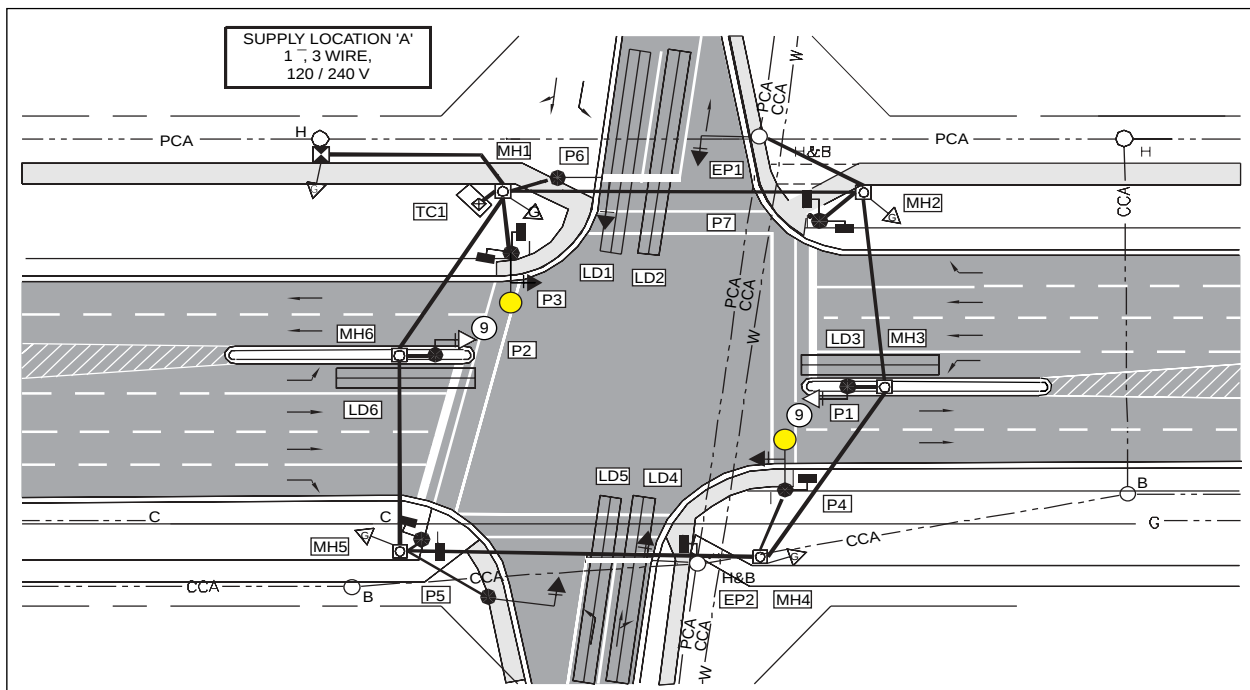


Figure 52 - Partial Lighting

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. No variation in the use of standard equipment should be considered without reviewing the need for such variation with the person in charge.

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 motorist hesitation and therefore may affect safety. The Ministry uses Ontario Provincial Standards Drawings (OPSD) for traffic signal purposes.

6.3 Other Considerations

Structural Considerations

Many components of traffic control signal hardware must have structural integrity. In many cases, manufacturers of items, such as poles and mast arms, design to an AASHTO code and the resultant designs are then checked to the requirements of the Ontario Highway Bridge Design Code (OHBDC) before being included in the Ministry's List of Designated Sources.

Other items requiring structural checking or approval are pole footings and electrical chambers. In the case of pole footings, the design should meet the requirements of the OHBDC for proper protection against legal liability in the event of a mishap or in the event of windy weather conditions causing failure. In the case of electrical chambers, the loading by vehicles should also meet the OHBDC for liability and cost of replacement reasons.

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. A large portion of the hardware and, of course, the wiring are electrical devices. The recommended practice with regard to electrical design of traffic control signals is:

- where in-house design capability does not exist, a consulting engineering firm with electrical design expertise in traffic signals may be selected;
- for each area or municipality, a range of equipment options and methods of wiring is available for use by the designer with the area or municipality preferences being used consistently;
- all electrical equipment items should be CSA approved, UL approved or have Ontario Hydro Special Inspection approval as a safety measure and as part of a pro-active risk management process. A traditional exception to this is controllers which are specifically manufactured to set standards (such as NEMA standards) for the traffic signal industry;
- where contracts for the traffic signal installation work are let, the contractors should use qualified licenced 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;

- the power supply cabinet and the grounding are subject to inspection by Ontario Hydro and the power is not connected by the local electrical Supply Authority until this approval has been obtained.

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 treatments which are not considered to be very pleasing. Some examples are:

- the number of poles should be kept to a minimum;
- the signal head displays and traffic signals are the only items which we really want to consciously "see". Poles and all other equipment should be as inconspicuous as practical;
- the length of single member arms should be kept to the minimums 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 for the sidewalk snowplow or should be closed to allow no more than a 450 mm space. (This may lessen 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 as to who should do the work.

Table 27 - Commonly Used Lamps for Traffic Signals

Lens Size (cm)	Lens Type	Lamp Centre Length (mm)	Lamp Wattage		Lamp Voltage	Lamp Type	Lamp Life (h)	
			Argon	Krypton			Argon	Krypton
30	All (round)	75	150	135	125	Clear, traffic	6000	8000
20	All (round)	63	100	90	125	Clear, traffic	8000	8000
30	Pedestrian (square)	75	100	90	125	Clear, traffic	8000	8000
30	Arrow	75	100	90	125	Clear, traffic	6000	8000

6.4 Lamps, Lenses & Visors

Lamps

Lamp data is given in Table 27. The lamps are chosen for compliance with ITE specifications for luminous output and for ruggedness and relative longevity. Incandescent lamps shall meet the general requirements of CSA C22.2, No. 84, and ITE ST-017.

Many municipalities use equivalent 69 Watt lamps with a minimum of 595 rated initial lumens for amber and green displays where the traffic signals are close together, such as in a downtown area, and where the posted speed is 60 km/h or less.

Lenses

Predominantly, lenses should be of the 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 a lens assemblies which can be set to produce a narrow cone of light such that the lenses do not appear to be illuminated from other than the traffic

lanes which they serve. 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. Caution should be exercised until these types of signal heads standardize. Performance requirements are given in ITE Publication ST-021, *Proposed Interim Purchase Specification: Light Emitting Diode (LED) Vehicle Traffic Signals Assemblies*.¹⁹

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.

APPENDIX A GLOSSARY

ACRONYMS

AASHTO:	American Association of State Highway and Transportation Officials;	EPROM:	Erasable Programmable Read-Only Memory;
AC:	Alternating Current;	FHWA:	Federal Highway Administration (U.S.A.);
AC+:	120 V a.c., 60 Hz power bus;	HCM:	Highway Capacity Manual;
AC-:	The 120 V a.c., 60 Hz neutral bus grounded at the power source;	HOV:	High Occupancy Vehicle;
ASTM:	American Society for Testing and Materials;	IPS:	Intersection Pedestrian Signals;
AWG:	American Wire Gauge;	ITE:	Institute of Transportation Engineers;
CCG:	Canadian Capacity Guide for Signalized (Urban) Intersections;	LED:	Light emitting diode;
CMOS:	Complimentary Metal Oxide Semiconductor;	LOS:	Level of Service;
CPU:	Central Processing Unit;	LTL:	Left Turn Lane;
CTS:	Clear to send;	MIST:	Management Information System for Traffic;
DCE:	Data communications equipment;	MODEM:	Modulate/Demodulate communications interface Unit;
DCP:	Data channel port;	MOS:	Metal Oxide Semiconductor;
DDE:	Data distribution equipment;	MOV:	Metal Oxide Varistor;
DHV:	Design Hourly Volume;	MPU:	Microprocessor Unit;
DTE:	Data terminal equipment;	MTO:	Ministry of Transportation, Ontario;
EEPROM:	Electrically Erasable Programmable Read Only Memory;	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 which 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 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 which 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 phase since it is normally part of a phase.

Non-conflicting Phases:

Two or more traffic phases which 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 which 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 which is locally programmed to suit the interval times required at the intersection but which 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 cable 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 which conveys a message to the observer.

Unit Extension:

The timing period during the extendible portion of a right-of-way interval which 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 which permits a controller unit to transfer right-of-way.

APPENDIX B REFERENCES

REFERENCES

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22. **Roadside Safety Manual**, Ministry of Transportation, Ontario, 1995.
23. **Traffic Signal Control at Offset Intersections**, Report to Transportation Committee, Metro Transportation, 1991.
24. **Traffic Control Systems**, NEMA Standards Publication No. TS 1, National Electrical Manufacturers Association, 1989.

- 25. **Traffic Control Signal Timing and Capacity Analysis at Signalized Intersections**, Ministry of Transportation, Ontario, 1989.
- 26. **Traffic Controller Assemblies**, NEMA Standards Publication No. TS 2, National Electrical Manufacturers Association, 1992.
- 27. **Vehicle Traffic Control Signal Heads**, ITE Publication No. ST-017.

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. 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, 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. 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;
- pedestrian heads must be indicated if used;
- 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;
- a phasing diagram is desirable on the signal drawing especially at complex intersections where multi-phasing may be required.

APPENDIX D LEGEND

ABBREVIATIONS			
AFG	Above Finish Grade	HH	Electrical Handhole
AC	Alternating Current	HV	High Voltage
AWG	American Wire Gauge	HEC	Hydro Electric Commission
AMB	Amber		
BFG	Below Finish Grade	IGRD	Insulated Ground (green)
BGRD	Bare Ground	IMPD	Impedance
BLK	Black	IND	Inductance
BLU	Blue	ITS	Intelligent Transportation Systems
		JB	Junction Box
CCT	Circuit	LCS	Lane Control Sign
CE CODE	Canadian Electrical Code	LV	Low Voltage
CMS	Changeable Message Sign		
CCTV	Closed Circuit Television	MH	Electrical Maintenance Hole
COMM	Communication	NEUT	Neutral
C/W	Complete With	NIC	Not Included in Contract
COND	Conductor	OESC	Ontario Electrical Safety Code
CONT	Control	PCS	Permanent Counting Station
CDT	Conduit	PUC	Public Utilities Commission
CSA	Canadian Standards Association	PXO	Pedestrian Crossover
CTMS	Corridor Traffic Management System		
DB	Direct Buried	RF	Radio Frequency
DC	Direct Current	RFI	Radio Frequency Interference
EC	Electrical Chamber	RMS	Ramp Metering Station
EMI	Electromagnetic Interference		
EQPT	Equipment	TS	Traffic Signal
ELV	Extra Low Voltage	XFMR	Transformer
FO	Fibre Optic	UPC	Underpavement Crossing
FTMS	Freeway Traffic Management System	VDS	Vehicle Detector Station
GRN	Green	WHT	White
GRD	Ground	YEL	Yellow
SYMBOLS			
Al	Aluminum	Ω	Ohm
A	Ampere	PVC	Polyvinyl Chloride
Cu	Copper	V	Volt
F	Farad	VA	Volt Ampere
H	Henry	W	Watt
Hz	Hertz	Wh	Watt Hour
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ELECTRICAL ABBREVIATIONS AND SYMBOLS		-----	
		Date -----	
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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
	R33	
		
		
		
		
		
		
		
		

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ELECTRICAL LEGEND II

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LUMINAIRES		
	Luminaire	
	Luminaire with Shield	
	Floodlighting Luminaire	
	Underpass or Surface Mounted Luminaire	
	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	
	Future Luminaire and Bracket, Note 1	
	Luminaire Identification Code	
POWER SUPPLY		
	Power Supply Equipment	
	Transformer	
	Generator	
	Power Supply Equipment, Pad and/or Footing Mounted, Note 2	
	Power Supply Equipment Identification Code Other applicable description may be used for transformer, generator, etc..	
	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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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
	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

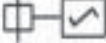
Date



OPSD - 2001.040



DETECTORS		
	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
		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		
	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
	PX03	Pedestrian Crossover with Identification Code
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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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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

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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MISCELLANEOUS

Ground Electrode(s)

Cable Protection Bricks, Concrete Cap, or Marker Tape in Trench

Identification Code for Removal Equipment

WIRING DIAGRAMS

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

Duct Size, Aerial, or Direct Buried

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

AWG Size of Conductor

Number of Conductors in Cable;

Not Required for Single Conductor

Number of Cables

In-Line Cable Splice; Number Denotes Number of Cables

Tap Cable Splice; Number Denotes Number of Cables

Wiring Enclosure, Manhole, Junction Box, etc., Identification Code Matches Layout Drawings

Equipment Item; Identification Code Matches Layout Drawings

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ELECTRICAL LEGEND VIII

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