TRAFFIC SIGNAL TIMING GUIDELINES

October 2023

Contents

1.0 Introduction

The City of Vancouver has requested that traffic signal timing guidelines be developed to unify standards, procedures, and specifications for all signal installations and upgrades City-wide. Guidelines for signal installations include pedestrian and bicycle traffic signals, and full traffic signals. This document is intended to provide a framework for preparing a Traffic Signal Record (TSR) and should be supplemented with the Manual of Uniform Traffic Control Devices for Canada (MUTCD).

2.0 Guiding Principles

The recommended guidelines were developed based on the following guiding principles:

- To ensure the safety of all road users;
- To ensure consistency, efficiency, and reliability in traffic signal operation;
- To enhance pedestrian and cyclist accessibility;
- To minimize pedestrian delay; and
- To maximize person throughput (transit).

3.0 Traffic Signal Operations Overview

There are various features of traffic control systems that can promote consistent, safe, and efficient control of traffic signals. This section discusses the key components of the Traffic Signal Record.

Examples of Traffic Signal Records in a horizontal template and an 8 phase template are provided in ***Figure 1*** and ***Figure 2*** respectively. A horizontal template is used when three or fewer phases are present at an intersection. For intersections with more than three phases, an 8 phase template is used.

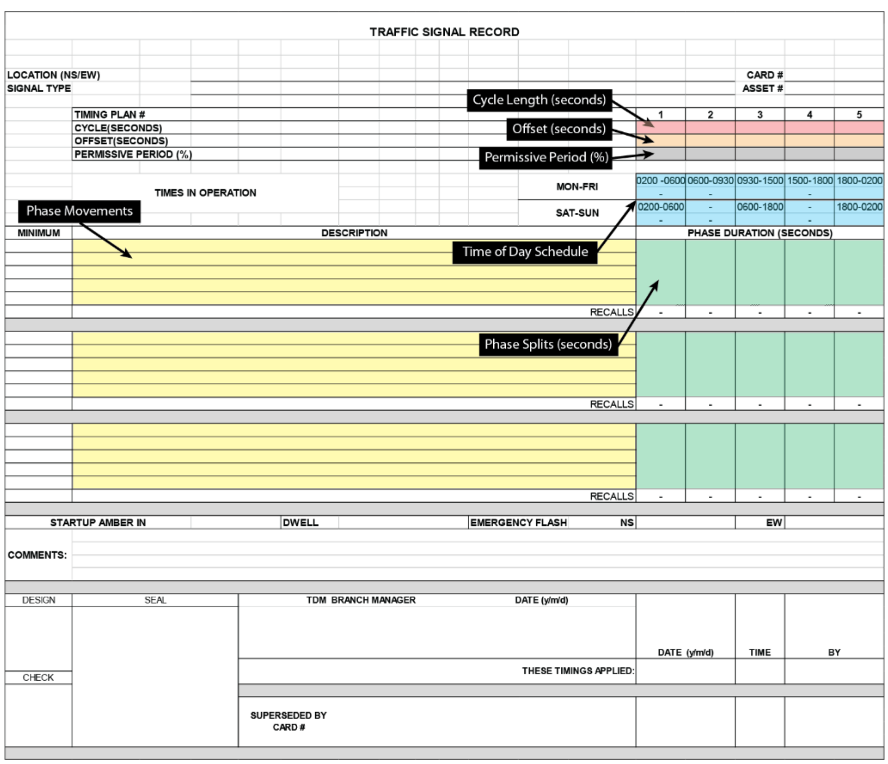
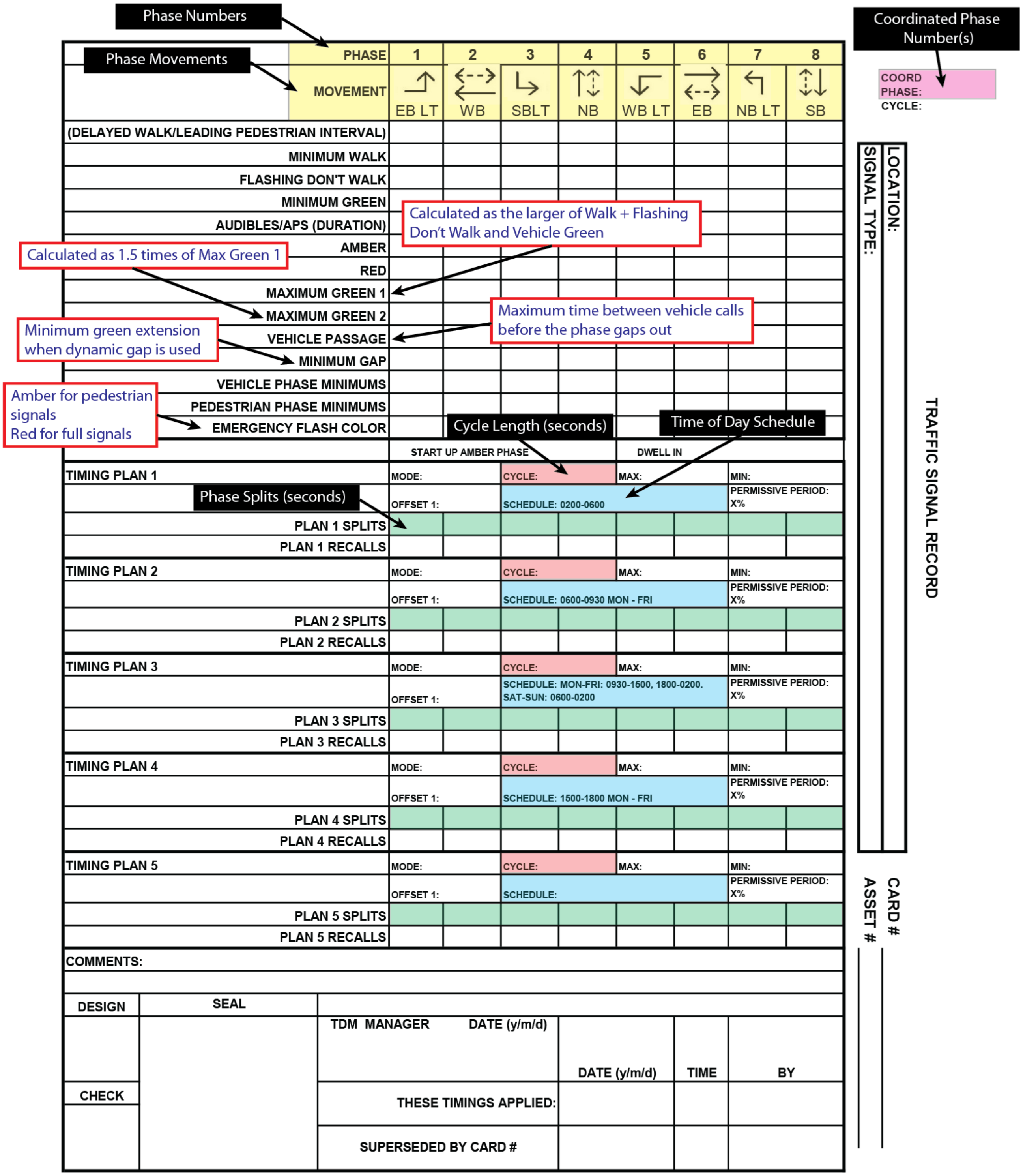


Figure 1: Example of City of Vancouver Horizontal Traffic Signal Record (TSR)



PHASE	1	2	3	4	5	6	7	8
MOVEMENT	EB LT	WB	SBLT	NB	WB LT	EB	NB LT	SB
(DELAYED WALK/LEADING PEDESTRIAN INTERVAL)								
MINIMUM WALK								
FLASHING DON'T WALK								
MINIMUM GREEN								
AUDIBLES/APS (DURATION)								
AMBER								
RED								
MAXIMUM GREEN 1								
MAXIMUM GREEN 2								
VEHICLE PASSAGE								
MINIMUM GAP								
VEHICLE PHASE MINIMUMS								
PEDESTRIAN PHASE MINIMUMS								
EMERGENCY FLASH COLOR								

START UP AMBER PHASE | DWELL IN

TIMING PLAN	MODE:	CYCLE:	MAX:	MIN:
TIMING PLAN 1	OFFSET 1:	SCHEDULE: 0200-0600		PERMISSIVE PERIOD: X%
TIMING PLAN 2	OFFSET 1:	SCHEDULE: 0600-0930 MON - FRI		PERMISSIVE PERIOD: X%
TIMING PLAN 3	OFFSET 1:	SCHEDULE: MON-FRI: 0930-1500, 1800-0200. SAT-SUN: 0600-0200		PERMISSIVE PERIOD: X%
TIMING PLAN 4	OFFSET 1:	SCHEDULE: 1500-1800 MON - FRI		PERMISSIVE PERIOD: X%
TIMING PLAN 5	OFFSET 1:	SCHEDULE:		PERMISSIVE PERIOD: X%

	1	2	3	4	5	6	7	8
PLAN 1 SPLITS								
PLAN 1 RECALLS								
PLAN 2 SPLITS								
PLAN 2 RECALLS								
PLAN 3 SPLITS								
PLAN 3 RECALLS								
PLAN 4 SPLITS								
PLAN 4 RECALLS								
PLAN 5 SPLITS								
PLAN 5 RECALLS								

COMMENTS:

DESIGN	SEAL	TDM MANAGER	DATE (y/m/d)	DATE (y/m/d)	TIME	BY
CHECK		THESE TIMINGS APPLIED:				
		SUPERSEDED BY CARD #				

COORD PHASE:
CYCLE:
LOCATION:
SIGNAL TYPE:
TRAFFIC SIGNAL RECORD
CARD #
ASSET #

Figure 2: Example City of Vancouver 8 Phase Traffic Signal Record (TSR)

The primary objective of a traffic signal is to move people through an intersection safely and efficiently. Achieving this objective requires allocating adequate right-of-way to the various users based on user demand as well as minimum clearances for all modes. Traffic signals control traffic with various timing parameters such as green, amber clearance, and all-red clearance intervals. The proper application, design, installation, operation, and maintenance of traffic signals and the associated timings are critical to the orderly movement of traffic and can improve the safety and traffic handling capacity of an intersection.

3.1 Phasing

The Manual on Uniform Traffic Control Devices (MUTCD) defines a signal phase as the right-of-way (green), amber, and all-red clearance intervals in a signal cycle that are assigned to an independent traffic movement or combination of non-conflicting traffic movements serving different modes (i.e. motorists, pedestrians, cyclists, and transit). Different phases are considered depending on the intersection configuration and site conditions to balance the different needs of road users. Splits are defined as the total time allocated to each individual phase. Signalized movements requiring actuation utilize detectors that identify users (i.e. cyclists, vehicles, and pedestrians) of the intersection. For fixed time signals, detection infrastructure may not be required. The signal phasing regime is operated by pre-programmed sequences. In the City of Vancouver, Novax controllers are most prevalent, but upgrades to new ATC controllers are underway. City of Vancouver engineering staff should be contacted for controller limitations and requirements. These controllers can accommodate eight separate phases in four operational scenarios including NEMA, dual-ring, sequential, and split phasing.

3.2 Cycle Lengths

Signal cycle lengths dictate the maximum amount of time to serve all phases of a traffic signal. The signal cycle lengths have a significant impact on the quality of the urban realm and consequently, the opportunities for people walking, biking, and taking transit to travel safely along a corridor.

Longer signal cycle lengths can potentially increase the vehicular capacity of an intersection as the proportion of lost time used to transition between signal phases is reduced. Delay to serve minor movements can also increase as a result and can discourage walking and could lead to an increase pedestrian non-compliance.

Shorter cycle lengths are ideal for denser urban areas such as the Metro Core as it permits frequent gaps and consistent crossing opportunities, creating a more permeable network. Outside of the Metro Core, longer signal cycle lengths may support directional travel on a corridor.

The City of Vancouver generally maintains consistent cycle lengths between major and minor intersections and aims to minimize cycle lengths wherever possible. The signal cycle length for each intersection in the City is provided in ***Figure 3***. Green coloured intersections have lower cycle lengths (around 65 seconds) while yellow and orange have higher cycles lengths up to 90 seconds and 115 seconds, respectively. As shown, in the Metro Core, the signal cycle lengths are all currently maintained at 65 seconds to support increased network permeability and greater crossing opportunities. Outside of the Metro Core, signal cycle lengths generally vary between 65 and 85 seconds with select intersections at the nexus of two arterials incurring higher signal cycle lengths. Generally, the signal cycle length should not exceed 120 seconds; however, for temporary traffic diversion plans, cycle lengths may be modified above this value.

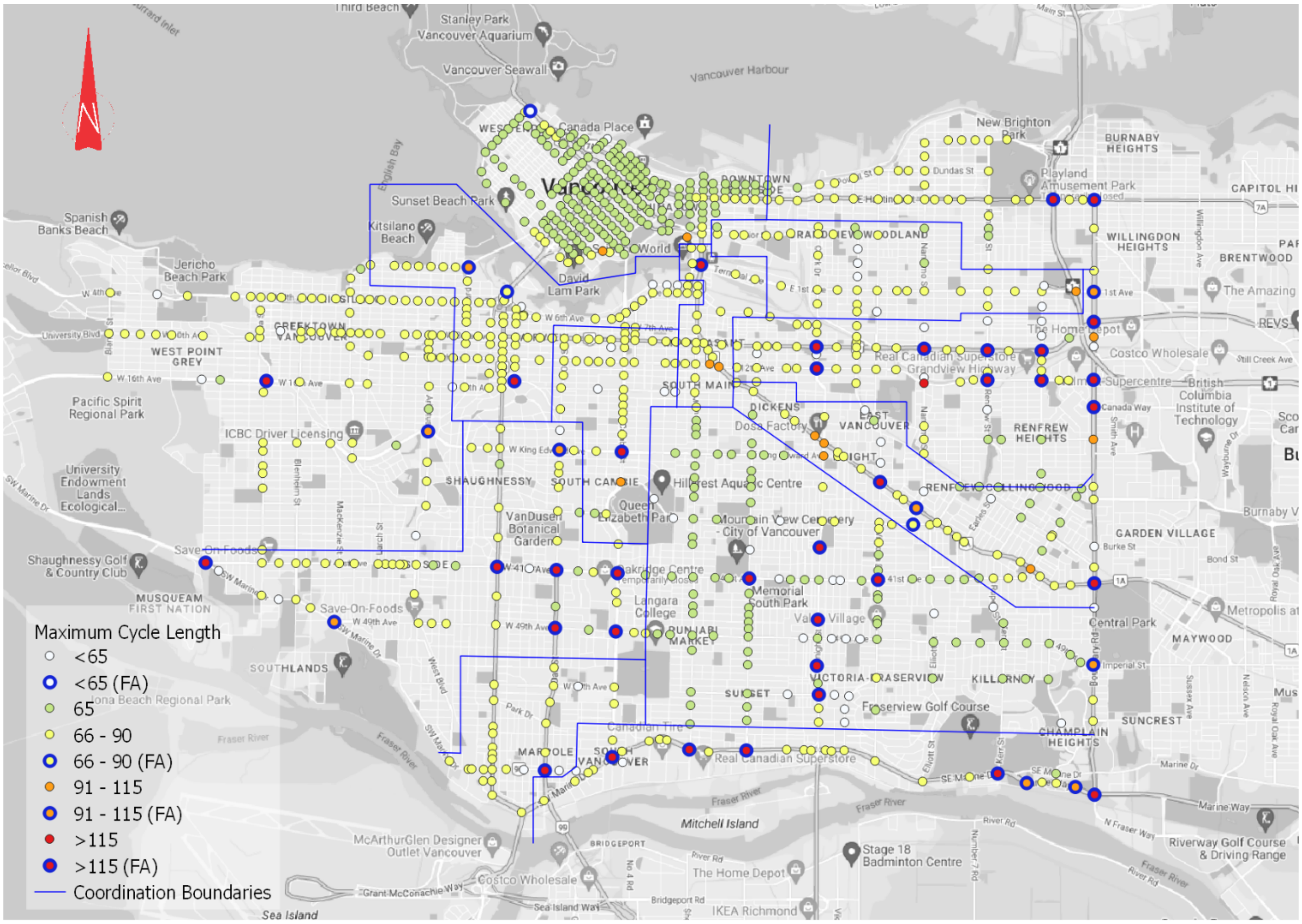


***Figure 3:* Signal Cycle Length Distribution**

3.3 Signal Timing Plans

Traffic conditions can vary depending on the time of day and day of the week. To address these variations, traffic controllers are typically coded with different signal timing plans that are active at different times of day and days of the week to best accommodate traffic conditions. The following periodic plans are implemented at all signalized intersections:

- Morning Peak;
- Afternoon Peak;
- Off-Peak;
- Evening; and
- Overnight.

In some cases, special timing plans may be developed for high volume special events, weekends, and/or emergencies. Plans should accommodate fluctuations in demand over the course of each day, week, and year. Changes in travel demand patterns occur over time and therefore periodic adjustments to signal timings are made to maintain intersection safety and efficiency. Each timing plan may have a distinct cycle length. The cycle length is determined by evaluating and minimizing the delay experienced by all road users, then optimizing the overall duration to provide adequate capacity.

All signal timings must be submitted on a Traffic Signal Record (TSR) which explicitly lays out the various signal timing parameters. An example of a typical 8 phase TSR for the City of Vancouver was previously shown in ***Figure* 2**.

City of Vancouver also presents signal timing information using a horizontal template. The horizontal template is used when the signal has three or fewer phases, or at pedestrian / bicycle signals. An example of a horizontal template is provided in ***Figure 1***.

3.4 Signal Coordination

Depending on the location of the route and time of day, signal coordination design strategies may be developed to optimize traffic flow along arterial routes (i.e. Pacific Boulevard, Georgia Street, etc.). Typically, coordination should balance overall delays and manage safe and reasonable speeds. During peak periods, one direction may be favoured due to a variety of considerations, some including higher volumes, user groups, and travel patterns. Engineering judgement should be used. Guidelines for signal coordination are discussed in **Section 4.6**. Three fundamental signal parameters are necessary for a coordinated system: cycle length, offset, and split. Within each cycle, splits represent a portion of time allocated to a sequence of movements which also typically includes an amber and all-red period. Lastly, offsets define the temporal relationship between coordinated phases at adjacent intersections and are dependent upon a common reference point within the signal cycle. It is through this association that coordinated phases are aligned between intersections allowing for synchronized movements through a network. If a signal is uncoordinated, it is referred as a “free” operation.

3.4.1 Intersection Spacing

The spacing between signalized intersections affects the dispersion of a vehicle platoon as it travels downstream from a signal. To maximize efficiency, the platoon should be relatively intact when it reaches the next signal for successful coordination. According to the Transportation Association of Canada (TAC), the desired distance between two signalized intersections along an arterial route is 400 m with a minimum recommended distance of 200 m. Intersection spacing at or below the 200 m minimum requires approval by City of Vancouver’s Traffic Data Management Group (TDM).

3.4.2 Phasing for Closely Spaced Intersections

Closely spaced intersections are intersections where two minor streets (which include greenways, driveways, and laneways) intersect the major street at an offset, thus forming two intersections. Although 100m minimum spacing is preferred, for intersections with spacing below 100m, signal interconnection should be considered and may be required by TDM. Amber coordination is also recommended.

3.4.3 Cross Jurisdictional Signal Coordination

Cross jurisdictional signal coordination is the collaboration between the City of Vancouver and adjacent jurisdictions to upgrade / improve traffic operations from one jurisdiction to the other. There are two primary boundaries; one to the west with the University Endowment Lands (UEL) that is defined at Blanca Street and the other on the eastern side demarking the division with the City of Burnaby at Boundary Road. Currently, the City of Vancouver controls the intersection signal timings at the interface intersections on both Blanca Street and Boundary Road. Typically, coordination with the adjacent jurisdictions for signal timing is limited to when funding of new infrastructure is required and/or when there is a major upgrade planned.

3.5 Signal Modes and Recalls

At signalized intersections, splits can vary between each cycle due to the settings in the traffic controller. A variety of situations may occur, from skipping a phase to servicing a phase longer than the programmed split. These behaviours are mostly controlled by signal modes and recalls, which will be discussed in this section.

At actuated signals, the splits for a signal phase may extend past the programmed duration due to one of two signal modes. If the relative mode is selected, any unused time will be reallocated to the coordinated phases. If the absolute mode is selected, any unused time will be reallocated to the next phase serviced. Both these modes will maintain the existing cycle length and only adjust the splits.

Recalls are another way to influence the duration of splits and are assigned to each phase at a signalized intersection. Recalls are also used when detection equipment fails. There are four types of recalls: maximum, minimum, none, and pedestrian recall.

By selecting maximum recall, the associated phase will be called for the maximum split even if no vehicles are detected at the approach. After the phase has maxed out, the signal will continue to rest on green unless a call is received for the next phase.

Assigning minimum recall will also call the phase during each cycle. However, the phase will only be shown for the minimum split unless vehicles are detected after the minimum. The phase will be continuously extended by the gap time until no vehicles are detected, or the maximum split is reached. Once the phase has reached the maximum split, the phase will rest on green until a call for the next phase is received.

The third type is called no recall, or “none". If recall is set to none, the associated phase will not be serviced unless a vehicle is detected at the approach, in which the phase will then operate similar to a minimum recall. This means the phase will be skipped if no vehicles are detected. No recall, or “none” is the default recall in the City.

In locations where high pedestrian volumes are prevalent, the use of pedestrian recall can be considered. Pedestrian recall ensures the crosswalk movements are always serviced which consist of the Walk and Flashing Don’t Walk periods. Pedestrian recall is often used in the Metro Core, at intersections with high pedestrian volumes, during construction, or for pedestrian safety reasons.

Phases that are assigned a pedestrian recall will always service the Walk and pedestrian clearance intervals. The Call to Non-Actuated (CNA) setting operates the same as the pedestrian recall but includes additional controller instructions. When using CNA, the phase will run for the programmed split time, operating as a maximum recall for vehicles and the pedestrian interval set to rest on the Walk phase. Before the phase terminates, the controller must also time the pedestrian clearance interval before proceeding to the amber and all-red phase.

3.6 Permissive Period

A permissive period is the amount of time a call to a non-coordinated phase is allowed to be serviced. If a call is received during the permissive period, the associated phase will be serviced. Permissive periods are typically used at pedestrian or semi-actuated signals.

4.0 Recommended Guidelines

The following subsections present the fundamental signal timing parameters and provides recommendations sourced from best practices for the City of Vancouver. Sound traffic engineering judgment should be exercised in applying these guidelines.

4.1 Traffic Signal Types

Traffic signals can be classified into different traffic signal types that cater to their localized environment. They may operate independently of any other traffic signal ("free") or their operation may be related to other traffic signals ("coordinated") forming a traffic control signal system.

Recommended Guideline	• The City currently operates the following types signalized traffic control: • **Full Signals:** • *Signal heads are placed at all approaches to the intersection. This includes unique signalized intersections where one major street movement is never required to stop, even during the minor street phases (ex. E King Edward Avenue and Kingsway).* • **Pedestrian / Bicycle (Ped/Bike) Signals:** • *Signal heads are placed on the major street only. Minor streets are stop controlled. When the minor street pedestrian or cyclist pushbutton is activated, the pedestrian phase is serviced, and the major street movements are shown a red signal. Ped/ Bike signals are also known as half signals.*

Recommended Guideline	• The City currently operates the following types of full traffic signals: • **Fully Actuated (FA):** • *Every movement contains vehicle, cyclists, and/or pedestrian detectors that moderate the length of green time based on the current demand.* • **Semi-Actuated (SA):** • *Maintains the through phase for the major street unless a minor street vehicle detector is actuated or a pedestrian or cyclist push-button is actuated.* • **Fixed Time (FxT):** • *The duration of each phase is fixed throughout a time of day plan alternating between the major street and minor street. Timings are all pre-determined. In some circumstances, an actuated protected / permissive left-turn phase may be provided along with the fixed time major and minor street phase.*

4.2 Traffic Signal Phasing Diagrams

To support the development of Traffic Signal Records, signal phasing can be depicted through phasing diagrams that show the general progression of the signal phasing. The diagrams describe the allowable movements for all users during each phase and indicate whether each turn is protected only, protective / permissive, or permissive, providing the framework for developing a traffic signal timing plan and signalized intersection design. Phasing diagrams are usually paired with colour charts that typically include the phase durations.

Phases progress in a clockwise fashion as indicated by the directionality of the arrows between phases. Phase (ϕ) A shall always be the dwell phase (where applicable) and if no dwell phase is indicated, Phase (ϕ) A shall be the coordinated phase.

Bolded arrows on the outer ring of the phasing diagram represent the full demand path whereby actuation of all phases occurs sequentially in a single signal cycle. Non-bolded arrows between phases indicate the variable demand paths that occur when one or more demand-based phases are skipped. The diagrams can also specify which phases can activate pedestrian and bike specific signals.

For each of the available signal types, sample signal phasing diagrams are presented below in ***Figure 5*** through ***Figure 10***. ***Figure 4*** defines the arrows used and precedes the sample diagrams. In general, protected movements are in bold and permissive movements are non-bold.

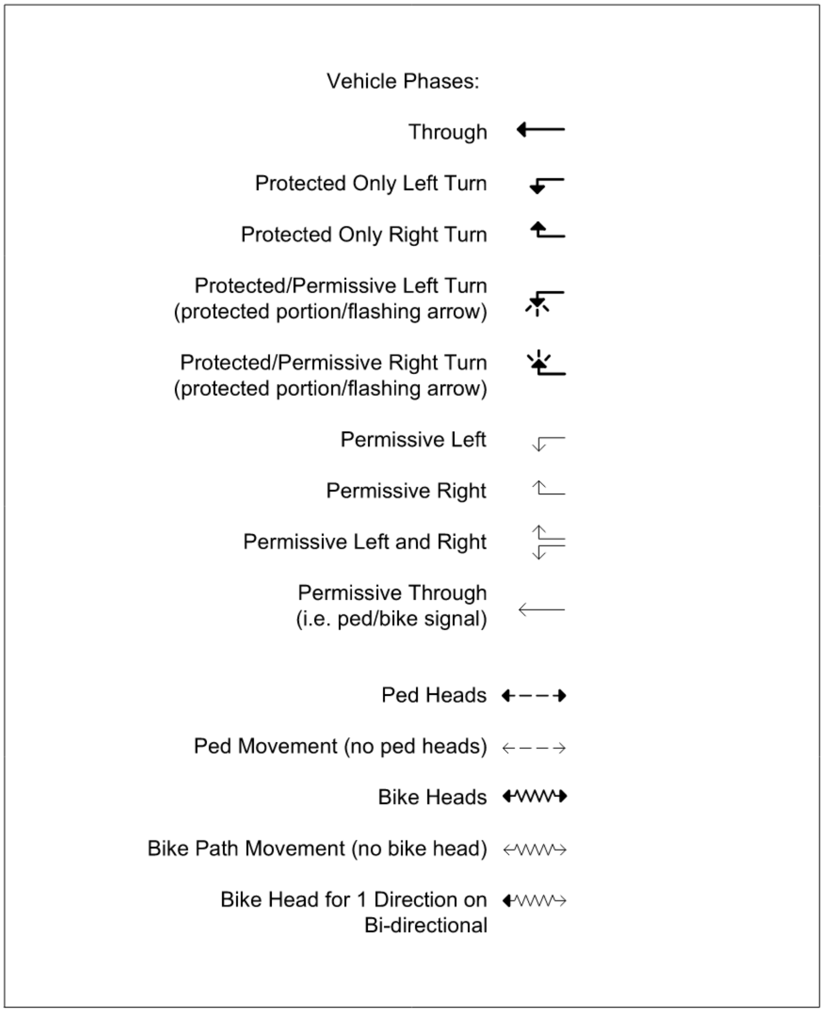


Figure 4: Phasing Diagram Arrow Descriptions

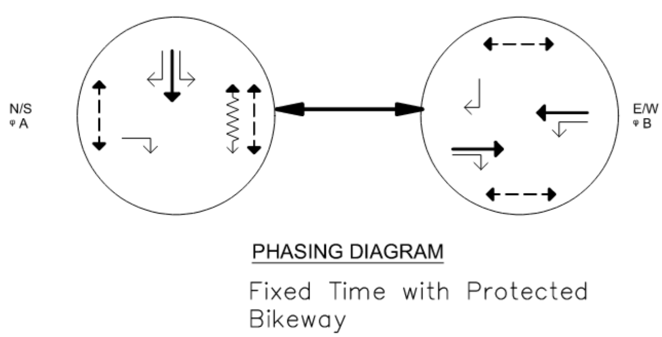


Figure 5: Sample Fixed Time Phasing Diagram

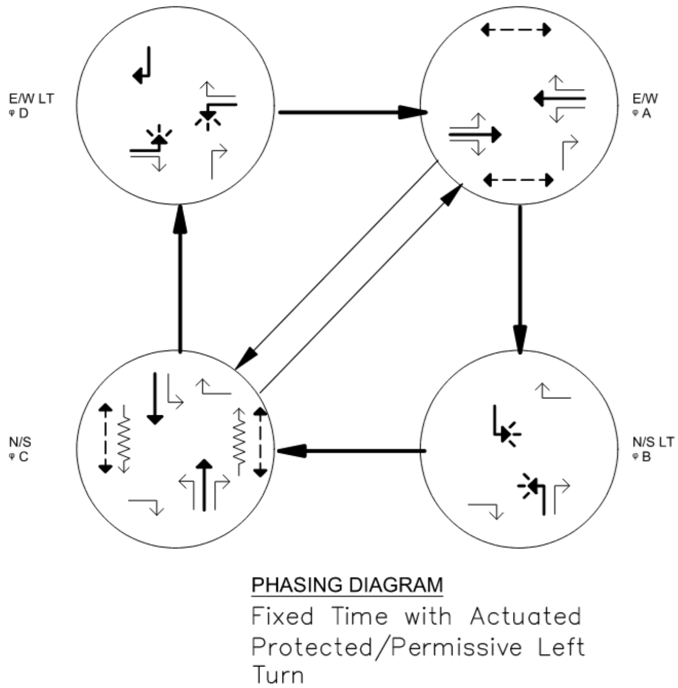


Figure 6: Sample Fixed Time with Actuated Protected/Permissive Left Turn Phasing Diagram

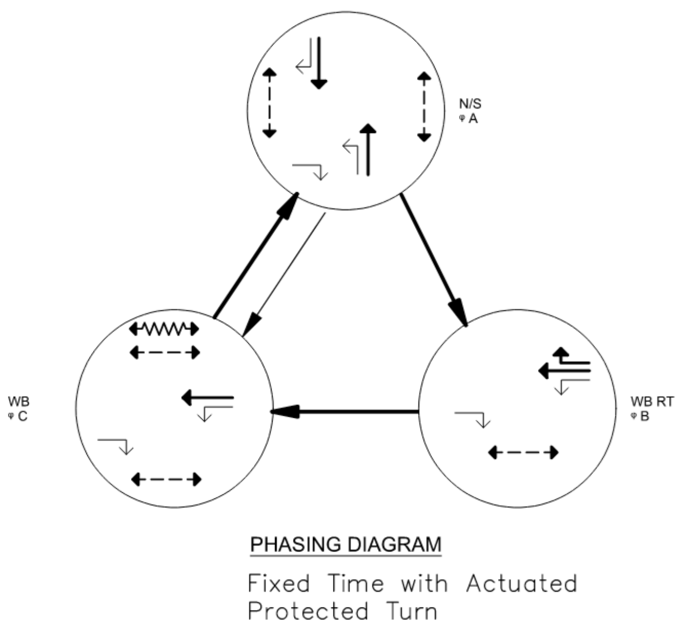


Figure 7: Sample Fixed Time with Actuated Protected Turn Phasing Diagram

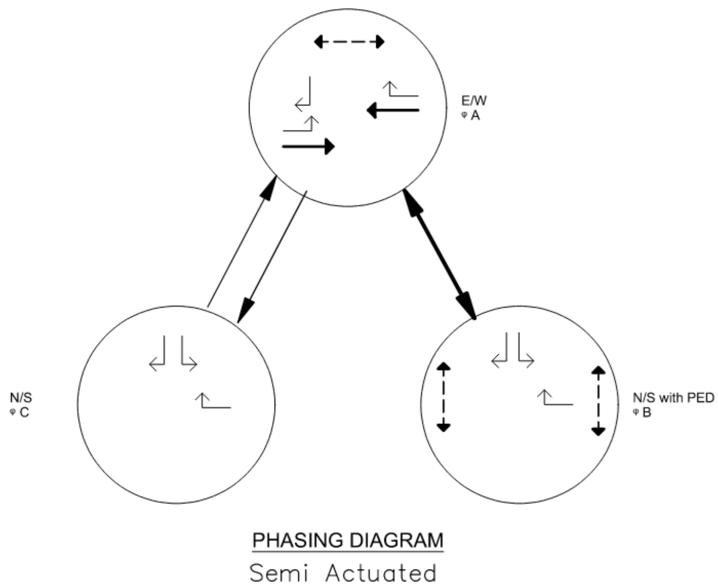


Figure 8: Sample Semi-Actuated Phasing Diagram

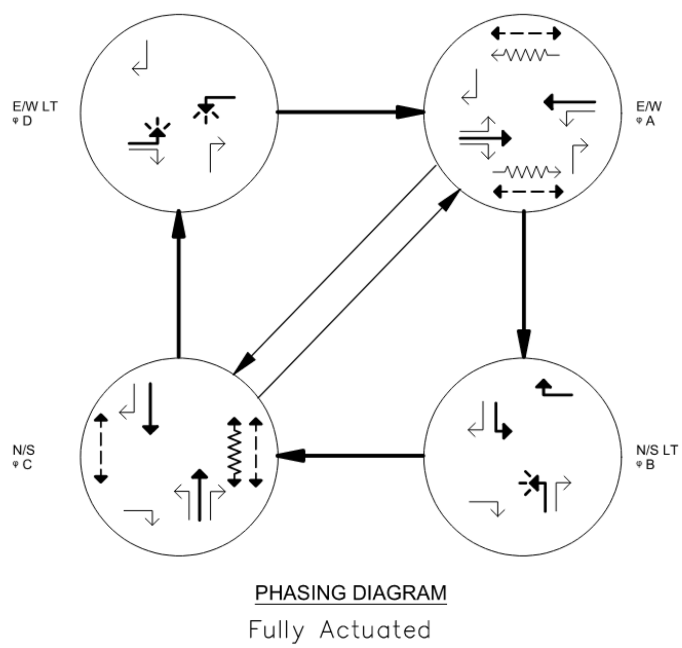


Figure 9: Sample Fully Actuated Phasing Diagram

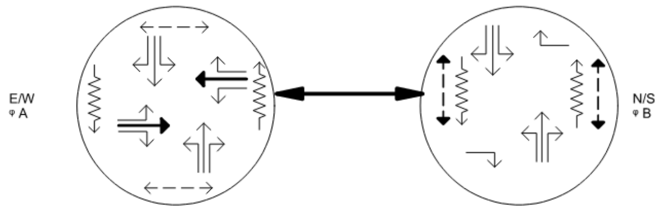


Figure 10: Sample Pedestrian / Bicycle Phasing Diagram

4.3 Interval Timings

Table 1 summarizes the minimum phase intervals at signalized intersections that will be discussed in the following sections.

Table 1: Minimum Phase Intervals

Signal Type	Phase	Min Green	Amber	Red / All-Red	Walk
Full Signal	Protected-Permissive Turn	5.0	4.0	0.0	N/A
	Protected Only Turn	8.0	3.5	1.5	N/A
	Major Street Through (Fixed Time, Fully Actuated, and Semi-Actuated Signal)	16.0	3.5	1.5	7.0*
	Minor Street – Actuated Through (With and Without Cyclists Actuation)	10.0	3.5	1.5	7.0*
	Minor Street – Fixed Time	16.0	3.5	1.5	7.0
Pedestrian / Bicycle	Major Street Through (Pedestrian / Bicycle Signal)	16.0	3.5	2.5	7.0

**At fully actuated intersections (i.e. phases are actuated along both major and minor streets), the minimum and maximum Walk durations are equal to one another.*

4.3.1 Minimum Green Intervals

The minimum vehicle green interval is the minimum period for which a vehicle receives a green indication to proceed. It is established to allow vehicles that are stopped between the detector on the approach and the stop line to get started and move into the intersection. Therefore, timing of this interval depends on the location of the detector and the number of vehicles that can be stored between the detector and the stop line. When the pedestrian phase is actuated, the minimum vehicle green should be equal or greater than the pedestrian crossing minimums, which consists of the minimum Walk and Flashing Don't Walk intervals. A minimum green that is too long may result in wasted time at the intersection; one that is too short may violate driver expectation and compromise safety by potentially reducing the compliance of drivers adhering to signal operations. A short green interval that is insufficient to process the vehicle demand may also result in increased queuing and could lead to vehicles blocking upstream intersections. The minimum green intervals provided in ***Table 1*** also apply to intersections where there are separate cycling facilities. Minimum green intervals can also be manually calculated using the FHWA equation below, although the use of ***Table 1*** values are preferred.

Recommended Guideline

- As per FHWA, one method that can be used to calculate the minimum green for a movement with a turn bay is:

  Minimum Green $= 5 + 2n$

  - Where:
  - "n" is the number of vehicles that can be stored between the stop line and the queue detector in one lane.
  - This is determined by dividing the distance (in feet) between the stop line and the detector by 25 since 25 is the average vehicle length plus stopped-headway in feet.

4.3.2 Amber Clearance Intervals

The purpose of an amber clearance interval is to alert motorists of an impending change in the right-of-way assignment. The duration of the amber interval is typically based upon driver perception-reaction time, plus the distance needed to safely stop or to travel safely through the intersection. Calculations for the amber clearance interval should only be carried out for locations with unique geometry including wide intersections. For intersections with cycling facilities, the same amber clearance interval that is provided below, is applied.

Recommended Guideline

- The typical amber clearance intervals are as follows:
  - ***A) Left-Turn or Right-Turn (Protected Only):***
  - *→ 3.5 seconds*
  - ***B) Left-Turn or Right-Turn (Protected / Permissive):***
  - *→ 4.0 seconds*
  - ***C) Through**:*
  - *→ 3.5 seconds*

  Amber clearance intervals can be adjusted based on community requests, in which engineering judgement should be used.

Recommended Guideline

- For locations with unique geometry (i.e. skewed, offset intersection, significant grade etc.) the amber clerance period should be calculated based on the equations provided in Section 3.3.3. of the Canadian Capacity Guide for Signalized Intersections (2008). The Amber clearance formula is provided below with a description of the variables provided in **Appendix B**. If the calculation indicates the amber time should be longer than 3.5 seconds for a protected only turn, the additional time should be allocated to the all-red phase for safety. All calculated values must be rounded to the nearest 0.5 seconds.

$$\text{Amber Clearance} = \left(t + \frac{V}{(2a + 70.6g)}\right)$$

4.3.3 All-Red Clearance Intervals

The purpose of the all-red clearance interval is to provide additional time as a safety factor for a motorist or cyclists that legally entered the intersection at the very last instant of the amber clearance interval to avoid conflict with traffic releasing from an adjacent opposing intersection approach. Consideration should be given to keeping the all-red clearance phases consistent to facilitate increased driver expectation. For intersections with cycling facilities, the same all-red clearance interval provided below is applied. This all-red interval may be increased by up to one second to account for intersections with high cyclist volumes, high truck volumes, or steep grades. For pedestrian / bicycle signals, 2.5 seconds is used to account for the lack of a solid green interval when the signal head changes from a flashing green to amber.

Recommended Guideline

- The typical All-Red Clearance intervals are as follows:
  - ***A) Protected Only Phase:***
  - *→ 1.5 seconds*
  - ***B) Protected / Permissive Phase:***
  - *→ 0.0 seconds*

  C) Ped / Bike Signal:
  - *→ 2.5 seconds*

Recommended Guideline

- For locations with unique geometry (i.e. skewed, offset intersection, significant grade etc.) the All-Red Clearance interval should be determined in accordance with the vehicle clearance equation shown in *Section 3.3.3* of the *Canadian Capacity Guide for Signalized Intersections* (2008). The All-Red Clearance interval shall be rounded to the nearest 0.5 seconds. The all-red clearance formula is provided below with a description of the variables provided in **Appendix B**.

$$\text{All-Red Clearance} = \left(3.6\left(\frac{W+l}{V}\right)\right)$$

- The all-red interval may be **increased by up to 1.0 second** above the minimum vehicle all-red clearance interval to accommodate concurrent bicycle traffic.

4.4 Pedestrian Phase

The pedestrian phase consists of Walk and Flashing Don't Walk (FDW) intervals. The Walk interval defines the period that allows pedestrians to notice the change in signal indications and begin their movement. This interval may combine both a visual and/or audible indication for pedestrians. The "FDW" interval defines the period that follows the Walk interval whereby sufficient crossing time is given for someone who entered the crosswalk at the end of the Walk interval to reach a designated pedestrian refuge or the other side of the road in a safe manner before conflicting traffic receives a green indication. The pedestrian phase should be less than or equal to the maximum split of the associated vehicular phase.

4.4.1 Pedestrian Walk Times

Recommended Guideline

- A minimum of **7.0 seconds** of initial Walk time shall be provided for pedestrian / bicycle signals. Typically, 7.0 seconds of inital Walk time is provided at all other signals. In areas with higher pedestrian volumes and/or where pedestrian storage is an issue, the Walk duration can extend beyond 7.0 seconds.

4.4.2 Pedestrian Walk Speeds

Pedestrian walking speed is used to determine the minimum safe pedestrian clearance interval for which a pedestrian may cross a signalized intersection. Pedestrian walking speeds vary depending on the demographics of the pedestrians who may use the facility. A reduction in walking speeds may be warranted if there is a significant proportion of older pedestrians or those that require assistive devices.

Recommended Guideline	• In accordance with the *Manual of Uniform Traffic Control Devices for Canada* (MUTCDC) guidelines, crossing time should be determined using a pedestrian walking speed ranging from 0.8 m/s to 1.0 m/s. Depending on the volume of older pedestrians and people with impairments, the range of walk speeds are described below: • *0.8 m/s - walking speed should be used near hospitals and senior centers where pedestrians crossing the signalized intersection use assistive devices for mobility.* • *0.9 m/s - walking speed should be used in cases where a moderate percentage of pedestrians crossing the signalized intersection are older pedestrians (65 years of age or older).* • *1.0 m/s - walking speed should be used to accommodate the general population.* • In special circumstances, an increase up to a walk speed of 1.2 m/s may be explored when maintaining coordination with adjacent signals and/or reducing the overall signal cycle length is deemed critical. Precaution should be taken when increasing walk speeds as any sight line obstructions or significant grade differences may inhibit the ability for conflicting vehicles to identify vulnerable pedestrians. Lastly, steep grades may hinder the desired walking speed of pedestrians, particularly if they are mobility challenged or elderly.
Recommended Guideline	• If additional crossing time is requested, first ensure the Flashing Don't Walk (FDW) is calculated based on a walking speed of 1.0 m/s. If additional time is still requested, below are guidelines for various areas in the City. • ***Schools*** *- increase walk time during school pick up / drop off hours.* • ***Areas with an Older Demographic*** *- increase Flashing Don't Walk (FDW) period.* • ***Greenways*** *- increase Walk time.* • ***Other Areas*** *- increase Walk time assuming Flashing Don't Walk (FDW) is already calculated using a walking speed of 1.0 m/s.*

4.4.3 Pedestrian Countdown Signals

Pedestrian countdown signals accompany the Flashing Don’t Walk (FDW) sign and is used to increase pedestrian safety. The signal indicates the remaining Flashing Don’t Walk (FDW) time and may also correspond to the time before a traffic light turns amber.

Recommended Guideline

In accordance with the *British Columbia Ministry of Transportation (BC MoTI) Section 400 Signal Design*, all new traffic signals shall include countdown pedestrian signals. When countdown signals are installed at signalized intersections, they should be installed on all signalized pedestrian legs. Countdown operations are described below:

- *The numeric display is activated and counts down simultaneously with the Flashing Don't Walk.*
- *After couting down to zero, the numeric display shall be turned off until the next pedestrian clearance interval.*
- *When a signal receives a railway pre-emption call, the pedestrian clearance interval (Flashing Don't Walk) should not be altered. The countdown interval should not be shortened. Instead, the pedestrian Walk time can be altered.*
- *If a pedestrian clearance time cannot be provided (ie. during railway pre-emption calls), pedestrian countdown signals should not be installed.*

4.4.4 Pedestrian Clearance Intervals

The pedestrian clearance interval allows for a pedestrian who begins crossing at the start of the Flashing Don't Walk (FDW) phase to clear the intersection before conflicting traffic streams receive a green indication. To maintain consistency with traffic signals throughout the City, the pedestrian clearance interval shall **include the amber and all-red clearance intervals**. Note that pedestrian signal heads are not present at half signals and pedestrian clearance intervals are based on vehicular amber and all-red intervals. At pedestrian / bicycle signals, pedestrians crossing a minor street only have 6 seconds to clear the intersection, regardless of the crosswalk width.

Depending on the type of signalized control, the Flashing Don't Walk (FDW) interval for two concurrent crosswalks at an intersection may start at different times. This only applies to fully actuated signals. At semi-actuated or fixed time intersections, the two Flashing Don't Walk periods must start in unison.

Recommended Guideline

- Flashing Don't Walk (FDW) interval shall be calculated in accordance with *Section 3.4.1* of *the Canadian Capacity Guide for Signalized Intersections (2008):*

$$FDW\ (sec) = \frac{D}{S} - Y - AR$$

where:

- *D = Curb-to-Curb Crossing Distance at the Middle of the Crosswalk (m)*
- *S = Walk Speed (m/s)*
  Y = Amber Interval (sec)
  AR = All-Red Interval (sec)

The selected Flashing Don't Walk (FDW) interval should be the greater of 7.0 seconds or the calculated value.

4.4.5 Leading Pedestrian Interval

Leading Pedestrian Interval (LPI) is a time period where the Walk interval begins before motorist traffic signals turn green. This is to ensure pedestrians have increased visibility from right turn vehicles and to ensure motorists will yield to pedestrians. The LPI shall provide a "Walk" display for a minimum of 5.0 seconds prior to the vehicle green display for that direction of travel. It may be accompanied with right-turn-on-red prohibitions for right-turn movements coming from an approach parallel to a crosswalk with an LPI.

Leading pedestrian intervals improve the visibility of pedestrians and reinforce their right-of-way over turning vehicles, especially in locations with a history of conflict. Based on the Urban Street Design Guide published by the National Association of City Transportation Officials (NACTO), locations with high pedestrian and turning volumes should also be considered for LPIs. If a bike route exists and conflicts with turning vehicles, a leading bicycle interval shown by a bike display should be considered alongside the LPI. ***Figure 11*** shows the typical progression for a crosswalk with an LPI.

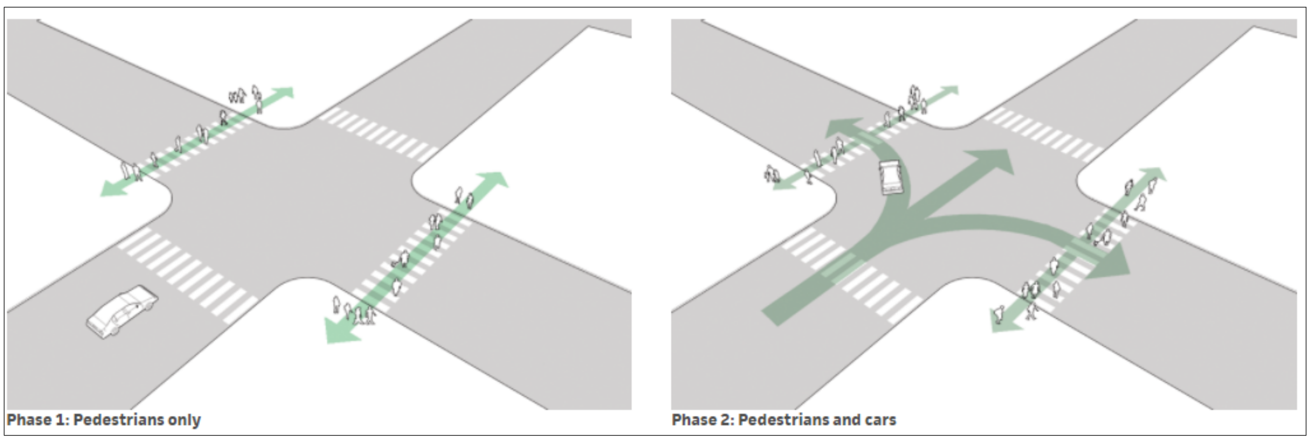


Figure 11: LPI Progression (Source: NACTO Intersection Design Elements, 2020)

4.5 Signal Timing Plans

Traffic conditions vary with time-of-day and day-of-week. As such, traditional signal controllers can be programmed to operate with different timing plans depending on the forecast demand.

Signal timing plans can vary the number of time-of-day plans from one to five; however, it is preferred that there are five timing plans. A graphic depicting the range of time-of-day plans across the City is provided in ***Figure 12*** below. As shown, the Downtown core operates almost exclusively on five time-of-day plans while the rest of the City operates on a mix of four or five time-of-day plans. It should be noted that schedules will be consistently under review and are subject to changes depending on changing traffic operations conditions.

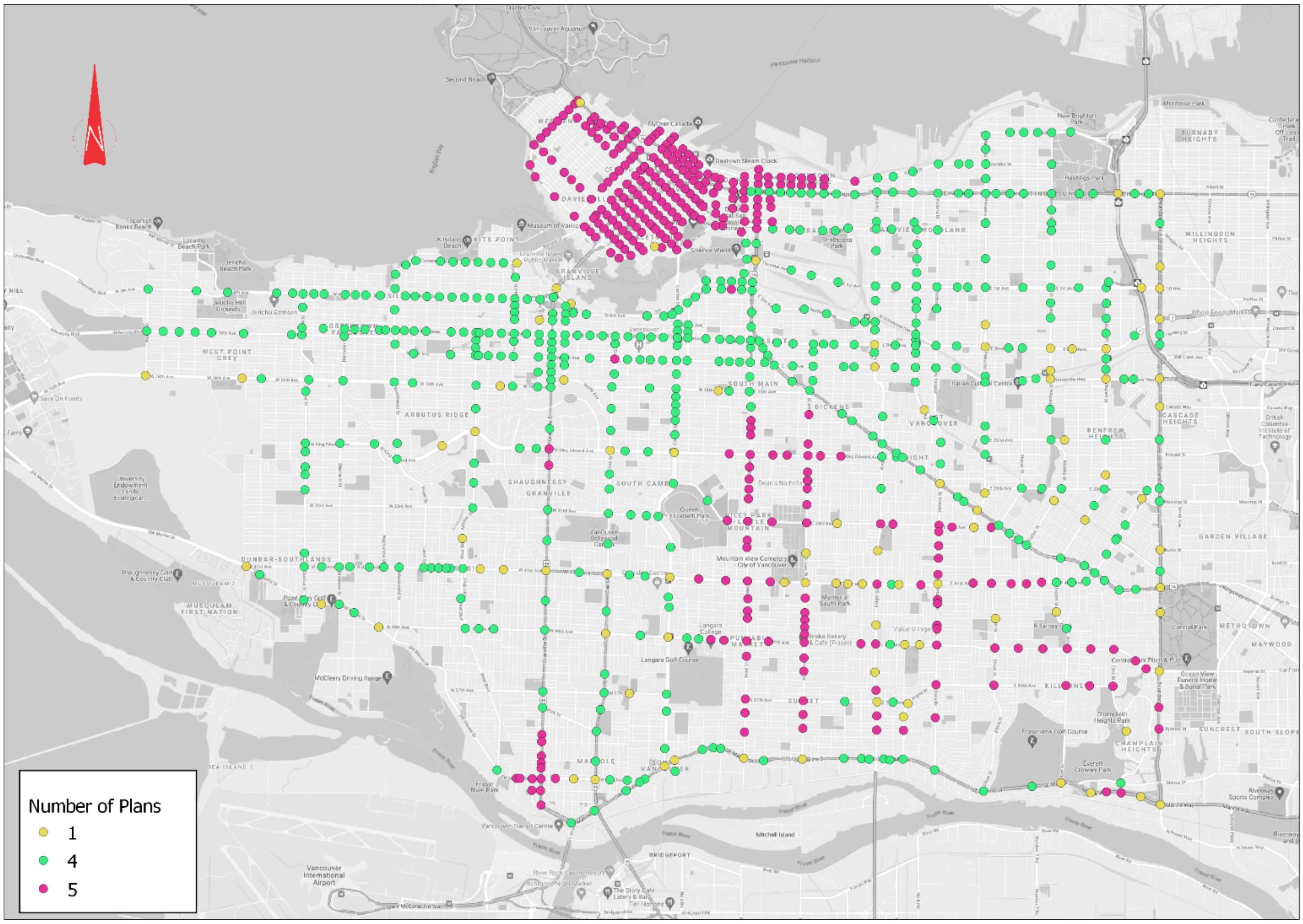


Figure 12: Distribution of Number of Time-of-Day Plans

An alternative to the traditional traffic signal controller is one that is responsive to changing traffic conditions. As part of the City's strategy to upgrade their traffic signal network, the City intends to adopt an intelligent response system.

Intelligent Response has the following key features:

- Continuously "learns" what recurrent congestion looks like in the network, and automatically identifies patterns of non-recurrent congestion relative to this baseline for purposes of responsive plan selection.
- No need to configure and maintain volume-occupancy thresholds and related configuration.
- Is tolerant to failed detectors. In the event of a detector failure, the system can look at the surrounding conditions and continue to make informed decisions.
- Can provide its "reasoning" for all historical plan changes in terms of its natural language expert rules. In the case of any past decision, one can go back to identify the expert rules involved and the corresponding traffic conditions driving these rules.

4.6 Signal Coordination

The intent of coordinated traffic signals is to provide efficient peak flow of traffic along arterial streets to reduce travel times, stops, delay, and fuel consumption with greater effectiveness than uncoordinated operation. Coordination can be achieved by aligning the start of green time for coordinated phases on adjacent traffic signal controllers to create a series of "offsets" between intersections based on distance and the posted speed. A graphic highlighting these zones was provided in ***Figure 3***. Revisions to the coordination zones may occur, and it is recommended to confirm the coordination boundaries with the City of Vancouver prior to modelling.

Recommended Guideline	Coordination shall be considered for signalized intersections whereby the spacing between intersections is less than 400 metres. Other factors that may warrant coordination include situations where a reduction in travel time, number of stops, average delay, and fuel consumption can be achieved with more effectiveness than uncoordinated operation. Coordination should also be considered when travelling from a larger intersection to a smaller intersection.

Recommended Guideline	• For coordination between signalized intersections: • *Minimize cycle length where possible to reduce delay for pedestrians.* • *Balance the pedestrian delay with person throughput.*

Recommended Guideline	• During **Overnight** periods, the following should be considered: • *Reduce cycle lengths relative to peak timing plans to balance overall delays.* • *Intersections may operate uncoordinated (free) from adjacent signals although this may depend on the proximity to adjacent signals.*

4.7 Protected and Permissive Turns

Protected signal phases allow a specified turning movement to be made while all other conflicting pedestrian / cyclist and vehicular traffic is stopped or only the adjacent through movement is allowed. For right turns, protected signal phasing allows vehicles to proceed while simultaneously stopping conflicting pedestrians and cyclists. Protected turning movements reduce the potential for conflicts between streams of traffic but may increase overall intersection cycle lengths, and therefore delay. Where geometry allows for the appropriate right-of-way, separate turning facilities for each movement should be provided when a vehicle movement conflicts with a protected bike lane.

For left turns, protected signal phasing allows vehicles to have right-of-way with no conflicting movements and may be immediately followed by permissive phasing where vehicles can turn when there are available gaps. This protected / permissive turning movement is indicated by a flashing green arrow, followed by an amber arrow. Typically, leading protected permissive left turns are preferred since drivers expect this convention. Lagging left turns are implemented for better signal coordination or where a geometric constraint exists. A geometric constraint exists when the turn paths of two opposing left turns overlaps one another, creating a potential collision. In most cases, this phase will normally be actuated with detectors placed at two locations: Firstly at the stop bar and a second placed upstream a minimum of three passenger car lengths from the stop bar in the turn bay (queue detector). Detector placement can be referenced in the **City of Vancouver Engineering Services Standard Detail Drawings**.

Please note protected only signal phases and overlap signal phases are similar in that the turning movements receiving green indications do not conflict with any other vehicle, pedestrian, or cyclist movement. However, protected only phases pertain to turning movements that can actuate / extend the protected only phase. Such phases will receive a solid green arrow, followed by an amber ball and red ball. Overlapping phases (typically right-turns), are similar but instead run concurrently with a standard "parent" phase. In this case, the overlap phase does not actuate or extend the phase duration but instead derives its operation from its assigned parent phase. An overlapping turning movement will receive a red ball with flashing green arrow indication. In some instances, a turning movement may function as both a protected only and overlapping turning movement when there are conflicting bikes and concurrent protected left-turns.

Typical signal head assemblies for a protected and permissive turns are shown in ***Figure 13*** to ***Figure 15***. Further details can be found in Part B of the **Manual of Uniform Traffic Control Devices for Canada, Fifth Edition.**

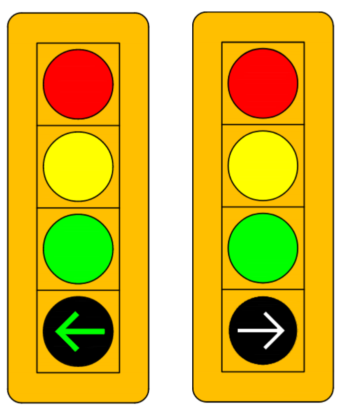


Figure 13: 4-Lens Traffic Signal Head (To be Used with Protected / Permissive Turn Movement)

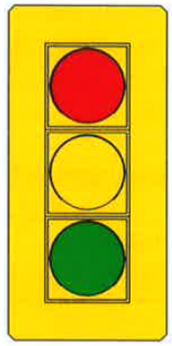


Figure 14: 3-Lens Traffic Signal Head (To be Used with Permissive Only Turn Movement)

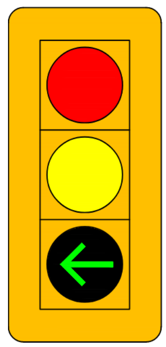


Figure 15: 3-Lens Traffic Signal Head (To be Used with Protected Only Left Turn Movement)

Recommended Guideline	• A protected only turn phase or bike phase with a separated turning facility or physically reinforced turn restriction should be provided in each of the following situations, unless otherwise approved by the City of Vancouver: • *Motor vehicle right-turn against a bi-directional cycle track.* • *Motor vehicle left-turn against a bi-directional cycle track (regardless of motor vehicle one-way or two-way operation).* • Motor vehicle right-turn against a uni-directional cycle track with peak hour vehicle turning volumes approaching 150 vehicles per hour. • Motor vehicle left-turn against an opposing uni-directional cycle track with peak hour vehicle volumes approaching 150 vehicles per hour, or if the left turn is across multiple vehicle lanes. • A protected only turn phase or bike phase with a separated turning facility or physically reinforced turn restriction should be provided if any of the following factors are present, unless otherwise approved by the City of Vancouver. • *Difficulty for drivers or cyclists caused by skewed geometry, reduced visibility, obscured sight-lines, or grade difference.* • *Opposing pedestrian or cyclist volumes are significantly high (i.e. areas in close proximity to transit stations and/or stadia).* • *High volume of turning heavy vehicles.* • *Outside urban areas where traffic speeds are higher and bicycle traffic is less predominant.* • *On or after a steep downhill grade.* • *Where bicycle traffic arrives from an unusual direction, such as turning to or from a bi-drectional bike lane directly into a crossing.* If a fully protected turn phase or bike phase is not provided, a protected-permissive or permissive only (yield-on-turn) design should be considered as per the City of Vancouver document "Guidelines and Design Changes for Yield-on-Turn Signage (2016)". Motor vehicle left and/or right-turns into building accesses/laneways/driveways that conflict with a cycling facility shall be assessed on a case-by-case basis.

4.8 Detection

Vehicle detection systems are installed at intersections to actuate and extend signal phases based on traffic demand. These systems operate with in-roadway sensors or utilize radar-based detection. Programmable inputs are also discussed in the following sections to improve overall intersection efficiency.

4.8.1 Queue Detector Loops for Turns

Queue detector loops are in-roadway sensors typically installed three car lengths upstream of a stop bar loop that can detect the presence of a vehicle and are used to actuate a left-turn phase while balancing the capacity requirements of opposing movements and overall intersection efficiency. Detector placement can be referenced in the **City of Vancouver Engineering Services Standard Detail Drawings**.

The protected portion of a protected/permissive phase is only actuated when there is presence on both the stop bar detector and the queue detector. The queue detector loops can also help to determine the presence of long queues which may adversely impact the safe movement of traffic (i.e., backup of traffic into adjacent through lane) and potentially call alternate timings when long queues are detected.

Radar based detection is also utilized within the City of Vancouver and is the new standard at major intersections along the Major Road Network (MRN) and truck routes. These detection units can actuate phases and operates similarly to in-ground detectors but will not be damaged due to heavy vehicles.

Recommended Guideline

- Queue detectors for left-turns are applicable for intersections where the left-turn operates as a **protected/permissive** phase within a dedicated left-turn-bay with a minimum storage length of 21 m. The actuation of an advanced left-turn actuation from the queue detector loop or stop bar loop shall be based on the discretion of the Traffic Engineer. Refer to the **City of Vancouver Engineering Services Standard Detail Drawings** regarding vehicle loop detector placement. External factors which affect the applicability of queue loop detector installation and actuation include:

  - The left-turn movement serves as the primary vehicle movement for the intersection with low opposing vehicle traffic;
  - Sightline issues affect the lead left-turning vehicle's ability to see opposing traffic and/or conflicting crosswalks/cycle tracks.
  - The storage bay length is insufficient to accommodate the standard loop detector placement (see City of Vancouver Standard Criteria Documents); and
  - The heavy vehicle turning movement volume (including buses and large trucks) is high.

4.8.2 Loop Delays

Detector loops can be set for locking or non-locking memory. When set to locking memory, vehicle presence is remembered until the call has been satisfied by a green signal. Under this setting, right turning vehicles can actuate a green phase even if their maneuver is complete and no additional vehicles are detected. When detectors are set as non-locking, the call is dropped after the vehicle is no longer detected.

Setting the detection memory should be determined through site observations. Within City of Vancouver, use of non-locking memory is typical for most locations. Locking memory is reserved for locations where detection may be missed such as protected only turn phases and right turns that are signed as no right turn on red. A delay can also be programmed with non-locking loops to only change the signal if a vehicle is detected for the predetermined delay time. The delay allows legal turning movements (such as permitted right turns on red) to complete the maneuver without triggering a signal change for the conflicting phase. Loop delays can also prevent premature activation of the Advanced Warning Flashers (AWF) for the conflicting phase.

4.8.3 Dynamic Gap Reduction

Vehicle extension or gap time is the time that the phase will be extended for each actuation. Dynamic gap reduction is the process of reducing gap time from a starting value (passage) to a lesser value (minimum gap) over a specified amount of time. Dynamic gap reduction techniques provide a longer gap at the beginning of the phase when volumes are low and headways are long. The gap would then be reduced to a lesser value as volume increases and headways decrease.

The Dynamic Gap reduction standard applies for any actuated phase and begins after the initial green time (typically 7 seconds). Following the start of the gap extension, the gap extension progression is as follows:

- 3 seconds decreases to 1.5 seconds in 0.2 second increments over a span of 8 seconds.

The progression is shown graphically in ***Figure 16*** below.

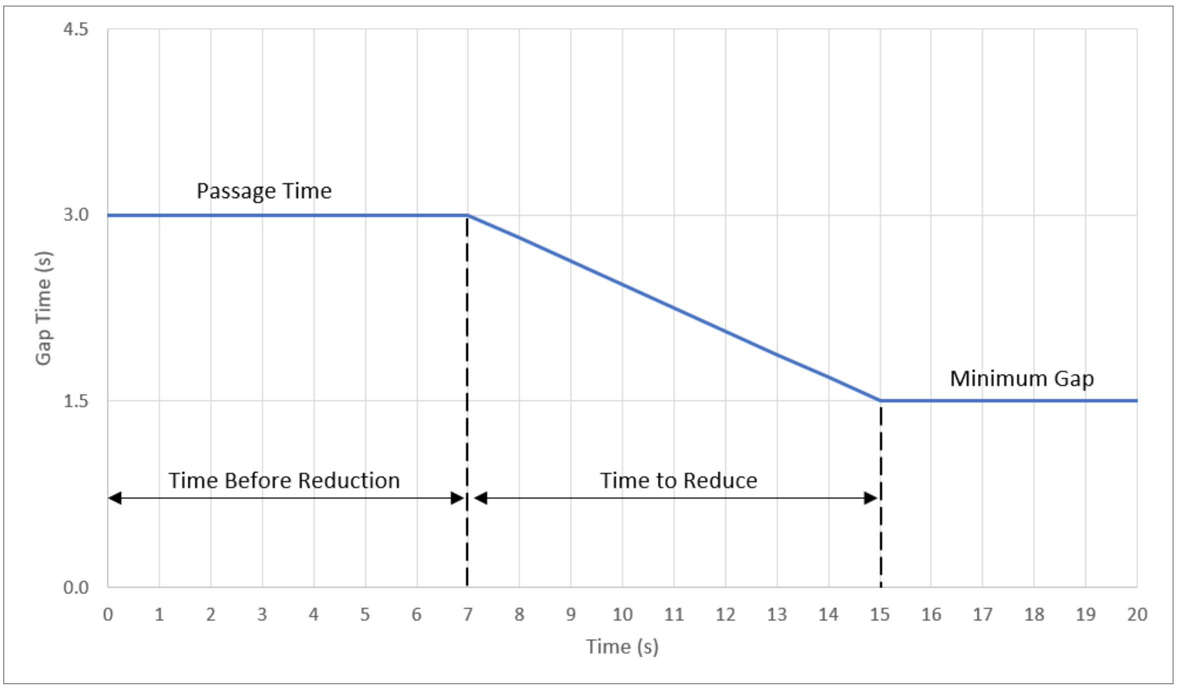


Figure 16: Dynamic Gap Reduction

4.9 Calculation of Control Delay

Control delays are used for analyzing the effects of coordination actuation and congestion. Control delay is the component of delay caused by the traffic control device.

a. Vehicular Delay

Recommended Guideline	• Vehicle control delay shall be calculated based on the Synchro Intersection Capacity software in accordance with the HCM 2000 delay equation (*Webster's Formula*).

b. Cyclist Delay

Recommended Guideline	• Cycling control delay shall be calculated in accordance with cycling LOS equation in *Chapter 18* of the Highway Capacity Manual.

c. Pedestrian Delay

Recommended Guideline	• Pedestrian control delay shall be calculated in accordance with the non-vehicular delay equation in *Section 4.8.2* of the Canadian Capacity Guide for Signalized Intersections (2008).

4.10 Advance Warning Flashers

Advance Warning Flashers (AWF) are used to alert motorists to a downstream signalized intersection. The devices are often employed as a countermeasure where drivers may encounter difficulty in seeing and stopping at a downstream intersection safely.

Recommended Guideline	AWF's shall be considered for intersections where one or more approaches satisfies at least one of the following: • The view of the signals is obstructed due to vertical or horizontal alignment, regardless of the posted speed limit; • There is a grade approaching an intersection sufficient to require more than the normal braking effort; • There is a speed differential where drivers are exposed to a high speed of driving and encounter a signal in a built up community; and • The minimum sight distances (MUTCD Table B3-1) are not met.

AWF's are rectangular in shape and are equipped with two 200-millimeter yellow signal head sections located on the two sides of the sign board. These signals operate in an alternate flashing mode, at a rate of 60 flashes per minute, and with the "on" period equal to the "off" period. Furthermore, AWF signs are retro-reflective and mounted overhead on standard sign poles positioned over the shoulder. The position of the AWF is site specific and must be visible from the travel lane. ***Figure 17*** shows a picture of a typical AWF in City of Vancouver.

Figure 17: City of Vancouver Advance Warning Flasher (AWF)

AWF's are timed to activate on at a pre-determined or calculated number of seconds before the signals at an intersection turns yellow (Refer to *BCMOTI Section 400 - Signal Design* for the formula to calculate the AWF activation point). This time is calculated so that a driver who passes the advance flashers just a fraction of a second before they are activated is afforded time to clear the intersection safely. AWF activation times are rounded to the nearest 0.5 seconds. ***Figure 18*** provides an example of a typical advance warning flasher entry for the City of Vancouver.

MINIMUM	DESCRIPTION
7	EW GREEN & WALK (NX) & EB VIADUCT ADVANCE FLASHER OFF
10	FDW & EB ADVANCE FLASHER ON
3.5	AMBER
1.5	ALL RED

Figure 18: Advance Warning Flasher Example

4.11 Rectangular Rapid-Flashing Beacon

Rectangular Rapid-Flashing Beacons (RRFBs) are used to warn motorists of pedestrians crossing. Typically, they are installed to improve safety at and visibility of uncontrolled, marked crosswalks.

RRFB's are rectangular yellow signs with an LED light source that flashes with high frequency in amber when pedestrian activated. A tone will also play while the lights flash, indicating "AMBER LIGHTS ARE FLASHING. CROSS STREET WITH CAUTION. VEHICLES MAY NOT STOP." The duration of the flashing will be 1 second for every meter of crossing length plus the standard amber vehicle clearance of 3.5 seconds, plus a pedestrian reaction time of 3 seconds. For example, an 8.5-meter crossing will have a flashing duration of 8.5 + 3.5 + 3 = 15 seconds. There is no delay in activation between pedestrian calls, and the duration resets on each call. A sample installation of an RRFB within the City is provided in ***Figure 19*** below, followed by a sample RRFB Traffic Signal Record in ***Figure 20***.

Figure 19: Application of RRFB on Commercial Drive

TRAFFIC SIGNAL RECORD

LOCATION (NS/EW)	ARBUTUS ST / W 57TH AV		
SIGNAL TYPE	RECTANGULAR RAPID FLASHING BEACON	**ELECTRICAL #**	RRFB-0060
CROSSING DISTANCE (M)	12.4	**ASSET #**	1288783

TIMES IN OPERATION	**MON-SUN**	24 HR

DESCRIPTION	**PHASE DURATION (s)**
EW FLASHING AMBER & TONE ON (ONLY ON PED CALL)	19

COMMENTS:	- 12.4 (CROSSING LENGTH/SPEED @ 1M/S) + 3.5 (STANDARD AMBER VEHICLE CLEARANCE INTERVAL) + 3 (PEDESTRIAN REACTION TIME) - NO DELAY IN ACTIVATION BETWEEN PED CALLS - PHASE DURATION RESETS UPON PED CALL - TONE: "AMBER LIGHTS ARE FLASHING. CROSS STREET WITH CAUTION. VEHICLES MAY NOT STOP."

DESIGN	SEAL	TDM BRANCH MANAGER :		DATE:	TIME:	BY:
		THESE TIMINGS APPLIED:				
CHECK		**SUPERSEDED BY CARD #**				

Figure 20: RRFB Traffic Signal Record at Arbutus Street & W 57th Avenue

4.12 Bicycle Signals

Exclusive bicycle signal heads are installed in areas where cyclist safety can be improved. Bicycle-specific phases with exclusive bicycle signal heads are generally installed at locations with exclusive bicycle right-of-way. ***Figure* 21** shows a sample at the intersection of West Georgia Street and Richards Street. Two types of bicycle signals can be implemented at intersections where bicycle traffic conflict with heavy vehicular traffic. They can be of Bicycle Leading Only Phase and Bicycle Only Phase. The minimum green intervals for exclusive bicycle signals are the same as for other vehicular signals. Please refer to ***Table 1***.

- Minor Street Through Phases – Minimum of 10.0 seconds
- Major Street Through Phases – Minimum of 16.0 seconds

Figure 21: Application of Bike Signal at West Georgia Street and Richards Street

4.13 Accessible Pedestrian Signals

Accessible Pedestrian Signals (APS) are used to assist visually and/or hearing-impaired pedestrians by providing the cues necessary to cross the street safely. APS are devices that use audible tones and vibrotactile feedback to guide people who are blind or have low vision as to when they can cross at a signalized intersection. The audio cues are a "cuckoo" for the north/south directions, and a "peep" for the east/west directions. Following the City of Toronto Accessibility Design Guidelines (2004), APS should advise pedestrians with visual and/or hearing impairments through audible and vibro-tactile indications of the following:

- That the intersection is equipped with special signalized features for people who are visually and/or hearing impaired
- Both audible and vibro-tactile indication of where pushbuttons may be found and acknowledgement that the button has been pushed
- Direction for which each of the pushbuttons activates the APS feature
- When to start crossing the street

Within the City of Vancouver, audio cues can sound for the entire Walk time or may terminate early. For audio cues lasting the duration of the Walk time, the typical description in the Traffic Signal Record is shown in ***Figure* 22**. Audio cues that terminate before the end of the Walk time are programmed to play for a set duration and are specified in the Traffic Signal Record as shown in ***Figure 23***. To determine if APS can be programmed at a specific crossing, please contact City of Vancouver's signal shop.

9	NS WALK & CUCKOO TONE ON
14	FDW & TONE OFF
5	DW

Figure 22: Sample Traffic Signal Record – Audio Cue for Entire Walk Period

7	EW WALK & 7 SEC PEEP TONE ON
14	FDW
5	DW

Figure 23: Sample Traffic Signal Record – 7 Second Audio Cue

The City of Vancouver developed the requirements for accessible pedestrian signals in consultation with the Canadian National Institute for the Blind (CNIB) and Access for Sight-Impaired Consumers (ASIC). ***Figure 24*** shows a sample APS at the intersection of Hornby Street / Robson Street.

Figure 24: Application of APS at Hornby Street / Robson Street

4.14 Synchro Guidelines

The City of Vancouver has developed their own guidelines for using Synchro, titled "Guidelines for Using Synchro Version 10, Revision 1.4, June 2022". The document can be found on the City of Vancouver's website by following the link, https://vancouver.ca/files/cov/synchro-modelling-guidelines.pdf. Reference should be made to the document for additional information related to coding and assessing intersection operations using Synchro.

4.15 Signal Timing due to Construction

Construction that impacts signalized intersection operations should be reviewed using Synchro. Adjustments to existing signal timings may be required to minimize delays and maximize person throughput. The use of recall when traffic loops are not in service due to construction should be considered. Also, reallocating green time to phases or movements that are capacity constrained should also be considered.

4.16 Future Traffic Signal Timing Optimization

Forecast demand and travel patterns are subject to change, particularly after protracted construction periods. Evaluation of the traffic signal control plans should be made to optimize the timing for future volumes.

Recommended Guideline	• It is recommended that the City conduct a series of post-construction turning movement counts within the study area to provide evidence for further optimization of the traffic signal controllers.

5.0 Conclusion

To promote consistent, safe, and efficient control of traffic signals for all road users (i.e. pedestrians, cyclists, transit, and vehicles), this document brings forward a series of recommended signal design guidelines that seeks to unify the development of intersection signal timings throughout the city. Sound traffic engineering judgment should be exercised in applying these guidelines and all traffic signal operations should be reviewed by a Professional Traffic Engineer.

6.0 Upcoming Additions

Future versions of this Traffic Signal Timing Guideline are anticipated to include the following additions:

- Signal and advance left turn warrants;
- Typical controller parameters for each signal type;
- Pedestrian scramble considerations and implementation;
- Pedestrian holds;
- Transit priority guidance;
- Pre-emption (with a potential railway subsection);
- Portable temporary traffic signals; and
- Colour charts

7.0 References

1. British Columbia Ministry of Transportation (BC MoTI), *Section 400 Signal Design, December* 2003
2. Canadian Institute of Transportation Engineers (CITE), *Canadian Capacity Guide for Signalized Intersections*, 3rd Edition, February 2008.
3. City of Toronto, *Traffic Signal Operations Policies and Strategies*, May 7, 2015.
4. City of Vancouver, *Traffic Signal Design Guidelines*, December 2016.
5. City of Vancouver, *Traffic Signal Supplemental Specifications*, September 3, 2016.
6. City of Vancouver, Guidelines and Design Changes for Yield-on-Turn Signage, 2017.
7. National Association of City Transportation Officials (NACTO), *Urban Street Design Guide*, September 2013.
8. Ontario Ministry of Transportation, Ontario Traffic Manual (OTM) Book 12: Traffic Signals, March 2012.
9. Ontario Ministry of Transportation, OTC Bike Traffic Signals, January 2015.
10. Transportation Association of Canada (TAC), *Manual on Uniform Traffic Control Devices*, 2009.
11. Transportation Association of Canada (TAC), *Manual on Uniform Traffic Control Devices*, 2014
12. Transportation Association of Canada (TAC)*, Pedestrian Walking Speed for Traffic Operations and Safety in Canada,* June 3, 2013
13. Transportation Research Board (TRB), *Highway Capacity Manual 2010*, March 2011.

Prepared By

Name: **Matthew Chan, P.Eng.**

Title: **Senior Transportation Engineer**
Date: **October 23, 2023**

Appendix A – Bicycle Clearance Phase Input Parameters

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

***Source**: OTC Bicycle Traffic Signals Guide (2012)*

Appendix B – Vehicle Clearance Equation Parameters

clearance = y+r = amber + all-red
= [t+V/(2a±70.6g)]+[3.6(W+l)/V]

Where:

y = amber interval clearance(s)

r = all-red interval clearance (s)

t = perception and reaction time (1 second minimum)

V = approach posted speed (km/h)

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

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

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

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

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

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

Source: Canadian Capacity Guide for Signalized Intersections (2008) – Section 3.3.3

Glossary

Absolute Mode	A setting in the traffic signal where any unused time will be reallocated to the next phase serviced within the current barrier. If the next phase serviced is in a separate barrier, any unused time remains on the current phase. This is less common than the relative mode and is typically used with actuated left turns at fixed time signals.
Accessible Pedestrian Signals (APS)	Devices that use audible tones and vibrotactile feedback to guide visually and/or hearing impaired pedestrians to safely cross at a signalized intersection.
Audibles	Audio cues played from a speaker placed above the pedestrian signal head to indicate when pedestrians can use the crosswalk. The audio cues are a “cuckoo” for the north/south directions, and a “peep” for the east/west directions.
Advance Warning Flashers (AWF)	Devices equipped with two 200-millimeter yellow signal head sections located on the two sides of the sign board. The devices alert motorists to a downstream signalized intersection.
All-Red Clearance Interval	The duration when red indicators are displayed at all intersection signals. This interval provides additional time as a safety factor for a motorist or cyclists that legally entered the intersection at the very last instant of the amber clearance interval to avoid conflict with traffic releasing from an adjacent opposing intersection approach.
Amber Clearance Interval	The duration when amber indicators are displayed alerting motorists of an impending change in the right-of-way assignment. The duration of the amber interval is typically based upon driver perception-reaction time, plus the distance needed to safely stop or to travel safely through the intersection.
Call to Non-Actuated (CNA)	Traffic signal operation where the Walk and pedestrian clearance interval will always be serviced. Once the phase has maxed out, the phase will then rest at the end of the Walk period. Before the phase terminates, the controller must also time the pedestrian clearance interval before proceeding to the amber and all-red phase.
Control Delay	The component of delay caused by the traffic control device.

Coordinated Signal	Signal operation which is related to other traffic signals to provide efficient peak flow of traffic along arterial streets to reduce travel times, stops, delay, and fuel consumption. Coordination can be achieved by aligning the start of green time for coordinated phases on adjacent traffic signal controllers to create a series of "offsets" between intersections based on distance and design speed.
Dynamic Gap Reduction	The process of reducing gap time by following vehicle headways from a starting value (passage) to a lesser value (minimum gap) over a specified amount of time.
Fixed Time (FxT) Signals	An intersection operation where the duration of each phase is predetermined and fixed throughout a time-of-day plan alternating between the major street and minor street.
Flashing Don't Walk (FDW)	The FDW interval defines the period that follows the Walk interval whereby sufficient crossing time is given for someone who entered the crosswalk at the end of the Walk interval to reach a designated pedestrian refuge or the other side of the road in a safe manner before conflicting traffic receives a green indication.
Full Signals	Signal heads that are placed at all approaches to the intersection.
Fully Actuated (FA) Signals	At an intersection, every movement contains vehicle, cyclists, and/or pedestrian detectors that moderate the length of green time based on the current demand.
Gap Time or Vehicle Extension	The time that the phase will be extended for each actuation.
Half Signals	Signal heads are placed on the major street only. Minor streets are stop controlled. When the minor street pedestrian or cyclist pushbutton is activated, the pedestrian phase is serviced, and the major street movements are shown a red signal.
Leading Pedestrian Interval (LPI)	The period where the Walk interval begins before motorist traffic signals turn green. This is to ensure pedestrians have increased visibility from right turn vehicles and to ensure motorists will yield to pedestrians.
Locking Memory	A setting in loop detectors where vehicle presence is remembered by the detector until the call has been satisfied by a green signal.
Lost-Time	Time that is not usable by vehicles during the signal phase transitions.

Maximum Recall	A recall mode where the phase will be serviced for the maximum split even if no vehicles are detected at the approach. After the phase has maxed out, the signal will continue to rest on green unless a call is received for the next phase. Detectors are not required when using maximum recall.
Minimum Vehicle Green Interval	The minimum period for which a vehicle receives a green indication to proceed. It is established to allow vehicles that are stopped between the detector on the approach and the stop line to get started and move into the intersection.
Minimum Recall	A recall mode where the phase will be serviced for the minimum split during each cycle. If vehicles are detected after the minimum, the phase will be continuously extended by the gap time until no vehicles are detected, or the maximum split is reached. Once the phase has reached the maximum split, the phase will rest on green until a call for the next phase is received.
Non-Locking Memory	A setting in loop detectors where vehicle presence is dropped after the vehicle is no longer detected.
Offsets	The temporal relationship between coordinated phases at adjacent intersections which are dependent upon a common reference point within the signal cycle.
Overlap Signal Phases	Turning movements that receive green indications and do not conflict with any other vehicle, pedestrian, or cyclist movement. However, the overlap phase does not actuate or extend the phase duration but instead derives its operation from its assigned parent phase.
Pedestrian / Bicycle (Ped/Bike) Signals	See “Half Signals”.
Pedestrian Phase	This phase consists of Walk and Flashing Don’t Walk (FDW) intervals. The pedestrian phase should be less than or equal to the maximum split of the associated vehicular phase.
Pedestrian Recall	A recall mode where the crosswalk movements are always serviced which consist of the Walk and Flashing Don’t Walk periods.
Permissive Period	The amount of time a call to a non-coordinated phase is allowed to be serviced. The duration is typically 50% or 100% of the cycle length.
Permissive Signal Phases	The phase where vehicles can turn when there are available gaps.

Protected Signal Phases	The phase where a specified turning movement is made while all other conflicting pedestrian / cyclist and vehicular traffic is stopped or only the adjacent through movement is allowed.
Queue Detector Loops	In-roadway sensors typically installed three car lengths upstream of a stop bar loop that can detect the presence of a vehicle. They are used to actuate and extend a left-turn phase while balancing the capacity requirements of opposing movements and overall intersection efficiency.
Rectangular Rapid-Flashing Beacons (RRFBs)	Devices with rectangular yellow signs and an LED light source that flashes with high frequency in amber when pedestrian activated. The device is used to warn motorists of pedestrians crossing. Typically, they are installed to improve safety at and visibility of uncontrolled, marked crosswalks.
Relative Mode	A setting in the traffic signal where any unused time will be assigned to the coordinated phases. This is more common than the absolute mode.
Semi-Actuated (SA)	Intersection operation that maintains the through phase for the major street unless a minor street vehicle detector is actuated or a pedestrian or cyclist push-button is actuated.
Signal Cycle Lengths	The amount of time to serve all phases of a traffic signal at an intersection.
Signal Phase	The right-of-way (green), amber, and all-red clearance intervals in a signal cycle that are assigned to an independent traffic movement or combination of non-conflicting traffic movements serving different modes (i.e. motorists, pedestrians, cyclists, and transit).
Splits	The portion of time allocated to a sequence of movements which also typically includes an amber and all-red period.
Traffic Signal Record (TSR)	A document where various signal timing parameters are provided for a specific intersection.
Uncoordinated Signal	Traffic signals that operate independently from adjacent intersections. The alternate term is a “Free” signal.
Walk Interval	The Walk interval defines the period that allows pedestrians to notice the change in signal indications and begin their movement. This interval may combine both a visual and/or audible indication for pedestrians.