Pedestrian Signal Head Warrant Project

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Paper prepared for presentation
at the “Traffic Improvements to Make Active Transportation More Efficient and Safer for Everyone” Session

of the 2013 Conference of the
Transportation Association of Canada
Winnipeg, Manitoba

ABSTRACT

The Traffic Operations and Management Standing Committee (TOMSC) of the Transportation Association of Canada (TAC) wanted to develop a national warrant for adding pedestrian signals to existing traffic signals or to determine whether pedestrian heads should be included for new signal installations.

This paper discusses the development of that national warrant and consists of three components: (1) an environmental scan; (2) the warrant methodology process; and (3) updating the Manual of Uniform Traffic Control Devices and Traffic Signal Warrant (TSW) user handbook.

This environmental scan comprises two elements: (1) a comprehensive review of literature on existing international warrants practices and a review of policies, by-laws and municipal initiatives for pedestrian warrants; and (2) extensive jurisdictional survey on current pedestrian signal head warrant practices.

The warrant methodology is based on a 'cumulative factors method' that results in a point score that takes into account pedestrian volumes, pedestrian-vehicle conflict, pedestrian demographics, signal operations, and crossing distance. Parameters used in the warrant calculation are based on the environmental scan, the traffic signal warrant, and recommendations from the project steering committee and the consulting team.

The existing TSW handbook is updated to provide traffic operations practitioners with instructions on how to use the pedestrian signal head warrant matrix in a consistent and comprehensive way. The handbook identifies the input data required for the warrant analysis and describes how each of the warrant components is calculated. Important notes, additional information or warnings are also provided in support of specific considerations.

Introduction

The installation of pedestrian signal heads is an important element of a traffic signal installation. However, for some traffic signal installations across Canada, pedestrian signal heads were not included in the initial signal construction program. As a result, the Traffic Operations and Management Standing Committee (TOMSC) of the Transportation Association of Canada (TAC) wants to develop a national warrant for adding pedestrian signals to existing traffic signals or to determine whether pedestrian heads should be included for new signal installation.

The major objective of the project was to develop a national warrant for adding pedestrian signals to intersections with existing vehicular signals.

This paper includes a description of the environmental scan, including the literature review and the jurisdictional survey that were conducted at the initial part of the study. The paper then describes the development of the methodology that forms the basis for the pedestrian signal head warrant calculation, and a description of how the pedestrian signal head warrant was integrated with the traffic signal warrant to produce a single procedure for the warrant of traffic signals, as well as the warrant for whether the traffic signals should include pedestrian signals.

Environmental Scan

Before the work commenced on developing a new warrant procedure, it was important to gather information on current practices and local warrants from many road authorities in Canada. Similarly, it was important to glean from literature other pedestrian signal head warrants used in the United States, Europe, Australia, and New Zealand.

This environmental scan comprises two elements: (1) a comprehensive review of literature on existing international warrants practices and a review of policies, by-laws and municipal initiatives for pedestrian warrants; and (2) extensive jurisdictional survey on current pedestrian signal head warrant practices.

The purpose of the literature review was to identify and review existing pedestrian signal head warrants already implemented in North America and innovative approaches used internationally. The literature review also provided in-depth information regarding policies, legislation, and regulations associated with pedestrian crossings at intersections. The purpose of the survey was to review and understand practices regarding the provision of pedestrian signals across Canada. The survey results support and augment the findings from the literature review.

Literature Review

Research Methodology

A comprehensive search of literature published in the last 20 years in engineering periodicals and journals, conference proceedings, and documents on the World Wide Web, was undertaken. Key examples of these source agencies are:

- Transportation Association of Canada (TAC)
- Institute of Transportation Engineers (ITE)
- Transportation Research Board (TRB)
- Transportation Research Information System (TRIS)
- National Cooperative Highway Research Program (NCHRP)
- US Federal Highway Administration (FHWA)
- Australian Transport Research Forum
- Institute for Transport Studies
- UK Department for Transport
- NSW Roads and Traffic Authority (RTA)
- Austroads

The literature review addressed the following topics:

- Existing warrants overview
- Pedestrian signal head warrant primary factors
- Pedestrian demographics factors
- Safety factors
- Roadway and signal characterises factors

Literature Review Findings

The literature identified key factors that may be considered for pedestrian signal head warrants as shown in Table 1 [1]. An overview of exiting warrants in Canada, United States, Australia, United Kingdom, and South Africa identified the most prominent pedestrian warranting factors as: pedestrian volume, pedestrian composition/demographics, vehicular volume, and proximity to nearest traffic signal. The literature research review found that the minimum pedestrian threshold for warranting pedestrian signal installation varied significantly even within the same country. Table 2 shows a summary of the minimum pedestrian thresholds.

Table 1: Pedestrian Warranting Factors

Warranting Factors	Canada	USA	UK	Australia	South Africa
Pedestrian Volume	X	X	X	X	X
Vehicle Gap Availability	X	X			
Vehicle Speed	X		X		X
Nearest Traffic Signal	X	X	X	X	
Vehicle Progression	X	X		X	
Nearest Crosswalk				X	
Adjacent Land Use			X		
Crash Experience	X		X	X	
Roadway Cross Section			X		X
Roadway Class			X		
Walking Speed		X	X		
Pedestrian Peak Hour Delay			X		
Pedestrian Composition		X	X	X	X
Vehicle Delay	X		X	X	
Vehicle Volume	X		X	X	X
Latent Demand (Vehicle)	X				

Table 2: Minimum Pedestrian Threshold Summary

Warrant	Minimum Threshold
Montreal Pedestrian Countdown Signal Guide – Canada [2]	The minimum number of pedestrians on one of the two crossing directions under analysis is larger than 30 pedestrians/ hour during 2 hours of the same day, or 50 pedestrians/ hour or more during 1 hour
Quebec Ministry of Transportation – Canada	80 pedestrians/ hour for 3 consecutive hours OR 90 pedestrians/ hour for 2 consecutive hours OR 110 pedestrians/ hour for any given hour
MUTCD Pedestrian Volume Warrant – US [3]	The pedestrian volume crossing the major street at an intersection or mid-block location during an average day is 100 or more for each of any 4 hours or 190 or more during 1 hour.
City of Boulder Pedestrian Crossing Treatment Warrant – US [4]	At least 100 pedestrians per hour for any one (peak) hour or 50 pedestrians per hour for any 4 hours, unless the crossing is on a designated multi-use path, bike corridors, or transit access
City of Redmond – US [5]	80 pedestrians per hour for any 4 hours or 152 pedestrian per hour for any 1 (peak) hour
New South Wales Pedestrian Warrant – Australia [6]	>600 vehicles/hour on the major road as well as the pedestrian flow >150 persons/hour expected to cross the major road
Victoria Pedestrian Warrant – Australia [7]	number of pedestrians crossing within 20m of the proposed site exceeds 100 persons/hour, and the number of vehicles which pedestrians have to cross exceeds 500 vehicles/hour on an undivided road, or 1,000 vehicles/hour where there is a median or pedestrian refuge
South African Road Traffic Signs Manual – South Africa [8]	pedestrian volume crossing the particular approach multiplied by the volume of conflicting turning traffic exceeds 10,000 in any 1 hour, or 5,000 for each of any 4 hours of a day

Pedestrian walking speeds were found to be consistently ranging from 0.8 m/s to 1.3 m/s with lower speeds applied at crossings with large number of children, seniors, and/or pedestrian with disabilities.

Jurisdictional Survey

Methodology & Screening

A total of 41 jurisdictions were contacted for this survey to identify Canadian experience with pedestrian signal installation and existing warrant methodology. The survey questionnaire consisted of 22 questions which took one of two forms: multiple-choice or text boxes with an expected time of completion of 30 minutes. The survey covered the following six topics: (1) introduction to the jurisdiction, (2) guidelines, policy and legislative requirements, (3) traffic engineering factors, (4) safety, (5) physical factors, and (6) traffic signal operations. Table 3 shows details of the information collected under each of the topics

Table 3: General Survey Topics and Information of Interest

General Topic	Information of Interest in the Survey
Introduction to Jurisdiction	• Contact information • Population of local jurisdiction
Policy and Legislative Requirements	• Installation of pedestrian display signals as a standard with new traffic signals • The presence of a policy on the installation of pedestrian display signals
Traffic Engineering Factors	• The factors considered for the installation of pedestrian signal either through formal warrants or informal rule of thumb • Pedestrian volume threshold requirements • Minimum level of conflicting vehicle volume • The presence of cyclists, heavy vehicles, and buses • Pedestrian crossing opportunities • Design pedestrian walking speed • Pedestrian demographics and special facilities
Safety	• Safety factors • Collision history • Bicycle traffic conformation
Physical Factors	• Physical geometry at crossing location • Presence of center median
Traffic Signal Operations	• Traffic signal operating elements • Accessible pedestrian and/or countdown signals • Staged crossing

In total, 17 responses from 8 provinces were received. Upon receiving the survey data, it was noted that not all responses were complete which was in part due to the fact that many jurisdictions indicated the automatic installation of pedestrian signals as part of signalizing an intersection. All city authorities that responded to this survey have indicated that they install pedestrian display signals as a standard with new traffic signals; most of which also don't have any other policy or guideline with respect to pedestrian signal installation. To ensure the validity of the analysis and results, two response categories were removed from the dataset: (1) those that provided minimal information, and (2) those which have indicated that their jurisdiction doesn't have a policy or guideline with respect to the installation of pedestrian signals

Survey Analysis

Traffic authorities were asked to indicate if their jurisdictions consider certain input variables through either a formal warrant system or through an informal 'rules of thumb' when considering the use of pedestrian display signals. They were also asked to identify variables that they think would be beneficial and feasible to consider in the future installation of a pedestrian signal at a signalized intersection and rate the importance of the factor in determining the need for the pedestrian signal.

The analysis of these factors was based on the responses received and validated. Table 4 illustrates the following key points:

- The percentage of responders who consider the input variable through a formal warrant process (1)
- The percentage of responders who consider the input variable through an informal 'rules of thumb' process (2)
- The percentage of responders who identified the input variable to be considered in future warrants (3)
- The percentage of responders who have identified that they consider the input variable in some way and/or that the variable should be considered in the future (4)
- The average rating based only on those responders who provided a rating (5)
- A modified rate which takes into account both the average rate (5) and the percentage of responders who identified the input variable (4)

Table 4: Pedestrian Signal Head Warrant Input Variables

Input Variable	# of Responders	Considered through formal warrants (1)	Considered through informal rule of thumb (2)	Beneficial and feasible to consider in future (3)	% Responders (4)	Rating 1 - High, 2 - Medium, 3 – Low (5)	Modified Rate
Pedestrian volume	12	58.3%	16.7%	41.7%	100.0%	1.11	1.11
Vehicular traffic volume	11	50.0%	16.7%	33.3%	91.7%	1.44	1.58
Collision history	9	33.3%	16.7%	33.3%	75.0%	1.33	1.78
Pedestrian crossing distance	10	25.0%	25.0%	50.0%	83.3%	1.50	1.80
Crossing opportunities or gaps	11	16.7%	41.7%	50.0%	91.7%	1.67	1.82
Proximity to alternate crossing	11	41.7%	8.3%	50.0%	91.7%	1.89	2.06
Pedestrian demographics	10	25.0%	25.0%	50.0%	83.3%	1.75	2.10
Vehicular traffic speed	8	25.0%	25.0%	25.0%	66.7%	1.50	2.25
Pedestrian traffic generators	10	16.7%	33.3%	50.0%	83.3%	1.88	2.25
Number of travel lanes	9	33.3%	25.0%	33.3%	75.0%	1.71	2.29
Adjacent land use	9	16.7%	33.3%	41.7%	75.0%	1.71	2.29
Pedestrian walking speed	9	25.0%	8.3%	50.0%	75.0%	1.75	2.33
Pedestrian delay	9	16.7%	16.7%	50.0%	75.0%	2.00	2.67
Presence of transit service	7	8.3%	25.0%	33.3%	58.3%	1.71	2.94
Vehicular conflicts in crossing	8	8.3%	25.0%	41.7%	66.7%	2.00	3.00
Presence of bike regional pathway	6	0.0%	41.7%	25.0%	50.0%	1.83	3.67
Size of the pedestrian refuge area	7	0.0%	41.7%	25.0%	58.3%	2.33	4.00
Presence of bike lanes	6	8.3%	25.0%	25.0%	50.0%	2.17	4.33
Community population	6	16.7%	25.0%	25.0%	50.0%	2.17	4.33
Weather conditions	6	8.3%	16.7%	25.0%	50.0%	2.67	5.33
Expected motorist compliance	5	8.3%	16.7%	25.0%	41.7%	2.67	6.40

Figure 1 shows the total percentage of responders who consider each input variable (by formal or informal means) in the installation of pedestrian signals.

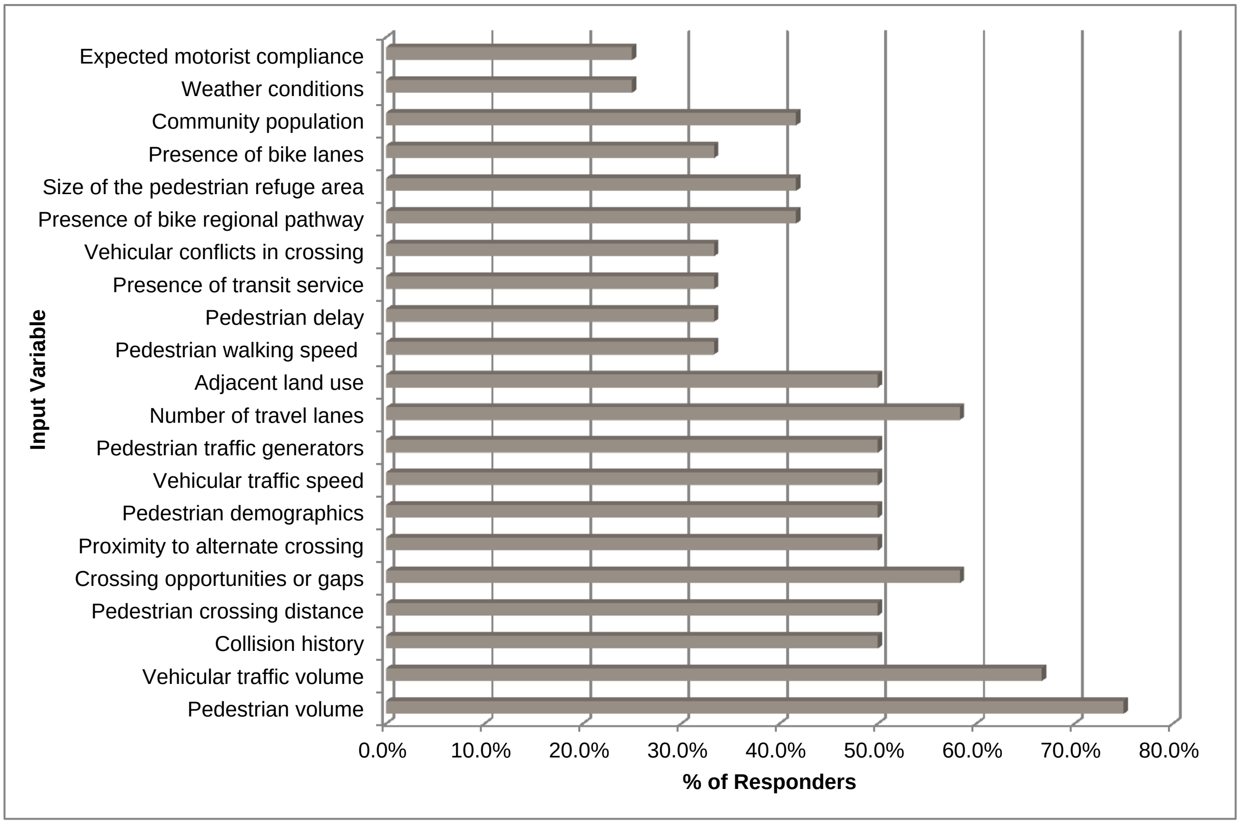


Figure 1: Variables Considered Through Formal or Informal Warrants

The top four variables identified were: pedestrian volume, vehicular traffic volume, collision history, and pedestrian crossing distance. More than half the jurisdictions have identified that they consider the following variables though formal or informal warrants: pedestrian volume, vehicular traffic volume, crossing opportunities or gaps, and the number of travel lanes.

Jurisdictions were also asked to specifically identify whether they consider the following when installing a pedestrian signal:

- Minimum level of conflicting vehicle volume within a prescribed time period
- The presence of cyclists, heavy vehicles, and buses
- Special pedestrian demographic segments that may warrant pedestrian signal displays regardless of any other factor (i.e. visually or mobility challenged, seniors, school children)
- Special facilities or locations that warrant pedestrian signal displays irrelevant of any other factor (i.e. transit facilities)
- Safety factors or measures
- Bicycle traffic conformation of the rules of the road
- The presence of a center median

Only the jurisdictions that indicated they have a policy or guideline for the installation of pedestrian signals were considered in this portion of the analysis. Figure 2 illustrates the pedestrian signal factors which were considered by jurisdictions in their installation procedure. The two factors regarded in the pedestrian signal installation by more than half the responders were pedestrian demographics and safety.

Average pedestrian walking speeds varied in jurisdictions and ranged from 1.0 m/s to 1.5 m/s, with many jurisdictions using the rate of 1.2 m/s. Four of the jurisdictions also indicated that they use lower speeds ranging between 0.9 m/s and 1.0 m/s for crossings frequented by seniors, children, and pedestrians with disability.

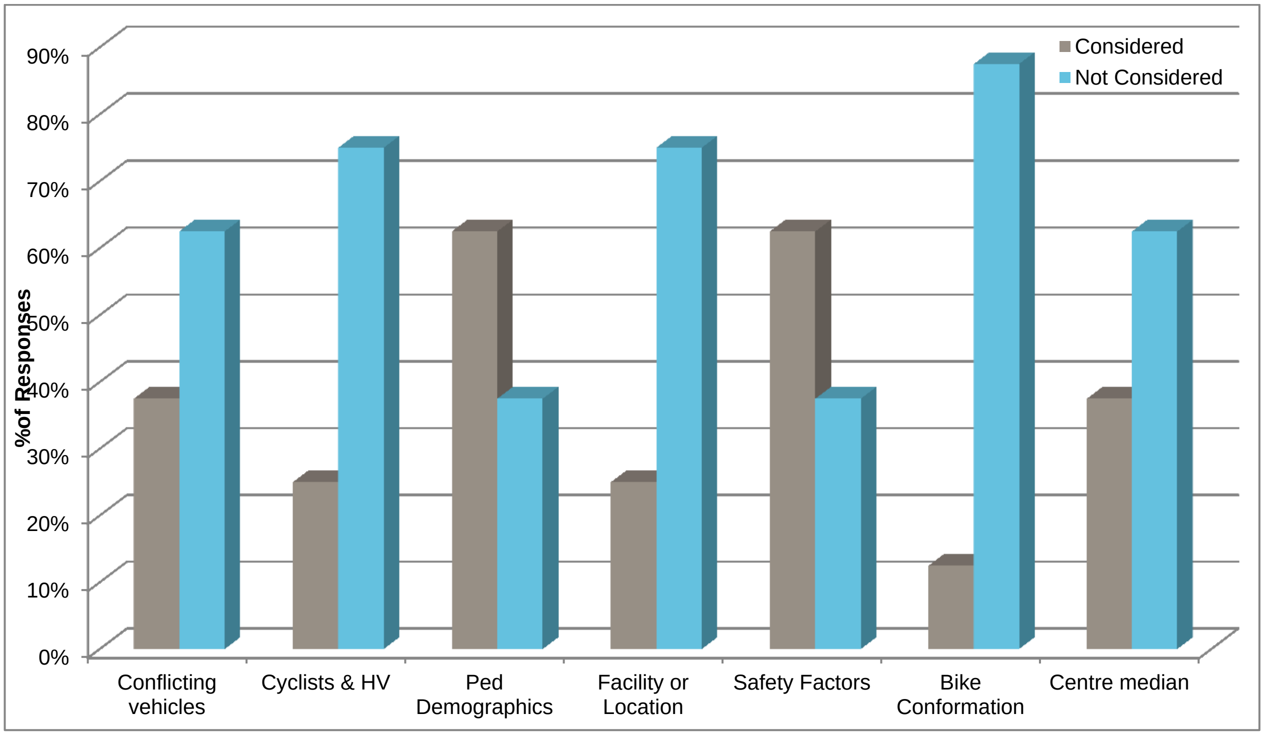


Figure 2: Factors Consideration in Pedestrian Signal Installation

Warrant Methodology Development

The development of the Pedestrian Signal Head Warrant (PSW) methodology was based on the factors in the Traffic Signal Warrant (TSW) methodology and the results of the environmental scan. The guiding principles for the PSW were determined to be as follows:

- The methodology should be a cumulative points warrant based on conflicting movements
- The methodology should be based on the Traffic Signal Warrant (TSW) methodology, as the inputs are very similar
- The methodology should consider:
    - Pedestrian volumes (with a minimum threshold)
    - Vehicle volumes (of conflicting movements)
    - Pedestrian demographics
    - Pedestrian crossing distance
    - Proximity to the nearest traffic signal (alternate crossing opportunity)
- Intersection configuration is a key consideration (right and left turn bays add crossing distance, but eliminate some conflicts
- The complexity of signal phasing as it dictates where conflicts exist and where they don’t
- Crossing distance at actuated signals, as it requires pedestrians to have an adequate amount of time to cross

Pedestrian Signal Head Warrant Calculations

PSW Equation Form

The proposed PSW procedure was based on the cross-product relationship of the vehicle-pedestrian conflict present at signalized intersections. Figure 3 is provided for discussion purposes and to identify the vehicle-pedestrian conflict points considered in the cross-product. The cross-product relationship was modified to account for local factors such as pedestrian demographics and roadway characteristics.

The warrant parameters and their application through the cross product methodology form a surrogate approach for the relative measure of pedestrian safety

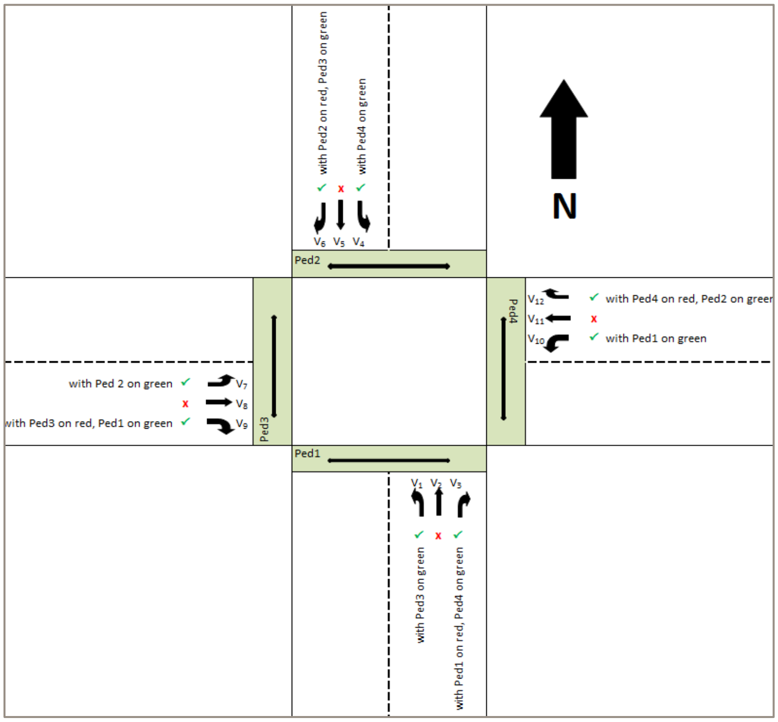


Figure 3: Sample Intersection Diagram

The methodology built upon the existing Traffic Signal Matrix Warrant Procedure, using many of the same inputs. A few additional inputs were required in order to accurately assess the pedestrian signal head warrant, and the Traffic Signal Matrix Warrant spreadsheet has been updated to allow for these inputs.

Essentially, the raw exposure created by pedestrian crossings and related conflicting vehicle movements was adjusted to account for the presence of protected turn movements such as a protected left turn phase or a channelized right turn. The exposure cross-product was further adjusted to account for the absence or presence of Right Turn on Red movements. This final adjusted cross-product was then modified to account for pedestrian demographics and relevant roadway characteristics to produce a 100-point based warrant value, using the following equation:

$$\mathbf{W_{ped} = \sum_{i\text{-}j} (F(X_{ped})\, L) \,/\, K_3}$$

Where:

F = pedestrian demographics factor

$\mathbf{X_{ped}}$ **=** adjusted pedestrian x vehicle cross product *

L = total number of lanes (or distance) crossed by the pedestrian
K_3 = Pedestrian signal head warrant denominator constant

Model Calibration

A trial calibration of the model was undertaken for three distinct scenarios, each involving the adjustment of the K_3 value. This same approach was taken in the TSW model. The selected K_3 values tested were:

- K_3 = 1,000
- K_3 = K_2 (K_2 = vehicle / pedestrian denominator constant from the TSW)
- K_3 = K_2 /0.3

Using the relevant data from the various jurisdictions noted above, the different values were tested for the pedestrian denominator factor. Initially, a value of 1,000 was tried to get a sense of what the results looked like with the 100 point value as the target for a warrant score. With that value in the equation, most of the intersections warranted pedestrian signals (the warrant value was over 100 in 30 of 37 relevant data sets).

The second attempt was to use a value for K_3 equal to K_2 divided by 0.3, where K_2 is based on the number of lanes on the main street, as noted in the diagram and the value of 30% was used in the original traffic signal warrant for the amount of influence the pedestrians would have on the overall traffic signal warrant score. This value resulted in almost none of the intersection warranting pedestrian signals (the warrant value was over 100 points in only 9 of the 37 relevant data sets).

The third attempt was to use a value for K_3 equal to K_2, where K_2 is based on the number of lanes on the main street, as noted in the diagram. Using this value, it was found that 16 of the 37 relevant data sets warranted pedestrian signals, which was deemed to be an acceptable result. Therefore the revised equation for the pedestrian denominator (as also shown in Figure 4) was found to be:

$$\mathbf{K_3 = -30L^2 + 1150L - 150} \text{ (TSW Procedure)}$$

Where:

L = total number of lanes (or distance) crossed by the pedestrian

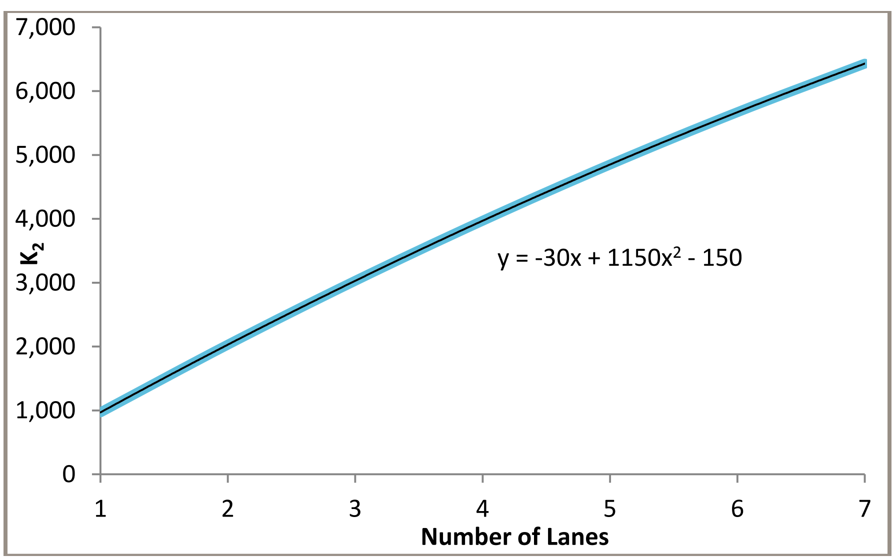


Figure 4: Pedestrian Warrant K_2 Values

Modified Form of Equation

When examining the results of the warrant calculations, another issue came to the forefront. Whereas the traffic signal warrant calculation used the K_2 constant, it was based on the number of lanes on the main street to cross, and did not take into account the width of the side street. For the PSW calculation, it was determined that the formula should be split into two segments using a different value of K_3 for the pedestrians crossing the main street and for those crossing the side street. The equation then becomes:

$$\mathbf{W_{ped} = \sum_{i\text{-}j} [F((X_{pedm})\, d_m) / K_2 + ((X_{peds})\, d_s) / K_3)]}$$

Where:

F = pedestrian demographics factor
X_{pedm} =adjusted pedestrian x vehicle cross product (pedestrians crossing main street)
X_{peds} =adjusted pedestrian x vehicle cross product (pedestrians crossing side street)
d_m = main street distance crossed by the pedestrian
d_s = side street distance crossed by the pedestrian
K_2 = Pedestrian signal head warrant denominator constant for main street
K_3 = Pedestrian signal head warrant denominator constant for side street

Warrant Exceptions

One issue that became apparent through the course of the warrant consideration was the issue of crossing distance and signal phasing complexity. Signal complexity relates to the degree or lack of signal phasing consistency. A fixed time signal has a high degree of predictability in terms of timing and preceding / following signal phasing displays. An actuated signal has far less predictability and thus predictability of sufficient pedestrian walk time or even walking opportunity is similarly far less.

As was noted, in an actuated signal operation, a pedestrian may not have sufficient time to cross the street on the green indication. While it is still of value to provide the pedestrian signal head warrant value for locations having side-street actuation, it will also be noted in the results box that there may be insufficient green time for pedestrians to cross a main street over 4 lane widths. This logic was added to the warrant analysis, resulting in a statement on the summary page that pedestrian signals are warranted in this case (no matter what value is calculated).

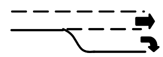
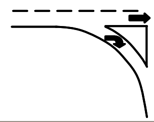
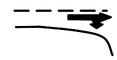
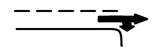
Similarly, traffic signals having multiple phases add a degree of complexity for the pedestrians in terms of their crossing decision as the observed sequencing and timing can appear to be random to the pedestrian; and thus affects the pedestrian crossing judgement. This logic was also added to the warrant analysis, resulting in a statement on the summary page that pedestrian signals are warranted in the case a signal has more than 3 phases (no matter what value is calculated).

Pedestrian Signal Head Warrant Excel Worksheet

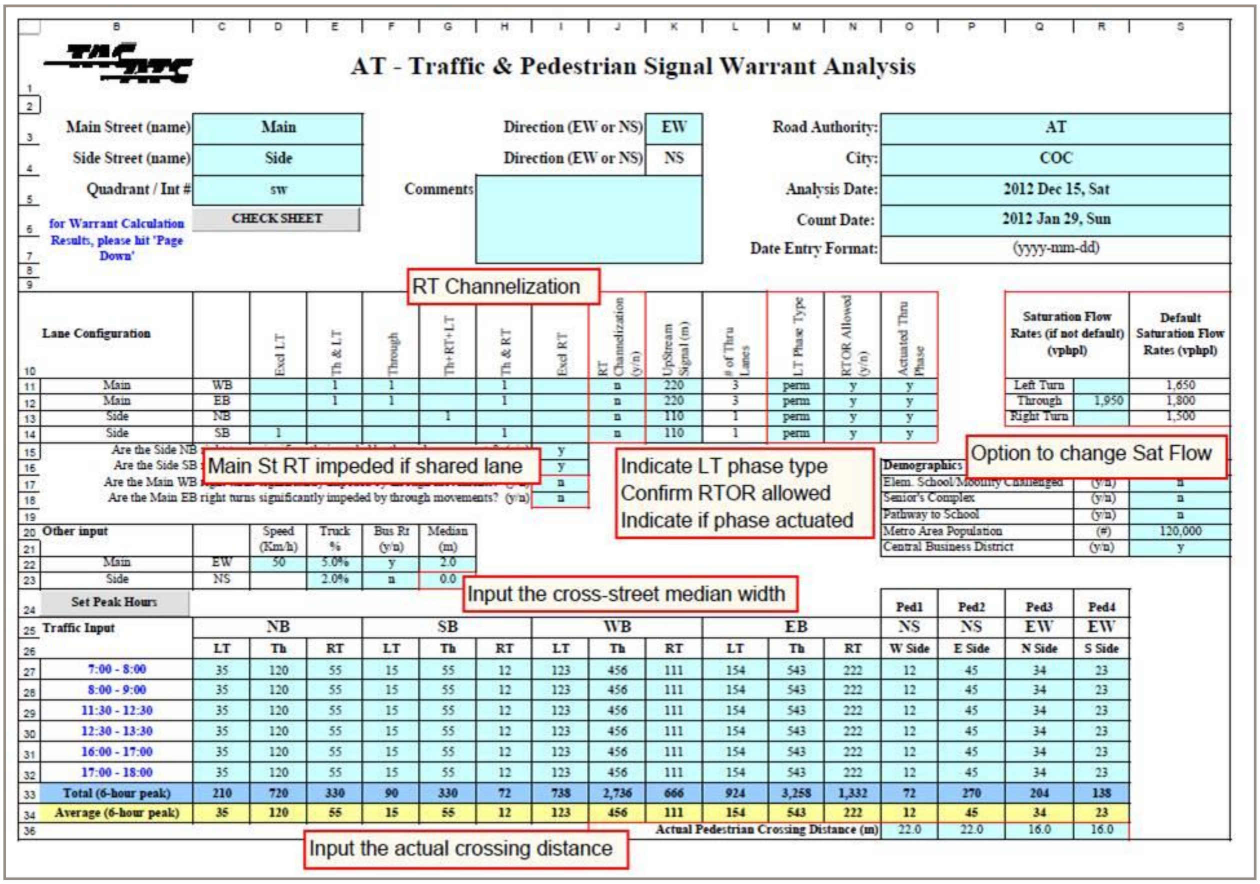
'Data Entry and Summary' Worksheet Modifications

The input data that was needed for a comprehensive pedestrian signal head warrant were very similar to those required for the existing traffic signal warrant. Specifically, cells have been added to the lane configuration tables to identify: Right Turn (RT) channelization; Left Turn (LT) Phasing; whether Right Turn on Red (RTOR) is allowed; and to indicate which phases are actuated.

In identifying right turn channelization (as shown below), some engineering judgement may be required for right turn curbed islands, and tapered right turns, some to determine if the lane configuration should be coded as "Exclusive Right Turn" or as a "Through+RT" lane.

	Right turn lane	Raised curb island	Tapered lane	No right turn treatment
				
Exclusive right turn in lane configuration Input?	Yes; code as an Exclusive Right Turn Lane	Apply engineering judgement; Are right turn movement typically impeded by through movements during the study period? If yes, code as a shared Through + Right Turn lane. If no, code as an Exclusive right turn		No; code as a shared Through+Right Turn lane

Data elements were also added to indicate if Right Turns are impeded by the through traffic on the main street in the case of shared lanes. Median width of the side street was not needed in the traffic signal warrant, but is required for the pedestrian analysis and was also added. The traffic signal warrant also used the number of lanes to “estimate” the street width. For pedestrian analysis, a more accurate value is needed and as such, the actual crossing distance has been incorporated to the input form. The additional input requirements are shown in Figure 5.



Main Street (name)	Main	Direction (EW or NS)	EW
Side Street (name)	Side	Direction (EW or NS)	NS
Quadrant / Int #	sw	Comments	
for Warrant Calculation Results, please hit 'Page Down'	CHECK SHEET		

Road Authority:	AT
City:	COC
Analysis Date:	2012 Dec 15, Sat
Count Date:	2012 Jan 29, Sun
Date Entry Format:	(yyyy-mm-dd)

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
Main	WB		1	1		1		n	220	3	perm	y	y
Main	EB		1	1		1		n	220	3	perm	y	y
Side	NB				1			n	110	1	perm	y	y
Side	SB	1				1		n	110	1	perm	y	y

	Saturation Flow Rates (if not default) (vphpl)	Default Saturation Flow Rates (vphpl)
Left Turn		1,650
Through	1,950	1,800
Right Turn		1,500

Are the Side NB	y
Are the Side SB	y
Are the Main WB	n
Are the Main EB right turns significantly impeded by through movements? (y/n)	n

Other input		Speed (Km/h)	Truck %	Bus Rt (y/n)	Median (m)
Main	EW	50	5.0%	y	2.0
Side	NS		2.0%	n	0.0

Demographics		
Elem. School/Mobility Challenged	(y/n)	n
Senior's Complex	(y/n)	n
Pathway to School	(y/n)	n
Metro Area Population	(#)	120,000
Central Business District	(y/n)	y

Set Peak Hours

Traffic Input	NB			SB			WB			EB			Ped1 NS	Ped2 NS	Ped3 EW	Ped4 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 5: Input Modifications to the Traffic Signal Warrant Spreadsheet

The output section of the warrant spreadsheet was also slightly modified to show the volume of pedestrians crossing the side streets, and of course, the pedestrian warrant calculation itself has been added to provide the user with a warrant value (whether or not pedestrian signals are warranted) for prioritization purposes. The comment box identifies the results of the analysis, and indicates if pedestrian signals are warranted or not with related comments. The added output features are highlighted in Figure 6.

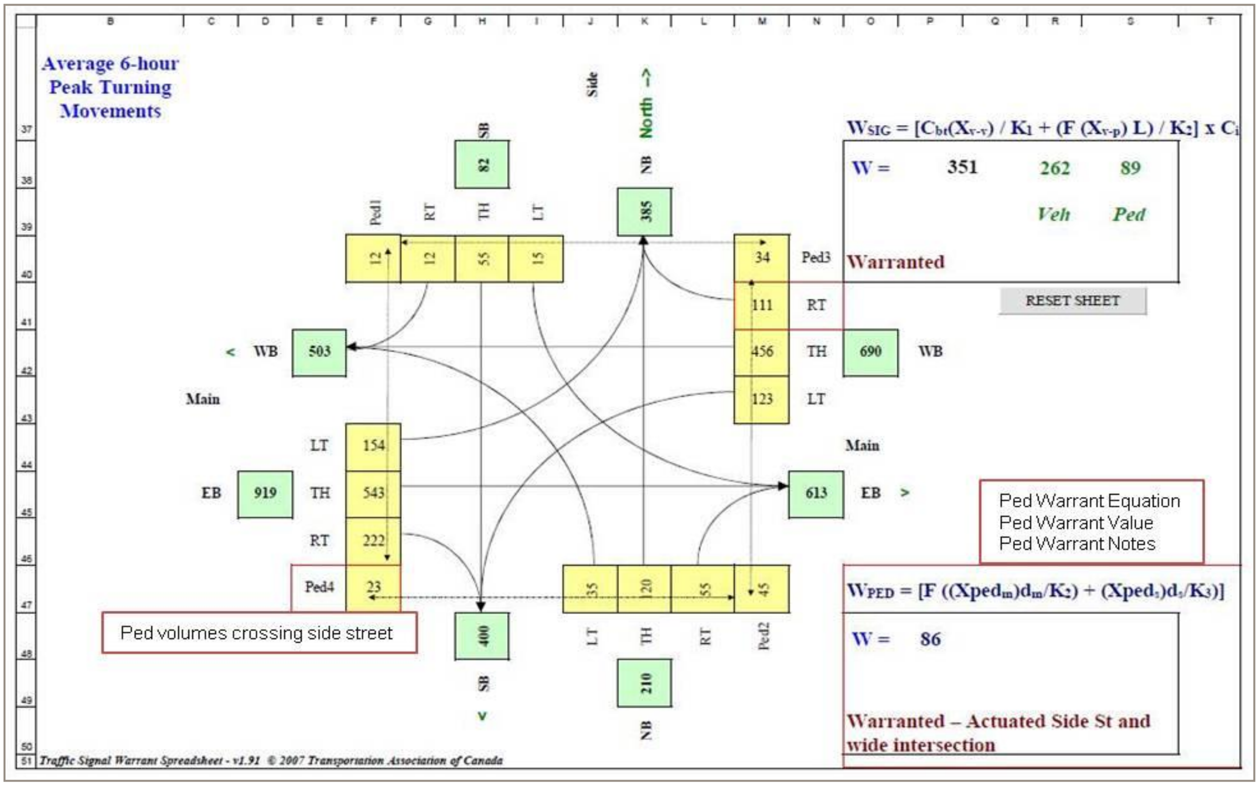


Figure 6: Output Modifications to the Traffic Signal Warrant Spreadsheet

'Formula and Calculations' Worksheet Modifications

A table was added to the worksheet to account for the approximate green and red time proportions for N/S and E/W approaches. This was developed by taking each average equivalent flow per number of through lanes and determining its percentage of the total intersection flow. The % Green Time allocated to each direction was based on the maximum required for the direction. For example, if the NB average equivalent flow / lane was 33 and the SB average equivalent flow / lane was 44, then it is assumed that the green time allocated to the N/S movements would be governed by the SB requirements. The same was then done for the E/W. This assumed a 2-phase signal, and provides a general proportion of how much green time will favour a certain direction.

The right turn vehicle conflicts were adjusted to account for the proportional amount of green or red time. Vehicles turning right during a green phase conflict with a different crosswalk than vehicles attempting a right turn during 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 right turn on a red during a certain portion of the cycle length.

Another table was added to the worksheet to account for the LT phase type, RT channelization and RTOR allowance factors. The LT phase type will reduce the exposure of pedestrians with left turning vehicles based on the type of left turn phase. A permissive left turn will return a LT Phase Type factor of 1.000 (no reduction), a protected-permitted left turn will return a LT Phase Type factor of 0.5 (50 percent reduction in exposure), and a protected left turn will return a LT Phase Type factor of 0.00 (100 percent reduction in exposure). If the input box is left blank, the assumption is that the left turn is permissive.

The RT channelization factor is similar. It checks whether the Right Turn Channelization input was returned as 'yes' or 'no'. If the input is 'yes', then the RT channelization factor will be 0.00 (100 percent reduction in exposure); and if no (or blank), then the Right Turn Channelization Factor will be 1.00 (no reduction). This was to account for instances where the right turn was removed through channelization from the pedestrian crossing, thereby removing the conflict between right turning vehicles and pedestrians.

The RTOR factor also identifies if the conflict between right turn vehicles and pedestrians is present. In cases where the data input on the 'Data Entry and Summary' worksheet returns a 'no' to RTOR, then a RTOR factor of 0.00 will be returned. This was used to reduce the exposure to 0 for right turning vehicles and pedestrians which were in conflict during a RTOR movement. If this box is left blank, the assumption is that RTOR is allowed.

A pedestrian screening (P_{scr}) calculation was added to identify if the pedestrian volumes pass a screening test to merit going through the warrant process. If either the N/S or E/W pedestrian volumes has an average over 6-hours greater than 25 OR either the N/S or E/W pedestrian volume in any given hour is larger than 100, then the full warrant equation will be conducted. If neither of these conditions were met, than P_{scr} will be returned as 'Not Warranted'.

Several tables were also expanded to include:

- Curb lane calculations;
- Factors for the side street approaches; and
- Right turn reduction factor for the side street approaches.

The pedestrian raw exposure is calculated based on all conflicting pedestrian/vehicle movements assuming signalization. The factors discussed in this section are applied to the raw exposure to result in a final adjusted exposure cross product. This process is summarized in Figure 7.

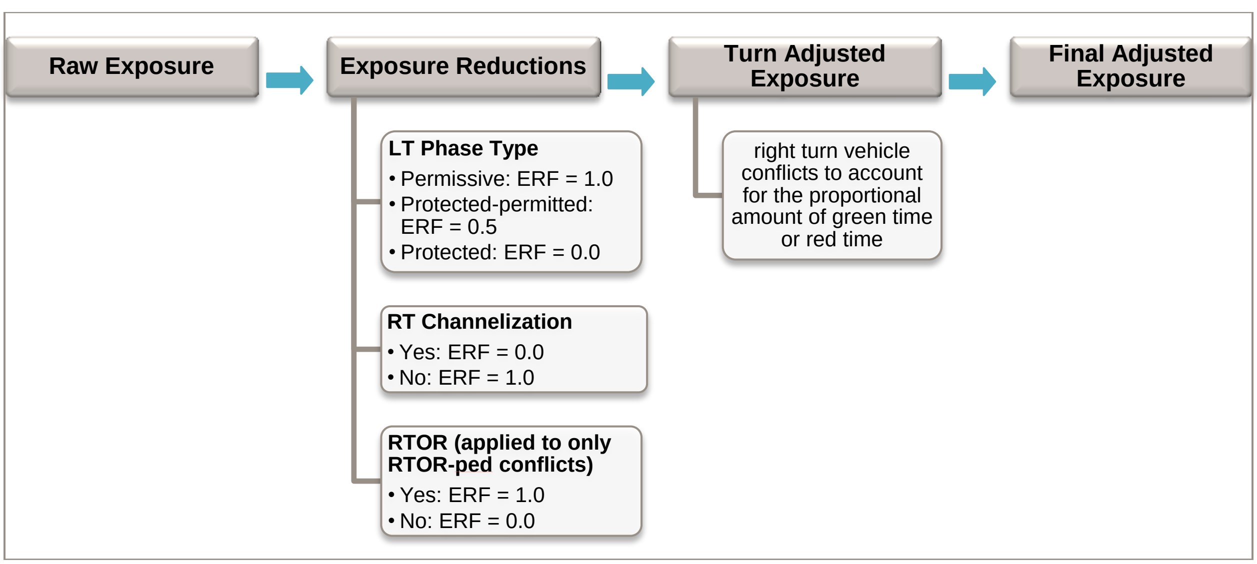


Figure 7: Pedestrian Exposure Process

Changes to the MUTCDC and the Traffic Signal Warrant Handbook

The Traffic Signal Warrant Handbook was updated to provide traffic operations practitioners with a guide on using the *Canadian Traffic Signal and Pedestrian Signal Head Warrant Matrix Procedure*. The Handbook describes the matrix warrant methodology and identifies the input data required for warrant analysis, as well as a description of how each warrant component is calculated. The purpose of updating the handbook was to ensure that the Canadian Traffic Signal and Pedestrian Signal Head Warrant Matrix Procedure is applied in a consistent and comprehensive way across Canada.

Part B – Division 2: *Installation Guidelines for Traffic Control Signals* of the Manual of Uniform Traffic Control Devices for Canada (MUTCDC) was also updated to include the requirement and application of pedestrian signal head installation. Section B2.2.2 – *Pedestrian Signal Warrant Equation* was added to the MUTCDC to discuss the pedestrian matrix warrant equation, the pedestrian vehicle denominators, the pedestrian demographics factor, the pedestrian – vehicle cross product, right turn channelization, the left turn factor, the RTOR factor, right turn adjustment exposure, and the pedestrian crossing distance.

Conclusion

This paper presents a methodology by which traffic engineering practitioners can evaluate the need for pedestrian signal display at a traffic signal. This methodology is an addition to the Traffic Signal Warrant Procedure developed for the Traffic Operations and Management Standing Committee (TOMSC) of the Transportation Association of Canada (TAC).

The pedestrian signal head warrant model, which is based on a pedestrian-vehicle cross product conflict method, was developed following an environmental scan involving: (1) a comprehensive review of literature on existing international warrant practices and a review of policies, by-laws and municipal initiatives for pedestrian warrants; and (2) an extensive jurisdictional survey on current pedestrian signal head warrant practices. As a result of this effort the following pedestrian warrant factors were identified:

- pedestrian volume,
- pedestrian composition/demographics,
- vehicular volume / crossing opportunities
- crossing distance / number of travel lanes

Subsequent to the environmental scan, a number of guiding principles were established to form the pedestrian signal head warrant development methodology. These principles and factors were similarly compared with the Traffic Signal Warrant Matrix Procedure factors resulting in a close alignment of both the methodology and traffic-pedestrian factors. By the inclusion of a few additional input requirements, the TSW Matrix can also provide an analysis of the pedestrian signal requirements and determine the relative pedestrian warrant value.

The Pedestrian signal head warrant model thus takes the form of:

$$\mathbf{W_{ped} = \sum_{i-j} [F((X_{pedm})\, d_m) / K_2 + ((X_{peds})\, d_s) / K_3)]}$$

Where:

F = pedestrian demographics factor
$\mathbf{X_{pedm}}$ **=**adjusted pedestrian x vehicle cross product (pedestrians crossing main street)
$\mathbf{X_{peds}}$ **=**adjusted pedestrian x vehicle cross product (pedestrians crossing side street)
$\mathbf{d_m}$ **=** main street distance crossed by the pedestrian
$\mathbf{d_s}$ **=** side street distance crossed by the pedestrian
$\mathbf{K_2}$ **=** Pedestrian signal head warrant denominator constant for main street
$\mathbf{K_3}$ **=** Pedestrian signal head warrant denominator constant for side street

Through the model calibration process, various application issues and operational concerns were identified and addressed. These included ‘T’ intersection and one-way street applications as well as recognizing issues such as signal phasing complexity, side street actuation, and need for actual crossing distance measurements.

The resulting Pedestrian signal head warrant output, which has been incorporated into the TSW procedure, now provides the user with a quantifiable pedestrian signal head warrant value. The summary output presents the warrant score as well as indicating whether pedestrian signals are or aren’t warranted. In addition to the warrant result, the model also provides the user with other operational notes such as whether the warrant was not met due to minimum pedestrian activity. Other operational notes have also been included to advise the user of possible insufficient side street green time for safe pedestrian crossings or suggest pedestrian signals be considered as a result of complex signal operations.

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