TRANSPORTATION SERVICES POLICY

TRAFFIC SYSTEMS OPERATIONS

Spacing of Traffic Signals

October 21, 2020

DOCUMENT CONTROL

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Original Version

Version	Revision Date (YYYY/MM/DD)	Details
Draft 1.0	2018/09/04	Original draft prepared by Nazli Dehghani, Engineer-in-Training - ITS Operations.
Draft 1.1	2018/09/18	Reviewed by Hao Le, Senior Engineer – ITS Operations
Draft 1.2	2020/07/10	Revised to address consultant's (peer review) comments.
Draft 1.3	2020/07/17	Reviewed by Rajnath Bissessar, Manager – Traffic Systems Operations
Draft 1.4	2020/07/24	Revised to address City's Transportation Engineering Subcommittee (TES)'s comments.
Final (Version 1)	2020/11/19	Approved by the Safety & Mobility Committee of Transportation Services.

Amendment History

Version	Revision Date (YYYY/MM/DD)	Details
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APPROVAL

The version of this document (Final – Version 1) dated October 21, 2020 was approved by the Safety & Mobility Committee of the Transportation Services Division.

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Abbreviations

LOS	Level of Service
FHWA	Federal Highway Administration
ITE	Institute of Transportation Engineers
MMU	Malfunction Management Unit
MOC	Mode of Control
MTQ	Ministry of Transportation Quebec
MUTCD	Manual on Uniform Traffic Control Devices (for USA)
MUTCDC	Manual on Uniform Traffic Control Devices for Canada
OTM	Ontario Traffic Manual
SOP	Standard Operating Procedure
SSD	Stopping Sight Distance
TAC	Transportation Association of Canada
TTC	Toronto Transit Commission
TSP	Transit Signal Priority

Glossary

Cone of Vision	The Cone of Vision is the area of sight – or the angle of sight
Controller (Timer)	A device that controls traffic at an intersection by alternating the right-of-way between conflicting streams of vehicular traffic, or vehicular traffic and pedestrians crossing a roadway. The device monitors and physically alters the operating conditions of a traffic signal.
Dedicated Interconnection	Interconnection between two controllers that is provided by multiple electrical wires (or potentially a dedicated wireless connection) so that a steady voltage can be applied or removed to indicate which pattern or plan is to be used.
Lead-Lag Left Turn	In a lead-lag left-turn phase sequence, an advanced left turn and through movement in one direction is followed by the through movements in both directions which in turn is followed by a left turn and through movement in the opposite direction.
Mode of Control (MOC)	A type of traffic signal operation at signalised intersections that is determined based on current off-peak pedestrian and vehicle volumes. Toronto uses the following MOCs: fully-actuated (FA), fixed-time (FT), semi-actuated (SA), semi-actuated pedestrian (SAP), semi-actuated vehicle (SAV), and pedestrian-actuated (PA).
Peer-to-Peer (P2P)	Interconnection between two modern controllers from the same manufacturer with capability for built-in logic and P2P communications. When the logic processor is enabled and communication is on, the master controller can apply 'call', 'omit', 'hold' and 'force-off' to control phases in the slave controller.
Signal Coordination	The ability to coordinate multiple intersections to enhance the operation of one or more directional movements in a system.
Streetcar CLRV	A streetcar used by the TTC since the 1970's. Generally speaking, a "streetcar" is a type of LRV which runs on tracks in mixed traffic. Specifications: Length: 15.3m, Max speed: 80km/h, Seating: 42, Capacity: 102, Braking rate: 1.6 m/s/s.
Streetcar ALRV	A longer articulated double model of the CLRV. Specifications: Length: 23.2m, Max speed: 80km/h, Seating: 61, Capacity: 155, Braking rate: 1.6 m/s/s.
Streetcar Flexity Outlook	The Flexity Outlook is the first modern low-floor and wheelchair accessible streetcar used in the city of Toronto by TTC. Specifications: Length: 30.2m, Max speed: 70km/h, Seating: 70, Service Load: 132, Crush Load: 251.

Transit Signal Priority (TSP)	TSP detects the arrival of a transit vehicle and modifies the phase times (in the form of transit green extension, non-transit phase truncation and/or transit only phase) within the cycle to better service the transit vehicle.
Uninterruptable Power Supply (UPS)	A device that provides backup power when regular power source fails, or voltage drops to an unacceptable level.
Visibly Limited Signal Indications	These devices limit the distance at which approaching drivers can see the signal indication. They may be louvred indications, or optically programmable signal indications.

1. TRAFFIC SIGNAL SPACING POLICY

1.1. Introduction

The City design, construct, and operate a safe and efficient road network that services all road users. Within this road network, traffic signals are often cited as a means of addressing safety issues, however, improperly installed signals can have an adverse effect on safety and efficiency, particularly when the new signals are too close to other existing signalized intersections.

This policy paper examines the minimum spacing thresholds for traffic signals. It considers spacing thresholds for both standard signals and pedestrian signals. However, it does not include the warrant and justification process for traffic signals; that process is documented elsewhere.

The City of Toronto is a unique environment in terms of urban density, and it places a high priority on the safety of all road users including cyclists, pedestrians, transit users and motorists. Consequently, traffic signals within the City must address the needs of all road users. However, with the exception of motorists, the safety of most road users is unaffected by the spacing between signals. For motorists, the challenges of closely spaced signals require additional consideration to avoid the following:

- drivers confusing the signals;
- difficulty optimizing signal progression, especially at signalised intersections with TSP.
- limited queue storage for vehicles between intersections.

There is very limited guidance available in industry standards and guidelines. The Ontario Traffic Manual (OTM), Book 12 – Traffic Signals recommends a minimum 215 m spacing at a posted speed of 60 km/h and a minimum 350 m spacing for a posted speed of 80 km/h. However, it provides insufficient information for other posted speeds and is largely based on the spacing required to accommodate turning lanes between the two signalised intersections.

This policy was developed to guide City staff on the spacing between traffic signals such that the safety and operational efficiencies are addressed while recognizing and balancing the needs of traffic and other road users with a responsible approach to general growth and new development.

The following goals were recognized to guide the development of this policy:

- Consider the needs of both safety and mobility
- Adopt defensible and realistic thresholds by:
  - Acknowledging the unique environment that is the City of Toronto.
  - Address the challenges associated with closely spaced signals.
- Acknowledge policies from other jurisdictions.
- Adopt industry standards, where available and where applicable.

Within the City of Toronto, roads with traffic signals range in purpose and character:

- Local roads in dense urban areas which mainly provide access to properties.
- Collector roads which gather traffic from multiple local roads and serve for traffic movement and property access.
- Minor arterials which primarily move traffic to community destinations and to major arterials.
- Major arterials which move traffic across the City and to expressways.
- Expressway ramps.

The City's traffic signal spacing policy recognizes and accommodates this broad range of road functions and characteristics.

The policy consists of two components:

1) A process to identify the minimum spacing, below which fundamental engineering principles become violated.
2) It also consists of several mitigating measures which can help to address the safety and efficiency issues that inevitably result from closely spaced signalized intersections.

The City's traffic signal spacing policy should leverage relevant and useful information as available. This information may originate from applicable research, and the best practices and policies of other agencies. A summary of this information is provided in Section 2.

The process developed to identify the minimum spacing between traffic signals is documented in Section 3. Section 4 then lists the mitigating measures to be considered.

2. AVAILABLE INFORMATION

2.1. Considerations

Traffic signals are commonly requested in response to safety issues or to reduce delays. These requests often cite safety issues such as providing protection to pedestrians to cross the road, lowering (calming) the speeds of traffic on a roadway or reducing the potential for right-angle collisions. Traffic signals are also requested to reduce the delays to side street traffic attempting to cross the main street or turn left onto the main street. Traffic signals generally enhance safety and reduce delays only if they are warranted; if unwarranted, they can introduce unintended consequences. For example, while traffic signals tend to reduce angle collisions, they are known to increase rear-end collisions. The following sections provide a more detailed review of factors related to safety and operations of signalized intersections and justify the need to develop a policy for the City of Toronto.

2.1.1. Safety Considerations - Pedestrians

The number of traffic signals along a stretch of road can determine the number of crossing opportunities for pedestrians. Existing literature contains limited information detailing where crossing points should be. According to the Manual on Uniform Traffic Control Devices (MUTCD[1]), the Pedestrian Volume Signal Warrant should not be applied at locations where the distance to the next protected crossing is less than 90 meters, unless the proposed traffic control signal will not restrict the progressive movement of traffic. The 90-meter distance (300 ft.) referred to in the MUTCD is believed to be based on the distance a pedestrian will walk in order to cross the major street[2]. The study does not provide any clarification about the reference point for this measurement.

A study published by ITE[3] conducted an exhaustive review and found very little original, or even substantiated recommendations with regards to the spacing of pedestrian crossings. According to this study, many guidelines seem to coalesce around 90 meters (300 ft.) but it appears that they are merely repeating each other. The same study also suggests applying a time-based spacing metric for pedestrian crossings (instead of distance-based). This approach would consider several parameters in addition to walking distance - walking speed, time to wait for a gap in traffic and width of the roadway. As an example, during the preparation of the Abu Dhabi Urban Street Design Manual[4], researchers were presented with the opportunity to document pedestrian crossing behaviour by applying this approach. The average crossing spacing in Abu Dhabi is 108 meters. Using the time-based approach, the total time to walk to a crossing location, wait for a gap in traffic, and cross the street would then be equal to 3 min and 19 sec for a walking speed of 0.9m/s. The study suggests that further research would be required to determine the universal applicability of the time-based metric.

Shorter signal spacing reduces vehicle speed and shortens walking distances to the nearest signalized intersection and decreases unprotected midblock crossings[5]. However, traffic signals every 180 meters (i.e. with 90 meters distance to each from the midpoint) would require the installation of many more traffic signals throughout the City and, even if coordinated, would create a great deal of congestion, and driver frustration, all of which could have detrimental effects on pedestrians. Furthermore, traffic may divert to other sensitive areas to by-pass sections of road with many signals, creating additional, unintended safety issues. Therefore, pedestrian safety considerations must be balanced with the other safety considerations and should not be the sole determining factor for signal spacing.

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[1] *Federal Highway Administration. Manual on Uniform Traffic Control Devices 2009, Section 4C-05, paragraph 4.*

[2] *Fitzpatrick, K., S. Turner, et al. "Improving Pedestrian Safety at Unsignalized Crossings." Transit Cooperative Research Program Report 112, National Cooperative Highway Research Program Report 562*

[3] *To Cross or Not to Cross, Examining the Practice of Determining Crosswalks*, Michael R. King, RA, ITE, 2014

[5] *Guide for the Analysis of Multimodal Corridor Access Management: Chapter 6 Traffic Signal Spacing 2018*

2.1.2. Operational Considerations

Progression

The efficient progression of vehicular traffic along arterial streets is dependant on the provision of optimal and uniform traffic signal spacing since signal progression is directly dependant on traffic speeds and intersection spacing. OTM Book 12 states that intersection spacing that is less than 415 m or greater than 625 m may affect progression efficiency at a posted speed of 50 km/h. OTM Book 12 indicates the minimum distance between signalized intersections is 215 m for roads with a posted speed limit of 60 km/h or less and up to 350 m for roads with a posted speed limit of 80 km/h. The above required minimum distances in OTM Book 12 are designed to allow "back-to-back" left-turn lanes and proper tapers and do not consider optimal signal progression. OTM Book 12 also indicates that signal spacing should include a progression analysis to ensure that proper coordination of the signals is possible for a range of traffic demands.

Traffic signals operate continuously and cannot be turned off. So, while they may provide right-of-way to side street traffic when gaps are lacking during peak periods, they will also add delays for side street traffic at all other times (compared to stop sign control) which can result in poor LOS operations. The delays introduced for the many hours outside of peak periods often exceed the savings realized during the peaks. As a result, an overall balance in delays should be considered when traffic signals are requested (as reflected in the warrant procedures for traffic signals).

One frequent issue occurs with the installation of new pedestrian signals (mid-block and intersection pedestrian signals). In accordance with the procedures listed in the City's "Traffic Signal Operations Policies and Strategies" document, the City coordinates these pedestrian signals with the operations of the other signals on the roadway. This helps to reduce congestion and lower the number stops. However, it requires pedestrians to wait for a break in the progression of traffic before crossing the road which may add to pedestrian delay. (Note, during late evening and over-night, pedestrian signals are sometimes not coordinated with other signals so that pedestrian delays are reduced.)

Closely spaced signals can result in delays which negatively impact transit delays and reliability, which increases transit customer wait and travel times.

Additional signal timing strategies designed to address the operational considerations associated with closely spaced signals are presented in Section 4.

Detailed signal operations features that promote consistent, safe, and efficient control of traffic signals are identified in the City's "Traffic Signal Operations Policies and Strategies".

Queue Spillback

Another important operational (and safety) concern is the queuing between two closely spaced signalized intersections, where long queues may result in the blockage of the upstream intersection and could impose excessive delays to cross street traffic; safety hazards can also arise. Queue spillback and safety hazards may also occur at locations with heavy traffic turning onto a road with closely spaced signals, such as at a highway off-ramp. A field visit is often conducted to evaluate the extent of the queues and the potential for gridlock. The signal timing strategies presented in Section 4 can sometimes be used to alleviate queuing issues.

2.1.3. Human Factors

Closely spaced traffic signals can pose a unique hazard for motorists. As drivers approach a set of closely spaced traffic signals, they can see the displays for both the downstream signal and upstream traffic signals at the same time, which has the potential to create confusion if the indications differ. Safety issues arise when the driver may look “through” the first signal and takes his/her cue from the farther signal, particularly when the far signal indication is green while the nearby signal indication is red.

The safety implications associated with human factors considerations at closely spaced signals justifies the need for mitigating measures. These measures are discussed further in Section 4.

2.2. Jurisdictional Survey

A survey was conducted by the City to gather an understanding of how other jurisdictions address closely spaced traffic signals. The survey received responses from twelve (12) jurisdictions across North America. A 50/50 split was found between those that have a policy in place and those that do not. Many of the jurisdictions that have a policy in place referenced existing guidelines such as provincial guidelines (OTM, MTQ), and MUTCDC. The key factors in determining distances for closely spaced traffic signals were focused on optimal corridor progression followed by vehicle traffic safety and pedestrian safety.

The minimum spacing is predominantly assessed on a case-by-case basis based on local factors in conjunction with industry references (e.g. OTM, MUTCDC, etc.). Spacing typically ranged from 100 m to 275 m where no mitigation measures were considered. Factors such as posted speed limit, or functional classification of the roadway did not impact policy decisions, but pedestrian/cyclist opportunities did factor in. Furthermore, external factors such as politics and source of requests (e.g. private developer) did play a role in policy decisions on a case-by-case basis.

The results of the literature review and jurisdictional survey suggest that the City of Toronto should develop its own policy. Any policy should be realistic, pragmatic and defensible.

3. POLICY FOR MINIMUM SPACING OF TRAFFIC SIGNALS

3.1. Recommended Minimum Spacing

Drivers must have adequate time to perceive and respond to all traffic control devices, including traffic signals. In the case of two closely spaced signalized intersections, drivers must be allowed to direct their full attention to the first intersection while approaching and passing through it. This allows drivers to identify and monitor the many conflict points that exist within all intersections, including those between vehicles, pedestrians, cyclists and other road users.

Therefore, the following three distances must be fully accommodated within the two closely spaced signals:

1. Stopping Sight Distance,
2. Signal Visibility Distance,
3. Geometric Requirements (such as left-turn lanes).

The stopping sight distance (SSD) is the distance travelled by a vehicle once the driver has been exposed to an impediment, such as another vehicle, debris on the road, or a traffic control device. The signal visibility distance (SVD) is the distance from which a driver can see and recognize traffic signal indications. SVD accounts for the driver's cone of vision extending 40° horizontally, and 15° vertically.

Signalized intersections commonly include left-turn lanes. Where left turn lanes are present, sufficient space between the two intersections must allow for storage in each direction and a taper to demarcate the two separate (back-to-back) lanes. However, when one of the signals is a pedestrian signal, or where no left turn lanes exist, the process used to assess geometric considerations should be based on the design vehicle length. The minimum signal spacing is then the largest of these three values (since the largest distance will also accommodate the other two).

The following process flow chart illustrates the recommended process.

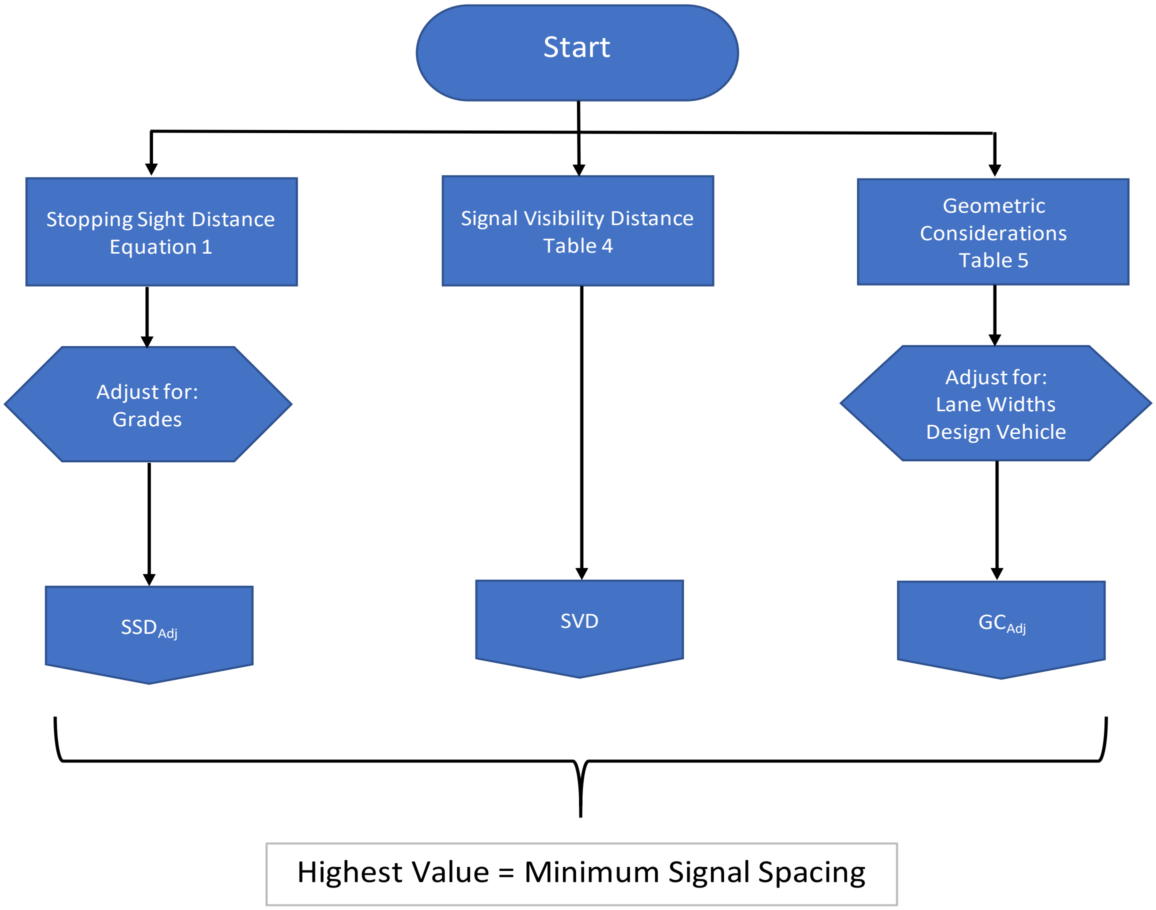

Figure 1 - Process Flow Chart for Determining Minimum Signal Spacing

The remaining sections of this policy further explain the recommended process and specify the adjustments needed to determine the recommended minimum spacing between traffic signals.

There are several distances that may be referenced between any two signalized intersections. These distances are shown in Figure 2 and described in Table 1.

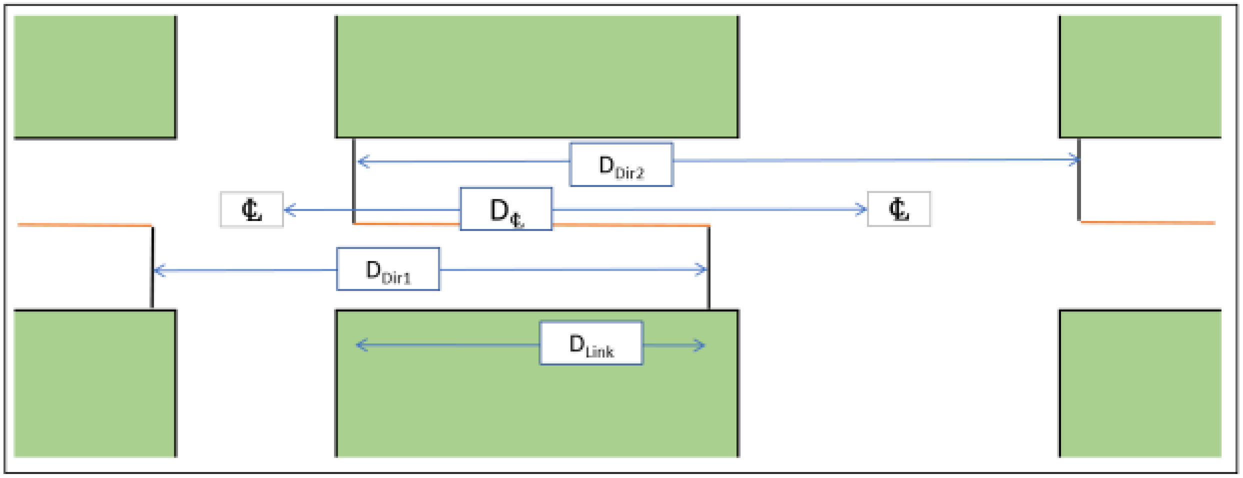

Figure 2 - Intersection Spacing References

Table 1 - Reference Distances for Closely Spaced Traffic Signals

Distance	Description	Applications
D_{Dir1}	Distance between stop lines in Direction 1	D_{Min} is the shorter of D_{Dir1} and D_{Dir2} should be used when considering signal offsets and driver confusion between signal indications
D_{Dir2}	Distance between stop lines in Direction 2	
D℄	Distance from the centreline of one intersection to the centreline of the other	Usually is similar to the average of D_{Dir1} and D_{Dir2} and can, therefore, be used when a reference to a single distance is required.
D_{Link}	Distance from the downstream curb of the crossing street at the first intersection to the stop line of the second intersection	To be used when considering stopping sight distance.

3.1.1. Stopping Sight Distance

The ability of a driver to safely slow down and stop his/her vehicle prior to a traffic control device is paramount to safety. In the case of two closely spaced signalized intersections, drivers must be allowed to direct their full attention to the first intersection while approaching and passing through it. As such, it is not until drivers exit the first intersection that they can be expected to focus on the second.

Stopping sight distance (SSD) is the distance travelled by a vehicle once the driver has been exposed to an impediment such as another vehicle, debris on the roadway or a traffic control device. As shown in Equation (1), SSD is comprised of two intervals - the distance travelled during the perception and reaction time of the driver, and the braking distance.

$$SSD = 0.278Vt + 0.039\frac{V^2}{a} \quad (1)$$

Where:

- SSD = Stopping sight distance (m)
- t = Brake reaction time, 2.5 s
- V = Design speed (km/h)
- a = Deceleration rate (m/s^2)

The following table lists the following SSDs for automobiles and a range of posted speeds. The table has been replicated from the TAC's Geometric Design Guide for Canadian Roads, which originally provides SSD for different design speeds. An estimate of the posted speeds was then added to the table. The estimates are based on the posted speed of the road approximated as design speed minus 10 km/h for design speeds of 80 km/h or below and design speed minus 20 km/h for design speeds of 90 km/h or higher. These assumptions result in the posted speed of 70 km/h being shown twice. In this case, the row showing a design speed of 90 km/h is recommended for a posted speed of 70 km/h as it results in a more conservative assumption.

Table 2 – Stopping Sight Distance on Level Roadways for Automobiles[6]

Posted speed (km/h)	Brake reaction distance (m)	Braking distance on level (m)	Stopping sight distance	
			Calculated (m)	Design (m)
10	13.9	4.6	18.5	20
20	20.9	10.3	31.2	35
30	27.8	18.4	46.2	50
40	34.8	28.7	63.5	65
50	41.7	41.3	83.0	85
60	48.7	56.2	104.9	105
70	55.6	73.4	129.0	130
70[7]	62.6	92.9	155.5	160
80	69.5	114.7	184.2	185
90	76.5	138.8	215.3	220
100	83.4	165.2	248.6	250
110	90.4	193.8	284.2	285

Note: Brake reaction distance predicated on a time of 2.5 s; deceleration rate of 3.4 m/s^2 used to determine calculated sight distance.

The TAC Geometric Design Guide for Canadian Roads suggests modification factors for grades. Table 3 lists revised stopping sight distance values for approaches with grades. The table has was replicated from the TAC's Geometric Design Guide for Canadian Roads, which originally provides SSD for different design speeds. An estimate of the posted speeds was then added to

[6] TAC *Geometric Design Guide for Canadian Roads, June 2017, Table 2.5.2 (modified with posted speed)*
[7] This row is recommended over the 80 km/h design speed to provide more conservative results

the table. Similar to the previous table, the estimates are based on the posted speed of the road approximated as design speed minus 10 km/h for design speeds of 80 km/h or below and design speed minus 20 km/h for design speeds of 90 km/h or higher. These assumptions result in the posted speed of 70 km/h being shown twice. In this case, the row showing a design speed of 90 km/h is recommended for a posted speed of 70 km/h as it results in a more conservative assumption.

Table 3 - Stopping Sight Distance on Grades [8]

Posted speed (km/h)	Stopping sight distance (m)					
	Downgrades (%)			Upgrades (%)		
	3	6	9	3	6	9
10	20	20	20	19	18	18
20	32	35	35	31	30	29
30	50	50	53	45	44	43
40	66	70	74	61	59	58
50	87	92	97	80	77	75
60	110	116	124	100	97	93
70	136	144	154	123	118	114
70	164	174	187	148	141	136
80	194	207	223	174	167	160
90	227	243	262	203	194	186
100	263	281	304	234	223	214
110	302	323	350	267	254	243

The values shown as appropriate in either Table 2 or Table 3 will form the SSD_{Adj} and compared with the values derived in Sections 3.1.2 and 3.1.3 for Signal Visibility Distance and Geometric Considerations respectively.

3.1.2. Signal Visibility Distance

The Ontario Traffic Manual provides guidance on the recommended visibility distance upstream from the stop line to provide the approaching driver with a sufficient distance from which the "*signal heads can be seen and recognized.*"[9] The distances provided consider the driver's cone of vision (vertically and horizontally) as well as the conspicuity of the signal heads. OTM Book 12, Figure 32 – Cones of Vision for Signal Visibility is presented in Figure 3 below:

[8] TAC *Geometric Design Guide for Canadian Roads, June 2017, Table 2.5.3 (modified with posted speed)*
[9] *Ontario Traffic Manual, Book 12 – Traffic Signals, March 2012, Page 113*

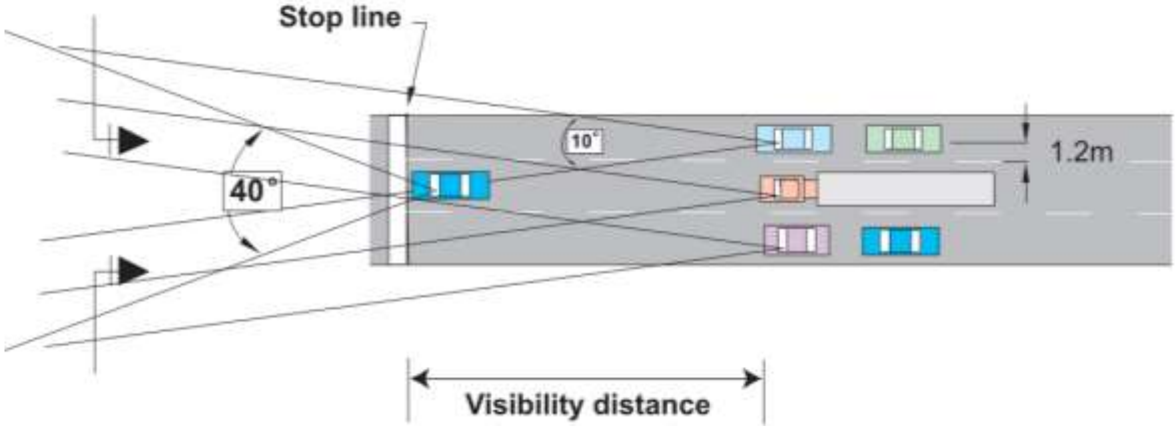

Figure 3 - Cones of Vision for Signal Visibility[10]

Table 25 of the same publication provides the minimum distance from the stop bar for which signal indications must be clearly visible for a range of 85th percentile speeds. The values shown in Table 4 were extracted from Table 25 and have been modified to show the minimum distances based on estimated posted speeds. Specifically, the estimates are based on the posted speeds approximated as 85th percentile speeds minus 10 km/h for 85th percentile speeds of 80 km/h or below and for 85th percentile speeds minus 20 km/h for 85th percentile speeds of 90 km/h or higher. Note these assumptions result in the posted speed of 70 km/h being shown twice. In this case, the row showing the 85th Percentile speed of 90 km/h is recommended for a posted speed of 70 km/h as it results in a more conservative assumption.

Table 4 – Signal Visibility Distance[11]

Posted Speed (km/h)	Minimum Distance from Stop Bar for Signal Indications to be Clearly Visible [D_{Link}] (m)
30	65
40	85
50	110
60	135
70	165
70	200
80	230

The distances shown in Table 4 constitute the parameter SVD shown in Figure 1 and shall be compared against the values derived for Stopping Sight Distance and the Geometric Requirements.

[10] *Ontario Traffic Manual, Book 12 – Traffic Signals, March 2012, Figure 32*
[11] *Ontario Traffic Manual, Book 12 – Traffic Signals, March 2012, Distance values extracted from Table 25*

3.1.3. Geometric Considerations

In cases where there are left turn lanes, there must be enough distance for the storage of vehicles in each direction, plus a tangent section to separate the two back-to-back lanes. These sections are denoted ‘a’, ‘b’ and ‘c’ in Figure 4.

The required minimum distance for geometric consideration shall be calculated using equation 2 below:

$$GC_{Adj} = 2 \times (DVL + 5) + (w \times 10) \qquad (2)$$

Where:

GC_{Adj} = Geometric Consideration Factor
DVL = Design Vehicle Length (Table 5)
w = Width of left-turning lanes

Note[12], a taper ratio of 10:1 is shown in equation 2 (i.e. w x 10) for the length of section b as shown in Figure 4, but a ratio of 13:1 (i.e. w x 13) should be considered for posted speeds greater than 60 km/h.

Table 5 lists the lengths for common design vehicles.

Table 5 - Design Vehicle Lengths

Vehicle Type	Reference	Length (m)
Tractors – Semi-Trailers (WB-19)	TAC Geometric Design Guide for Canadian Roads, Chapter 2, Figure 2.4.5	20.7
Tractors – Semi-Trailers (WB-20)	TAC Geometric Design Guide for Canadian Roads, Chapter 2, Figure 2.4.6	22.7
A –Train Double (ATD)	TAC Geometric Design Guide for Canadian Roads, Chapter 2, Figure 2.4.7	24.5
B –Train Double (BTD)	TAC Geometric Design Guide for Canadian Roads, Chapter 2, Figure 2.4.8	25.0
Streetcar – CLRV	Glossary Section	15.3
Streetcar – ALRV	Glossary Section	23.2
Streetcar – Flexity Outlook	Glossary Section	30.2
Double Streetcars	N/A	65

[12] TAC *Geometric Design Guide for Canadian Roads, June 2017, Table 9.17.2 – Bay Tapers Straight Line*

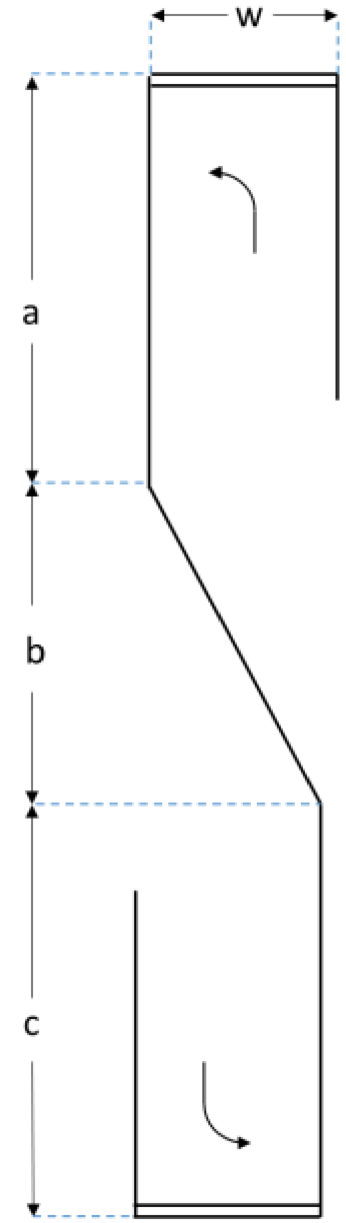

Figure 4 - Geometric Considerations for Closely Spaced Signals

If there is one or no left turn lanes between the two closely spaced intersections, then the required minimum distance for geometric consideration shall be calculated using equation 3 below:

$$GC_{Adj} = DVL + 10 \quad (3)$$

Where:

GC_{Adj} = Geometric Consideration Factor
DVL = Design Vehicle Length (Table 5)

3.2. Recommended Signal Spacing Policy

The minimum spacing between two closely spaced signals (D_{Link} as shown in Figure 2) shall be the greater of:

1. The Stopping Sight Distance (SSD_{Adj})
2. The Signal Visibility Distance (SVD)
3. Geometric Considerations (GC_{Adj})

The placement of adjacent signalized intersections at distances closer than the minimum spacing identified through this recommended process will result in the violation of fundamental traffic engineering principles and safety and efficiency issues are highly likely. In these circumstances, mitigating measures as listed in Section 4 must be used.

However, these mitigating measures may also be used to improve operational and safety measures where the distance between two intersections is greater than the minimum thresholds identified above.

4. MITIGATING MEASURES FOR CLOSELY SPACED TRAFFIC SIGNALS

Measures that may be taken to mitigate the negative consequences of closely spaced signals take several different forms, as listed in Table 6.

Although one or a combination of the following measures must be considered when the minimum signal spacing as documented in Section 03 is violated, these mitigating measures may also be used to improve operational and safety measures where the distance between two intersections is greater than the minimum thresholds identified above but at the discretion of the City and on a case by case basis.

Table 6 - Mitigating Measures for Closely Spaced Traffic Signals

Mitigating Measure	Description	Criteria for Use
Signal Coordination Techniques	These techniques address queuing issues between closely spaced signals. Descriptions of the proposed techniques are provided in Table 7.	To limit or control queues To improve traffic flow To reduce conflicting signal indications
Visibly Limited Signal Indications	These devices limit the distance at which approaching drivers can see the signal indication. They may be louvred indications, or optically programmable signal indications.	To eliminate conflicting signal indications

Mitigating Measure	Description	Criteria for Use
Dedicated Interconnection	The traffic signal controllers are linked (e.g. a hardwire or dedicated wireless link) such that they remain synchronized. A dedicated interconnection between two modern controllers from the same manufacturer with capability for built-in logic is a Peer-to-Peer (P2P) communication. When the logic processor is enabled and communication is on, the master controller can apply 'call', 'omit', 'hold' and 'force-off' to control phases in the slave controller.	To eliminate unwanted changes in offsets between signals due to clock drift. To be used where the distance between the two intersections is less than the SSD calculated as per Table 2 and Table 3.
Common Signal Controller	For very closely spaced intersections, the traffic signal equipment (indications, detectors, auxiliary devices) at both locations can be operated through a single traffic signal controller.	To be used where signal indications may conflict while in flash or during power failures (i.e. a single MMU will be of benefit or if individual controllers are in separate power grids)
Uninterruptable Power Supply (UPS)	When power is interrupted at traffic signals, they become all-way stop-controlled. Two closely spaced all-way stop intersections have a high potential to generate long delays and gridlock. This situation may be avoided for shorter duration power interruptions with the use of a UPS.	To be used whenever common signal controllers are used. Can also be considered if dedicated interconnect is used.
300 mm Signal Indications	OTM Book 12 – Traffic Signals recommends the use of 300 mm for at least red indications where drivers may confuse the signal indications, or there is conflicting or competing background distractions.	To be used on a case by case basis based on findings from field investigations.
Transit Signal Priority (TSP)	TSP detects the arrival of a transit vehicle and modifies the phase times (in the form of transit green extension, non-transit phase truncation and/or transit only phase) within the cycle to better service the transit vehicle. TSP could be added to the new signal provided that TSP already exists at the adjacent closely spaced signal.	To be used where transit vehicles are delayed or service becomes unreliable.

The signal coordination techniques may be further defined as listed in Table 7.

Table 7 - Signal Coordination Techniques for Closely Spaced Traffic Signals

Risk	Signal Coordination Techniques
Queuing through upstream signal	One or more of: • Split optimization for downstream intersection/green time • Synchronize ambers/reds of closely spaced signals • Optimize green band for neighbouring signals • Upstream signal gating (i.e. shorter split for upstream signal)
Queue spillback in left-turn lanes	One or more of: • Add/Extend left-turn phase • Opportunities to extend left turn lane, especially if it is in paint • Simultaneous through green indications • Lead-lag phasing • Critical intersection control
Mode of Control (MOC)	Closely spaced traffic signals may also need to use harmonized MOCs. Details of this requirement are provided in the City's Standard Operating Practice (SOP).

The City may adopt one or more of these mitigating measures to apply to a given set of problems or challenges at a specific location. As each location is unique, an engineering assessment to identify the presence of the challenges and safety issues as described in Section 2.1 is recommended. It is strongly recommended that the approval of new closely spaced signals only be issued in conjunction with the applicable mitigating measures.