OTC Bicycle Traffic Signals Guide

Ontario Traffic Council
www.otc.org

OTC Bicycle Traffic Signals

Foreword

The purpose of the Ontario Traffic Council's Bicycle Signals Guide is to act as a practitioner's accompaniment to Ontario Traffic Manual (OTM) Book 12 (Traffic Signals) until such time as the Ontario Ministry of Transportation releases a document that will be known as OTM Book 12A (Bicycle Signals).

The OTC's Bicycle Signals Guide was developed in parallel with the recently released OTM Book 18: Cycling Facilities. OTM Book 18 was created to address cycling facility issues but excludes signals because it was decided that a bicycle signals document would be more appropriately placed with OTM Book 12, which deals exclusively with signals.

The OTM series of Books is designed 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 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 the guidelines 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

The Ontario Traffic Manual (OTM) Book 12 – Traffic Signals contains information about all aspects of traffic signal operation. Book 12 currently contains several references to bicycles at signalized intersections. However, the existing manual contains only limited information, guidance and direction with regard to the use of traffic signals or special signal phasing for bicycles.

This document is intended as a companion to OTM Book 12 and therefore is to be used in conjunction with Book 12. Unless otherwise specifically stated, all of the information and guidance contained in Book 12, particularly that contained in Section 1 of the Book, is deemed to apply to this volume.

This guide is also intended to be used in conjunction with OTM Book 18 - Bicycle Facilities and in conjunction with OTM Book 15 - Pedestrian Crossing Facilities.

1.2 Relationship with OTM Book 12

Except in very specific instances, information contained in OTM Book 12 will not be reproduced in this guide. The practitioner is reminded to ensure that appropriate reference to Book 12 is made when considering new or revised signal installations.

OTM Book 12 currently contains a reference to bicycle signals in section 2.5, Proposed Future Legislated Items. This section recognizes that there are no current legal regulations or statutes for separate bicycle signal heads in the province of Ontario.

In section 3.10 of Book 12, there is information about bicycle signal indications, timing and phasing. This guide will reproduce and elaborate on that information.

1.3 Relationship with OTM Book 18

Ontario Traffic Manual Book 18 is a new guide providing information about bicycle facilities. Book 18 provides detailed information about signage and pavement markings near signalized crossings in section 5.8. This guide provides detailed operational information about signal displays, timing, phasing and detection. Therefore, this guide and Book 18 are companion guides and are to be used together when necessary.

1.4 Relationship with Transportation Association of Canada Guides

The Transportation Association of Canada (TAC) is a national not-for-profit association that promotes the provision of safe, secure, efficient, effective and environmentally and financially sustainable transportation services in support of Canada's social and economic goals. TAC is a forum for exchanging ideas, information and knowledge on technical guidelines and best practices in Canada's transportation and roadways sectors.

The Transportation Association of Canada (TAC) undertook a project which commenced in 2004 to develop a traffic signal guide for bicycles. The guide was published in 2014. Some of the information contained in the TAC guide (particularly regarding the bicycle signal head) has already been entered into the 2008 revision of the Manual of Uniform Traffic Control Devices for Canada (MUTCDC). In preparing this guide, reference was made to the draft TAC Traffic Signal Guide as well as the TAC MUTCDC (2008). Wherever possible throughout this guide, attempts were made to maintain consistency with Canadian standards or guidance.

1.5 Immediate and Future Applicability

In terms of the Highway Traffic Act of the Province of Ontario (HTA) or the Regulations under that Act, the information contained in this guide is immediately applicable. In some cases, implementation may require changes to local municipal by-laws. The guide is written and presented based on the current available legislation and rules.

1.6 Range of Applicability

Bicycle scenarios have a wide range of possible characteristics. The volumes of bicycles, pedestrians, motor vehicles and transit vehicles at a signalized intersection may be quite different site to site. The appropriate treatments need to be, in response, equally diverse.

This guide has been prepared to respond to a wide range of situations. Some of the more extensive and complicated solutions may be totally unnecessary for simpler, lower volume examples. It is certainly not intended that more complex solutions be applied every time. The practitioner must understand thoroughly both the site in question and the advantages and disadvantages of a proposed treatment, before making a decision on implementation.

2. Legislative Framework

2.1 General

This section provides an overview of various sections of the Highway Traffic Act (HTA) and regulations under that act, associated with traffic control signal systems, traffic control signals, bicycle signals and bicycle movements. The current HTA sections and regulation which are relevant include:

- Section 1 – Interpretation;
- Section 130 – Careless Driving
- Section 144 – Traffic Signals
- Section 195 – Effect of by-laws; and
- Regulation 626 – Traffic Signal Heads.

As well, portions of the Municipal Act may be found useful in some circumstances. Those are detailed in this section as well.

2.2 Definitions

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

- "bicycle" includes a tricycle, a unicycle and a power-assisted bicycle but does not include a motor-assisted bicycle; ("bicyclette");
- "vehicle" includes a **bicycle** (emphasis added) and any vehicle drawn, propelled or driven by any kind of power, including muscular power;
- "traffic control signal system" means the entire signalized intersection, which includes all electrical components, signage and pavement markings. The system also includes the "traffic control signals", which are the actual traffic signal heads.

2.3 Existing Relevant HTA Regulations

2.3.1 HTA Section 130 Careless Driving

1. Legal Requirements

Every person is guilty of the offence of driving carelessly who drives a vehicle or street car on a highway without due care and attention or without reasonable consideration for other persons using the highway and on conviction is liable to a fine of not less than $400 and not more than $2,000 or to imprisonment for a term of not more than six months, or to both, and in addition his or her licence or permit may be suspended for a period of not more than two years.

2. Interpretation

Anyone operating a vehicle must take due care and attention to ensure that they do not endanger the safety of other roadway users.

3. Specific Applicability

Should a cyclist be within an intersection or road section, all drivers must ensure that they take specific action to ensure the safety of the cyclist.

2.3.2 HTA Subsection 144 (8) Yielding to Traffic

1. Legal Requirements

When under this section a driver is permitted to proceed, he or she shall yield the right of way to traffic lawfully using an intersection or, where traffic control signals are erected where a private road or driveway meets a highway, lawfully using the area controlled by the traffic control signals.

2. Interpretation

Any road user facing a green signal indication must first yield the right-of-way to other users lawfully using an intersection, such as may have entered on a previous signal phase or during the signal clearance period.

This also implies that right- or left-turning vehicles must yield to oncoming bicycles travelling straight ahead.

3. Specific Applicability

A motorist must yield the right-of-way to any cyclist that may be within the confines of an intersection during the red signal indication who first legally entered it during the green or amber indications.

Turning vehicles must yield to straight through bicycles, such as parallel movements with a bike lane/bike track. Straight through motor vehicles must yield to bicycles that have been released earlier, such as from a bike box, or leading bicycle phase.

2.3.3 HTA Subsection 144(10) Obeying Lane Lights

1. Legal Requirements

Every driver shall obey every traffic control signal that applies to the lane that he or she is in.

2. Interpretation

Traffic signal indications may be configured to be given specific displays for individual or specific lanes.

3. Recommended Practice

Traffic signals may be used to give direction to designated bicycle lanes, bicycle tracks, bicycle paths or multi-use trails.

2.3.4 HTA Subsection 144(29) Riding in Crosswalks Prohibited

1. Legal Requirements

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

2. Interpretation

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

3. Recommended Practice

Where a formal bicycle facility merges with a traffic signal, such as at a mid-block signalized path crossing or where a multi-use trail parallel to a sidewalk ("boulevard path") merges at a full signal, the treatment is to erect "Dismount and Walk" signs and require the cyclist to become a pedestrian when using the crosswalk. The alternative is to separate the pedestrian and bicycle crossings by providing separate crosswalks and crossride (described in detail later) areas. In order that this does not leave the bicycles without any form of protected crossing, this suggests the need for a form of traffic control for the bicycles and/or the parallel traffic whenever crossing volumes are significant.

2.3.5 HTA Regulation 626 Subsection 1. (4) Traffic Control Signal Systems

1. Legal Requirements

"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."

2. Interpretation

i. Every traffic approach to an intersection requires that two signal heads must face oncoming traffic from the far side of the intersection. The "far side" of the intersection is the half or side of the intersection that is across the intersecting roadway from the traffic approaching the signals.

ii. At least one signal head must be mounted at the far right 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.

3. Recommended Practice

i The signal head on the far right side is designated as the "primary" signal head. The signal head on the left of the primary head is designated as the "secondary" signal head. A signal head installed in addition to the primary and secondary signal heads is for the purposes of aiding in signal visibility and is termed an "auxiliary" signal head.

ii Auxiliary signal heads shall display the same indications at the same times as the primary and secondary heads. If signal head indications are timed differently, they must be on a separate phase from the primary and secondary heads.

iii Two separate signal heads shall be provided for any fully protected phase, such as a left turn operation, a separate bicycle phase (please note: this is current Book 12 wording), or a phase that represents the only opportunity for traffic to be served during a cycle.

2.4 Bill 130, Respecting the Municipal Act of Ontario

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

1. Legal Requirements

Scope of powers

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

Ambiguity

8 (2) In the event of ambiguity in whether or not a municipality has the authority under this or any other Act to pass a by-law or to take any other action, the ambiguity shall be resolved so as to include, rather than exclude, powers the

municipality had on the day before this Act came into force.

Scope of by-law making power

8(3) Without limiting the generality of subsections (1) and (2), a by-law under sections 10 and 11 respecting a matter may,

(a) regulate or prohibit respecting the matter;

(b) require persons to do things respecting the matter;

(c) provide for a system of licences respecting the matter.

Scope of by-laws generally

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

Interpretation

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

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

195(1) If a provision of a municipal by-law passed by the council of a municipality or police services board for,

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

Recommended Practice

The topics of bicycle traffic signals and cyclist actions when directed by bicycle traffic signals are not addressed in the HTA. Therefore, it appears that municipalities are free to make decisions, take actions and implement by-laws to:

(a) implement bicycle-specific signal phasing using standard traffic signals, with appropriate signing;

(b) pass by-laws regulating the movement and behaviour of cyclists under bicycle-specific phasing; (as long as those regulations do not conflict with section 144 of the HTA).

For the above actions, it would be appropriate to have municipal by-laws in place, defining specifically the signs, cyclist responsibilities and penalties for failure to obey the by-laws.

3. Traffic Signal Timing

3.1 General

Specialized bicycle traffic signal timing must fit within the framework of the existing vehicular and pedestrian signal timing. Most aspects of standard traffic signal timing are unaffected by specialized bicycle timing, but, when required, there are two potential changes which might be implemented specifically for bicycles. These are: modified initial green interval and revised vehicle intergreen intervals. This section will address these two specific issues.

3.2 Background Information

In order to undertake some of the assessments noted in this section, current information about bicycle volumes and movements are required. If possible, regular turning movement counts as undertaken at signalized intersections should specifically segregate the volume of bicycle traffic and types of turns taken. If this is not possible, special counts may have to be undertaken in order to properly evaluate conditions.

In addition, network screening or other types of collision assessments may indicate specific issues which might be remedied through the use of bicycle specific signal timing.

3.3 Factors Affecting the Choice and Use of Constants

It would appear that the level of knowledge is relatively limited regarding cyclist behaviour and performance. In addition, there are a wide range of factors which impact these constants. As with vehicular traffic, intersection characteristics such as grade, visibility or travel speeds may have an impact on a cyclist decision-making and performance. Some literature also demonstrates that demographics such as gender and age impact behaviour. As such, if the practitioner decides to adjust traffic signal timings from those which would traditionally be used for motor vehicles, the practitioner should learn as much as possible about the specific operation of the intersection or intersections in question before implementing changes.

3.4 Initial or Minimum Green Interval

3.4.1 Description and Justification

A cyclist at rest may not be able to accelerate as quickly as a motorized vehicle. In most typical signal timing designs, sufficient time is available at the start of the green interval to allow bicycles to accelerate from rest and cross the intersection prior to the conflicting phase being initiated. The one situation in which special treatment for bicycles might be necessary is at the sidestreet of an actuated intersection with an extremely short initial or minimum green interval. As with most of the recommendations in this guide, the justification for changing the signal timing would be based on a fairly heavy volume of bicycle traffic and/or a known condition or situation relating to bicycles crossing the intersection.

3.4.2 Formulae

The length of time for a cyclist to cross an intersection is based on three major components. These are: the perception reaction time, which includes the time to react to the change of signal to green and to commence pedaling– the Perception Reaction Time (PRT); a period of time to accelerate to regular travelling speed – the Start-

Up Acceleration (ACC): and the remaining time to cross the intersection at normal cycling speed – the Clearance Time (TCLEAR).

The first two components can be described discreetly or they can be combined and a constant provided as an alternate. The two formulae are described in the next two sections:

3.4.2.1 Discrete Formula for Minimum Green

The minimum green plus amber plus all red must be greater than or equal to the total crossing time required. The basic formula is:

Gmin + Y + AR => PRT + ACC + TCLEAR

Where:

Gmin is the minimum green

Y is the amber time (seconds)

AR is the all-red interval (seconds)

PRT is the cyclist Perception-Reaction Time (seconds)

ACC is the start-up acceleration time =

V/2a, where V is normal cyclist speed (metres/second) and

a is average acceleration from rest (metres/sec/sec or m/s^2)

TCLEAR is the time required to finish the crossing after accelerating to normal cycling speed =

$(W + L - (V^2/2a)) / V$ where:

W is the width of the intersection (metres), and;

L is the length of the bicycle (metres)

The complete formula is:

Gmin => PRT + V/2a + $((W + L - (V^2/2a)) / V) - (Y + AR)$

3.4.2.2 Simplified Minimum Green Formula

The total crossing should be equal to or greater than the minimum green plus amber and all-red. The basic formula is:

Gmin + Y + AR => SU + TCLEAR

Where:

SU is a start-up constant incorporating both perception-reaction time and acceleration to normal speed (seconds)

TCLEAR is the time required to finish the crossing after accelerating to normal cycling speed, which in the simplified formula does not consider the distance covered during start-up acceleration = (W + L)/V

The complete formula is:

Gmin => SU +((W + L)/V) – (Y+ AR)

3.4.3 Constants

It would appear the science of cycling is still in the developing stages and there have been few in-depth investigations into cyclist dynamics. As can be seen in Appendix A, there is a wide range of advice in the existing manuals and publications in regard to the specific values for constants to be used in computational formulae. As such, a range of values have been provided in various guides and manuals for each of the parameters required to calculate this and other formulae.

Appendix A contains summary of constants available in major guides. The practitioner is encouraged to find as much information as possible about the cyclist population and behaviours in their own jurisdiction before choosing constants. To ensure that a newly installed bicycle signal works for the greatest number of cyclists, the practitioner is encouraged to consider both existing and future cyclist demographics in their jurisdiction.

3.4.4 Application Guidance

The use of a longer than standard initial green impacts an intersection's efficiency. If there are a large number of cyclists using the intersection on a regular basis and cyclists are left in the intersection when conflicting traffic is shown the green on a regular basis, it may be appropriate to lengthen the minimum green. Conversely, if there is special detection for bicycles, such as through the use of a pushbutton or video detection, it may be possible to implement additional green time only on those occasions when bicycles are present.

A simpler alternative is to invoke the pedestrian timings whenever necessary to serve cyclists, by having bicycle detection place a pedestrian call.

3.5 Amber and All-Red Clearances

3.5.1 Description and Justification

Bicycles have very different performance characteristics than motor vehicles. They have a lower top speed and despite narrow tires, typically a shorter stopping time and distance. Conversely, if a bicycle enters the intersection just before or during the amber display, the lower speed may mean that the all-red clearance interval is insufficient.

This section defines the calculation of amber/all-red timing based on bicycle performance. Section 3.5.4 provides further insight into the need, impacts and alternatives to bicycle-specific clearance intervals.

In the case of a bicycle specific phase, where no motor vehicles are being served, clearance interval timing that is specific to bicycles should be implemented.

3.5.2 Formula

The formula for the intergreen for a bicycle is the same as that contained in section 3.6 of OTM Book 12, except that, since consistent units are used, no adjusting constants are required. The formula is as follows:

$$\text{Amber} + \text{All-red} = PRT + V/(2d) + (W + L)/V$$

Where:

d = bicycle deceleration rate

Amber is $PRT + V/(2d)$ and All-red is $(W + L)/V$

3.5.3 Constants

Information on constants is contained in Appendix A. As noted above, the practitioner is encouraged to find as much information as possible about the cyclist population and behaviours in their own jurisdiction before choosing constants.

3.5.4 Application Guidance

The vehicle clearance interval timing is the most important safety component of traffic signal timing. It should be adjusted or modified only with extreme care and knowledge of the potential consequences. The 2012 AASHTO guide [1] states that “the yellow interval is based on the approach speeds of automobiles, and therefore, should not be adjusted to accommodate bicycles”. This implies that any adjustment to the vehicle clearance intervals should be made only in the all-red interval, which is the appropriate methodology given that the amber required for a bicycle is much shorter than for motor vehicle traffic and would create an unsafe condition for motor vehicle traffic. As noted in Chapter 2, the Ontario Highway Traffic Act makes more than one provision for a situation in which a vehicle or pedestrian which has legally entered the intersection but has not completed their movement retains the right of way over conflicting traffic even if that conflicting traffic is presented with a green indication. Therefore it is not absolutely necessary to have a full clearance interval for bicycles, and if the intersection is operating safely there may be no need to adjust signal timings specifically for bicycles.

The formulae above will generate bicycle timings with very short ambers and very long all-red intervals. In mixed traffic, the amber must remain as set for vehicular traffic. However, the overall clearance interval for very narrow intersections (12-15 m) will be almost the same as required for bicycles. With larger intersections, the all-red may be so long that motorists may consider the signal to be faulty.

Alternative designs of detection, such as long-distance cyclist loops, may also serve to extend the green interval and minimize cyclist interaction with the clearance interval. Serious consideration should be given to any or all alternate techniques before considering modifying the current clearance interval timing.

1 Guide for the Development of Bicycle Facilities”, AASHTO, 2012, page 4-46 as quoted in “Operational Guidance for Bicycle-Specific Traffic Signals in the United States: A Review”, Oregon DOT Project SPR 747, Interim Report #1, August 2012.

4. Bicycle-Specific Signal Displays

4.1 Use of Bicycle-Specific Displays

Bicycles integrate with roadway traffic in many ways. Bicycles riding parallel to the flow of traffic may be in one of the general purpose traffic lanes, in a specific designated marked bike lane, in a separated cycle track beside the roadway or on a multiuse or bike trail behind the sidewalk. In the perpendicular direction, bicycles may cross the road at signalized intersections, at stop controlled intersections or at a mid-block location.

In the vast majority of cases, specialized signal displays specific to bicycles are not required at signalized intersections or special crossings. However, situations do occur in which specific information may or must be provided to cyclists to coordinate movements which are separate from those of the regular vehicular (including transit) and pedestrian traffic streams. This is particularly true in the Province of Ontario, since the HTA currently forbids riding of bicycles in crosswalks at signalized intersections. There is a very close relationship between the use of bicycle-specific signal displays and bicycle-specific phasing which will be discussed in detail in Section 5 of this guide.

To communicate bicycle-specific information to cyclists at signalised intersections, a form of traditional red-amber-green traffic signal may be used with appropriate signing. The legal implications of a bicycle-specific signal display are detailed in Section 2.

Under the current Highway Traffic Act and regulations, the only recognized option for bicycle-specific traffic signals is the use of standard traffic signals. Appendix B provides information on the bicycle symbol signal which is in the Manual of Uniform Traffic Control Devices for Canada and is in use in the province of Quebec. When a standard traffic signal head is used to provide direction to cyclists, a regulatory sign immediately adjacent to

Figure 3 – Bicycle Signal and Sign - English

Figure 4 – Bicycle Sign - Bilingual

the signal head should be installed. The sign will typically have the words "Bicycle Signal" or the French equivalent and may be symbolized and/or bilingual. Figures 1 and 2 show two examples.

4.2 Differentiating Bicycle Signal Heads

It is important to create differences between bicycle signals and the regular vehicular signals, to minimize motorist confusion, and thereby maximize safety. Where a bicycle specific traffic signal head is used, the bicycle signal heads should be differentiated from the vehicle signal heads through one or more of the following options:

- the signal head housing can be a different colour than the jurisdiction's standard colour, preferably one that is less visible to motorists such as dark green or black;
- the signal head may be installed with no backboard, which is more effective if the nearby vehicle signal heads are equipped with backboards;
- the signal head should be smaller, typically with three 200 mm sections, which is more effective if the jurisdiction's standard signal is a Highway head or an oversize highway head (300/300/300);
- wherever possible, the signal head should be positioned lower and out of the typical line of sight of the vehicle driver while being placed in line of sight of the cyclist.

The above can usually be achieved without reducing the effectiveness or value of the bicycle signal head to cyclists.

4.3 Bicycle Signal Head Size and Type

Given the slower speeds that cyclists would typically be approaching specialized traffic signals, the use of the 200/200/200 mm size is generally acceptable. Where conditions dictate, based on good engineering judgment, the practitioner may select the use of a 300/300/300 mm size bicycle signal head.

4.4 Bicycle Signal Head Placement

It is preferred that the bicycle signals are placed over the sidewalk or boulevard. In this case, the first priority is to place bicycle signal heads where they will not impede or potentially injure a passing cyclist or pedestrian. Mounting of bicycle signals, especially height, should generally conform to the guidance for pedestrian signals provided in section 5.7 of OTM Book 12 in the subsection entitled Mounting Height and Location.

In the less common case that it is absolutely necessary to place a bicycle signal so that it overhangs the traveled roadway, signal head clearance should be consistent with that used for regular traffic signals. Information in this regard is provided in section 5.5 of OTM Book 12 in the subsection entitled Mounting Height.

The Highway Traffic Act requires two signal heads on the far side of the intersection. Where bicycles are operating with the exact same signal phasing as the parallel vehicular movements, signal heads provided for bicycles are considered auxiliary only, and if appropriate, a single additional signal head for bicycles may be provided. Bicycle signals should be aligned to serve cyclists, with the understanding that a cyclist's field of vision may be quite low to the ground due to the cyclists' positioning on the bicycle.

Where bicycle movements are separated from parallel vehicular or pedestrian movements, OTM Book 12 notes that two signal heads must be provided on the far side of the intersection. If circumstances require, an auxiliary bicycle signal may be located on the near side.

5. Bicycle Specific Signal Phasing

At the vast majority of signalized intersections, bicycles are able to traverse the intersection without the assistance of bicycle phasing to specifically control bicycle movements. There are, however, unusual circumstances which will provide increased safety, throughput or convenience to cyclists at minimal or no impact to conflicting or adjacent motorized traffic or pedestrians. In these cases, special signal phasing using bicycle specific signal heads may be employed.

5.1 Common Applications of Bicycle Specific Phasing

Following are some examples of situations in which bicycle specific phasing might be advantageous:

- Where, at a mid-block or intersection crossing (often connecting to a mixed-use trail facility), the bicycle flows are mixed with pedestrian flows. This is particularly true in Ontario with the requirement that cyclists must dismount and walk to use the pedestrian crosswalk.
- Where large volumes of traffic travelling straight ahead on a designated bike lane or bike track conflict with heavy movements of turning traffic, it may be advantageous to both streams to provide temporal separation using separate signalization.
- At locations where no signal indication would otherwise be provided to bicycle traffic. An example of this would be a contraflow bike lane on a one-way street.
- At locations where bicycles are permitted to make movements which are otherwise prohibited for the rest of the vehicle stream. An example would be the restricted entrance to a residential neighbourhood for which vehicular traffic is required to turn but bicycle traffic is permitted to travel straight ahead to enter the neighbourhood.
- At extremely complex intersections where cyclists may be assisted by the provision of separately defined right of way.
- At otherwise traditional locations with high bicycle collision rates that may be mitigated by separating various movements.

Criteria are presented formally in Section 6. Many are similar to the concepts above.

5.2 Operational Considerations for Bicycle Phasing

Since bicycle phasing is not commonplace, it is incumbent on the practitioner to use engineering judgement as to the appropriateness of installing bicycle phasing and the best way to implement it. Some factors to be considered are as follows:

- Conformity and Consistency.
    - o Driver and cyclist performance improves with familiarity and confidence. Therefore, if special phasing is used at a location, consideration should be given to using it at all locations similar in nature or at least similar locations along a cycling corridor.
    - o Conversely, if bicycle phasing is only intended to be used at an individual intersection which is unique, very careful consideration must be given to the implementation to ensure clarity to both motorized and non-motorized users.

- Cyclist Behaviour.
  - Because of the energy necessary to accelerate a bicycle from a stop position to travel speed, momentum is valuable to cyclists. Cycling facility designs have to recognize that cyclists tend to be reluctant to stop unless absolutely necessary.
- Overall Benefits.
  - In the course of designing bicycle specific phasing, consideration must be given not only to the improvements in safety and efficiency for non-motorized users but to the potential decrease in safety and or efficiency for motorized users. It is understood that in order to promote healthy lifestyles and to promote a move away from the use of single occupant motor vehicles, special promotion of cycling will occur. However, the practitioner must consider the negative consequences, especially on motorist or pedestrian safety, as well as the advantages.
- Introductory Period.
  - The most difficult time of any new device or operational condition is immediately after implementation. The unfamiliarity of users can lead to erratic driving or riding and the risk of collisions is highest directly after any change. This is similar to the introduction of new signals or signs for which special precautions are sometimes taken.
  - To maximize the success and safety of any new installation, a combination of the classic 3E's should be employed:
    - Educational campaigns utilising both traditional and non-traditional techniques are important.
    - Law enforcement should be involved and should provide the necessary level of enforcement and encouragement.
    - Engineering: Advance information signing or other techniques should be employed on a temporary basis to heighten user awareness. This would be similar to the use of the "NEW" warning sign which accompanies new Stop signs, Yield signs or traffic signals for 30-60 days after installation.

5.3 Combined Bicycle and Pedestrian Crossings (Without Bicycle-Specific Phasing)

This section explores the options for locations where the bicycles and the pedestrians cross together or immediately beside each other. This may occur at or near a crosswalk at a full traffic signal, or may occur at a mid-block crossing. The options are presented in increasing complexity, and it is expected that the more complex solutions would only be required where large numbers of bicycles and/or pedestrians and/or motor vehicles interact.

5.3.1 Use of the Same Crosswalk – Cyclists to Walk Across

The most basic method of managing the situation at locations where multi-use trails cross the road or where bike paths merge with sidewalks at intersections, is to require cyclists to default to the basic HTA requirement to dismount and walk across a signalized intersection crosswalk. The TAC Dismount and Walk Sign MUTCDC RB-79 should be used. As well, a stop sign and stop line may be considered on the path or trail to further encourage cyclists to comply.

This organization would be an option where the addition of a crossride is not possible, but the large volume of pedestrians in a crosswalk and/or the width of the crosswalk suggest that the best organization is to require cyclists to walk. While this is feasible, in many cases cyclists find the requirement onerous or unreasonable and disobey the regulation, therefore the implementation of a crossride should be considered wherever possible.

5.3.2 Parallel Pedestrian and Bicycle Crossings – No Bicycle Signal Traffic Control

Where a multi-use trail (combination of bicycles, pedestrians and other non-motorized users) crosses a roadway in close proximity to a signalized intersection, there are two choices. Either the cyclists and pedestrians are combined in the pedestrian crosswalk (as described in 5.3.1) or a separate crossing denoted by the “elephants feet” pavement marking (called a “crossride”) is provided. While similar to the configuration in 5.3.1, the use of the crossride means that the interaction of bicycles and pedestrians in the crossing is greatly reduced or eliminated. One minor concern is that the TAC recommended design places all bicycles on one side, while a typical multi-use trail operates with the pedestrians on the outside and the faster-moving bicycles closer to the centre. Since most users will have to stop before crossing, this organization of cyclists and pedestrian should operate satisfactorily.

The design also uses the pedestrian signal to serve both pedestrians on the sidewalk and those on the multi-use trail.

The most basic version of this layout provides pedestrian signals but uses stop control for bicycles. This is shown in Figure 3. By definition, the pedestrian signals do not control the bicycle movements, so there is a need for an alternate form of control for the bicycles. Figure 4 shows an alternative configuration of the crosswalk and crossride with no signalization of the bicycle movements.

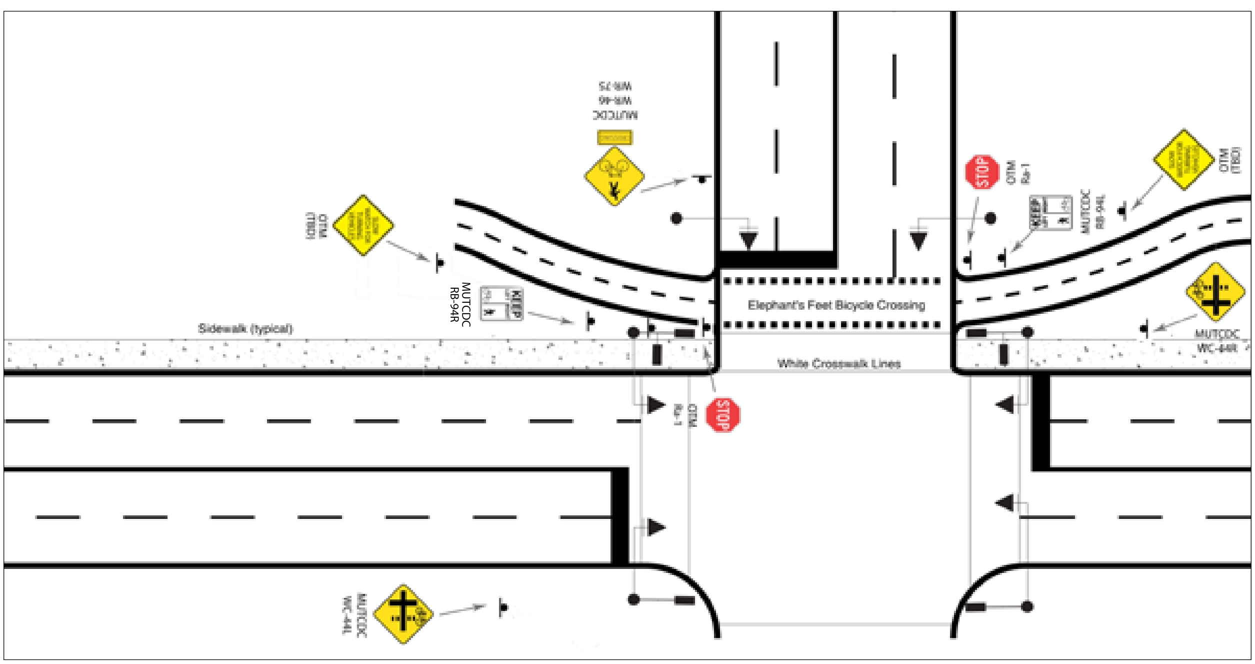


Figure 3 – Multi-Use Trail Crossing Road at Signalized Intersection with No Signal Control for Bicycles

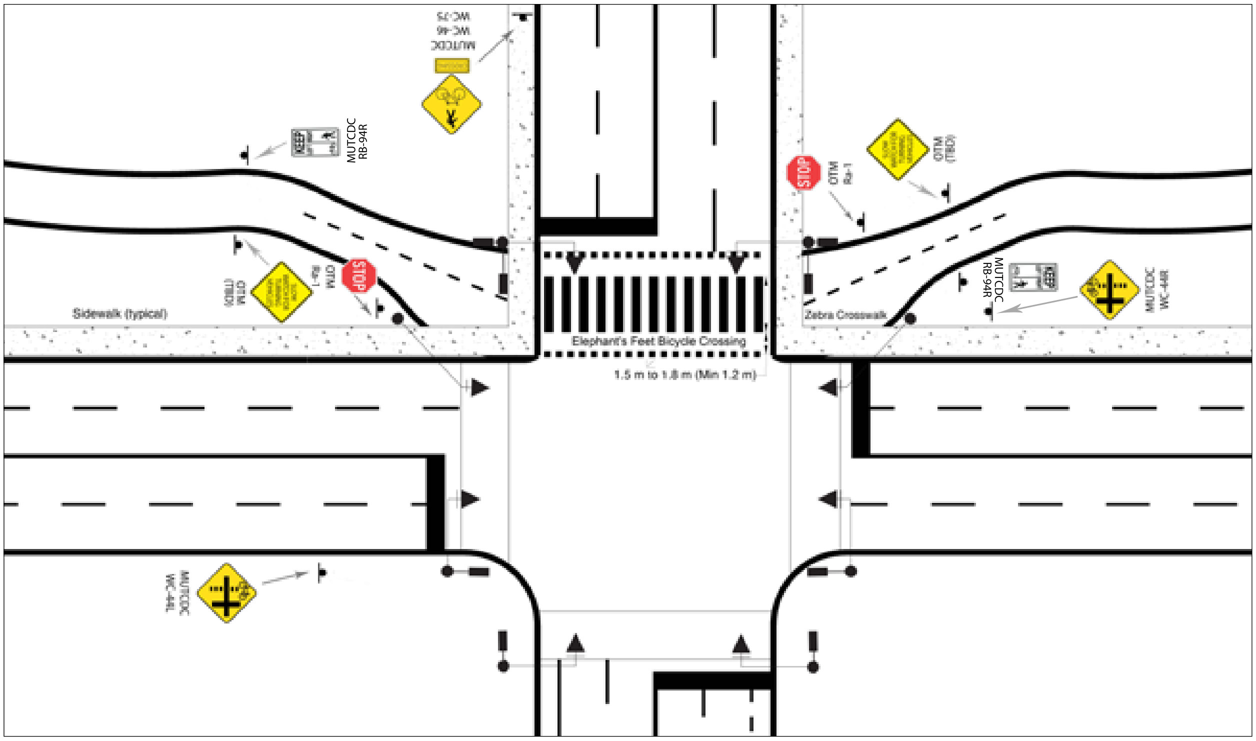


Figure 4 – Multi-Use Trail Crossing Road with No Signal Control for Bicycles - Alternate Crossride Configuration

Figure 5 – Multi-Use Trail Path Crossing Road at Signalized Intersection - No Separate Signal Control for Bicycles

Even with stop control for the bicycle path, a potential concern is that left- or right-turning traffic will not anticipate the presence or correctly judge the speed of bicycles travelling parallel to traffic. If there is an observed conflict situation, a combination of reduced speed warning for the bicycles in the vicinity of the crossing and the Bicycle Trail Crossing Side Street sign MUTCDC WC-44 for both directions of parallel traffic may serve to minimize conflicts between bicycles and turning traffic.

The choice of placement of the crossride relative to the crosswalk often depends on the exact configuration of the intersection.

Figure 5 shows an alternative configuration of the crosswalk and crossride with no specific signalization of the bicycle movements. Bicycle movements are governed by the regular vehicle signals, rather than signs or specific signals on the path. This configuration may be used if the practitioner is satisfied that the cyclists will consistently obey the standard vehicle signals. An auxiliary signal specific to cyclists may also be added (not shown), if showing exactly the same displays as the main vehicle signals, to improve cyclist compliance.

5.3.3 Parallel Pedestrian and Bicycle Crossings – With Bicycle Signals

In circumstances that necessitate, both at signalized intersections and at mid-block locations, the crossride may be signalized. Bicycle traffic signals are provided in order to maximize safety and throughput of bicycles. Figures 6 and 7 show a crosswalk/crossride design with a signalized pedestrian crosswalk and signalized crossride.

To best organize the crossing, the TAC Pathway Organization Sign MUTCDC RB-94 or RB-95 may be used. The ID-20 pushbutton sign is used when the bicycle signal operation is actuated.

If there is an observed conflict between path users, a combination of reduced speed warning for the bicycles in the vicinity of the crossing through the use of the "Slow Watch for Turning Traffic" sign

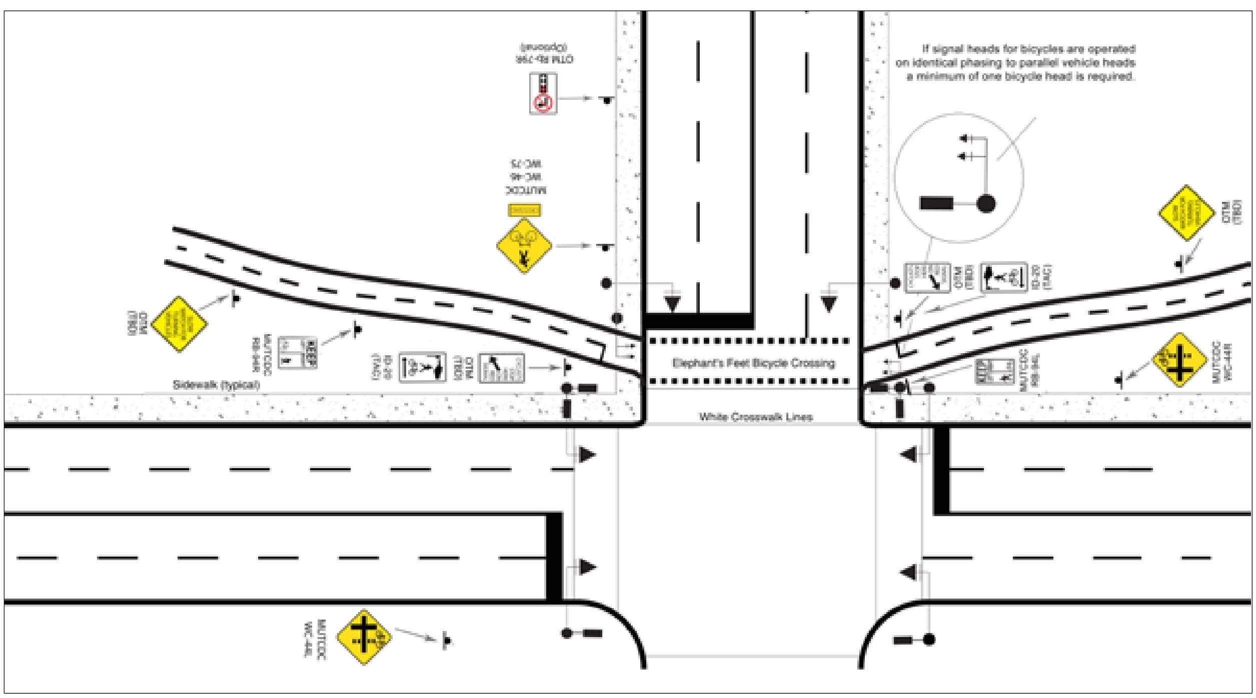


Figure 6 – Multi-Use Trail Crossing Road at Signalized Intersection - Signalized Bike Crossing

Figure 7 – Multi-Use Trail Crossing Road at Signalized Intersection - Signalized Bicycle Crossing

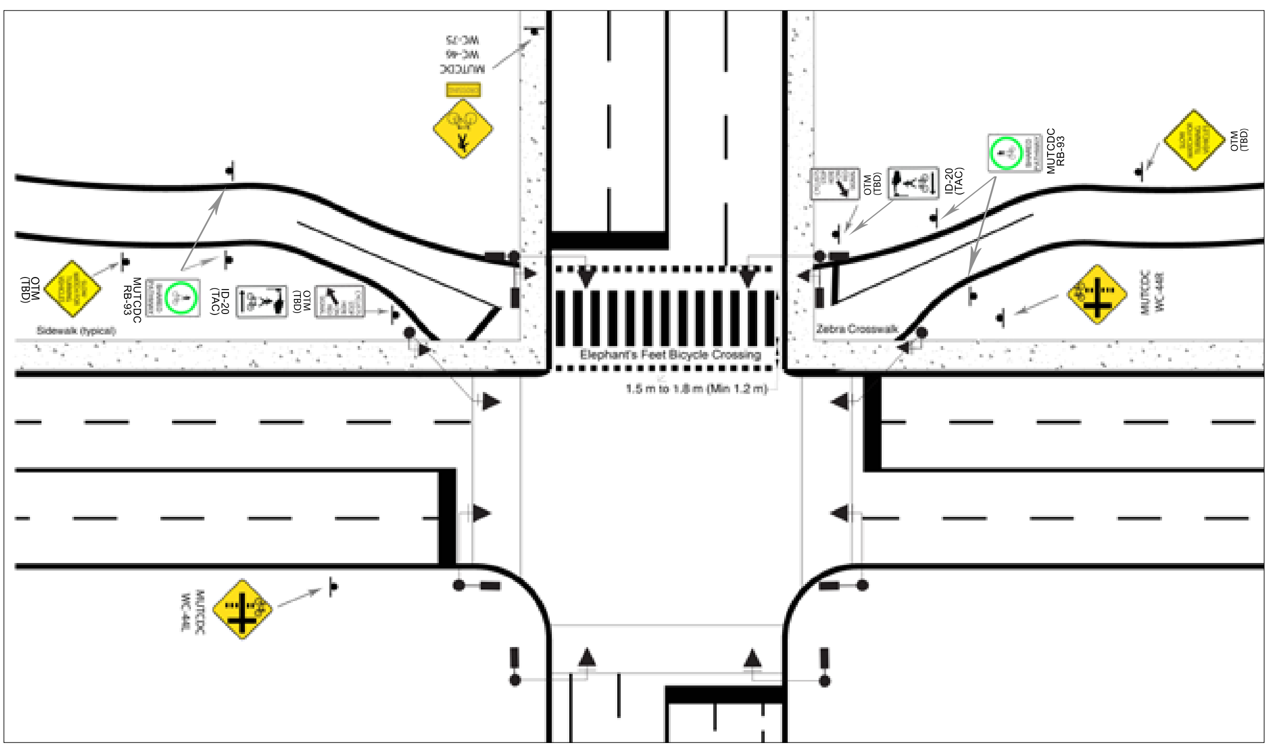


Figure 8 – Multi-Use Trail Crossing Road at Signalized Intersection - Alternate Crossing Configuration

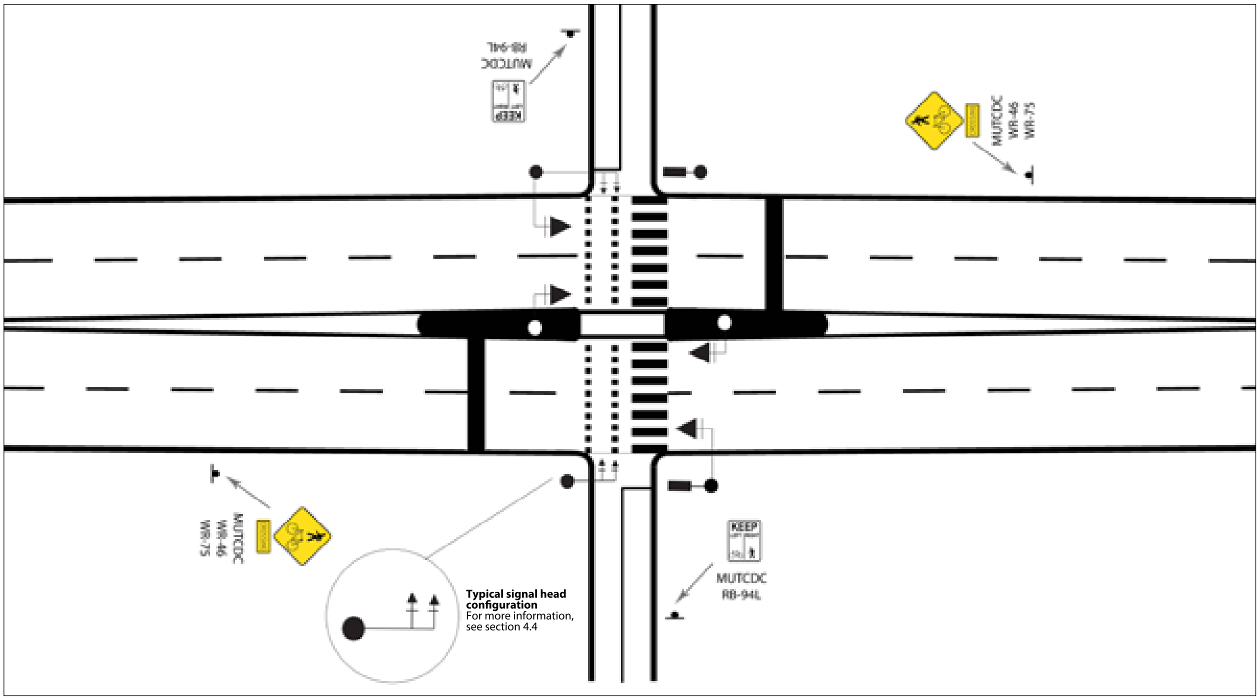


Figure 9 – Signalized Mid-Block Crossing with Separate Bicycle Crossride, Both Crosswalk and Crossride Signalized

and the Bicycle Trail Crossing Side Street sign MUTCDC WC-44 for both directions of parallel traffic will serve to minimize conflicts between bicycles and turning traffic. The "Cyclists Stop Here on Red Sign" may be used if lack of signal compliance is noted.

The pedestrians on the sidewalks walking in a direction perpendicular to the multi-use path are not provided with specific information about the right-of-way status of bicycle traffic on the path.

Generally, this is not an issue and there are examples of this type of configuration in general use, as shown in Figure 7, which have been operating satisfactorily in cities such as Toronto for many years.

However, in the event that conflicts between pedestrians on the sidewalk and multi-use trail cyclists are noted, one option would be to install signs on the trail to inform the cyclists to watch for crossing pedestrians and/or to install signs on the sidewalk informing the pedestrians that cyclists do not have to stop.

In the rare extreme case, the pedestrian signal heads could be relocated to extend the pedestrian crosswalk across the arterial roadway to include the multi-use trail as well, although this could have a significant affect on the signal timing and operational efficiency of the intersection.

Figure 8 shows an alternative version of the signalized crosswalk/crossride layout.

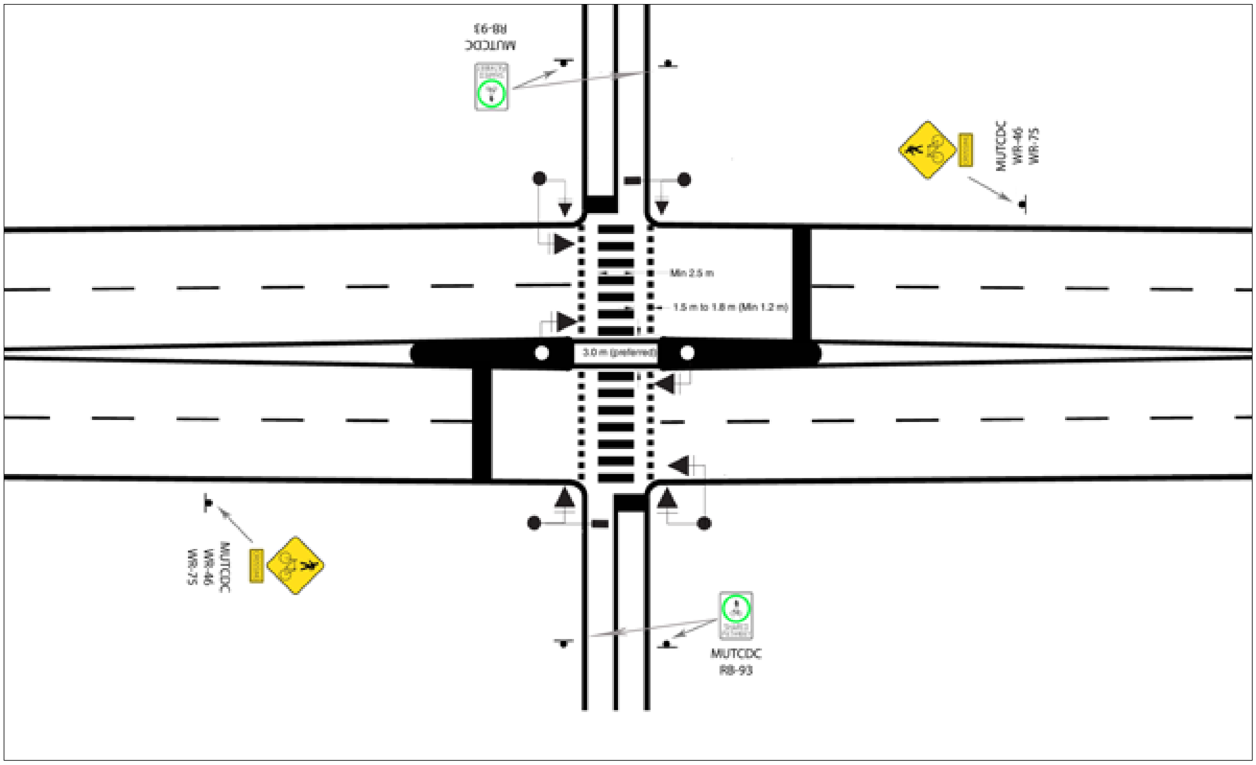


Figure 10 – Signalized Mid-Block Crossing with Alternate Crosswalk / Crossride Configuration

Figure 11 – Signalized Mid-Block Crossing with Both Crosswalk and Crossride Signalized

5.3.4 Mid-Block Crossing Configurations

Figures 9, 10 and 11 show three configurations of signalized mid-block crossings of multi-use trails with both crosswalk and crossride signalized. As noted previously, the final choice of layout will often be a function of the crossing configuration and the practitioner should make a decision based on typical layouts nearby and engineering judgement.

5.4 Combined Bicycle and Pedestrian Crossings – Bicycle-Specific Phasing

For some situations, bicycle specific signal heads and warning signs may not provide the bicycle crossing with a sufficient level of safety. This may occur due to poor visibility, where the boulevard trail is set back a large distance from the parallel roadway, where cyclists are travelling at high speeds or where there are very high volumes of bicycles and/or turning traffic, resulting in conflicts. An option is to partially or completely separate the parallel right and left vehicular turning movements from the bicycle phase.

5.4.1 Bicycle Leading Only Phase

At locations with a designated bike lane or cycle track and heavy through bicycle traffic conflicting with heavy turning traffic, particularly right turning traffic, a leading bicycle phase may be helpful. This is similar to a pedestrian-only leading phase. Vehicular traffic is controlled by a four section head with the straight through green arrow and a green ball. Vehicular traffic is initially shown the straight up green arrow at the same time that the bike signal displays green. After a short green bicycle interval, which allows the group of standing bicycles an opportunity to proceed into the intersection and take possession of the conflict space, the vehicle indication changes from straight up green arrow to green ball. The bicycle green remains on for the full phase, changing to amber and red only at the end of the vehicle phase. Figure 12 shows the phasing diagram.

The drawback is the somewhat increased delay for motorists.

Pedestrian movements may also receive advanced movement status under this phasing configuration.

This phasing is applicable to the crosswalk/crossride combination of crossing, for intersections with bicycle boxes or for reserved bicycle lanes or cycle tracks.

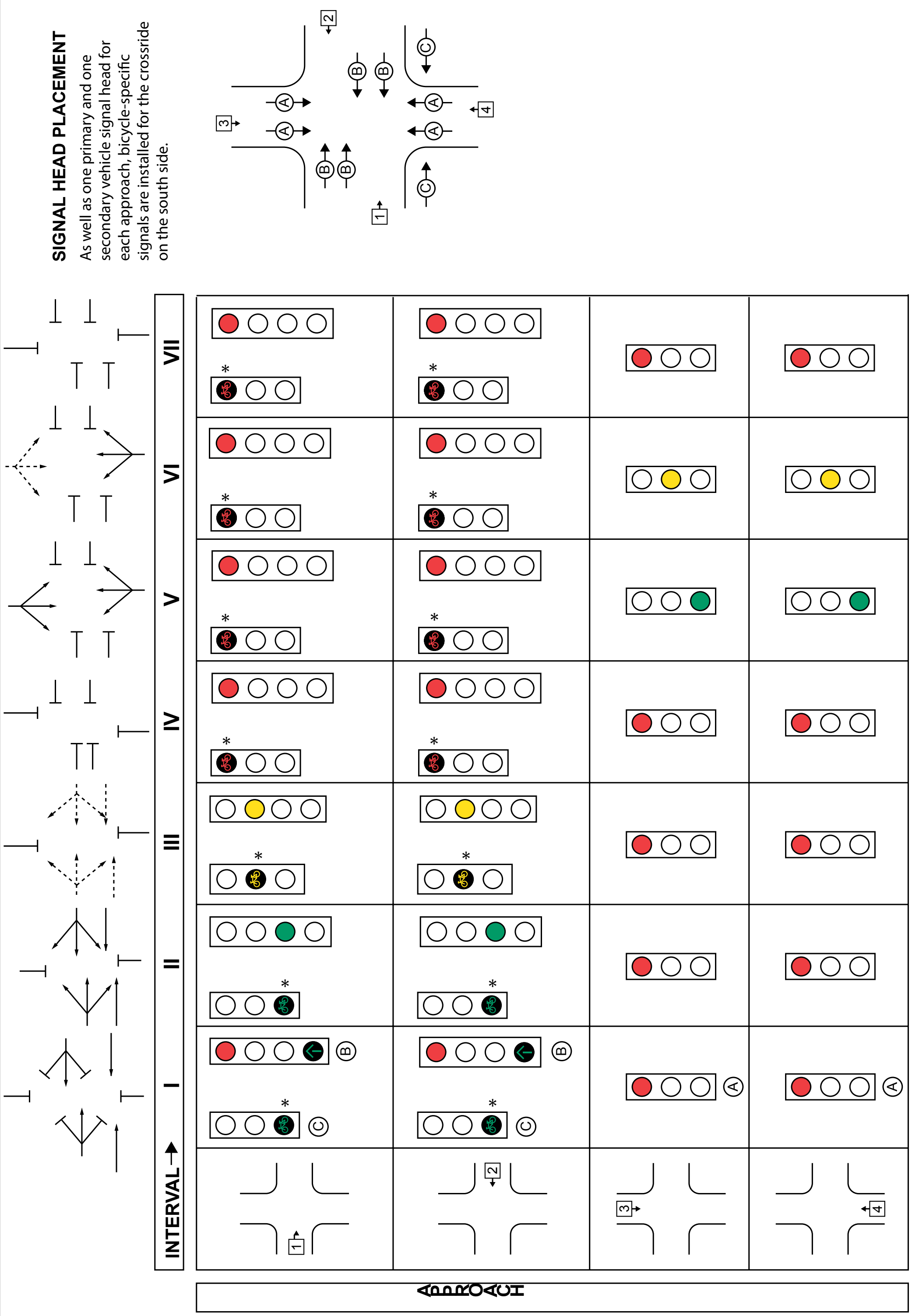
5.4.2 Bicycle Only Phase

The most restrictive but effective manner of separating bicycles and turning traffic is to allow the bicycles a minimum green to start, and then transition to bicycle amber and red immediately. Parallel turning traffic is held until the bicycle red is displayed. This provides limited signal time for bicycles but provides complete separation of the conflicting traffic streams. This phasing is shown in Figure 13.

The chief drawback is the short time interval available for bicycles, which may generate complaints and/or result in lack of compliance, as well as increased delay for motorists.

5.5 Partially Signalized Intersection (IPS) Crossings

The situation will occur where a neighbourhood bike route or a designated bike lane crosses the major roadway at a location equipped with an intersection pedestrian signal. The cyclist is expected to use the IPS as a vehicle, regulated by the stop sign. An alternative is to equip the IPS to be activated



NOTE: The phasing shown has bicycle clearance concurrent with vehicle clearance intervals. That is generally preferred to eliminate confusion. However, if required, the bicycle amber and all-red intervals may be different, as long as the bicycle signal heads are carefully oriented to minimize viewing by motorists.

OPERATION:
Motor vehicle traffic is shown "Through-Only" arrows while bicycles start into the intersection. This then changes to green ball indications and the remaining phasing is the same as a basic two-way phase operation.

* Bicycle symbol signal heads are for diagram purposes only.

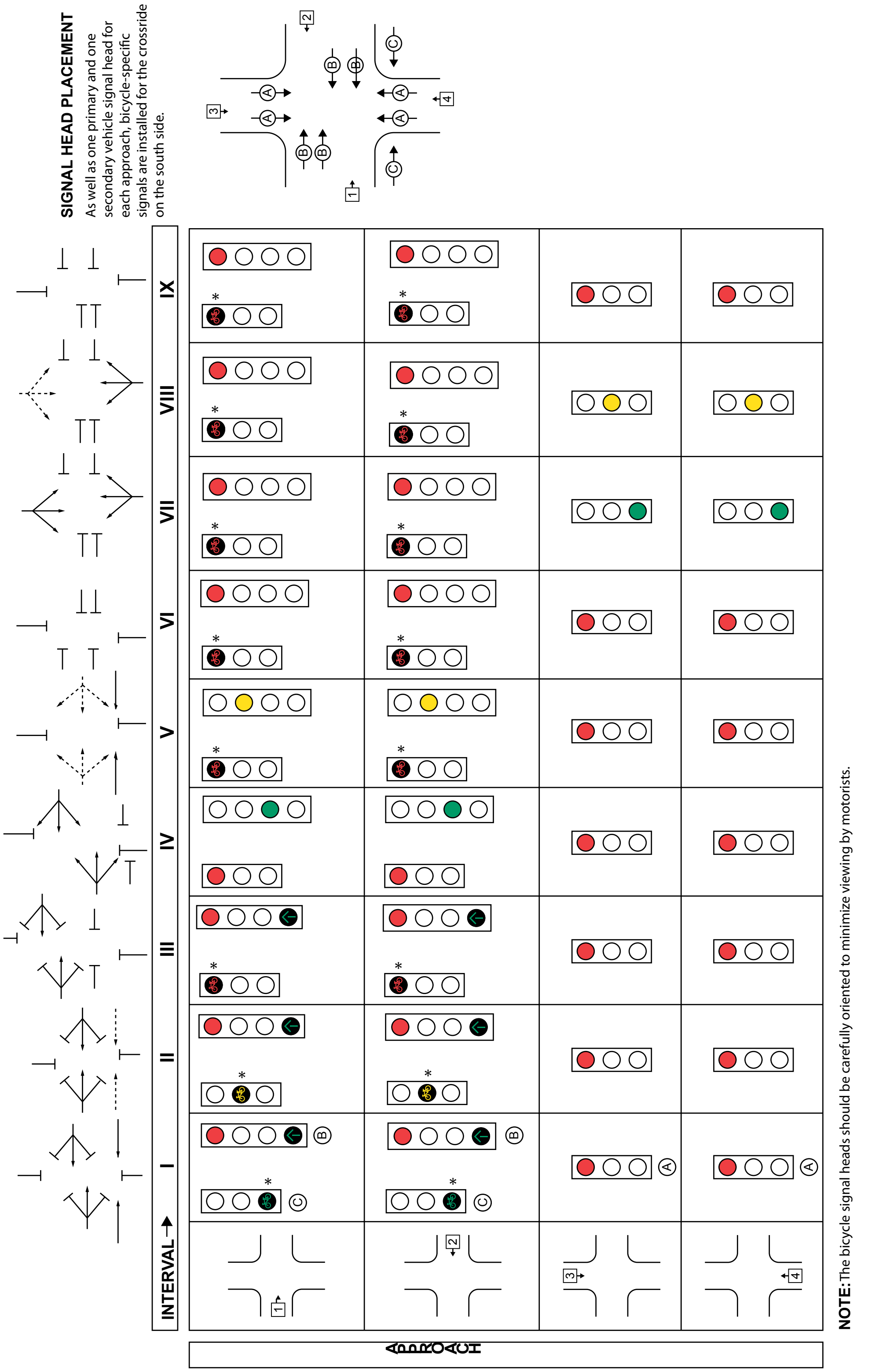
Figure 12 – Bicycle-Only Leading Phasing

by either a loop in the bicycle lane or by a bicycle specific pushbutton. The option of bicycle signals for the sidestreet would conflict with the stop signs (which govern cyclist movements) and is not permitted.

5.6 Contraflow Bicycle System

In order to provide continuity in the bike network, it is sometimes necessary to operate bicycles in a direction opposite to the vehicular flow on a one-way street. The lanes may be separated simply by pavement markings or by physical barriers such as curbs. Where the contraflow bicycle lane intersects with a signalized intersection, the only indication that is available would be pedestrian signals. To provide throughput and safety benefits, bicycle traffic signals may assist. The bicycle signal phasing generally parallels the vehicular signal phasing for the opposite direction (considering turn phases), but may utilize bicycle-specific signal timings.

Figure 14 shows the signal configuration for one option for a contraflow bicycle operation.



NOTE: The bicycle signal heads should be carefully oriented to minimize viewing by motorists.

OPERATION:
Motor vehicle traffic is shown "Through-Only" arrows while bicycles start into the intersection. The bicycle phase is completed before the motor vehicle displays.

* Bicycle signal heads are for diagram purposes only.

Figure 13 – Bicycle-Only Separate Phase

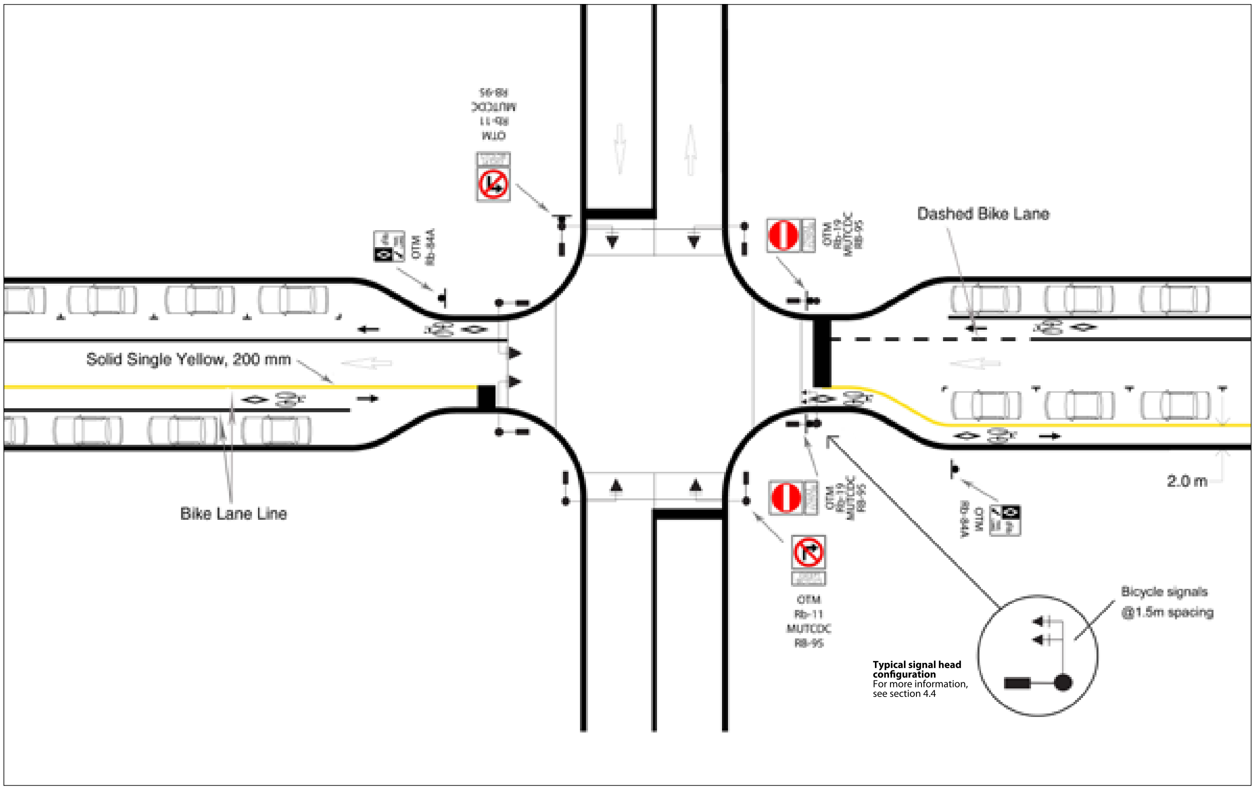


Figure 14 – Contraflow Bicycle Lane - Parking on Contraflow Side of Street

6. Decision Criteria

There are two types of decision or input criteria which are applicable to bicycle signal/bicycle phasing installation. Bicycle signal phasing and bicycle signal heads may be installed where circumstances suggest benefit to cyclists, motorists, pedestrians or all three. Bicycle demand may also be used as a factor in the decision to install a full or partial traffic signal. This section will discuss the two types of justification.

6.1 Criteria Which May Be Used When Considering Separate Bicycle Phases

The term "bicycle-specific phases" includes separate movements, leading or separate phases, and includes contraflow bicycle movements. It is almost always the case that separate bicycle signal heads are only required if bicycle-specific phases are used. A report for Oregon Department of Transportation[2] provides references from several states and cities that have published guidance for the installation of bicycle specific signals. The following is a summary of the factors which are used by one or more jurisdictions. Since conditions vary from jurisdiction to jurisdiction and from site to site, the following are presented to provide the practitioner with some options for choosing criteria which may be appropriate.

Volume/Delay Criteria

- volume, based on the number of bicycles per peak hour (at least 50) and the number of vehicles at the peak hour entering the intersection
- to reduce overall delay to cyclists where delay is significant

2 Operational Guidance for Bicycle-Specific Traffic Signals in the United States: A Review", Interim Report #1, Oregon Department of Transportation, ODOT Project SPR 247, August 2012.

Collision/Conflict Criteria

- a bicycle signal phase should only be considered for use when an engineering study finds that a significant number of bicycle/motor vehicle conflicts occur or may be expected to occur at the intersection and that other less restrictive measures would not be effective
- collisions (when two or more bicycle/vehicle collisions of types susceptible to correction by a bicycle signal have occurred over a 12 month period and a responsible public-works official determines that a bicycle signal will reduce the number of collisions)
- when there is a need to provide a leading interval for cyclists in order to increase their visibility and safety
- geometric factors – to control the separation of conflicting movements between cyclists and motorists

Planning Criteria

- Where the addition of a special phase would complete the continuity of a bicycle system and where the movement protected or encouraged would otherwise be challenging

Geometric Criteria

- geometric (a path connection or to allow movement not allowed by vehicles)
- geometric factors: an intersection that impedes cyclist crossings that could be mitigated with the bicycle phase
- an approach to a signalized intersection is intended for bicycles only and it is desirable to signalize that approach
- examples of geometric configurations that might benefit from the use of a bicycle signal phase include:

- o a bike lane to the right of a high volume right turn; and,
- o a multi-use path that comes into the intersection in such a way that motorists may not see or yield to cyclists approaching the intersection

Timing/Phasing Criteria

- where paths cross roadways – to provide a shorter green time for cyclists when no pedestrians are present
- if there is a bicycle movement that is not accommodated by typical traffic signals

Demographic/Geographic Criteria

- proximity to schools, parks, and popular bike routes should be considered

Impacts to Consider

- the bicycle signal should only be used after other alternatives have been used or rejected
- additional delay to all roadway users should be considered

6.2 Input to Existing Traffic Signal Warrants

6.2.1 Full Traffic Signal Justification

Bicycles which are part of the general traffic stream or are on designated bike lanes or cycle tracks within the roadway should be counted along with motor vehicles when performing traffic counts for the purpose of considering whether a new full traffic signal is justified.

6.2.2 IPS or Mid-Block Pedestrian Signal Justification

While intersection pedestrian signals and mid-block pedestrian signals are primarily devices to aid pedestrians in crossing the roadway, they can serve that purpose for bicycles equally well, as long as the signal is equipped with a form of bicycle detection. IPS are particularly useful in providing continuity for neighbourhood bike routes when crossing an arterial, while mid-block signals fit well with multi-use or bicycle trail crossings. In the case of a new IPS or mid-block signal to be equipped with bicycle detection or a retrofit to serve bicycles, it is appropriate to add the bicycle traffic to the pedestrian volumes when considering the justification for installation of the signal.

7. Bicycle Detection

7.1 General

Bicycles may be detected using the equipment already in place for general motor vehicle traffic. Alternately, detection specific to bicycles may be installed. A bicycle detector is a vehicle or pedestrian detector that has been provided for or assigned to indicate the presence or passage of bicycles in a designated area of the roadway at a traffic signalized intersection.

General differences in detection between motor vehicles and bicycles include:

- Use of existing versus bicycle-specific detection
- Active or passive detection, requiring various levels of involvement by the cyclist;
- Technologies with differing requirements and impacts on the infrastructure, most specifically the roadway pavement; and
- Differing sensitivities to bicycles constructed of different materials, specifically the difference between ferrous (steel) and non-ferrous frame and wheel materials.

Bicycle detection is typically installed to measure the presence of bicycles:

- on actuated approaches at semi- or fully-actuated intersections,
- travelling in the general purpose lanes at intersection approaches without bicycle lanes;
- riding in a bicycle lane;
- at intersections with bicycle signals and/or bicycle specific timings and phasing that are actuated (e.g. green extension, bicycle-only phase, etc.);
- in left-turn lanes where bicycles may also turn left.

While it should be a basic requirement to provide bicycle specific detection wherever bicycles are present, the provision of reliable bicycle detection can assist in establishing bicycling as a legitimate mode of transport. The benefits of providing for bicycle detection at signalized intersections include the improved efficiency and reduced delay for bicycles, increased safety and convenience, the discouraging of red light running and the provision of adequate green and/or clearance times for bicycles.

It is important to note that bicycles are more difficult to detect with some common types of vehicle detection technologies than a motor vehicle. Therefore, attention should be paid at both the design and installation stages to ensure that bicycle detectors are appropriate to the environment and will operate reliably.

7.2 Common Types of Bicycle Detectors

Induction Loops

General Vehicle Loops

The most common type of detector in many jurisdictions is the in-pavement induction loop. When the existing vehicle detection is to be used, specific attention must be paid to the sensitivity settings of the detection amplifier. The goal is to set the sensitivity as high as possible without having the detection system “lock up” and place a steady call instead of detecting the arrival of vehicles. Significant testing and a number of visits to ensure reliable operation may be required. In some cases, such as when there are long lead lengths from the loop to the controller, it may simply not be possible to use existing loops.

Given the lower sensitivity to bicycles of regular general purpose loops, the use of pavement markings and signing, as discussed later in this chapter, indicating to cyclists where to position their bicycles to have the best chance of being detected, is very important.

Bicycle Specific Loops

Introducing loops designed specifically to detect bicycles will improve overall intersection operation for both general purpose traffic and cyclists. For bicycles, the loops have greater sensitivity and will be more reliable over the long run. Generally, these loops are capable of detecting ferrous and non-ferrous metal bicycles with reasonable accuracy. The regular vehicle loops can be adjusted with lower sensitivity, meaning higher reliability (less likelihood of lock-up.) It is relatively easy (and not overly expensive) to design in bicycle detection when introducing all-new detection to a roadway approach. However, retrofitting bicycle loops often means the destruction of the general purpose loops, and therefore, other types of bicycle detection may be a better choice.

To help ensure that bicycles are detected, quadrupole or diagonal quadrupole loop detectors are recommended because they are bicycle sensitive over their entire area. Four turns of #16 gauge copper wire is recommended to effectively detect a wide range of bicycle types. Ideally, loops should be placed in locations that are logical and convenient to cyclists, such as close to the edge of the roadway in a through or combined lane, and close to the right side of a left-turn lane. In order to maximize the loop's effectiveness, supplemental bicycle detector pavement markings and informational signs may be utilized. These markings are discussed in more detail later in this section.

Other loop designs can work but may be less effective and may require a cyclist to position

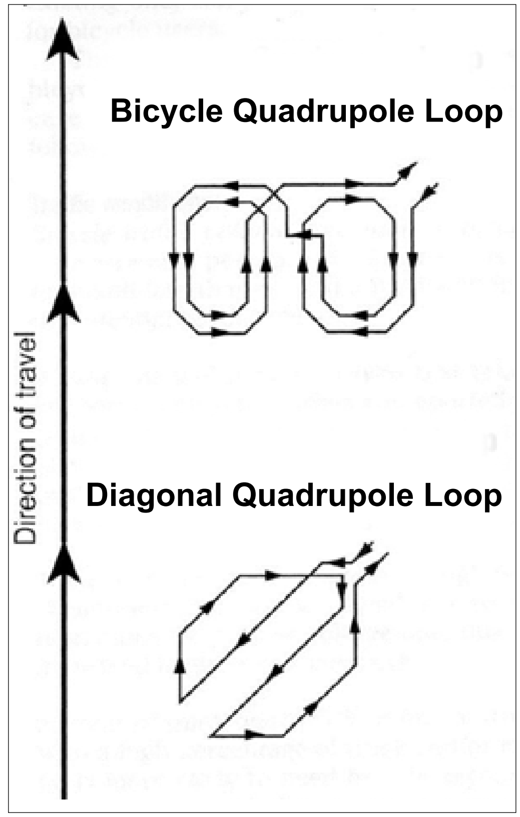


Figure 15 – Quadrupole Detectors

themselves within a much smaller detection area. Therefore, the importance of the use of the supplementary bicycle detector pavement marking and informational signage is increased with other loop designs.

Some municipalities, such as the City of Mississauga, have successfully implemented long-distance detection using induction loops placed upstream of an intersection within a bicycle lane.

Video

Detection methods that utilize image recognition from video detectors are capable of detecting a cyclist at an intersection over a larger area than a loop detector. However, video detectors have been shown to have a reduced effectiveness in the dark, including registering false calls when shadows appear within the detection zone.

A typical video detector is comprised of a camera and an image processor that is programmed to analyze video images and mimics a loop detector. Defined detection zones can be relatively easily modified , which offers increased flexibility in detector layouts. Video detectors present an excellent alternative to loop detectors in a variety of situations, including where the pavement quality is poor and installation of in-pavement loops can be challenging. Costs for video detection are typically higher than for loop installations.

Emerging Technologies

LED

LED detectors emit non-visible light into the detection area and measure the time taken for the light to reflect off of objects and return to the sensor. This technology can detect many types of vehicles bicycles in all weather conditions, any time of the day. The system can also determine the direction of travel of vehicles, thereby preventing false calls to traffic signal controllers.

These non-intrusive detectors are mounted directly to current traffic infrastructure similar to video detection. Some models also include an onboard image processor with the capability to transmit video images back to the jurisdiction.

Microwave

Microwave detectors are mounted above the ground similar to video and beam a cone shaped area to an approaching bicycle, which reflects some of the microwave energy back to the detector. This type of detection can be considered in areas where detector pavement installation is not possible.

Pushbuttons

As with vehicle detection, a cyclist may make use of existing detection in the form of the pedestrian pushbuttons. However, since the placement of pushbuttons is now designed to meet the needs of the visually- and mobility-challenged, the pushbutton placement is likely less than ideal, and may be very inconvenient for cyclists. This is particularly true in urban conditions, with pushbuttons on poles behind curbs and sidewalks. Depending on the cyclist using the existing pedestrian pushbuttons is not generally recommended, and should preferably be limited to rural, low bicycle volume locations.

However, if placed specifically for a cyclist, a cyclist who dismounts briefly, or stops and reaches from his/her bicycle may be able to make use of pushbutton at an intersection as a form of bicycle detection. This approach works best for single lane approaches, for designated bicycle lanes and other forms of operation where the cyclist is naturally riding next to the right side curb. Bicycle specific pushbuttons can be used at intersections where existing loops are insufficient to detect bicycles, in place of loops or on the side street at Intersection

Pedestrian Signal locations where the cyclist would otherwise be required to cross traffic from the stop-controlled approach. The installation of a pushbutton is a relatively low-cost form of bicycle detection.

Where pushbuttons are used, tactile and visual feedback buttons can help to increase the cyclist's confidence that the traffic signal will change thereby increasing compliance with the signal indication and ultimately increasing safety and efficiency of/for the cyclist. The pushbutton could be used to call either a bicycle specific timing or phase or to call the pedestrian phase.

The pushbutton should be placed on the right side of the intersection approach and positioned in a manner that is relatively convenient for the cyclist and away from the radius of the curve where it could be struck by large vehicles making a turn. Additionally, the pushbutton should be positioned so that a cyclist wishing to make a left-turn has the ability to proceed to the appropriate lane without inconvenience. These requirements result in the pushbutton being installed near the curb and upstream of the crosswalk about 5 to 10 metres depending on the number of lanes the cyclist would be required to cross.

The drawback is, that despite careful design and planning, inadvertent and intentional activation by motorists will occur. Bicycle-specific pushbuttons should be considered only when other alternatives are not considered feasible.

7.3 Pavement Markings and Signage

As opposed to vehicles which have greater size and mass and are more easily detected, bicycle detection is highly dependent on the position of the bicycle in relation to the position of the loop detector. In order to realize the maximum level of effectiveness from bicycle detectors, it is important that the cyclist position themselves in the area that provides the highest detection signals from the loop. Cyclists can be aided in improving their likelihood of being detected by in-pavement loops by careful application of pavement markings, possibly in combination with information signage, which clearly indicates where to place the bicycle in order to be detected. This is especially critical for dipole loops.

Figure 16 shows the TAC approved symbol which indicates to cyclists where to position the bicycle on the roadway. Figure 17 shows the typical placement of the pavement marking symbol on various loop configurations. Figure 18 shows the TAC approved sign which should accompany this pavement marking stencil, especially for the introductory period.

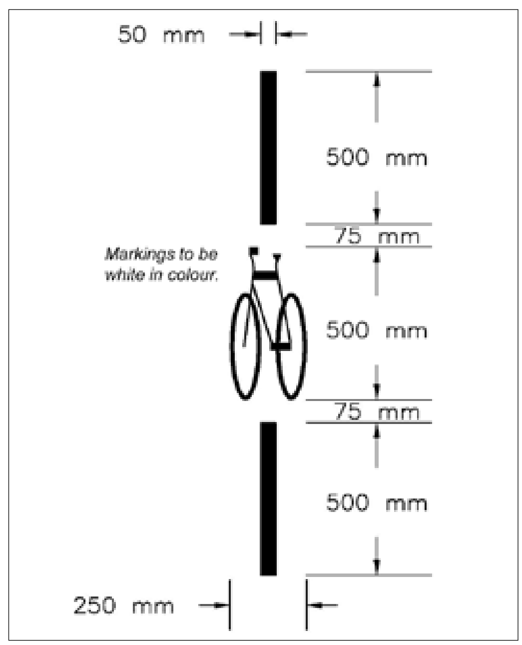


Figure 16 – Bicycle Detector Pavement Marking

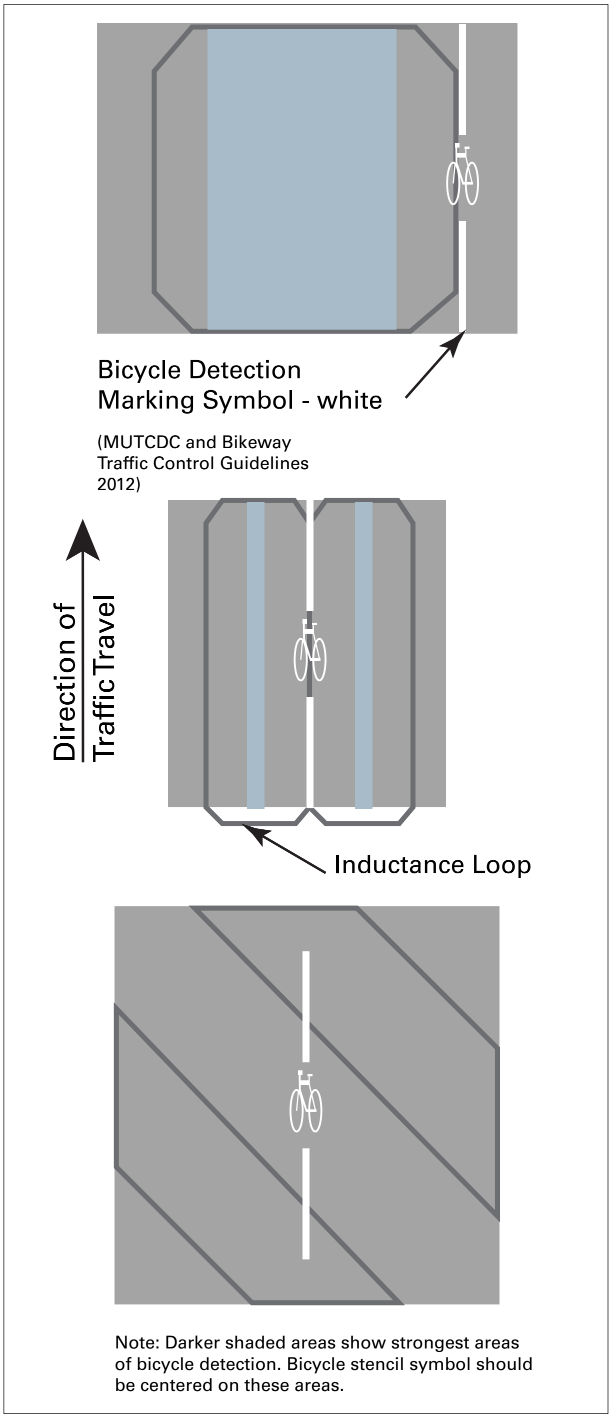


Figure 17 – Signal Detection Areas by Loop Detector Type

Figure 18 – Bicycle Signal Loop Detection Stencil Sign (MUTCDC ID-24)

8. Sample Bicycle Traffic Signal Installations

8.1 Bicycle-Only Phase

Figures 19 and 20 show an intersection in Ottawa with a bicycle-only phase.

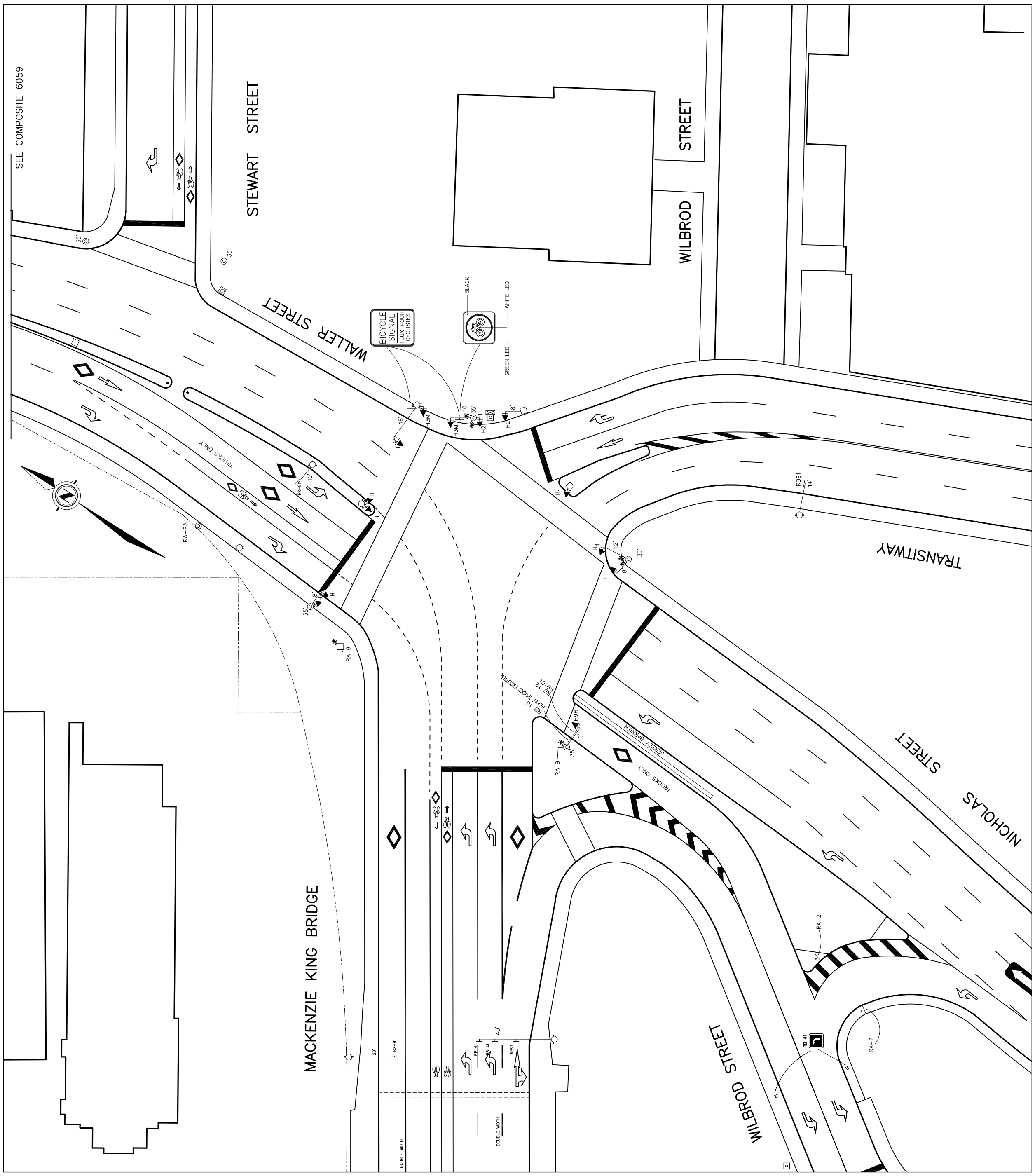


Figure 19 – Bicycle-Only Phase

Figure 20 – Bicycle-Only Phase - Signal Heads and Sign

8.2 Residential Restriction

Figures 21 and 22 show a location in Ottawa where a cyclist is permitted to travel straight ahead through an intersection for which that movement is otherwise prohibited.

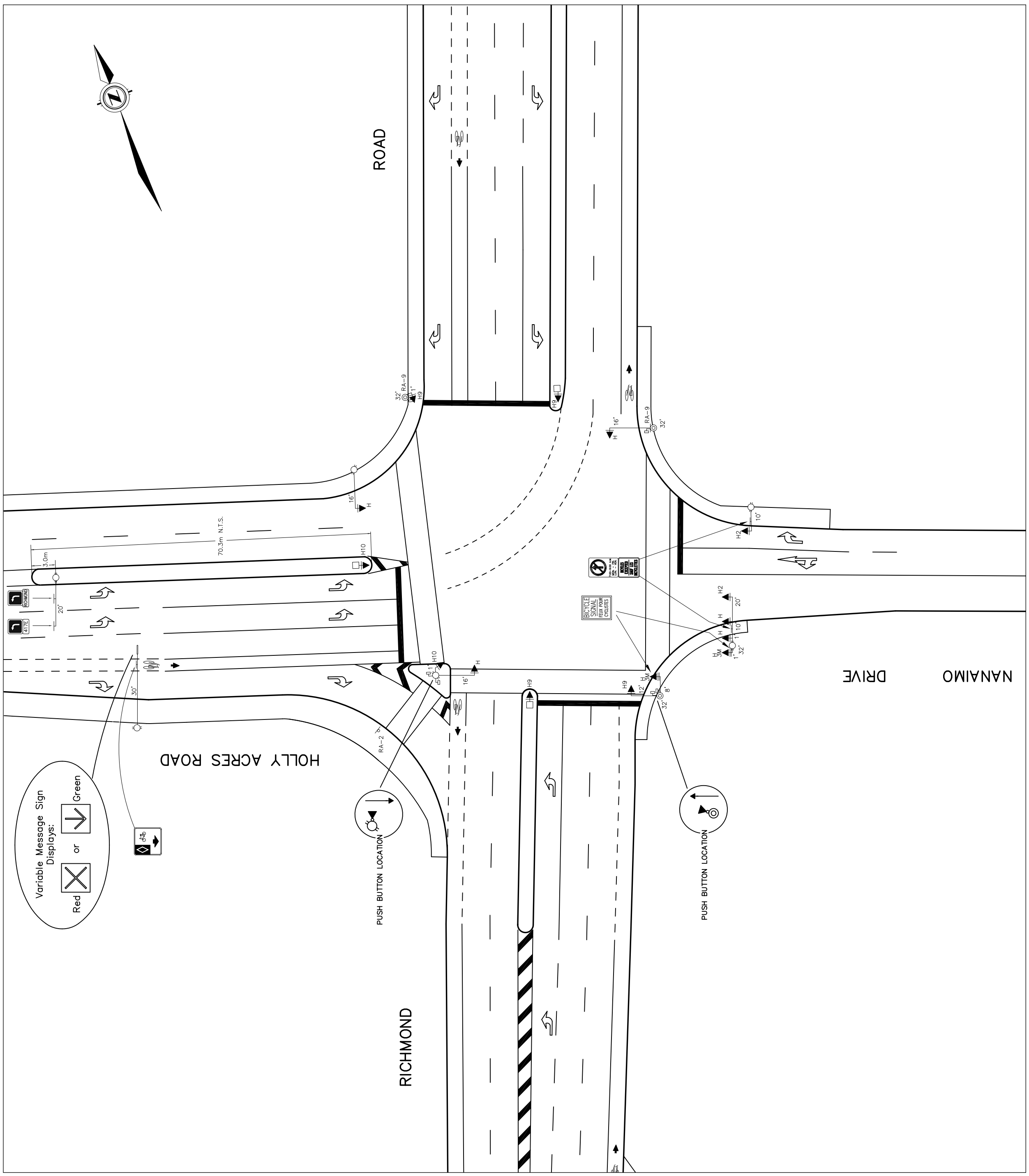


Figure 21 – Residential Restriction

Figure 22 – Residential Restriction - Bicycle Signal Heads and Sign

8.3 Contra-Flow Bicycle Lane

Figures 23 and 24 show signalization for the termination of a contraflow bicycle lane in Ottawa.

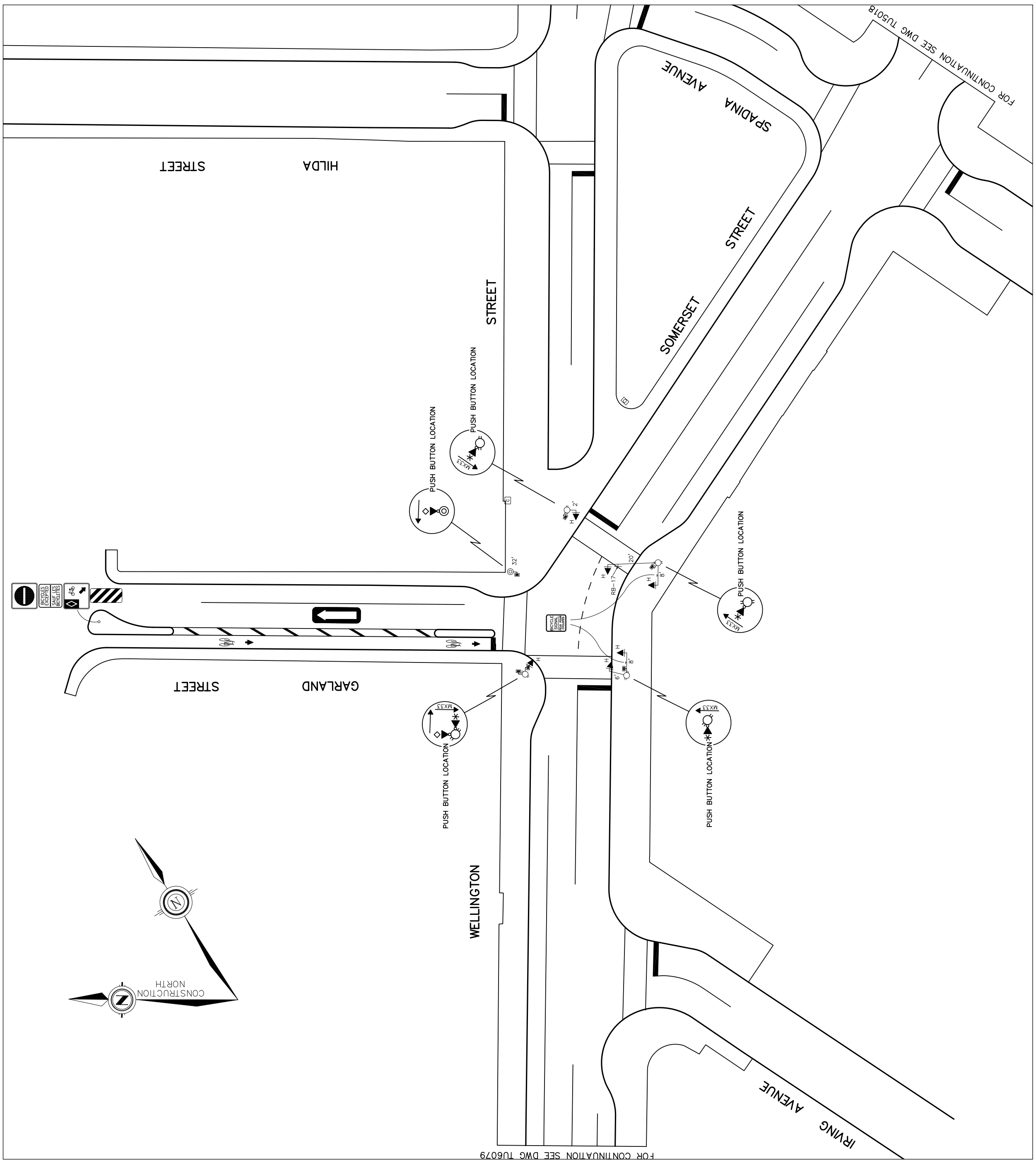


Figure 23 – Contra-Flow Bicycle Lane

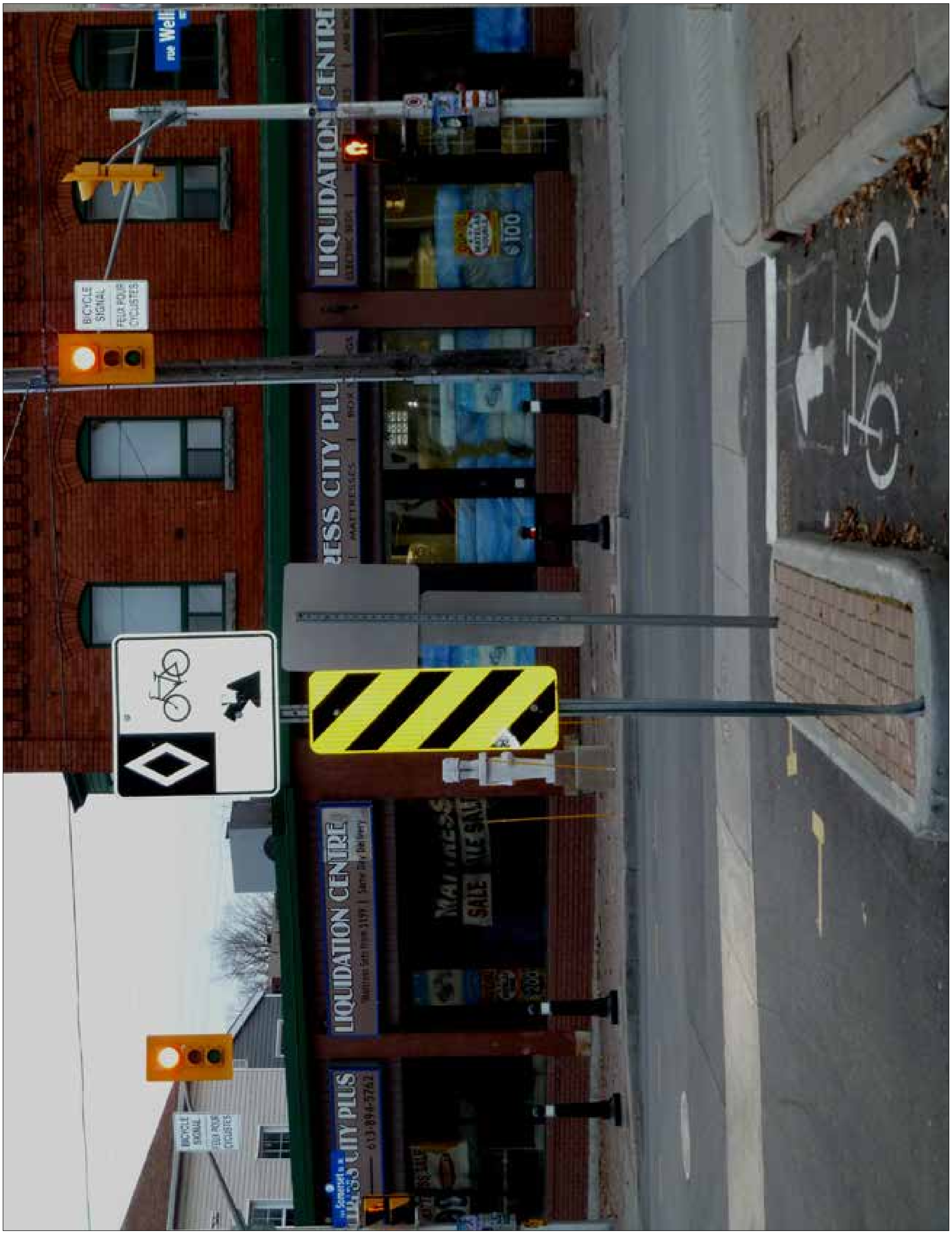


Figure 24 – Contra-Flow Bicycle Lane - Signal Heads and Sign

APPENDIX A
Constants for Use in Minimum Green and Clearance Interval Timing

Constant	Source1	Value	%ile of Population
V	NACTO	14 f/s	15th
W	NACTO	stop line to mid-point of far lane	
V, level	AASHTO (2012)	13-24 km/h	
V, level	California	14.7 f/sec	
V	TAC	20 km/h	
V	CROW	20 km/h	
V, downhill	AASHTO (2012)	32-50 km/h	
V, uphill	AASHTO (2012)	8-19 km/h	
PRT	AASHTO (2012)	1.0 – 2.5 seconds	
PRT	CROW	1.0 second	
Deceleration, dry	AASHTO (2012)	4.8 m/s^2	
Deceleration, wet	AASHTO (2012)	2.4-3.0 m/sec^2	
Deceleration	CROW	1.5 m/s^2	
L	AASHTO (2012)	1.8 m	
a	AASHTO (2012)	0.5 – 1.5 m/s^2	
a	CROW	0.8 – 1.2 m/s^2	
SU	California	6 seconds	
Tmin	TAC	5 – 15 seconds	

In the absence of empirical information, the following suggested values may be considered:

Starting PRT = 1.0 s

V = 20 m/sec

a = 1.0 m/s^2

L = 1.8 m

SU = 6 seconds

W = typically measured from stop bar to far crosswalk line or equivalents if marking is not present

PRT for stopping = 2.5 seconds

d = deceleration rate of 3.0 m/sec^2

APPENDIX B
Bicycle Symbol Signal Head

Figure 25 – Bicycle Symbol Signal

Traffic signal heads with special lenses containing the silhouette outline of a bicycle have been used to provide direction to cyclists in Europe and North America for some time. In Canada, this type of traffic signal, as illustrated in the figure above was originally adopted in the province of Québec and subsequently was added to the MUTCDC in the 2008 revision. The bicycle symbol signal head is being considered for inclusion in the HTA through future legislative changes.

Ontario Traffic Council

www.otc.org