PART B — TRAFFIC CONTROL SIGNALS

Division 2

INSTALLATION GUIDELINES FOR TRAFFIC CONTROL SIGNALS

B2.1 TO B2.5

JULY 2020

B2 INSTALLATION GUIDELINES FOR TRAFFIC CONTROL SIGNALS

The description of installation guidelines for traffic control signals and their application is organized as follows:

Section B2.1 General considerations for installation of traffic control signals
Section B2.2 Methodology
Section B2.3 Traffic Signal Warrant Procedure
Section B2.4 Pedestrian Signal Head Warrant Procedure
Section B2.5 Data Collection Requirements

B2.1 GENERAL CONSIDERATIONS FOR INSTALLATION OF TRAFFIC CONTROL SIGNALS

The Canadian Traffic Signal and Pedestrian Signal Head Warrant Matrix Procedure is built on a foundation of existing practices combining relevant adjustment factors to create a warrant procedure that minimizes data collection efforts, is easy to use and is based on sound engineering principles and Canadian needs.

B2.1.1 Safety Considerations

An extensive literature search was undertaken into safety research, existing policies and guidelines for the installation of traffic signals. From this research the following observations were made:

(a) Traffic signals can improve the safety at an intersection. It is widely accepted in research that traffic signals will improve safety at an intersection, in particular with respect to collisions involving right-of-way conflicts. They also give clear right-of-way assignment to pedestrians, reduce driver discomfort at rural high-speed intersections and provide safety for minor movements.

(b) Traffic signals can introduce safety issues at an intersection. Safety issues associated with the installation of a traffic signal at an intersection can at times be significant. Rear end and sideswipe collisions usually increase after a signal is introduced. Signal installation can cause infiltration of traffic onto local neighbourhood streets. Traffic signals can also encourage driver non-compliance and give pedestrians a false sense of security.

(c) Alternatives should be considered first. Many safety practitioners suggest that the placement of a traffic signal at an intersection should be seen as an option to be used after all other safety options are exhausted. Alternative forms of traffic control or design and operational modifications to the existing intersection (including roundabouts) should be considered before a traffic signal is selected as an option.

(d) Existing practice regarding signal warrants is collision frequency based. A vast majority of existing practice on traffic signal warrants suggests that once an unsignalized intersection has more than a specified number of collisions in a given period of time, a traffic signal should be considered. This practice of using collision frequency is flawed, in that collisions fluctuate randomly around a mean, and tend to return to a lower frequency after an abnormally high frequency is observed. A reduction in collision frequency has been observed to occur whether a safety intervention (i.e. the installation of a traffic signal) is implemented or not. The practice of using collision frequency is also reactive, as it is done *after* a series of collisions has occurred at a site.

The field of traffic safety research is evolving rapidly due to a new partnership between statisticians and traffic safety engineering. What has come out of this research is a series of models that allow safety practitioners to predict the safety of a location based on past performance and a set of equations developed through examining the collision history observed at a set of similar unsignalized and signalized intersections.

The implications of this comparison how an intersection is expected to perform (as either an un-signalized or signalized intersection) to how the intersection is currently performing. If the intersection is expected to perform at a lower collision rate when a traffic signal is installed and the level of improvement is merited, then a traffic signal should be considered on this basis. When these same equations are used at all locations where collision and traffic volume is available, intersections could be ranked in order of the potential for reduction in future collisions if a signal were installed. This is a a powerful tool for jurisdictions to have in their possession, since it is a defendable and objective means of determining when and where traffic signals should be placed.

In reviewing research on safety warrants, it was found that most collision prediction theory is based on the same factors that are already being used in signal warrant analyses. In the context of signal warrants, collision risk is taken into account when looking at vehicle-vehicle conflicts, the vehicle-pedestrian conflicts, as well as the intersection geometry and the demographics of the area. The historical collision rate can be used as a basis for statistical comparison with other similar intersections to determine where a detailed engineering safety review is required, but is not included in the Canadian traffic signal and pedestrian signal head warrant matrix procedure.

B2.1.2 Operational Considerations

The management of delay for both pedestrians and drivers is another reason for the utilization of traffic signals. Traffic signal control, in conjunction with appropriate geometric design and pavement markings, can minimize delay and queuing. The operational characteristics that lead to a requirement for traffic signals include:

(a) Approaches at times of peak demand; or,

(b) Abnormal delays to through and left-turning vehicles.

Before adopting traffic signal control as a response strategy to the observed conditions, the following must be considered:

(i) Could operational improvements be accomplished by reorganizing traffic flow (e.g., left-turn lanes, channelized right turns or turn prohibitions)?

(ii) Could a less restrictive form of intersection control be implemented with success (e.g., stop sign control to replace yield sign control or multi-way stop sign control to replace two-way stop sign control)?

(iii) Is it possible to implement traffic signal control without seriously affecting adjacent intersections and nearby roads?

(iv) Would traffic signal control at this location only be beneficial for a very short period of the day? (If the six-hour average side street traffic is below 75 vehicles per hour, then signals should not typically be considered)

(v) Is sufficient intersection capacity available to implement traffic signal control?

(vi) Will left turns impede through traffic if traffic signal control is implemented?

(vii) Are left-turn lanes available? Will they be required?

(viii) Will the installation of the traffic control signals promote the use of less desirable routes?

(ix) Will the installation negatively affect safety?

In a situation where pedestrian activity is quite heavy and vehicle activity is low, it may be reasonable to consider a pedestrian signal rather than a full traffic signal. Further review and possible application of the Pedestrian Crossing Warrant procedure may be considered to determine if a pedestrian signal would be more appropriate control device.

B2.1.3 Physical Conditions

The physical characteristics of the intersection and its approaches must be evaluated to determine whether a traffic control signal may be operated safely and effectively. Examples of factors that may make traffic signal control difficult include the following:

(a) Steep grades on one or more approach legs could make stopping or starting of vehicles difficult or impractical, especially during adverse road and weather conditions;

(b) A severely skewed angle of intersection could result in excessively long vehicle and pedestrian clearance phases, and a very inefficient signal operation;

(c) Offset intersection legs could result in excessively long vehicle and pedestrian clearance intervals and undue conflict between vehicles and pedestrians; or,

(d) Horizontal or vertical alignments could reduce signal visibility.

B2.1.4 Strategic Considerations

Traffic signal control has effects beyond the immediate controlled intersection. Therefore, the following must be considered when such control is contemplated:

(a) Distance to and coordination with adjacent signalized intersections;
(b) Uniformity of traffic control signals operation;
(c) Capacity of the subject intersection relative to upstream and downstream intersections;
(d) Potential for adjacent network disruption or over-saturation;
(e) Effect on adjacent land uses; and,
(f) Effect on neighbourhoods.

B2.1.5 Special Considerations

Situations may arise that require preferential traffic control, at regular or intermittent intervals, for public transit, emergency response, opening bridges at waterways or railway control integration purposes. The following must be considered when traffic control signals are used in such circumstances:

(a) Overall vehicular and pedestrian safety;
(b) The benefit to the special user; and,
(c) The effect on overall traffic movement (vehicular and pedestrian).

When a traffic control signal is operated in close proximity to a railway grade crossing equipped with an active warning system, care should be taken to ensure that the operation of the traffic control signal does not cause blockage of the railway tracks. Where an automatic grade crossing warning system is in place, the operation of the traffic control signal on the road approach must be preempted. Furthermore, visual conflict between the traffic signal indications and the road/railway crossing protection equipment must be avoided.

The regulatory authority is mandated to provide policies, standards and guidelines on the design and operation of traffic control signal systems in the vicinity of grade crossing active warning systems, and these should be consulted prior to installation of pre-emption.

B2.2 METHODOLOGY

The critical element that tends to be the determining factor for identifying the need for traffic signal control is the conflict between the stream of traffic on the main street and vehicles on the side street that desire to either cross or enter the main street. The secondary, but also important element is the conflict between the stream of traffic on the main street and the pedestrians and cyclists on the side street that desire to cross the main street.

The Canadian Traffic Signal and Pedestrian Signal Head Warrant Matrix Procedure is a "Cumulative Factors Methodology" (CFM) that includes a cross-product relationship of the vehicle-vehicle conflict and the vehicle-pedestrian conflict. It also considers various local factors such as pedestrian demographics, pedestrian exposure and roadway characteristics. In developing the Canadian Traffic Signal and Pedestrian Signal Head Warrant Matrix Procedure, one of the key considerations related to conflicting traffic movements was the time period for which the warrant applies. Many warrant procedures do not identify a specific time period for which traffic counts are to be conducted, but use the average annual daily traffic (AADT) values. The CFM method has been developed on the assumption that most road authorities would prefer to take traffic counts over specific time periods. The CFM uses traffic flow data for the normal peak periods of 7:00 a.m. to 9:00 a.m., 11:00 a.m. to 1:00 p.m. and 4:00 p.m. to 6:00 p.m. The selection of these hours may also assist the practitioner in establishing signal timing plans, if a traffic signal is installed. The other issue considered in the development of the CFM is the number of approach lanes at the intersection in question.

Other warrant procedures use total approach volumes, instead of individual turning movements. In the Canadian Traffic Signal and Pedestrian Signal Head Warrant Matrix Procedure, the vehicle-vehicle conflict consists of the summation of the individual cross-products of the turning movements from the main street and side street vehicular traffic. The pedestrian-vehicle conflict consists of the summation of the individual cross-products of the turning movements from the main street and pedestrian traffic crossing the main street. These cross products are then modified by a series of factors.

B2.3 TRAFFIC SIGNAL WARRANT PROCEDURE

The simplified CFM matrix for the traffic signal warrant equation is in the form as shown below:

$$W = [(V) + (P \times F \times L)] \times C$$

W = Cumulative warrant points

V = Function of individual vehicle-vehicle conflicts

P = Function of individual vehicle-pedestrian conflicts

F = Pedestrian Demographics Factor

L = Pedestrian Exposure Factor

C = Roadway Characteristics Factors

The Pedestrian Demographics Factor (F) considers the proximity of the intersection to elementary schools or seniors' complexes. The Pedestrian Exposure Factor (L) considers the number of traffic lanes that the pedestrians have to cross. The Roadway Characteristics Factors (C) take into account:

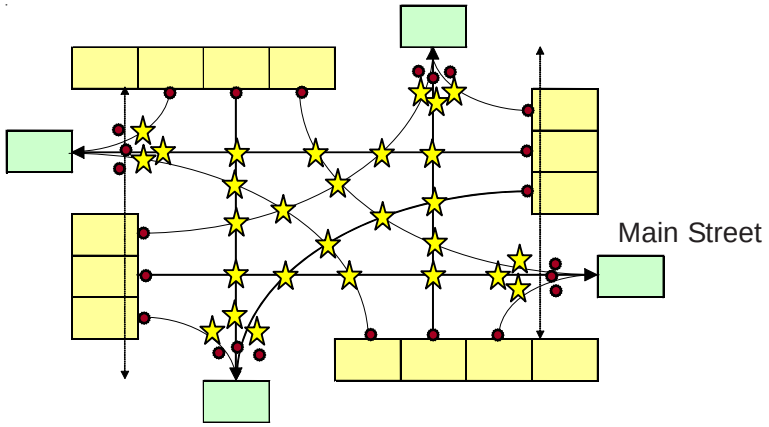
(a) Width of the median (on the main street);
(b) Intersection spacing (distance to upstream main street signals);
(c) Truck traffic (on both streets);
(d) Bus routes (on the side street);
(e) Speed limit (on the main street); and,
(f) Overall population of the area.

Using individual turning movements in a "matrix" format automatically takes the different intersection configurations into account because the methodology only identifies the movements that are in conflict. Figure B2-1 shows the significant differences in conflict points for four-legged, three-legged and one-way intersections.

The CFM traffic signal warrant equation is calibrated to utilize a value of 100 points as the basis of determining traffic signalization need.

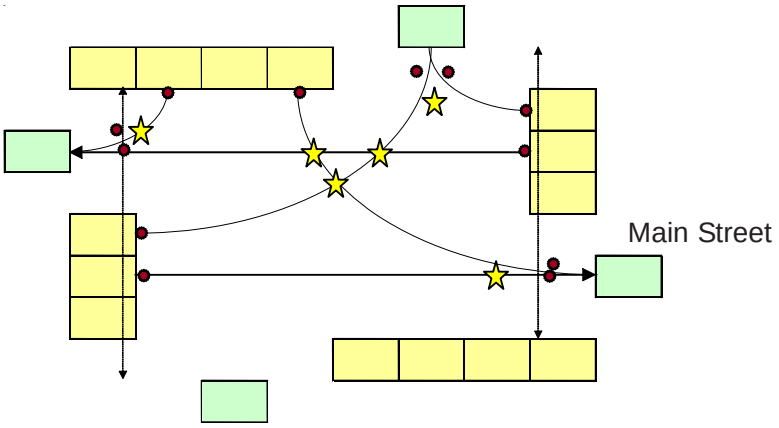
Table B2-1 provides an example of the "matrix" methodology, where individual cross products are summed up at the side of the matrix, for both the vehicle-vehicle conflicts, as well as the vehicle-pedestrian conflicts. The bottom-left portion of the matrix (in red) is a mirror image of the top-right portion and, therefore, not included in the summations.

INTERSECTION CONFLICT POINTS



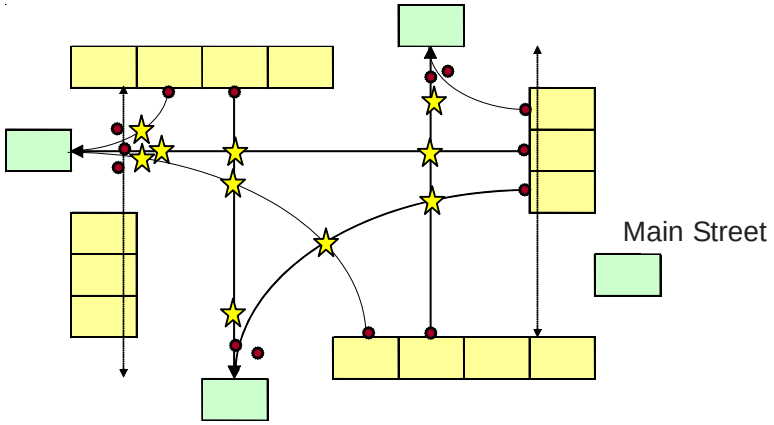
Four-Leg Intersection

28-veh-veh conflict points
24 veh-ped conflict points



Three-Leg Intersection

6-veh-veh conflict points
12 veh-ped conflict points



One-Way Intersection

10-veh-veh conflict points
14 veh-ped conflict points

FIGURE B2-1

TABLE B2-1
MATRIX CALCULATION FORMAT

			NB			SB			WB			EB			Ped3 EW	Ped4 EW		
			LT	Th	RT	LT	Th	RT	LT	Th	RT	LT	Th	RT	NSide	SSide	V-P	V-V
			30	225	45	33	245	47	10	75	15	15	112	23	30	30		
NB	LT	30	x	x	x	x	7,350	1,410	300	2,250	x	450	3,360	x	x	900	900	15,120
	Th	225	x	x	x	7,425	x	x	2,250	16,875	3,375	3,375	25,200	x	6,750	6,750	13,500	58,500
	RT	45	x	x	x	1,485	x	x	x	x	x	x	5,040	x	x	1,350	1,350	6,525
SB	LT	33	x	7,425	1,485	x	x	x	330	2,475	x	495	3,696	x	990	x	990	6,996
	Th	245	7,350	x	x	x	x	x	2,450	18,375	x	3,675	27,440	5,635	7,350	7,350	14,700	57,575
	RT	47	1,410	x	x	x	x	x	x	3,525	x	x	x	x	1,410	x	1,410	3,525
WB	LT	10	300	2,250	x	330	2,450	x	x	x	x	x	1,120	230	x	300	300	1,350
	Th	75	2,250	16,875	x	2,475	18,375	3,525	x	x	x	1,125	x	x	x	x	0	1,125
	RT	15	x	3,375	x	x	x	x	x	x	x	225	x	x	450	x	450	225
EB	LT	15	450	3,375	x	495	3,675	x	x	1,125	225	x	x	x	450	x	450	0
	Th	112	3,360	25,200	5,040	3,696	27,440	x	1,120	x	x	x	x	x	x	x	0	0
	RT	23	x	x	x	x	5,635	x	230	x	x	x	x	x	x	690	690	0
Totals																	34,740	150,941

The final form of the CFM traffic signal warrant equation is shown below:

$$W = \left[\frac{C_{bt} \times X_{v\text{-}v}}{K_1} + \frac{X_{v\text{-}p} \times F \times L}{K_2} \right] \times C_i$$

W = Cumulative warrant points

C_{bt} = Side Street Bus/Truck Factor

$X_{v\text{-}v}$ = Sum of the individual cross products of the actual conflicting vehicle-vehicle movements

$X_{v\text{-}p}$ = Sum of the individual cross products of the actual conflicting vehicle-pedestrian movements

K_1 = Vehicle-Vehicle Denominator constant

K_2 = Vehicle-Pedestrian Denominator constant

F = Pedestrian Demographics Factor

L = Number of lanes on the main street

C_i = Product of the Roadway Characteristics Factors

B2.3.1 Vehicle and Pedestrian Denominator

The Vehicle-Vehicle Denominator (K_1) and the Vehicle-Pedestrian Denominator (K_2) in the formula are calibrated to result in a cumulative threshold of 100 points for an intersection that warrants traffic signals, with an approximately 30 to 40% pedestrian component and 70 to 60% vehicle component depending on the number of lanes. The downward adjustment in the vehicle component and the corresponding upward adjustment in the pedestrian component weighting are in recognition of the increased pedestrian exposure risk of crossing wider roadways.

B2.3.1.1 Vehicle - Vehicle Denominator (K_1)

In developing the relationship for the vehicle component, the following warrant principles were used (as summarized in Table B2-2):

(a) The weighting of the vehicle component is given a lesser priority as the pedestrian crossing exposure increases. The vehicle component of the equation decreases in priority, ranging from 70% for a two-lane roadway (L = 2) to 60% for a six-lane divided roadway with left turn lanes (L = 7).

(b) The side street vehicle conflict volume as it relates to roadway crossing exposure is reduced from a value of 250 vehicles per hour for a two-lane roadway (L = 2) to 175 vehicles per hour for a six lane divided roadway with left turn lanes (L = 7).

(c) Main street vehicle conflict volume as it relates to roadway crossing exposure is increased from the base value of 500 vehicles per hour for a two-lane roadway (L = 2), to 800 vehicles per hour for a six lane divided roadway with left turn lanes (L = 7). The increase in both main street and side street volumes is in consideration of higher volume expectation on roadways with increased travel lanes.

TABLE B2-2
VEHICLE COMPONENT VALUES

Number of Lanes (L)	Vehicle Component Weight (%)	Side Street Vehicle Conflict Volume (vehicles/hour)	Main Street Vehicle Conflict Volume (vehicles/hour)
1	72	265	435
2	70	250	500
3	68	235	550
4	66	220	625
5	64	205	675
6	62	190	750
7	60	175	800

The values for the Vehicle-Vehicle Denominator (K_1) in the formula can be derived from the following equation and are illustrated in Figure B2-2.

$$K_1 = -10(L)^2 + 200(L) + 1400$$

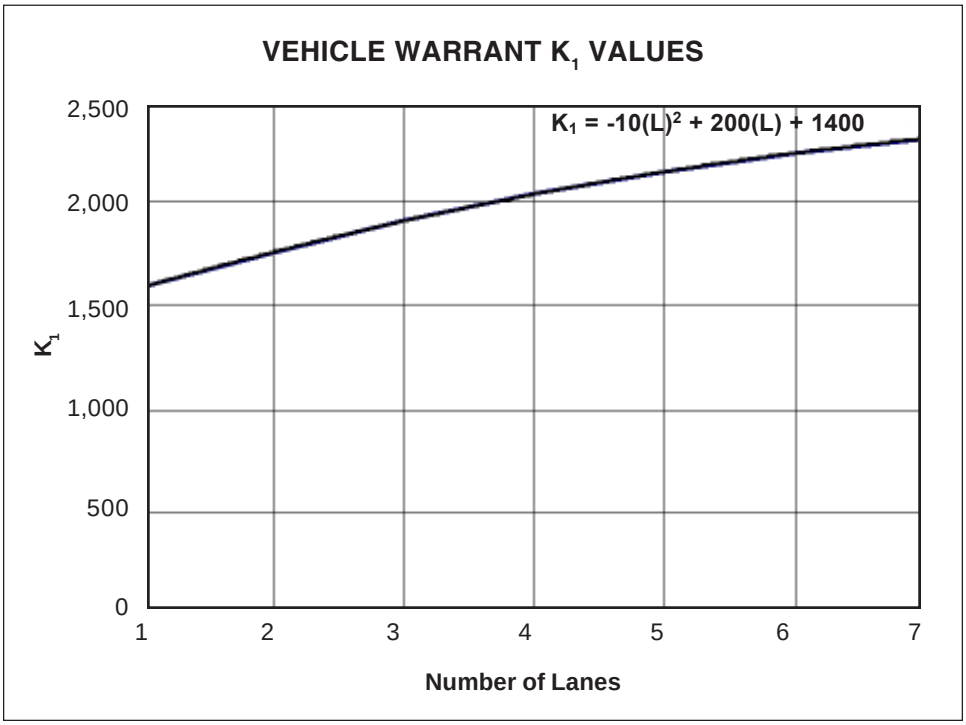


FIGURE B2-2

B2.3.1.2 Vehicle-Pedestrian Denominator (K_2)

In developing the relationship for the pedestrian component, the following warrant principles were used (as summarized in Table B2-3):

(a) Weighting of the pedestrian component is given a greater priority as the pedestrian crossing exposure increases. The pedestrian component of the equation increases in priority, ranging from 30% for a two-lane roadway (L = 2) up to 40% for a six lane divided roadway with left turn lanes (L = 7).

(b) Pedestrian volume as it relates to roadway crossing exposure is reduced from a value of 60 crossings per hour for a two-lane roadway (L = 2) to 45 crossings per hour for a six lane divided roadway with left turn lanes (L = 7).

(c) Vehicle volume as it relates to pedestrian crossing conflict is increased from a value of 500 vehicles per hour for a two-lane roadway (L = 2) to 800 vehicles per hour for a six lane divided roadway with left turn lanes (L = 7).

TABLE B2-3
PEDESTRIAN WARRANT COMPONENT VALUES

Number of Lanes (L)	Pedestrian Component Weight (%)	Pedestrian Warrant Volume (crossings/hour)	Vehicle Warrant Volume (vehicles/hour)
1	28	63	435
2	30	60	500
3	32	57	550
4	34	54	625
5	36	51	675
6	38	48	750
7	40	45	800

The values for the Vehicle-Pedestrian Denominator (K_2) in the formula can be derived from the following equation and are illustrated in Figure B2-3.

$$K_2 = -30(L)^2 + 1150(L) - 150$$

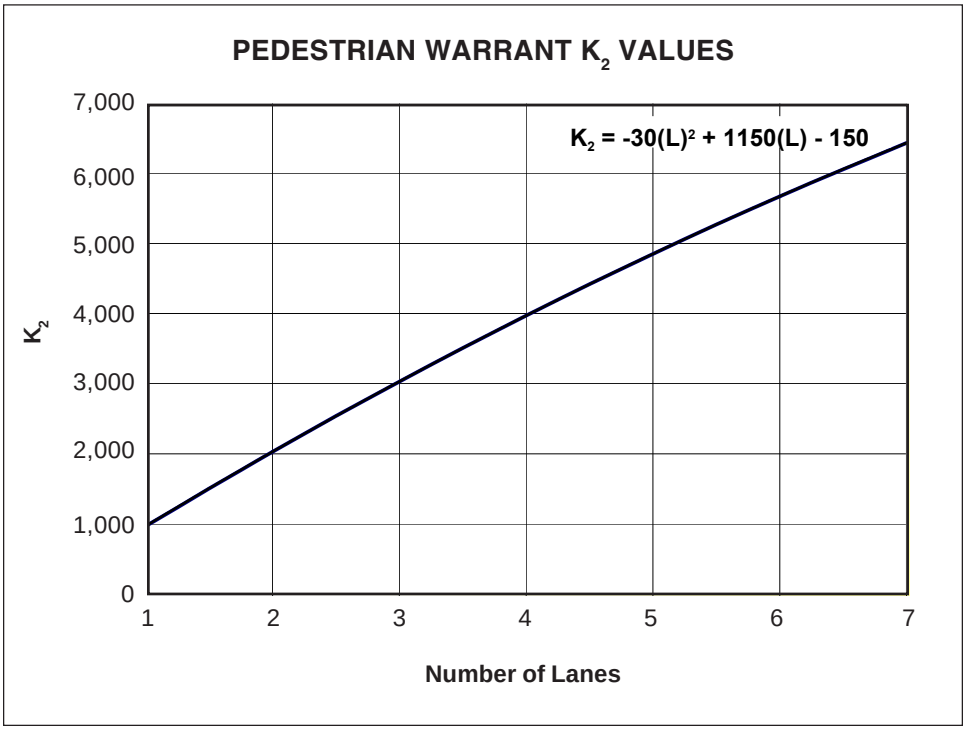


FIGURE B2-3

B2.3.2 Pedestrian Demographics Factor (F)

The Pedestrian Demographics Factor (F) is related to adjacent land use. It is based on the idea that, rather than using actual pedestrian counts by hours of the day and age category, a surrogate adjustment factor based on the pedestrian demographics of the area near the intersection will be easier to identify and more consistently applied. The practitioner will use local judgment to determine if the demographics represent the mix of pedestrians at the intersection under analysis. The Pedestrian Demographics Factor is subjective based on engineering judgment of the impact of the following factors on the operation of the intersection, corresponding to a maximum of:

(a) F = 1.2 if there is an elementary school in the area

(b) F = 1.2 if crosswalk is regularly used by mobility challenged pedestrians

(c) F = 1.1 if there is a seniors' centre or junior high school in the area

(d) F = 1.1 if the intersection crosswalk across the main street forms part of the “safe” walkway path to an elementary school

(e) F = 1.0 in all other cases

B2.3.3 Roadway Characteristics Factor (C_i)

The Roadway Characteristics Factor (C_i) is the cross-product of a number of individual factors that combine to identify the operating characteristics and the type of intersection being considered. Those factors are described below:

$$C_i = C_s \times C_{mt} \times C_v \times C_p$$

B2.3.3.1 Intersection Spacing Factor (C_s)

This factor is intended to correlate the progression of vehicles within a signal system with the spacing of intersections within the system. It should be noted that this factor is not normally used for intersections in the central business district (CBD), where $C_s = 1.0$.

Intersection spacing has always been a factor in the overall efficiency of an arterial or network of signals. It is difficult to quantify the impact of installing a new signal within an existing network due to the number of variables involved (e.g. vehicle speed, cycle length, bandwidth, queue storage, etc.).

A sensitivity analysis was performed, using a micro-simulation model, on an arterial network and varying the distance (d) of an intersection from 100 to 800 metres from the next signalized intersection. The range for this factor was found to vary from 0.92 to 1.06. These results may be simplified to the following equation, showing a range of 0.90 to 1.05, as displayed graphically in Figure B2-4.

(a) For $d \geq 200$ m, $C_s = 1.05 - 0.3/(2^{(d/200)})$

(b) For $d < 200$m, $C_s = 0.9$

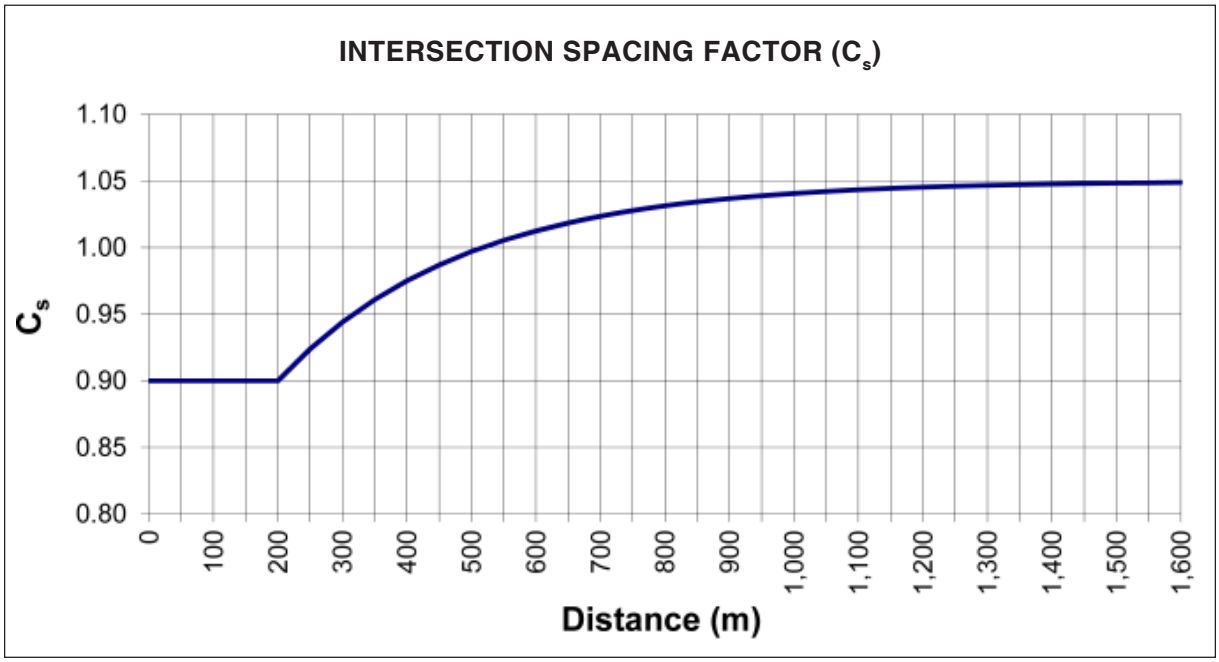


FIGURE B2-4

B2.3.3.2 Vehicle Classification Factor (C_{mt})

The Vehicle Classification Factor is intended to rationalize the impact of heavy vehicles on the main street and the safety implications they have on the side street traffic. Heavy vehicles can be considered either by a conversion to passenger car units (pcu's) or by applying a factor that takes them into account. The latter is simpler, less data intensive and is recommended here. The range for this factor is based on using an average equivalent passenger car unit value of 2.0 for trucks. The equation for the percentage of heavy vehicles (CV) may be expressed as follows and is shown graphically in Figure B2-5.

(a) For HV ≤ 5%, $C_{mt} = 1.00$

(b) For 5% < HV < 20%, $C_{mt} = 0.95 + HV$

(c) For HV ≥ 20%, $C_{mt} = 1.15$

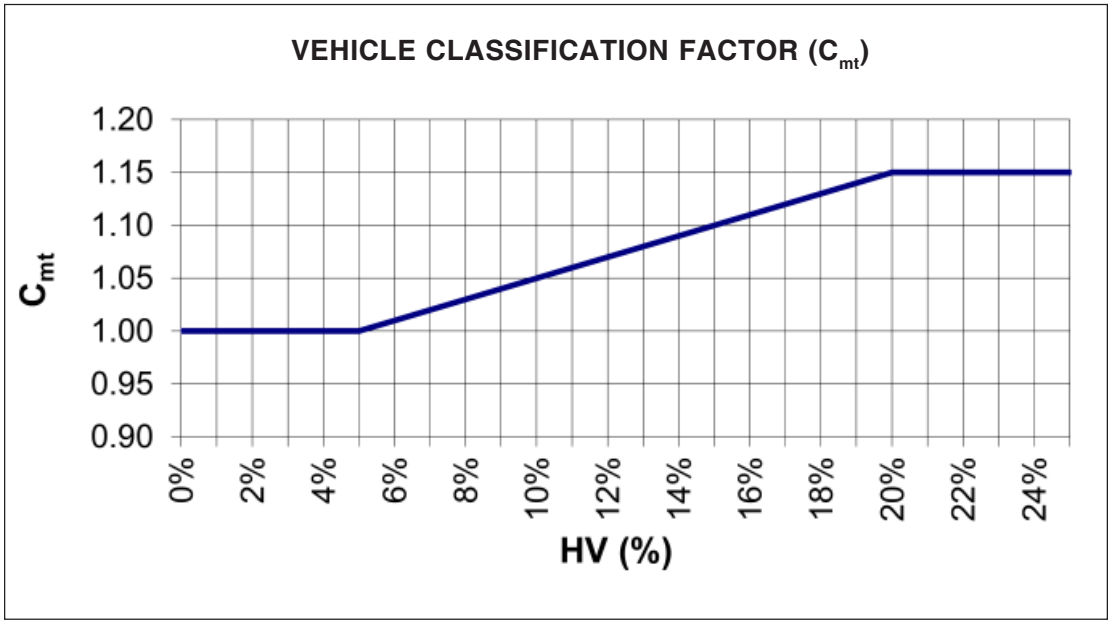


FIGURE B2-5

B2.3.3.3 Speed Factor (C_v)

The Speed Factor represents the added difficulty that side street traffic may have when facing main street traffic at higher speeds. Speed is either considered by using the posted speed limit on the main street or the 85th percentile operating speed. Again for simplicity, the posted speed has been used in calibrating this methodology, acknowledging that actual operating speeds vary about the mean. For simplicity, it was assumed that there is a linear relationship for this factor between the threshold values of 60 km/h and 80 km/h. The equation used for this factor is:

(a) For $V \leq 60$, $C_v = 1.00$

(b) For $60 < V < 80$, $C_v = 1.00 + (V-60)/200$

(c) For $V \geq 80$, $C_v = 1.10$

This relationship is shown in Figure B2-6.

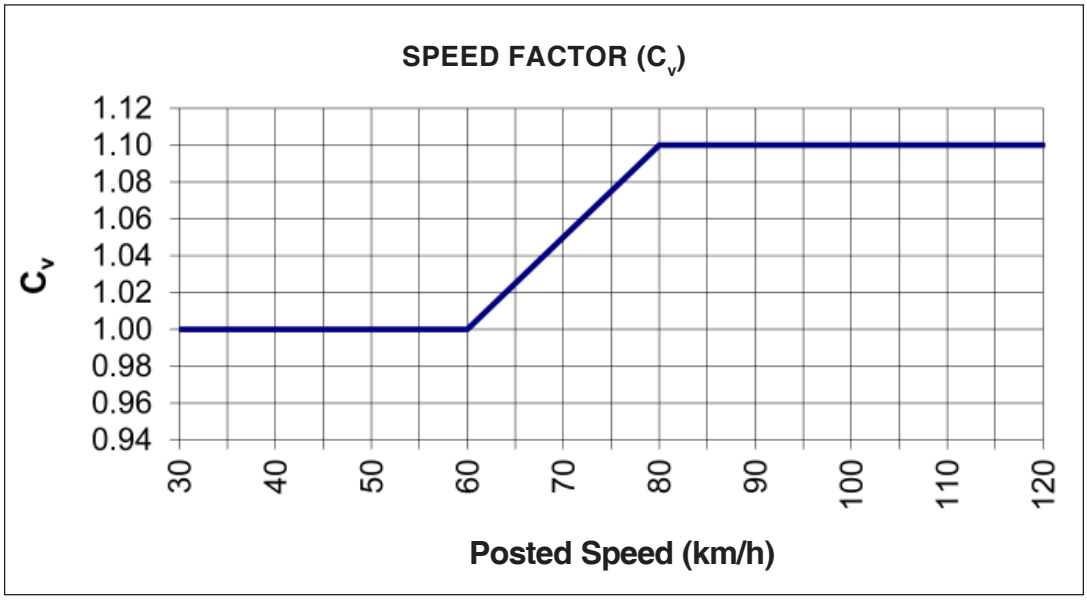


FIGURE B2-6

B2.3.3.4 Population Demographic Factor (C_p)

Most signal warrant methodologies take into account the urban and/or rural nature of the intersection, indicating that "driver expectation" differs from large to small communities. The range for this factor is based on similar values and cut-off points used in other warrant procedures, namely: large city (greater than 250,000 population), small to medium city (10,000 to 250,000 population) and rural area or towns of populations less than 10,000.

(a) For population ≤ 10,000, $C_p = 1.20$

(b) For 10,000 < population < 250,000, $C_p = 1.10$

(c) For population ≥ 250,000, $C_p = 1.00$

This relationship is shown in Figure B2-7.

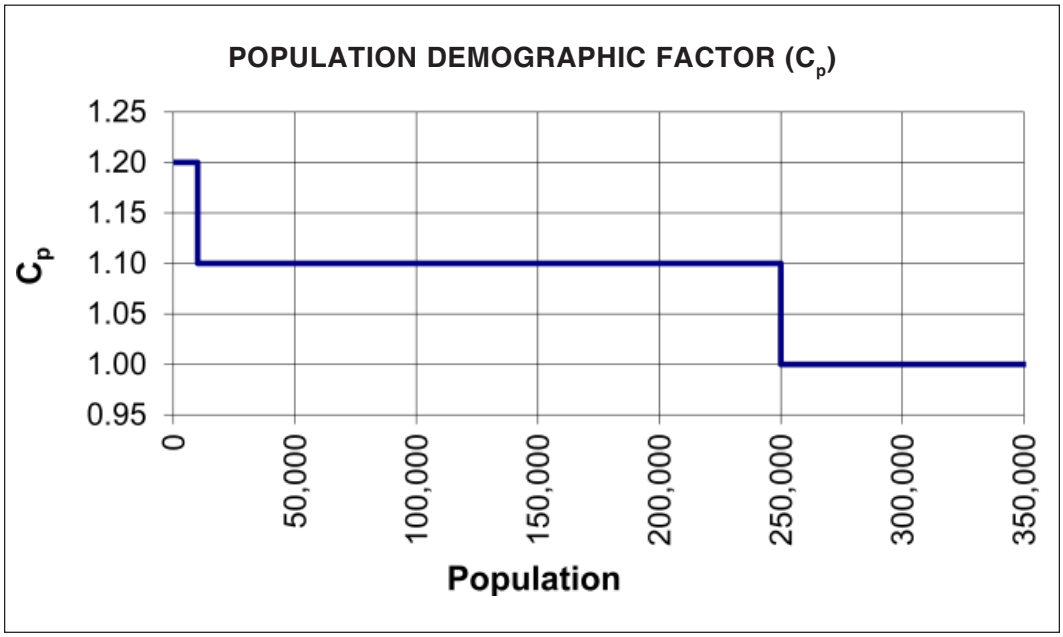


FIGURE B2-7

B2.3.4 Side Street Bus/Truck Factor (C_{bt})

C_{bt} is the Side Street Bus/Truck Factor. If the side street has either high truck volume or is used as a bus route, there will be more risk (due to the inherent operating characteristics of these vehicles) in crossing the traffic stream on the main street.

C_{bt} is assigned to a value of 1.05 if the side street either is a bus route (C_{sb}), or has more than 10% trucks (C_{st}), otherwise it has a value of 1.00. These conditions only affect the side street vehicles trying to cross the main street.

Side Street Condition	C_{bt}
More than 10% Trucks on Side Street (Cs ≥ 10%)	1.05
Bus Route on Side Street (sb = yes)	1.05
Neither situation	1.05

B2.3.5 Right Turn Reduction Factor Calculations

The Canadian Traffic Signal and Pedestrian Signal Head Warrant Matrix Procedure provides a means of applying a special factor for side street right turns onto the main street. In order to deal with the side street right turns within the warrant analysis (to assist the engineering judgment component), a right turn reduction factor has been developed.

The basic assumption is that, the relative ease to which the right-turning traffic can gain access to the main street is a function of the volume of the conflicting traffic in the curb lane on the main street. A review of the various factors that affect the capacity of the right turn movement determined that a theoretical model based on gap acceptance theory is the most appropriate model to be used in a national context. A good model to use is one that is based on the proportion of free vehicles (a measure of the platoon dispersion) approaching the intersection on the main street. The right turn reduction factor is assumed to be a function of the congestion created in the curb lane by the two movements (i.e., the sum of the side street right turn traffic and the main street through traffic in the curb lane) and also a function of any platooning effects of an upstream traffic signal.

B2.3.5.1 Estimating Curb-Lane Flow

A means of estimating the flow in this curb lane requires an understanding of the intersection geometry and lanes usage. The basic intersection geometry is identified in the sample input as shown in Table B2-4.

TABLE B2-4
INTERSECTION GEOMETRY INPUT

Lane Configuration		Excl LT	Th & LT	Through	Th+RT+LT	Th & RT	Excl RT	Upstream Signal (m)	# of Thru Lanes
25th Street	WB	1		2			1	3,000	2
25th Street	EB		1			1		800	2
Trafficshire Ave	NB				1				
Trafficshire Ave	SB		1				1		
Are the Trafficshire Ave NB right turns significantly impeded by through movement? (y/n)							y		

With this simple table, the basic lane configuration can be determined. The number of approach lanes as well as the number of shared and turning lanes can then be used to approximate the proportion of traffic in the curb lane. The *Canadian Capacity Guide for Signalized Intersections* provides a description of how to allocate the total approach flow to specific lanes at an intersection:

> *"Having more than one lane to choose from for the intended intersection movement, drivers tend to select the lane which has the shortest queue… Lane flow ratio can be employed as a surrogate for driver's decisions and used as the parameter underlying the allocation of the arrival flows to individual lanes."*[1]

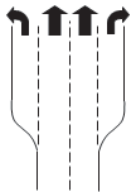
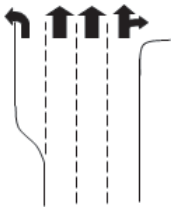
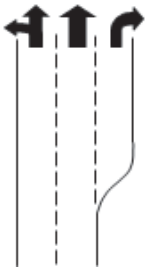
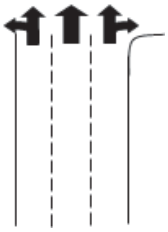
By using the appropriate saturation flow for individual lanes, an estimate of the curb lane flow can be made. The following basic saturation flows for each movement (for unobstructed flow) have been assumed:

(a) Through lanes = 1,800 pcu/h
(b) Left turn lanes = 1,650 pcu/h
(c) Right turn lanes = 1,500 pcu/h

The allocation of flow to individual lanes is then determined according to an example from the *Canadian Capacity Guide for Signalized Intersections*.

1 Canadian Capacity Guide, 3rd Edition, Canadian Institute of Transportation Engineers, 2008

There are four different scenarios to take into account when estimating the volume of main street through traffic using the curb lane:

No Shared Through & Left Turn or Through & Right Turn Lanes	
	• In this case, the flow will be equal in each through lane
No Shared Through & Left Turn, but Shared Through & Right Turn	
	• In this case, if there is more than one lane, the through traffic will “shy away” from the curb lane in a proportion based on the amount of right turns. • The saturation flow of the traffic in the shared lane is reduced, due to the turning traffic slowing to make the right turn movement.
Shared Through & Left Turn, but No Shared Through & Right Turn	
	• In this case, if there is more than one lane, the through traffic will “shy away” from the left lane in a proportion based on the amount of left turns and the availability of gaps in the opposing traffic. • The saturation flow of the left turn is reduced by the vehicles slowing to make the turning movement. It is further reduced by the volume of the opposing traffic and the number of lanes of opposing traffic.
Shared Through & Left Turn, and Shared Through & Right Turn	
	• In this case, the through traffic will “shy away” from the most congested lane in a proportion based on the amount of left turns and the availability of gaps in the opposing traffic, compared to the amount of right-turn traffic. • The saturation flow of the left turn is reduced by the vehicles slowing to make the turning movement. It is further reduced by the volume of the opposing traffic and the number of lanes of opposing traffic. • The saturation flow of the right turn traffic is reduced, due to the turning traffic slowing to make the right turn movement.

The calculation for the through traffic distribution for shared lane scenarios is determined by using the methodology found in the *Canadian Capacity Guide for Signalized Intersections, 3rd Edition,* Section 3.1.6, Flow Allocation to Lanes.

B2.3.5.2 Platoon Adjustment Factor ($RT_{platoon}$)

The estimated curb lane traffic must then be adjusted by the "platoon" factor that modifies the curb lane traffic, calculated above, by the proportion of free vehicles. Typically, the more free vehicles there are (i.e., the platoon is spread out to a more random arrival pattern), the fewer gaps there will be. The platoon factor is based on the distance (d) to the nearest upstream signal. It was assumed that, at a distance of 1,000 metres or more, platooning effects are no longer influenced by the presence of the upstream signals, and therefore display a random arrival pattern.

The Platoon Adjustment Factor ($RT_{platoon}$), which is based on the distance upstream to the nearest signalized intersection, can then be calculated as:

(a) For $d < 1{,}000$, $RT_{platoon} = [0.69+0.31(d/1{,}000)]$

(b) For $d \geq 1{,}000$, $RT_{platoon} = 1.0$

The relationship is shown in Figure B2-8.

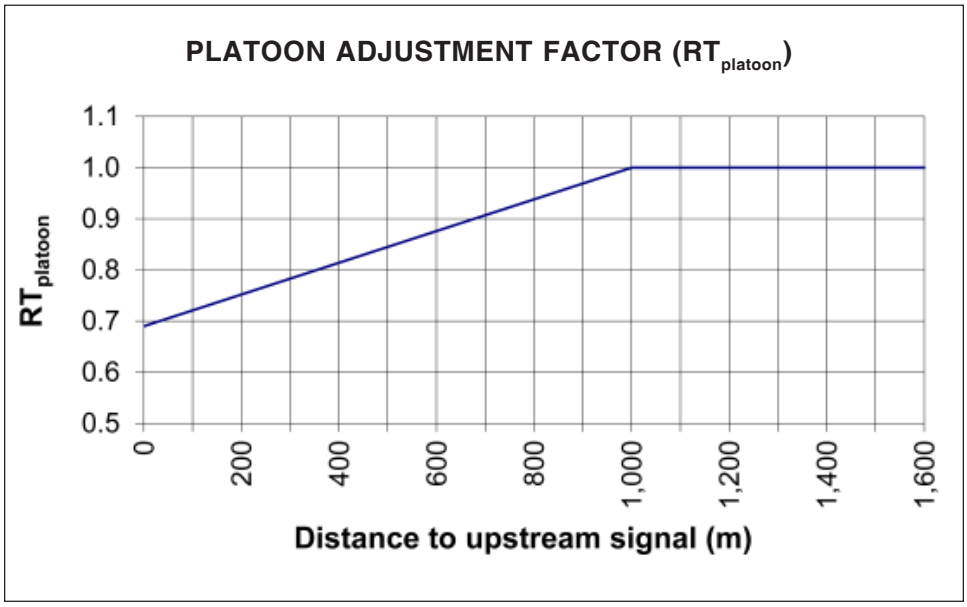


FIGURE B2-8

B2.3.5.3 Right Turn Reduction Factor (RT_{rd})

The maximum combined flow (i.e., right turns plus curb lane through traffic) is based on the typical saturation flow of 1,800 vehicles per hour of green per lane, adjusted for the 6-peak hour average, as used in the warrant calculations. Typically, the relationship between the 6-peak hour average and the peak hour is approximately 61%. Therefore, the maximum combined flow for the curb lane in these calculations is 1,100.

The Right Turn Reduction Factor can then be determined by summing the number of side street right turns (q_s) and the adjusted main street through vehicles (q_m) in the curb lane, and comparing that number to the maximum value of 1,100.

(a) if $q_{s+m} < 1{,}100$, $RT_{rd} = q_{s+m} / 1{,}100$, where:

$$q_{s+m} = q_s + q_m (RT_{platoon})$$

(b) if $q_{s+m} \geq 1{,}100$, $RT_{rd} = 1.0$

The Right Turn Reduction Factor is illustrated in Figure B2-9.

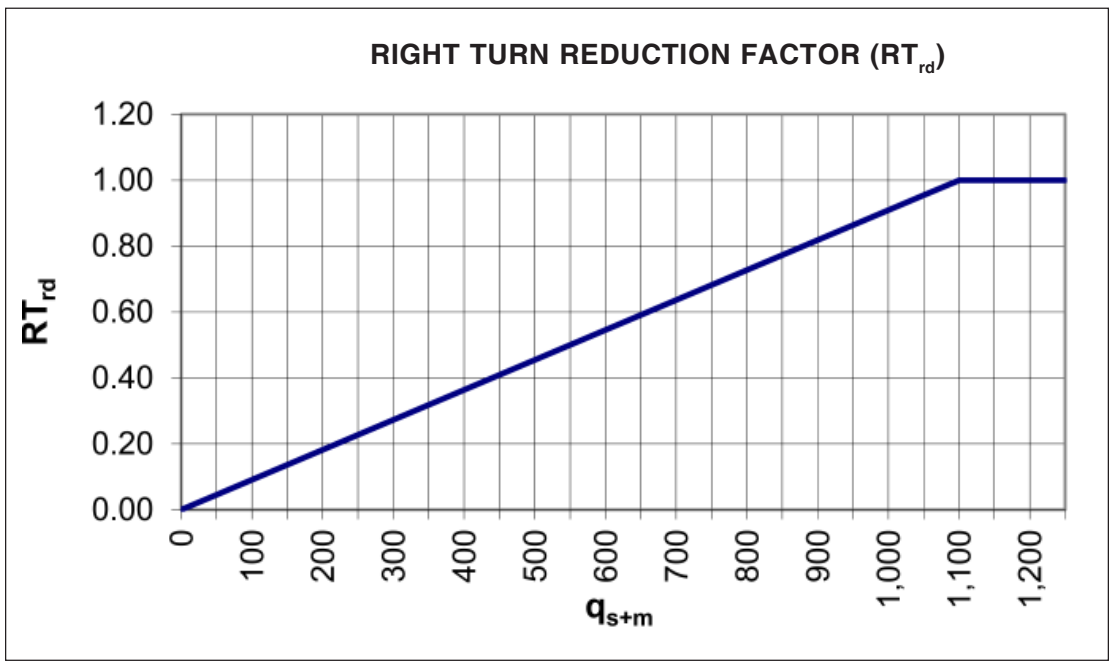


FIGURE B2-9

This value (RT_{rd}) is then used to modify the two cells in the matrix that deal with the side street right turn and main street through conflict. The adjusted matrix is then used in the warrant calculation.

B2.4 PEDESTRIAN SIGNAL HEAD WARRANT PROCEDURE

The Pedestrian Signal Head Warrant provides the practitioner with the numerical value and recommendation for the installation of pedestrian signals in conjunction with traffic signal controls. Similarly, based on the data input provided, the calculations are performed using the pedestrian signal head warrant equation:

The CFM Pedestrian Signal Head Warrant equation takes the form as shown below:

$$W_{ped} = F\left[\frac{(X_{pedm} \times d_m)}{K_2} + \frac{(X_{peds} \times d_s)}{K_3}\right]$$

F = Pedestrian demographic factor

X_{pedm} = Adjusted pedestrian - vehicle cross product for pedestrians crossing main street

X_{peds} = Adjusted pedestrian vehicle cross product for pedestrians crossing side street

d_m = Main street pedestrian crossing distance

d_s = Side street pedestrian crossing distance

K_2 = Pedestrian - vehicle denominator constant for main street

K_3 = Pedestrian - vehicle denominator constant for side street

This equation provides the practitioner with a numerical value and recommendation regarding the installation of pedestrian signal heads in conjunction with traffic control signals.

B2.4.1 Pedestrian-Vehicle Denominators (K_2 and K_3)

Determination of the pedestrian warrant denominator factors K_2 and K_3 follows the same equation format as the traffic signal warrant and are shown below:

$$K_2 = -30(d_m)^2 + 1150\ (d_m) -150$$

$$K_3 = -30(d_s)2 + 1150(d_s) -150$$

B2.4.2 Pedestrian Demographics Factor (F)

The Pedestrian Demographics Factor (F) is related to adjacent land use. It is based on the idea that, rather than using actual pedestrian counts by hours of the day and age category, a surrogate adjustment factor based on the pedestrian demographics of the area near the intersection will be easier to identify and more consistently applied. The practitioner will use judgement to determine if the demographics represent the mix of pedestrians at the intersection under analysis. The factor is subjective based on engineering judgement of the impact of the following factors on the operation of the intersection, corresponding to a maximum of:

(a) F = 1.2 if there is an elementary school in the area

(b) F = 1.2 if crosswalk is regularly used by mobility challenged pedestrians

(c) F = 1.1 if there is a seniors' centre or junior high school in the area

(d) F = 1.1 if the intersection crosswalk across the main street forms part of the "safe" walkway path to an elementary school

(e) F = 1.0 in all other case

B2.4.3 Pedestrian-Vehicle Cross Product (X_{pedm} and X_{peds})

The pedestrian-vehicle cross product begins with the raw exposure values for all pedestrian-vehicle conflict movements. A number of adjustment factors are then applied to the raw cross-product values to account for the presence of channelized right turns, the type of left turn movements, and allowable right turn on red movements.

B2.4.3.1 Channelized Right Turn Factor

If a right turn movement is channelized then the pedestrian conflict with right turning vehicles is removed from the signalized intersection and the factor is set to 0.00, representing a 100% reduction in exposure. For a non-channelized right turn movement the factor is set to 1.00, representing no reduction in exposure.

B2.4.3.2 Left Turn Factor

Certain left turn phasing will reduce the exposure of pedestrians to left turning vehicles. A permissive left turn, where crossing pedestrians are in conflict with left turn vehicles, will use a left turn factor of 1.00, representing no reduction in exposure. Protected-permissive left turn phasing where crossing pedestrians are in conflict during only the permissive phase, will use a left turn factor of 0.50, representing a reduction of 50% in exposure. A fully protected left turn phase will have a left turn factor of 0.00, representing a 100% reduction in exposure.

B2.4.3.3 Right Turn on Red Factor

The Right Turn on Red (RTOR) factor identifies whether or not a conflict is present between pedestrians and vehicles turning right on red. Where RTOR is not allowed a RTOR Factor of 0.00 will be used. If the RTOR movement is allowed, the RTOR factor is 1.00.

B2.4.3.4 Right Turn Adjustment Exposure

Adjustments are made to the right turn vehicle-pedestrian conflicts to account for the proportional amount of green time or red time in a cycle. Vehicles turning right during a green phase will conflict with a different crosswalk than the same direction turning right on a red phase. A red phase right turn conflict is multiplied by the proportional amount of red time to account for the fact that vehicles will only attempt to make a RTOR during a certain portion of the cycle. The percentage of green phase and red phase is estimated from taking each average equivalent flow per lane and determining its percentage of the total intersection flow.

The percent green time allocated to each direction is based on the maximum required for the direction. This assumes a two-phase signal and provides a general proportion of how much green time will favour a certain direction.

B2.4.4 Pedestrian Crossing Distance (d_m and d_s)

In the Pedestrian Signal Head Warrant analysis the actual crossing distance in metres is required. The crossing distance is measured from curb to curb, or curb to designated refuge area, along the path that a typical pedestrian would travel.

B2.4.5 Pedestrian Signal Head Warrant Recommendation

Pedestrian signal heads are recommended for installation if the warrant score equals or exceeds the 100 point threshold value. There are a few circumstances where the warrant value will be calculated but is over-ridden by other factors including:

(a) Minimum pedestrian activity;

(b) Actuated signal operation;

(c) Wide crossing distance; and

(d) Complex signal phasing.

B2.4.5.1 Minimum Pedestrian Activity Threshold

In some cases, pedestrian activity may be very low and it is useful to highlight where activity is below a set minimum value. The pedestrian signal warrant value will be valid under the following pedestrian conditions:

(a) The north-south or east-west pedestrian average hourly volume (over six hours) exceeds 25; or

(b) The north-south or east-west pedestrian volume in any given hour exceeds 100.

If neither of these conditions is met, the pedestrian signal heads are not warranted.

B2.4.5.2 Actuated Controller and Pedestrian Crossing Distance

Another matter that confronts pedestrians at signalized intersections is the issue of crossing distance under traffic responsive operation. A fixed time signal has a high degree of predictability in terms of timing and signal phasing. An actuated signal has far less predictability, and thus the guarantee of adequate pedestrian crossing opportunity and crossing time is similarly far less. At an actuated signal a pedestrian may not have sufficient crossing time if the desired green phase is triggered by a single vehicle presence. In these situations where side street green is actuated, and pedestrians are present, the pedestrian signal head warrant is met and pedestrian signal heads and push buttons should be employed to provide pedestrian crossing time.

B2.4.5.3 Signal Phasing Complexity

Signal phasing complexity adds another element of uncertainty for pedestrians. Signal complexity relates to the number of different phases, especially phases designed to accommodate left turning movements. A two phase, fixed time signal has a high degree of predictability in terms of phase sequence, phase times, and pedestrian crossing opportunities. A complex, actuated signal has far less predictability. In situations where phasing is complex, and the timing plan has one or more phases to manage left turns, the pedestrian signal head warrant is met and pedestrian signal heads should be employed. Pedestrian push buttons should be employed where necessary to provide pedestrian crossing time.

B2.5 DATA COLLECTION REQUIREMENTS

Data collection requirements for the Canadian Traffic Signal and Pedestrian Signal Head Matrix Warrant Procedure are not exhaustive and within the scope of most road jurisdictions' traffic data collection processes. The input requirements fall into the following categories:

(a) Intersection identification and orientation

(b) Roadway conditions (lane configurations and designations, pedestrian crossing distances)

(c) Proposed signal control (fixed time/actuated, phasing)

(d) Pedestrian and location demographics

(e) Traffic conditions (6 peak hour turning movement counts, vehicle and pedestrian characteristics)

(f) Control conditions (speed limit, turn restrictions)

(g) Transit routes

The complete input form from Canadian Traffic Signal and Pedestrian Signal Head Matrix Warrant Procedure is shown in Figure B2-10.

Main Street (name)	Main	Direction (EW or NS)	NS	Road Authority:	AT
Side Street (name)	Side	Direction (EW or NS)	[redacted]	City:	COC
Quadrant / Int #	sw	Comments		Analysis Date:	2012 Dec 15, Sat
for Warrant Calculation Results, please hit 'Page Down'	CHECK SHEET			Count Date:	2012 Jan 29, Sun
				Date Entry Format:	[redacted]

Lane Configuration		Excl LT	Th & LT	Through	Th+RT+LT	Th & RT	Excl RT	RT Channelization (y/n)	UpStream Signal (m)	# of Thru Lanes	LT Phase Type	RTOR Allowed (y/n)	Actuated Thru Phase	[redacted]	Saturation Flow Rates (if not default) (vphpl)		Default Saturation Flow Rates (vphpl)
[redacted]	[redacted]		1	1		1		n	220	[redacted]	perm	y	y	[redacted]	[redacted]		[redacted]
[redacted]	[redacted]		1	1		1		n	220	[redacted]	perm	y	y	[redacted]	[redacted]	1,950	[redacted]
[redacted]	[redacted]				1			n	110	[redacted]	perm	y	y	[redacted]	[redacted]		[redacted]
[redacted]	[redacted]	1				1		n	110	[redacted]	perm	y	y	[redacted]	[redacted]		[redacted]
[redacted]	WB right turns significantly impeded by through movements? (y/n)						y							[redacted]			[redacted]
	Are the Side EB right turns significantly impeded by through movements? (y/n)						y							Demographics			[redacted]
	Are the Main NB right turns significantly impeded by through movements? (y/n)						n							Elem. School/Mobility Challenged	[redacted]	n	
	Are the Main SB right turns significantly impeded by through movements? (y/n)						n							Senior's Complex	[redacted]	n	
														Pathway to School	[redacted]	n	
Other input		Speed	Truck	Bus Rt	Median									Metro Area Population	[redacted]	120,000	
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]									Central Business District	[redacted]	y	
[redacted]	[redacted]	50	5.0%	y	2.0												
[redacted]	[redacted]	[redacted]	2.0%	n	0.0												
Set Peak Hours														[redacted]			

Traffic Input	NB			SB			WB			EB			NS	NS	EW	EW
	LT	Th	RT	LT	Th	RT	LT	Th	RT	LT	Th	RT	W Side	E Side	N Side	S Side
7:00 - 8:00	35	120	55	15	55	12	123	456	111	154	543	222	12	45	34	23
8:00 - 9:00	35	120	55	15	55	12	123	456	111	154	543	222	12	45	34	23
11:30 - 12:30	35	120	55	15	55	12	123	456	111	154	543	222	12	45	34	23
12:30 - 13:30	35	120	55	15	55	12	123	456	111	154	543	222	12	45	34	23
16:00 - 17:00	35	120	55	15	55	12	123	456	111	154	543	222	12	45	34	23
17:00 - 18:00	35	120	55	15	55	12	123	456	111	154	543	222	12	45	34	23
Total (6-hour peak)	210	720	330	90	330	72	738	2,736	666	924	3,258	1,332	72	270	204	138
Average (6-hour peak)	35	120	55	15	55	12	123	456	111	154	543	222	12	45	34	23
												Actual Pedestrian Crossing Distance (m)	22.0	22.0	16.0	16.0

FIGURE B2-10