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Feasibility Study of Drivers Yielding Behavior to the Pedestrians at Unsignalized Crossing

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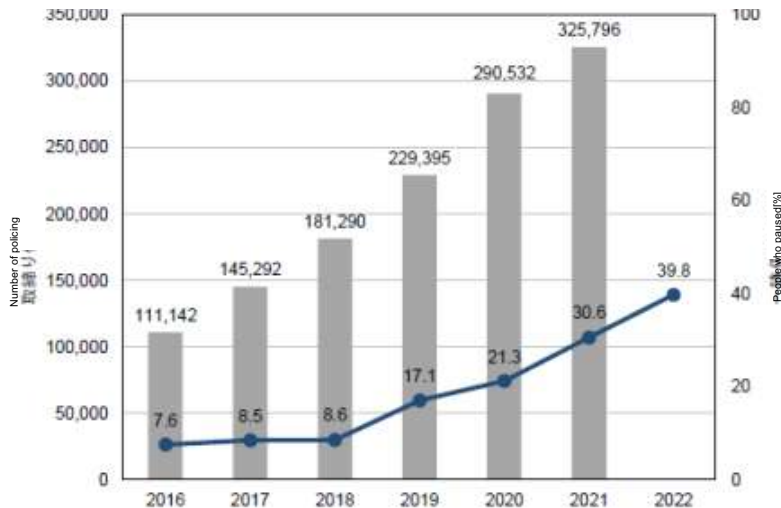
Project Background

- Need sustainable traffic signal management
- Need to address aging traffic signals and maintenance problems
- May lead to the need of pedestrian crossings management without use of traffic signals

Standard unsignalized pedestrian crossing
(Traffic signs and indications)



Percentage of stopping at crosswalks
Nationwide average 39.8%
(JAF investigation conducted in FY2022)



Traffic safety facility measures



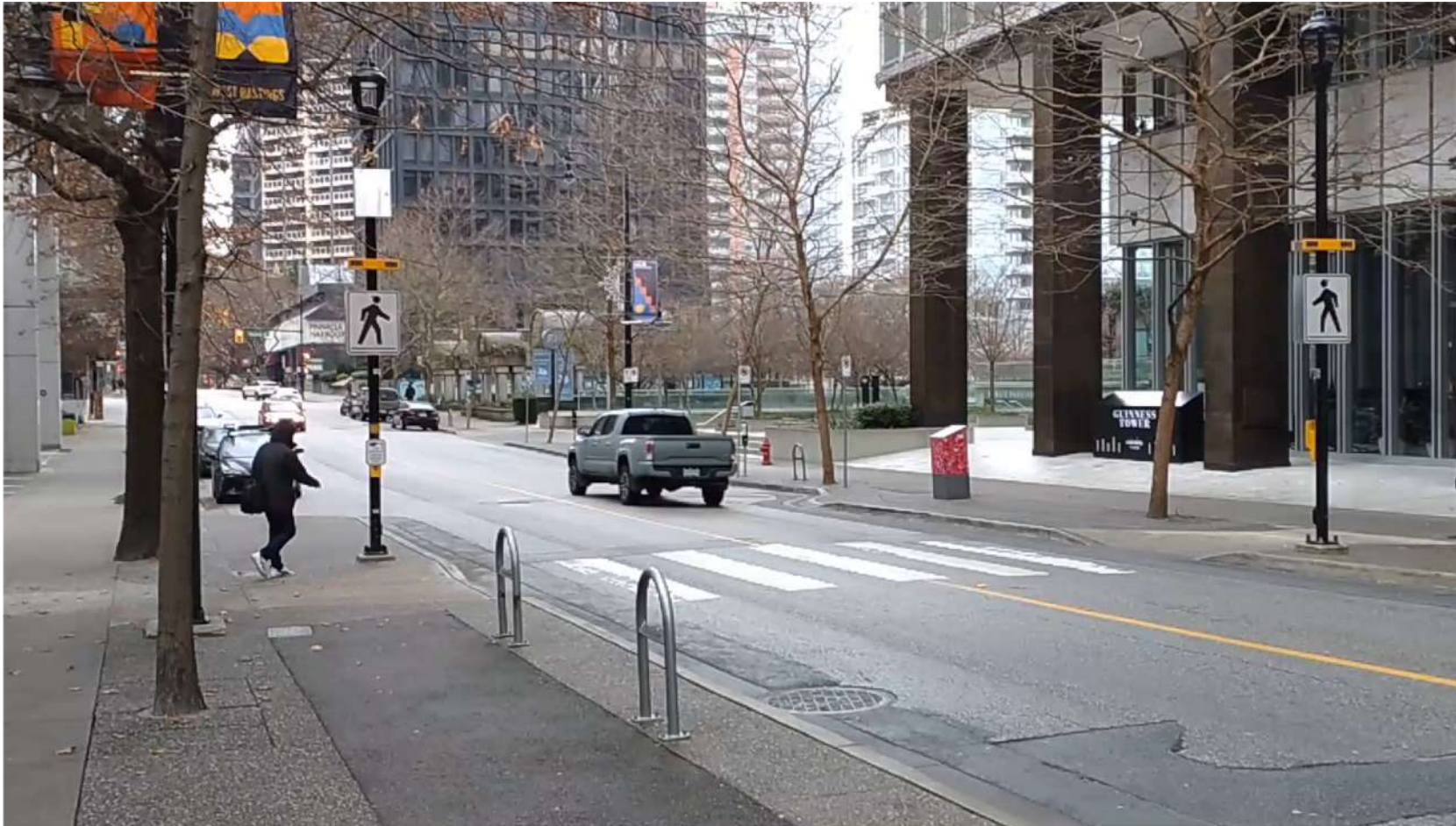
Traffic safety facilities that enhances traffic control
(overhanging signs, colored pavement, caution signs, etc.)



Source: Compiled by the author based on data from the National Police Agency and JAF
(The number for FY 2022 has not yet been announced.)

New traffic safety facilities are needed

Examples of Measures Taken Overseas



Rectangular Rapid Flashing Beacons (RRFB) have been introduced overseas to alert drivers with flashing lights.

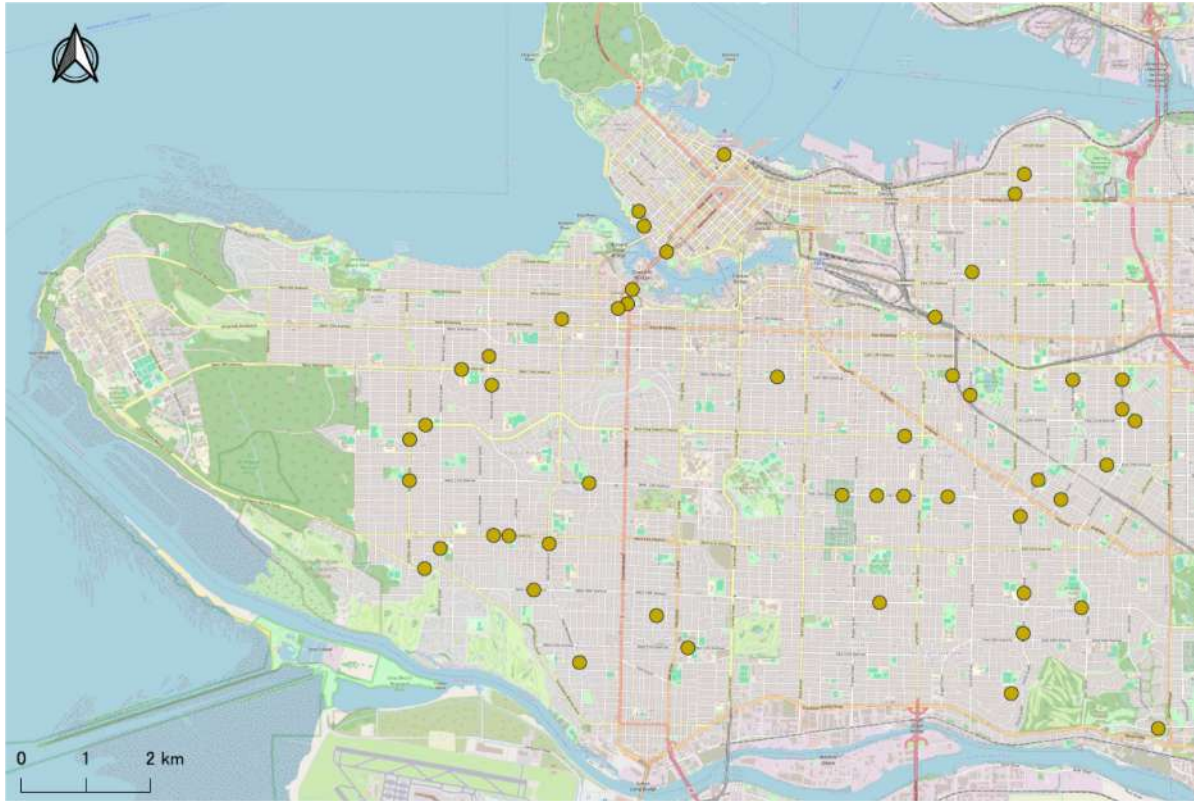
Project Objectives

- This study will organize the concept of safety improvement facilities for unsignalized pedestrian crossings and measures to encourage vehicles to make a stop at unsignalized crosswalks in other countries.
- Will analyze vehicle and pedestrian behavior at unsignalized crosswalks in Japan to examine the potential for flash-type alert facilities in Japan and suggestions for encouraging vehicles to yield at unsignalized crosswalks.

Visit to CARMANAH Technologies



Status of RRFB Installment



Vancouver City
 50 installed
 RRFBs *1 * 2 * 3

- *1 RRFBs were confirmed to be installed mainly from Google Streetview in 2022~2023.
- * 2 The list of installation locations is provided by Carmanah Technologies.
- * 3 Includes old model RRFBs.

Vancouver City Open Data on RRFBs installment by road levels shows that secondary road has most installments

Arterial Road	Secondary Road	Collector	Residential Road	Total
14 locations	23 locations	11 locations	2 locations	50 locations

Arterial Road : Road connecting to a highway
 Secondary Road: Road connecting to an arterial road
 Collector: Road connecting to secondary road
 Residential Road: Local street

RRFB Installment Status



RRFB Installment Status



Status of RRFB implementation



Status of RRFB implementation



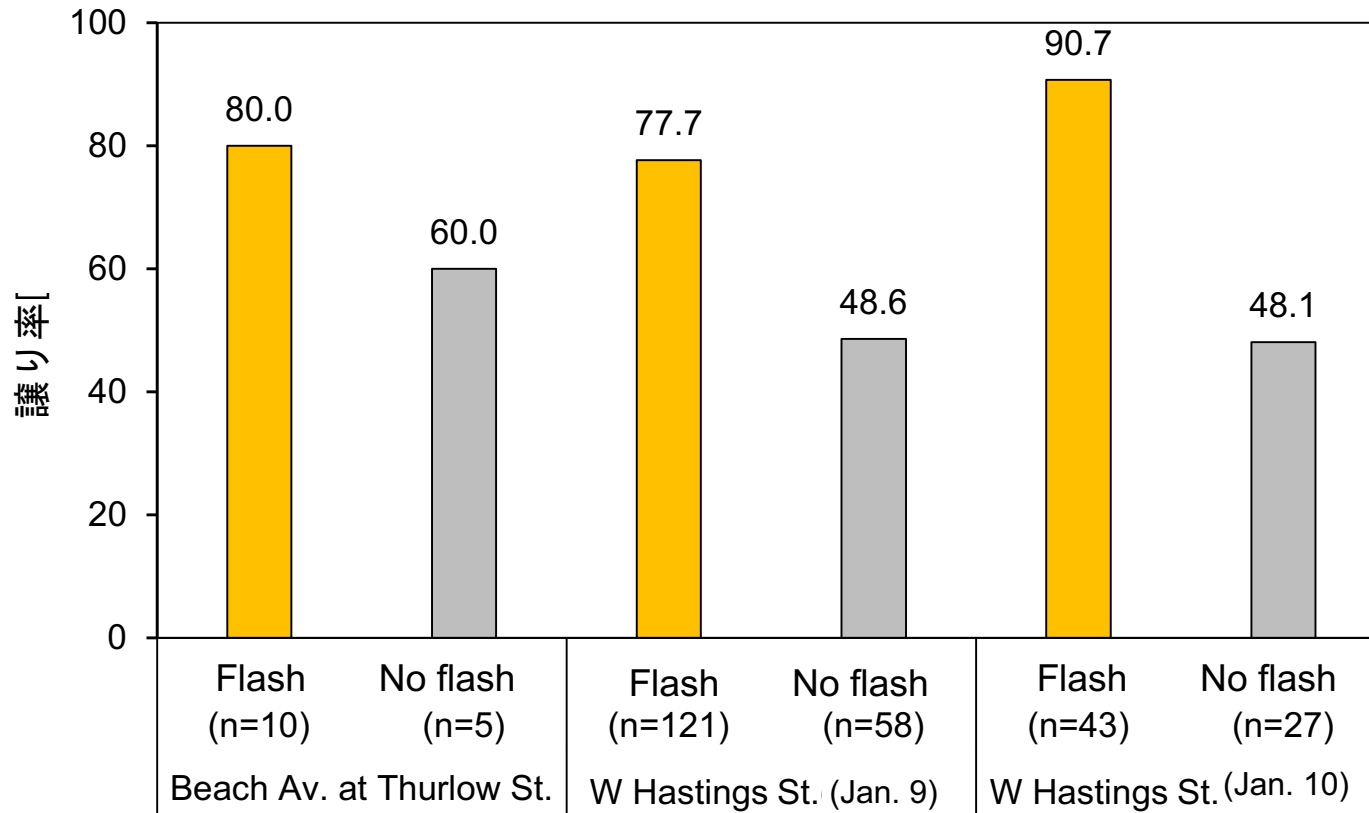
Status of RRFB implementation



Investigation Results in North America



Percentage of yield with and without flash



Duration of flash

- Beach Av. at Thurlow St. 17 sec.
(Crossing distance: approx. 11 m)
- W Hastings St. 15 sec.
(Crossing distance: approx. 8 m)

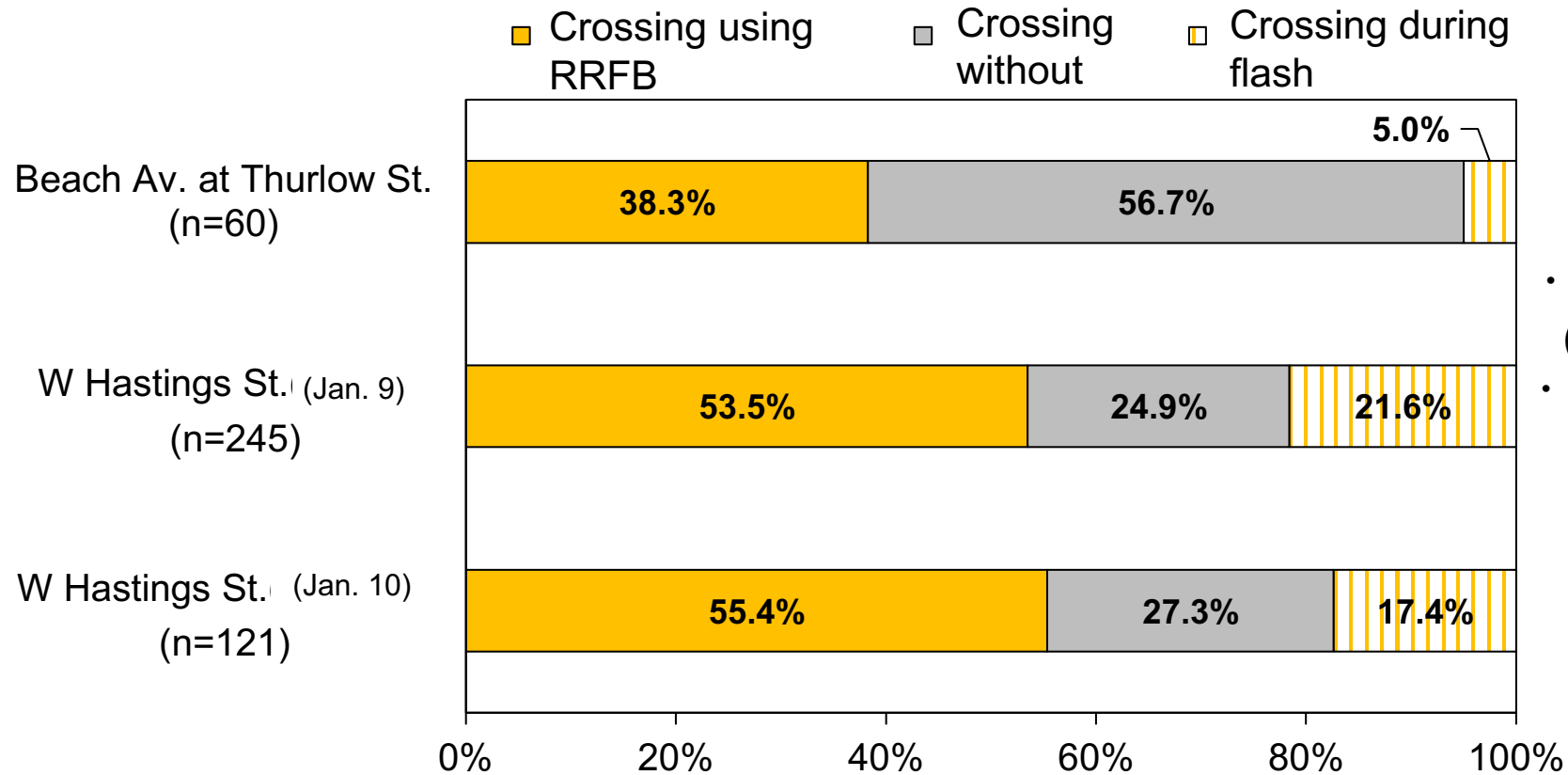
The yield rate is higher with flash

*Investigated in a situation where a vehicle was approaching a crosswalk.

Investigation Results in North America



RRFB utilization rate by pedestrians crossing the street



- Duration of flash
- Beach Av. at Thurlow St. 17 sec. (Crossing distance: approx. 11 m)
 - W Hastings St. 15 sec. (Crossing distance: approx. 8 m)

RRFB utilization is high

*Circumstances in which the vehicle is not approaching a crosswalk are also included in the sample count.

Hearing on RRFB



- RRFBs were developed around 2006, and the 2007 Florida experiment reported significant improvements in yielding rates, which led to RRFB introduction in many locations.
- It was initially a temporary measure and was not officially recognized in the MUTCD until 2023.
- There are three potential areas to introduce RRFB: Downtown, Suburban, and Rural. Introducing RRFB in the Suburban area is thought to be most appropriate.
- The deciding factor will be the vehicle and pedestrian traffic amount.
- Vehicle and pedestrian speed are also important factors but are difficult to measure in practice, so traffic amount is being considered.

Manual on Uniform Traffic Control Devices for Streets and Highways 11th Edition



CHAPTER 4L. RECTANGULAR RAPID FLASHING BEACONS

Section 4L.01 Application of Rectangular Rapid Flashing Beacons

Option:

01 A pedestrian-activated and/or bicyclist-activated rectangular rapid flashing beacon (RRFB) may be used to provide supplemental emphasis to pedestrian, school, and trail warning signs at marked crosswalks across uncontrolled approaches.

Standard:

02 An RRFB shall only be installed to function as a Warning Beacon (see Section 4S.03). Except as otherwise provided in this Chapter, all other provisions of the MUTCD applicable to Warning Beacons shall apply to RRFBs.

03 An RRFB shall only be used to supplement a post-mounted W11-2 (Pedestrian), S1-1 (School), or W11-15 (Trail) crossing warning sign with a diagonal downward arrow (W16-7P) plaque, or an overhead-mounted W11-2, S1-1, or W11-15 crossing warning sign, located at or immediately adjacent to a marked crosswalk.

04 Except for crosswalks across the approach to or egress from a roundabout, or crosswalks across free-flow turn lanes separated by a channelizing island, an RRFB shall not be used for crosswalks across approaches controlled by YIELD signs, STOP signs, traffic control signals, or pedestrian hybrid beacons.

Option:

05 An additional RRFB may be installed on that approach in advance of the crosswalk, as a Warning Beacon to supplement a W11-2 (Pedestrian), S1-1 (School), or W11-15 (Trail) crossing warning sign with an AHEAD (W16-9P) or distance (W16-2P or W16-2aP) plaque.

Standard:

06 If an additional RRFB is installed on the approach in advance of the crosswalk, it shall be supplemental to and not a replacement for the RRFB at the crosswalk itself.

Section 4L.02 Design of Rectangular Rapid Flashing Beacons

Standard:

01 Each RRFB unit shall consist of two rapidly-flashed rectangular-shaped yellow indications, each with an LED-array based pulsing light source. The size of each RRFB indication shall be at least 5 inches wide by at least 2 inches high.

02 The two RRFB indications for each RRFB unit shall be aligned horizontally, with the longer dimension horizontal and with a minimum space between the two indications of at least 7 inches, measured from nearest edge of one indication to the nearest edge of the other indication. The outside edges of the RRFB indications, including any housings, shall not project beyond the outside edges of the W11-2, S1-1, or W11-15 sign that it supplements.

Rectangular Rapid Flashing Beacons (RRFBs)

APPLICATION GUIDE



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RRFB Selection Matrix

Legend

= RRFBs are not recommended but are an optional enhancement with or following engineering judgment

= RRFBs are a candidate treatment to improving crossing safety on this roadway

= RRFBs are an ideal treatment for this roadway

Use this chart to determine the roadway conditions where RRFBs are recommended or should be considered to maximize pedestrian safety.

Crossing distance (e.g. number of lanes)	Median presence	Posted Speed Limit (mph) and Annual Average Daily Traffic (AADT)								
		< 9,000 AADT			9,000 – 15,000 AADT			> 15,000 AADT		
2 lanes (1 lane in each direction)	-									
3 lanes (1 lane in each direction with two-way left-turn lane)	Yes									
	No									
4+ lanes (2 or more in each direction)	Yes									
	No									

Source: Adapted from Federal Highway Administration, Report No. FHWA-SA-17-072, [Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations](#)

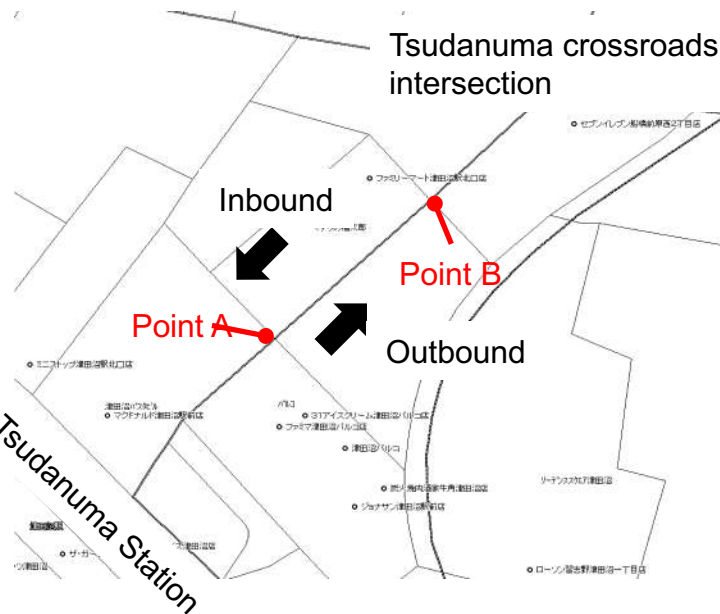


Traffic Investigation of Unsignalized Pedestrian Crossings in Japan



Investigation Point: Pedestrian crossing in front of JR Tsudanuma Station (2 locations)

Ground plan



On-site viewpoint



*Taken from the pedestrian deck of JR Tsudanuma Station

Investigation Location	Point A: Crossing at 2-18 Maehara-nishi, Funabashi City, Chiba Prefecture Point B: Crossing at 2-21 Maehara-nishi, Funabashi City, Chiba Prefecture
Investigation Date	Investigation Date: September 11, 2023 (Mon) - Wednesday, September 13, 2023 Survey hours: 12:00 to 22:00 (10 consecutive hours per day)
Investigation Method	Observation survey by high altitude video camera (view pole) Number of cameras placed: 2 at point A, 1 at point B

Number of accidents

Number of traffic accidents (people vs. vehicles) Cumulative total for FY 2021 and 2022	
Point A	Point B
2 cases/2 years	5 cases/2 years

*Accident data provided by Chiba Prefectural Police.

- Unsignalized pedestrian crossing installed on a four-lane round-trip road
- Distance from adjacent traffic signals makes it difficult to install traffic signals

Observation Method

Tsudanuma crossroads intersection



Tsudanuma crossroads intersection



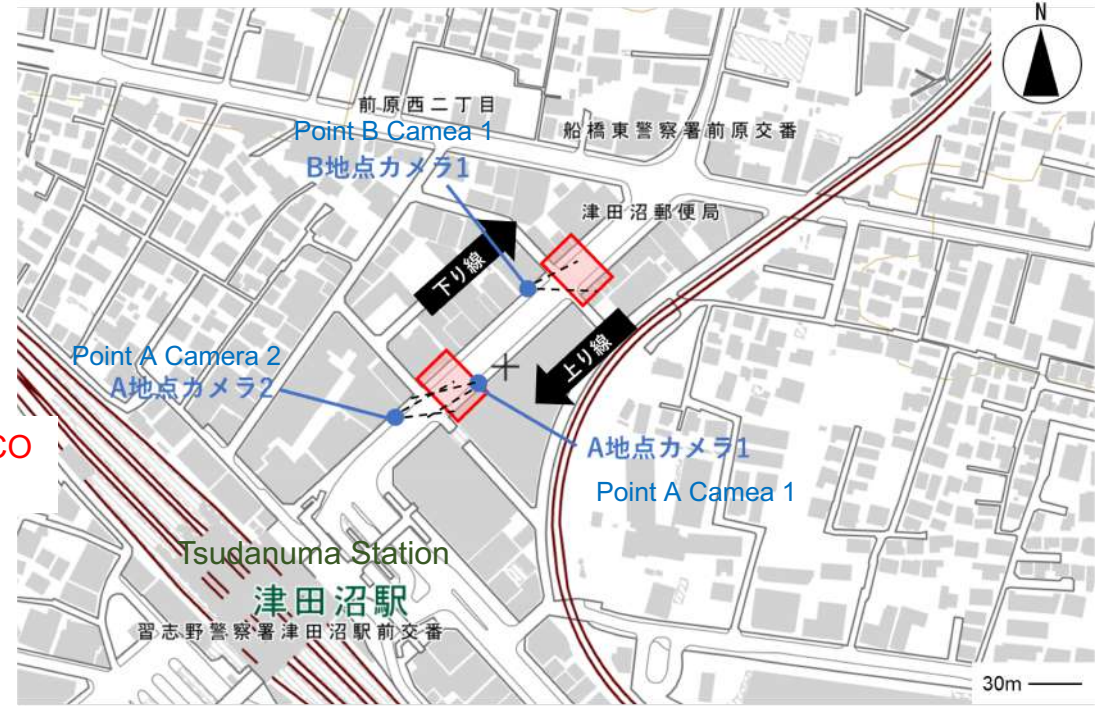
Point B camera 1



JR Tsudanuma Station



Former PARCO (Now Viit)



*Created by processing Geographical Survey Institute maps



Former PARCO (now Viit)

Point A Camera 2



JR Tsudanuma Station

Point A Camera 1

Determination of yielding behavior based on pedestrian crossing patterns

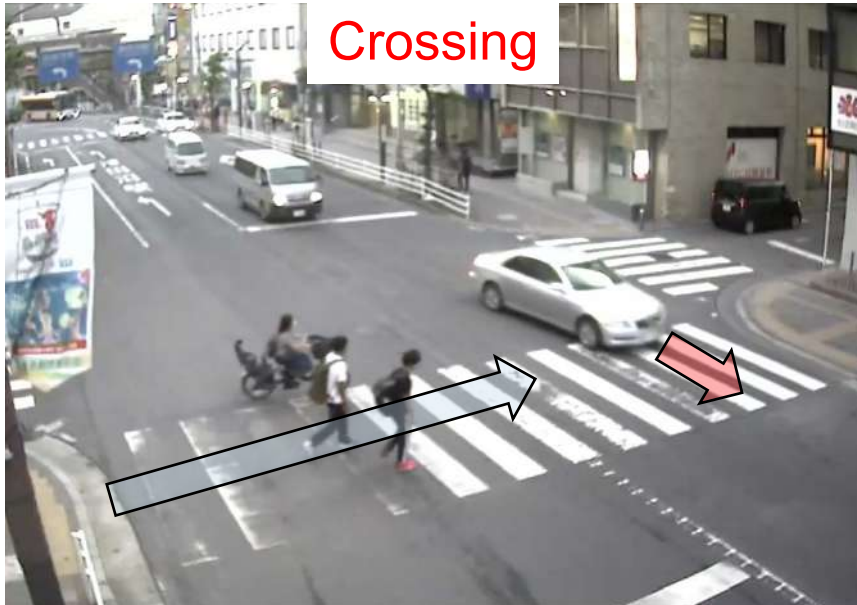
Standing on the sidewalk



Standing in the roadway



Crossing



Moving through sidewalk



Observation results : Vehicle type and pedestrian (Point A)

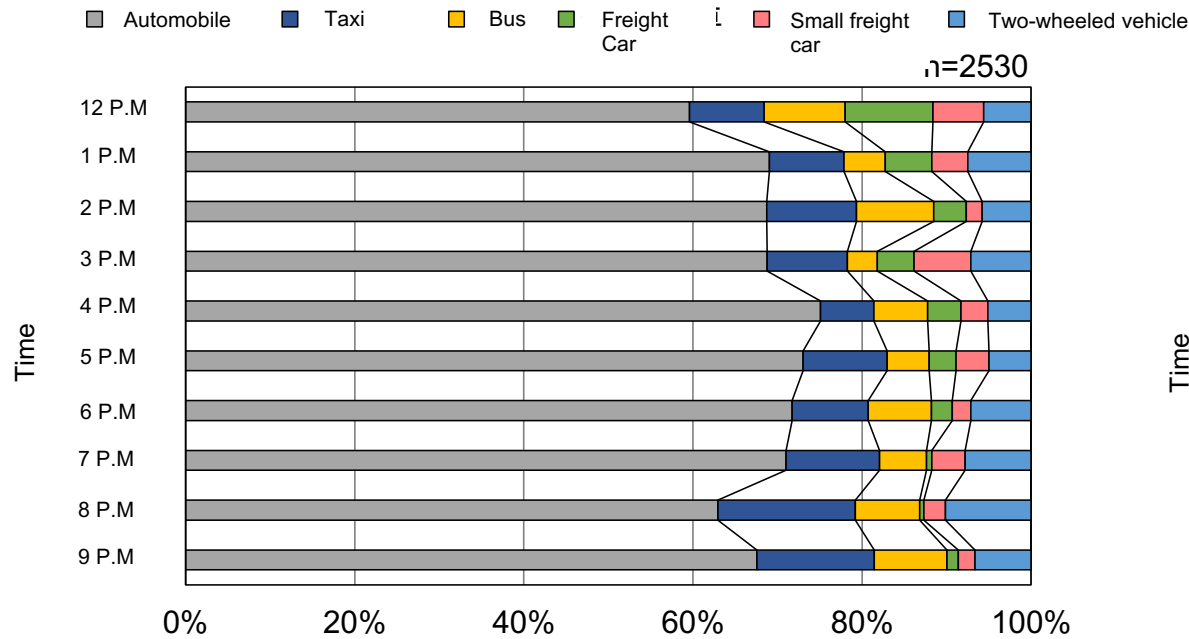
Sample size

Vehicle type (n)[%] (n)[%] (n)[%] (n)						
Automobile	Cab	Bus	Freight car	Small freight car	Two-wheeled vehicle	Total
1749	255	166	94	95	171	2530
[69.1]	[10.1]	[6.5]	[3.7]	[3.8]	[6.8]	[100]

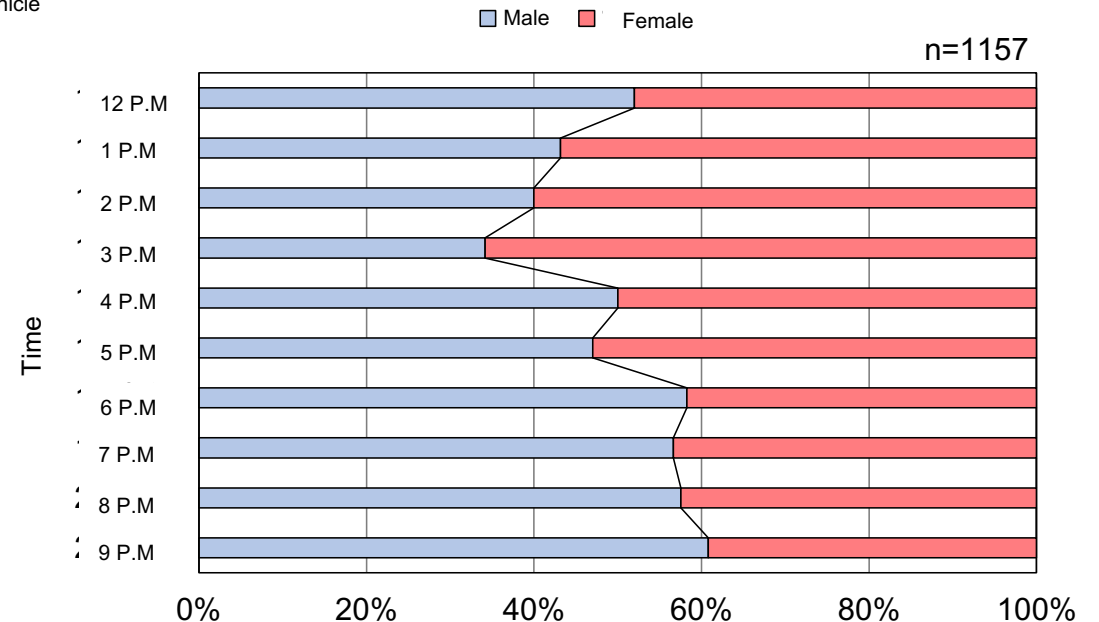
Sample size

Gender (n)[%].			
Male	Female	Unknwn	Total
571	583	3	1157
[49.4]	[50.3]	[0.3]	[100]

Composition by time



Composition by time



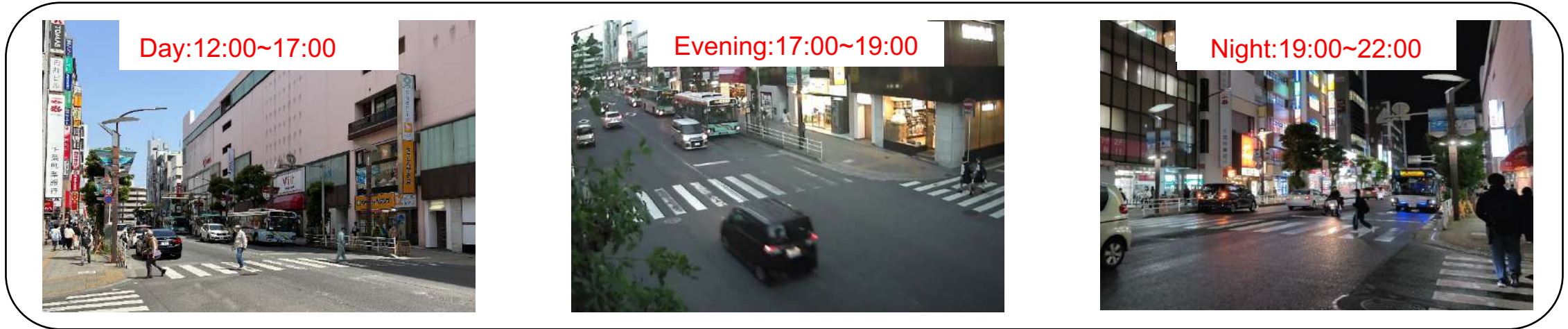
*If multiple vehicles pass by one pedestrian, all passing vehicles are counted.

*Even if multiple vehicles pass through per 1 pedestrian at the crossing, it is counted as one in terms of the number of pedestrians per event.

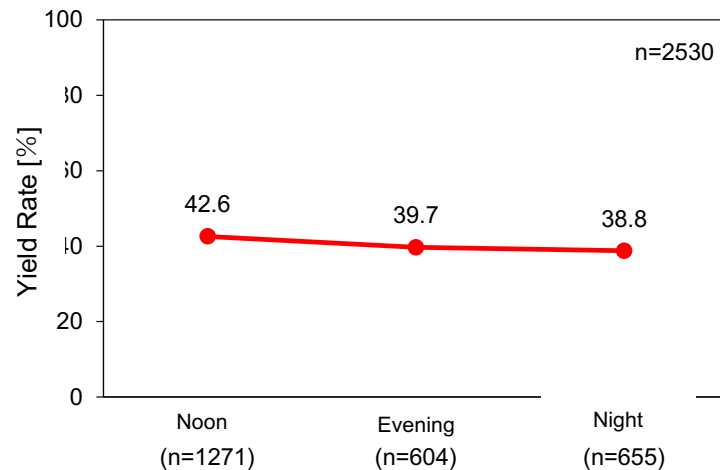
Observations Yield Rate (Actual Situation of Pedestrian Priority)

Yield rate at 2 pedestrian crossings in front of JR Tsudanuma Station (3-day total)
 Location A (n=2530) **40.9%** Location B (n=1829) **40.9 %**

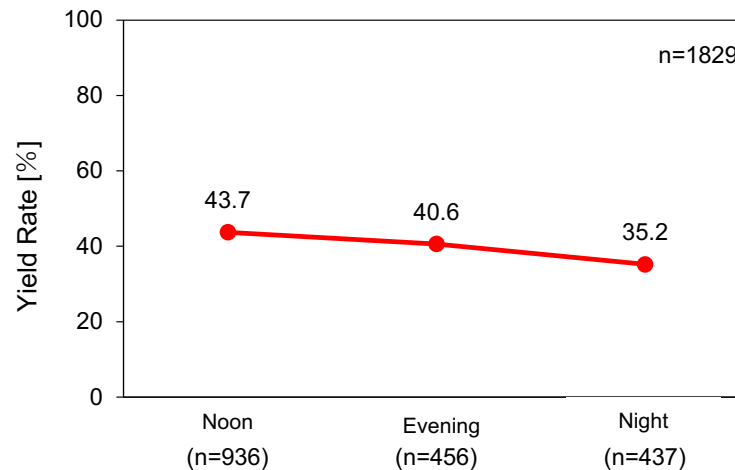
*The term "yield" is defined in this investigation as the combination of "stop" and "decelerate (go slowly)".



Yield Rate at Point A throughout the day



Yield Rate at Point B throughout the day



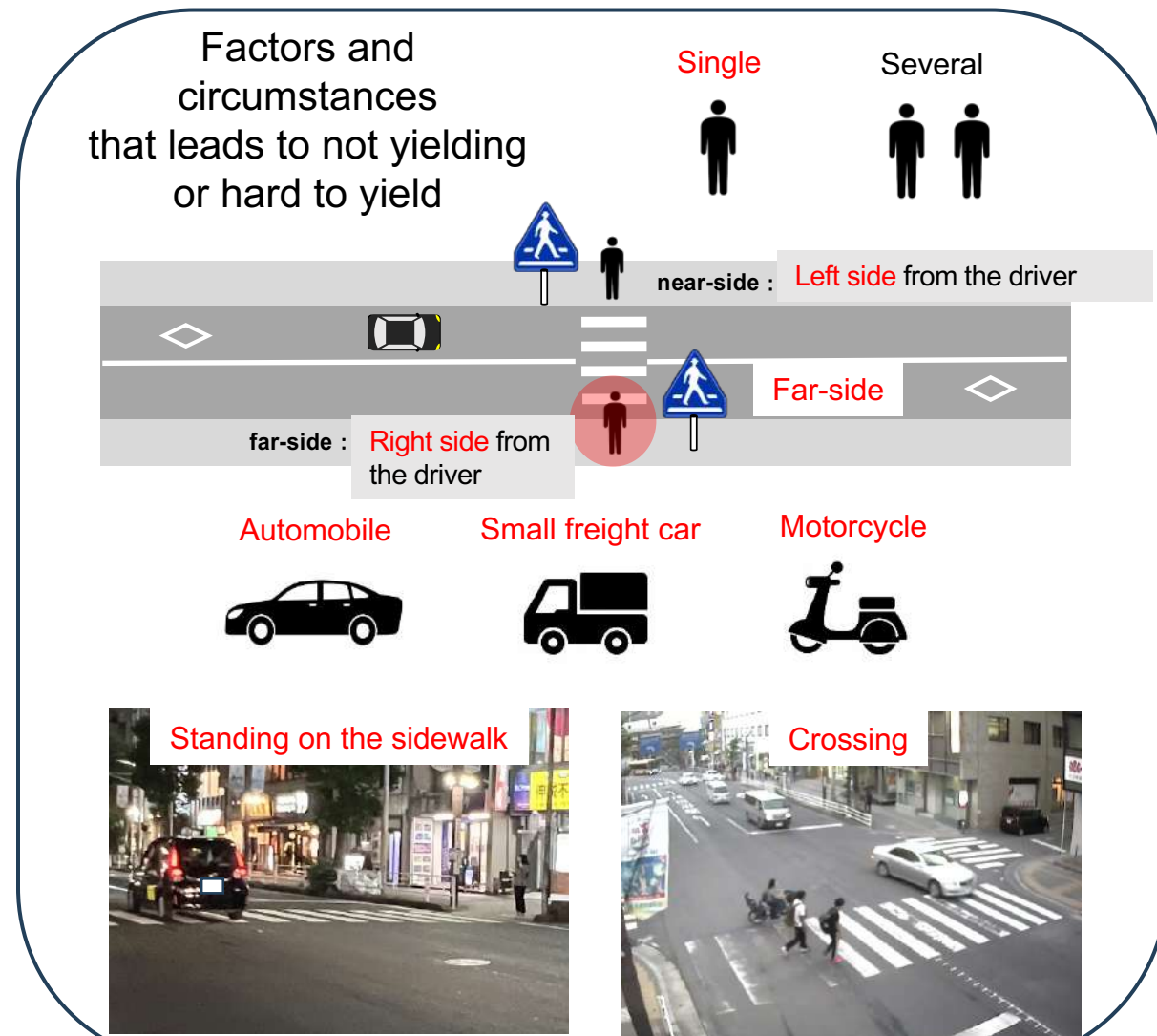
■ No significant difference in yield rates when broken down by time of day

Factors Affecting Yield

■ Is there a difference in yield rate when investigation items are subdivided (Analyzed at Site A)

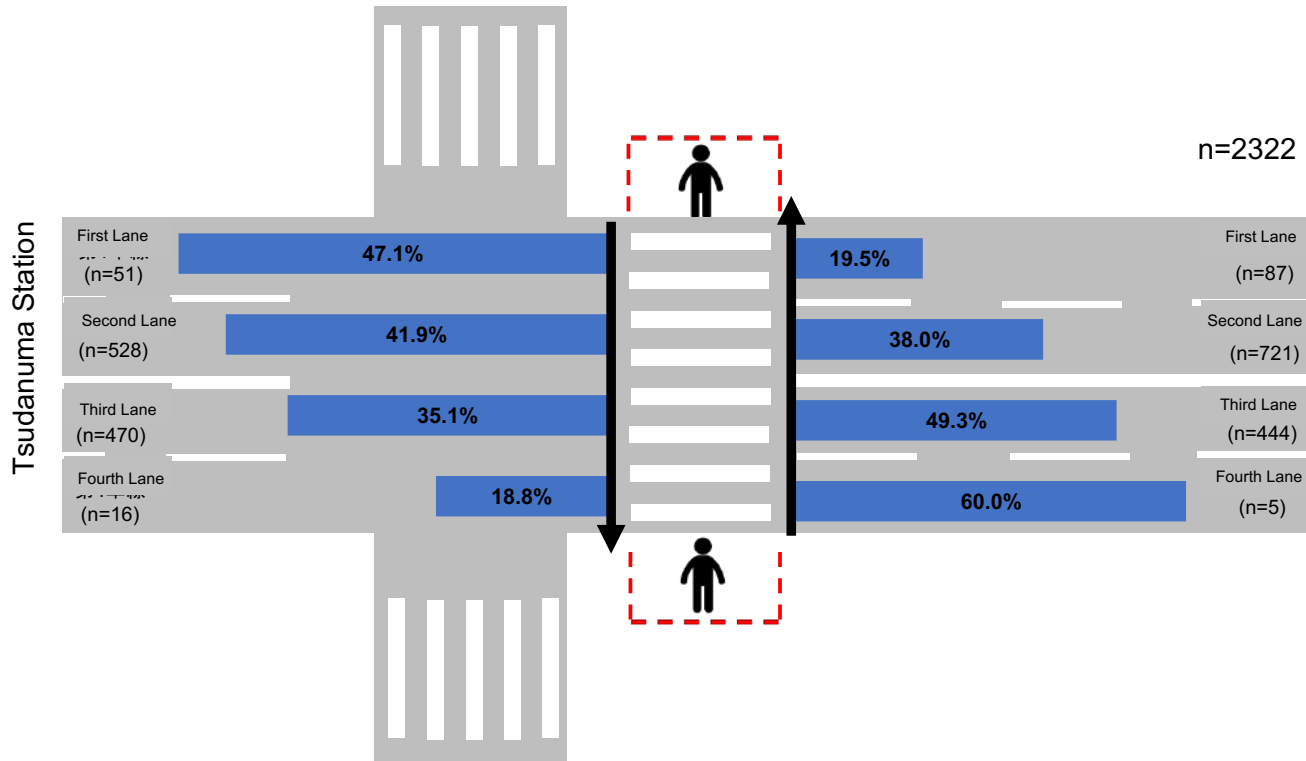
		Number of vehicles (N=2530)		P-value
		Yielded. (n=1036)	intransigent (n=1494)	
Number of pedestrians (n)[%].	Single	681[37.6].	1131[62.4].	<0.001**
	Several	355[49.4]	363[50.6].	
Pedestrian crossing position (n)[%].	Near-side	467 [45.4].	561[54.6].	<0.001**
	Far-side	459 [35.5].	835[64.5].	
	Both sides	110 [52.9].	98 [47.1].	
Vehicle Type (n)[%].	Automobile	674[38.5].	1075[61.5].	<0.001**
	Taxi	130 [51.0].	125[49.0]	
	Bus	127 [76.5].	39[23.5]	
	Freight	45[47.9]	49[52.1]	
	Small freight	26[27.4]	69[72.6]	
	Motorcycle	34[19.9].	137[80.1]	
Pedestrian behavior (n)[%].	Standing at the sidewalk	130 [29.7].	308[70.3]	<0.001**
	Standing in the roadway	61[51.3].	58[48.7]	
	Crossing	82 [26.9].	223[73.1].	
	Moving through the sidewalk	125[42.4]	170[57.6]	
Time zone (n)[%].	Day	542[42.6].	729[57.4].	0.21
	Evening	240 [39.7].	364[60.3].	
	Night	254[38.8]	401[61.2].	

*A residual analysis was performed to compare groups as a subanalysis, but the results are omitted.



Yield Rate Results by Lane (Point A)

Yield rate by lane (location A)



Tsudanuma crossroads intersection

On-site Situation

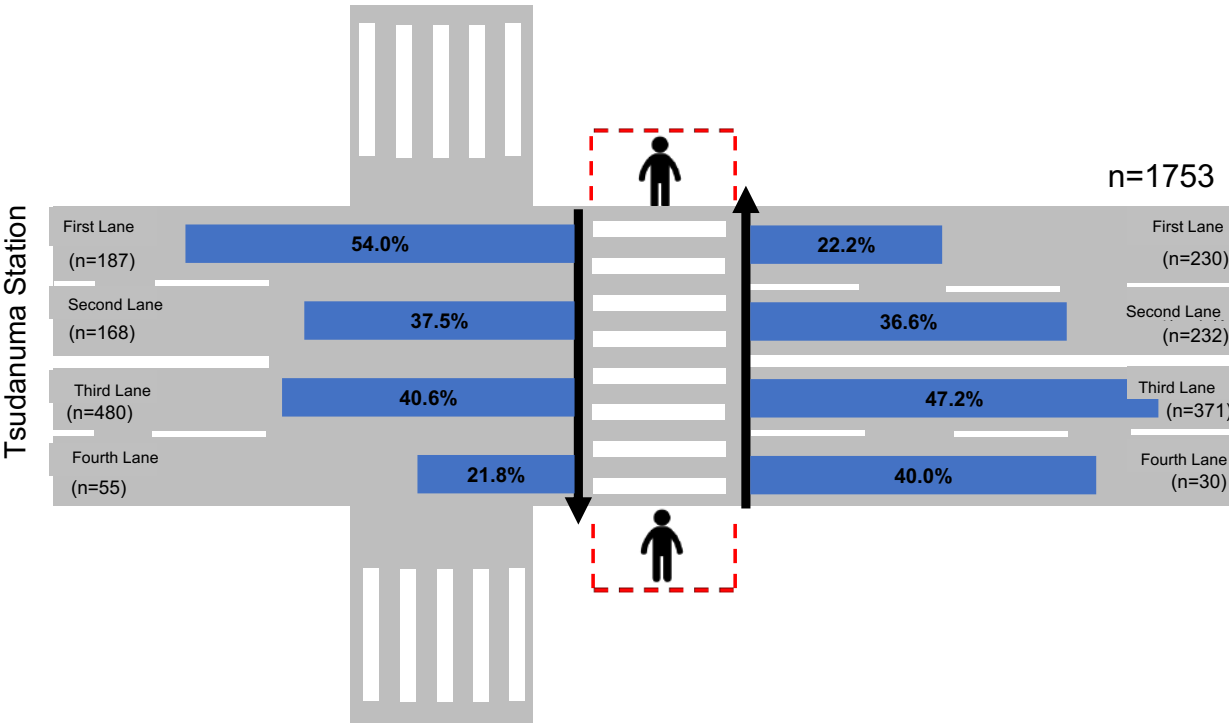


Analysis based on near-side and far-side data, excluding both sides with single and multiple pedestrians.

■ The yield rate is higher for vehicles traveling in the lane closer to the pedestrian crossing position.

Yield Rate Results by Lane (Point B)

Yield rate by lane (Position B)



Comparison of yield rates by signal light color



Tsudanuma crossroads intersection

Investigation result

		Number of vehicles (N=851)		P-value
		Yielded (n=325)	Did not yield (n=526)	
Signal light color	Red	232[41.4] [2.6]	329 [58.6]. [-2.6].	<0.001**
[Adjusted residuals errors]	Green	72 [29.4]. [-3.4].	173[70.6]. [3.4	
	Yellow	21[46.7] [1.2	24 [53.3]. [-1.2].	

■ Yield rate by lane tends to be the same as at Point A

■ Significantly more likely to yield when the signal light color is green compared to red

Summary of Investigation on Pedestrian Priority

- Average yield rates (3-day/10-hour observation) at points A and B are both **40.9%**
- There was no significant trend in yield rates across time periods
- As for crossing behavior, yield rate when **standing on the sidewalk** and **crossing** tends to decrease
- Measures to increase legal compliance and attention to pedestrians for drivers are necessary

Research issues gained from this investigation

Due to differences in the number of lanes (crossing distance) and other factors, some crossing behaviors may be observed at crossings on four-lane roundtrip roads that are less frequently observed at crossings on two-lane roundtrip roads.

→ Requires behavior categorization regarding crossing in this study

Stop at the edge of the crossing or the street and look carefully to the right and left to see if a car is approaching.

(Rules of the road, Chapter 2 Pedestrian Tips, Section 3 How to Cross the Street, Article 3.2 partial excerpt)

Preferably, pedestrians should also stop before the crossing for safety

To move forward with measures to improve safety,



Need to analyze pedestrian crossing behavior at crossings on multi-lane roads

Previous studies on Pedestrian Road Crossing Behavior

Pedestrian Decisions (Human Factors)

Tendency to make crossing decisions based on vehicle arrival time rather than distance from vehicle

Petzoldt (2014)

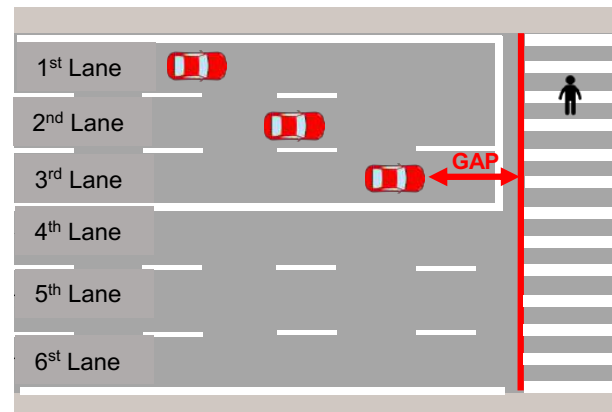
Psychophysics-based Gap Acceptance (PGA Model)

- Model that incorporates vehicle arrival time as a crossing decision
- Analysis based on representative values, variance, distribution, etc. of gaps

Kadali & Perumal (2012), Yannis et al. (2010), Ishiyama et al. (2018)

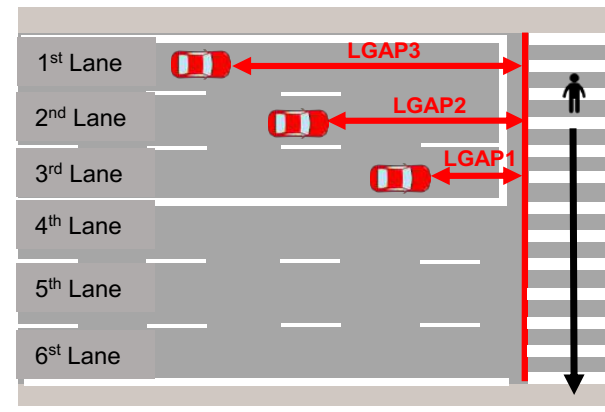
Challenges exist when applying to multi-lane roads (Figure Normal Gap)

Analysis from three cross-sectional methods based on Lane-Based Gap (LGAP) Zhang(2018)



Normal Gap

Assume that the shortest gap concerning the crossing surface determines the crossing decision
Issue: gap that would normally be rejected



LGAP

LGAP of lanes 1 and 2 are long, so lane 3, through which the vehicle passes, is judged to be crossable.
Characteristic: Analysis considering subsequent gaps (1st and 2nd) is possible.

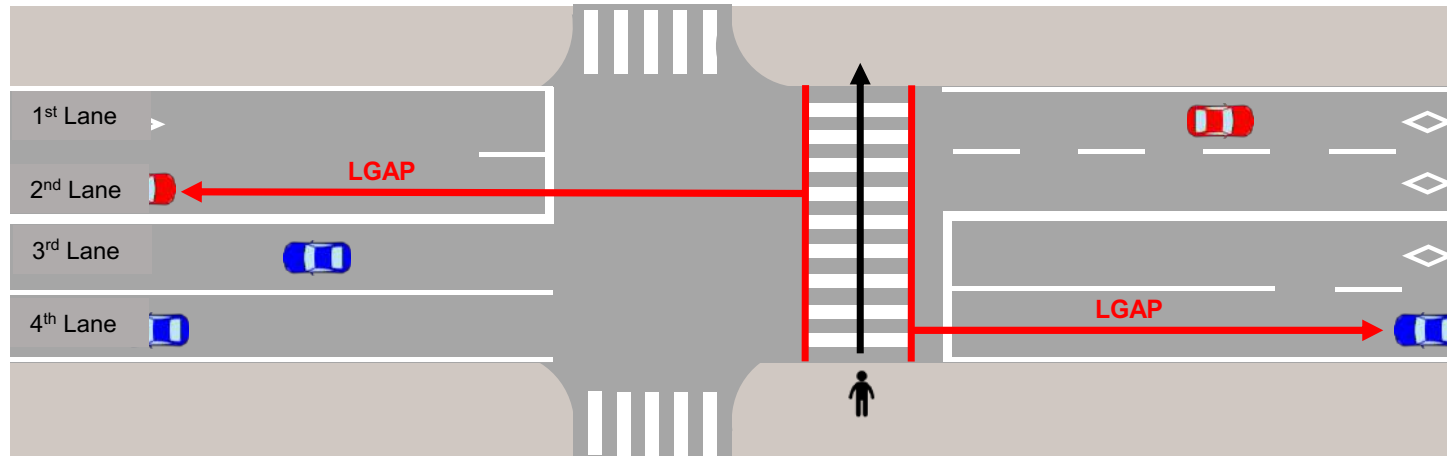
Pedestrians' choice of crossing method

1. Single Crossing, 2. Two-Stage Crossing, 3. Rolling Gap Crossing

LGAP and Crossing Method 1

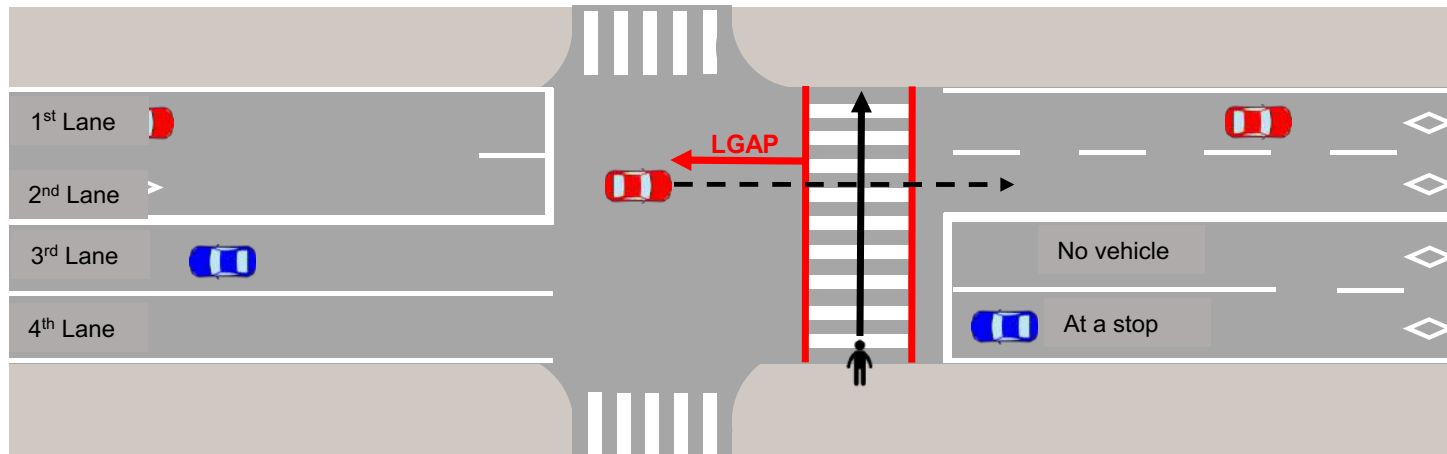
Typical gap value = time [s] (distance/velocity)
 Gap value in this investigation = distance from vehicle [m] (surveyed every 5 m)

Single Crossing



1. Crossing in a situation where a gap with the vehicle is maintained until the end of the crossing

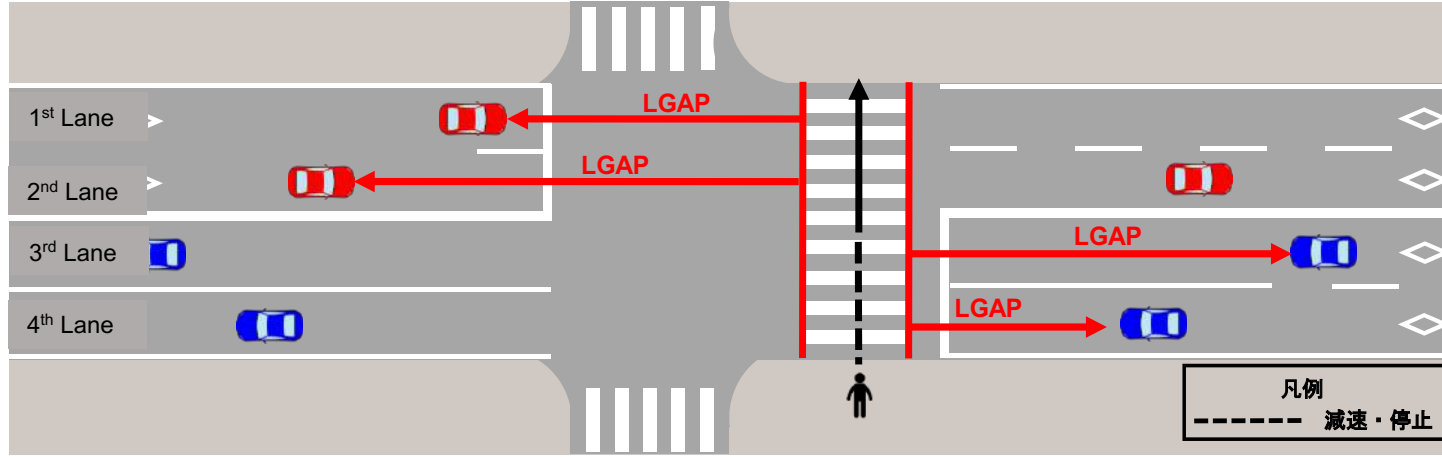
Two-Stage Crossing



1. When there is no vehicle in the front lane or a vehicle in the front lane is at a stop sign
 2. A vehicle in the rear lane passes through the crosswalk while crossing

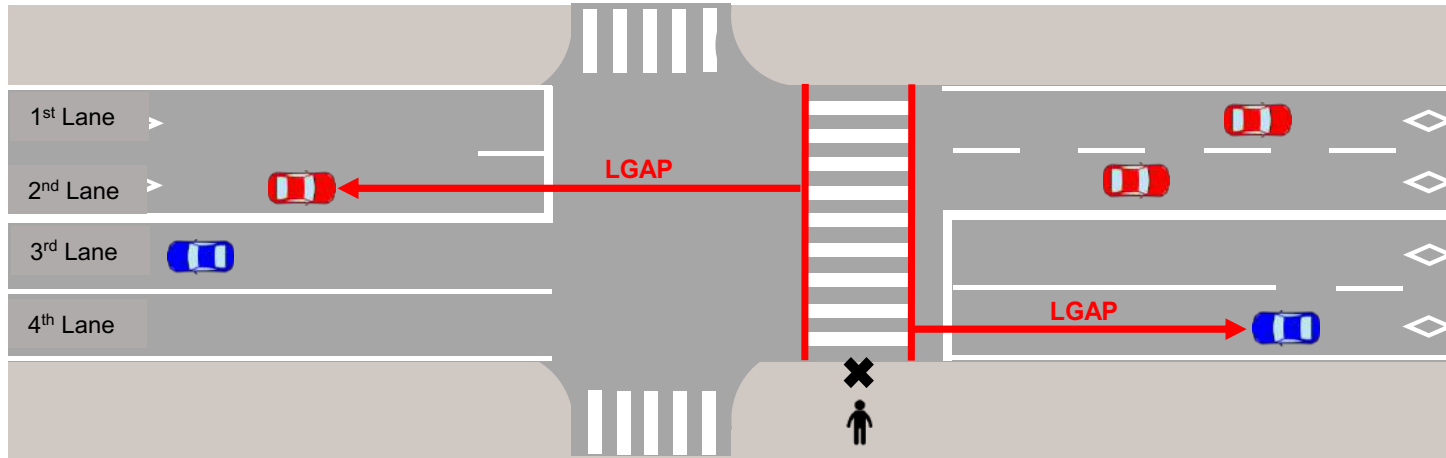
LGAP and Crossing Method 2

Rolling Gap Crossing



1 A situation where a pedestrian slows down or stops to avoid crossing a vehicle in the front lane and a vehicle is moving in the far-side lane.

Standing on the Sidewalk

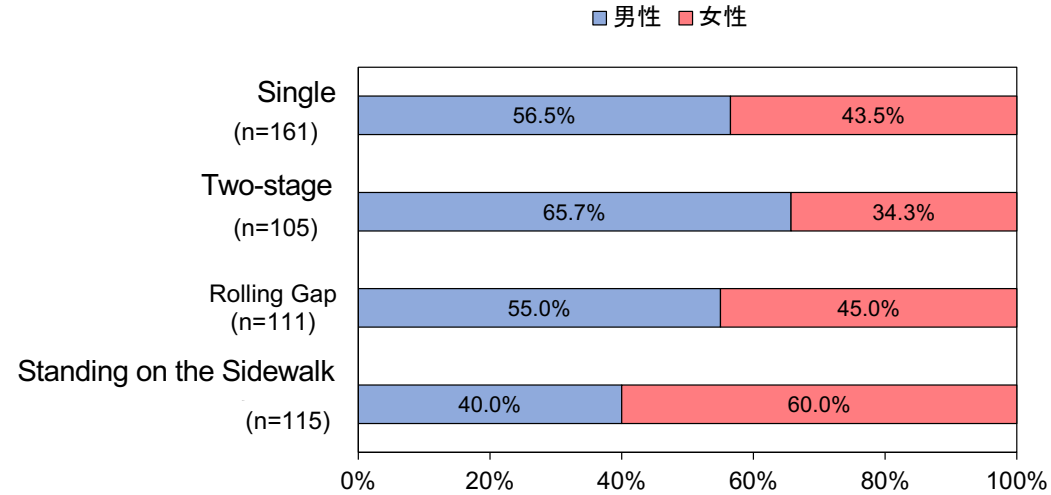
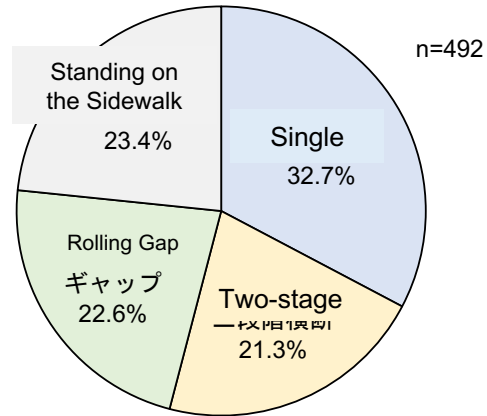


1 Situation where a pedestrian stops on the sidewalk while a vehicle is approaching
 2 A situation where a vehicle has started to cross the street after stopping or passing through a pedestrian crossing.

*Analysis based on single pedestrian only

*LGAP is the distance from the crosswalk cross section to the vehicle at the time the pedestrian begins crossing.

Investigation Results (partial) and Analysis



■ Percentages of the four crossing methods are about the same

■ Men are more likely to cross in two stages while women are more likely to stand on the sidewalk

Analysis

- About 40% of pedestrians (two-stage and rolling gap) choose a different crossing method than recommended
- Expect more pedestrians to attempt to cross based on gap decision than to indicate intention to cross ahead of time
 - At night, that decision could be made incorrectly.
- In cases where the gap is small, it is necessary to reexamine and reintroduce the method of stopping before the pedestrian crossing to inform drivers of their intention to cross (including raising their hands).

Discussions at Research Project Meetings



- Discussion of the relationship between the **yield** rate and the **stop** rate
- Importance of indicating **willingness to cross**
- Relationship with other devices

Road Traffic Law Article 38, Paragraph 1

When a vehicle crosses or is about to cross in front of its path at a pedestrian crossing, the vehicle shall **stop immediately in front of the pedestrian crossing** and shall not obstruct the passage of pedestrians.

*Excerpts applicable to pedestrians only

City of Vancouver Traffic Regulations (Streets and Traffic By-Law No. 2849), Article 11, Section 1

"The driver of a vehicle shall yield the right-of-way, **slowing down** or **stopping** if necessary to so yield, to a pedestrian crossing the roadway within a crosswalk when the pedestrian:"

Canadian traffic rules determine whether pedestrians have priority based on two vehicle behaviors: "stopping" and "slowing down".

Discussions at Research Project Meetings



- In North America, the indication of the **intention to cross** (push the button) is considered important
 - Indicate the intention → car yields → learn that if they push the button, the car will yield → many people will push the button
 - Positive learning effects may be evident.
 - Reduce the number of pedestrians who do not know whether to cross
 - Push-buttons are better than sensors

Discussions at Research Project Meetings



- Relationship with other devices
 - The relationship between pedestrian and automobile traffic is important.
 - Relationship between traffic smoothness (vehicle-side smoothness and pedestrian-side smoothness) and safety
 - Effective on secondary arterial roads (quasi-arterial roads) that connect arterial roads with residential roads
- If the rate of pause is improved by signaling intent, then RRFB may be very effective



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