公益財団法人 国際交通安全学会
International Association of Traffic and Safety Sciences

April 12, 2024
Research and Investigation
Meeting Report

2303A
Feasibility Study of Drivers Yielding Behavior to the Pedestrians at Unsignalized Crossing

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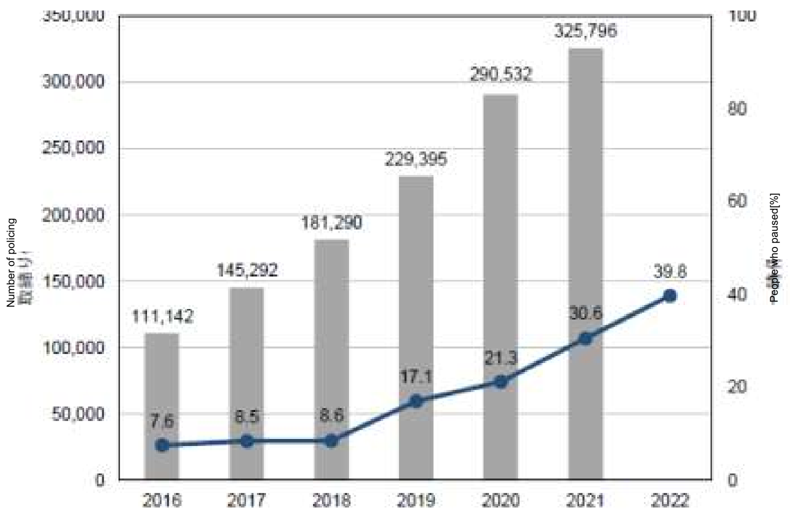
Project Background

- 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)



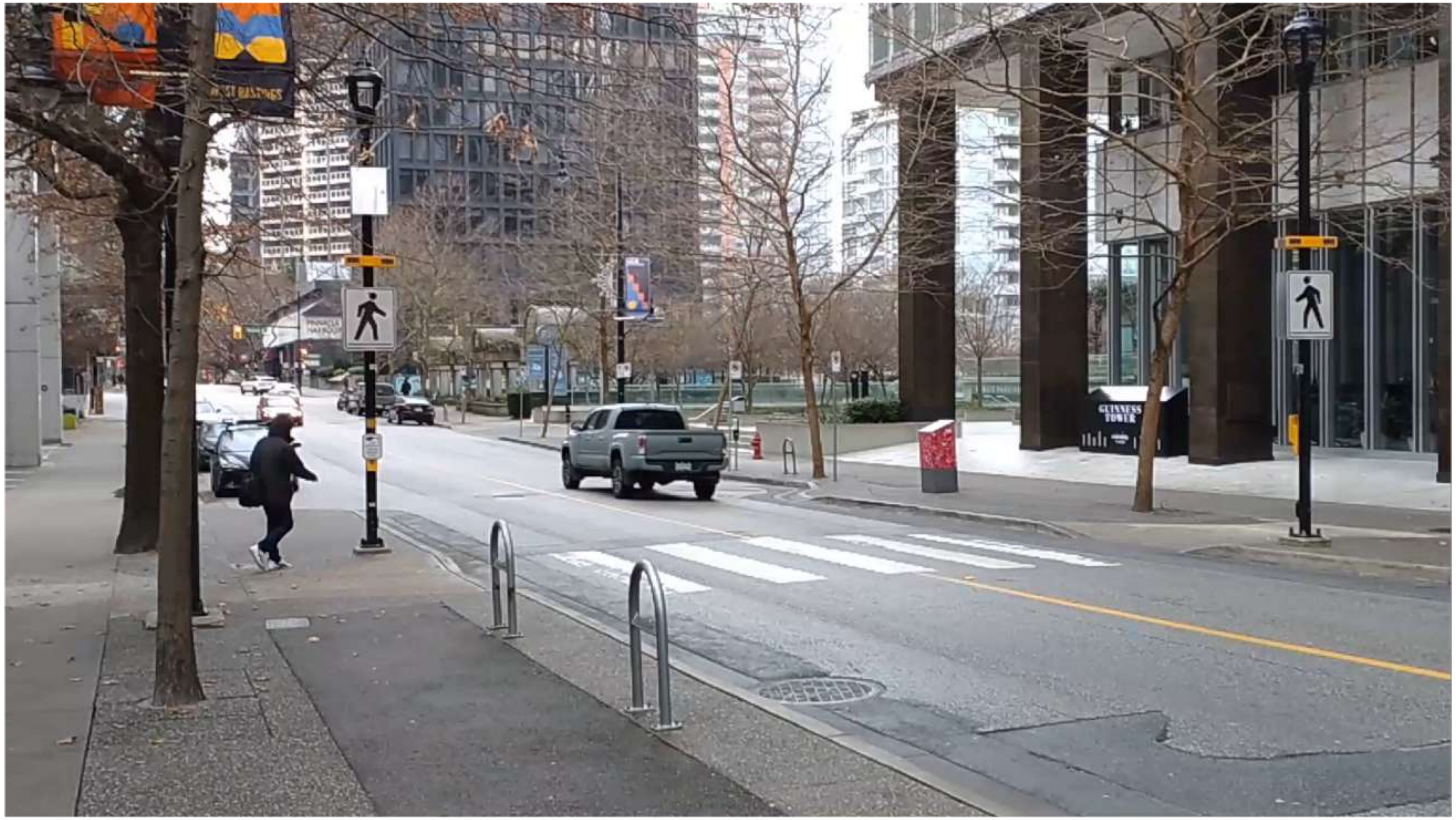
Source: Compiled by the author based on data from the National Police Agency and JAF
(The number for FY 2022 has not yet been announced.)

Traffic safety facility measures

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

New traffic safety facilities are needed

Examples of Measures Taken Overseas



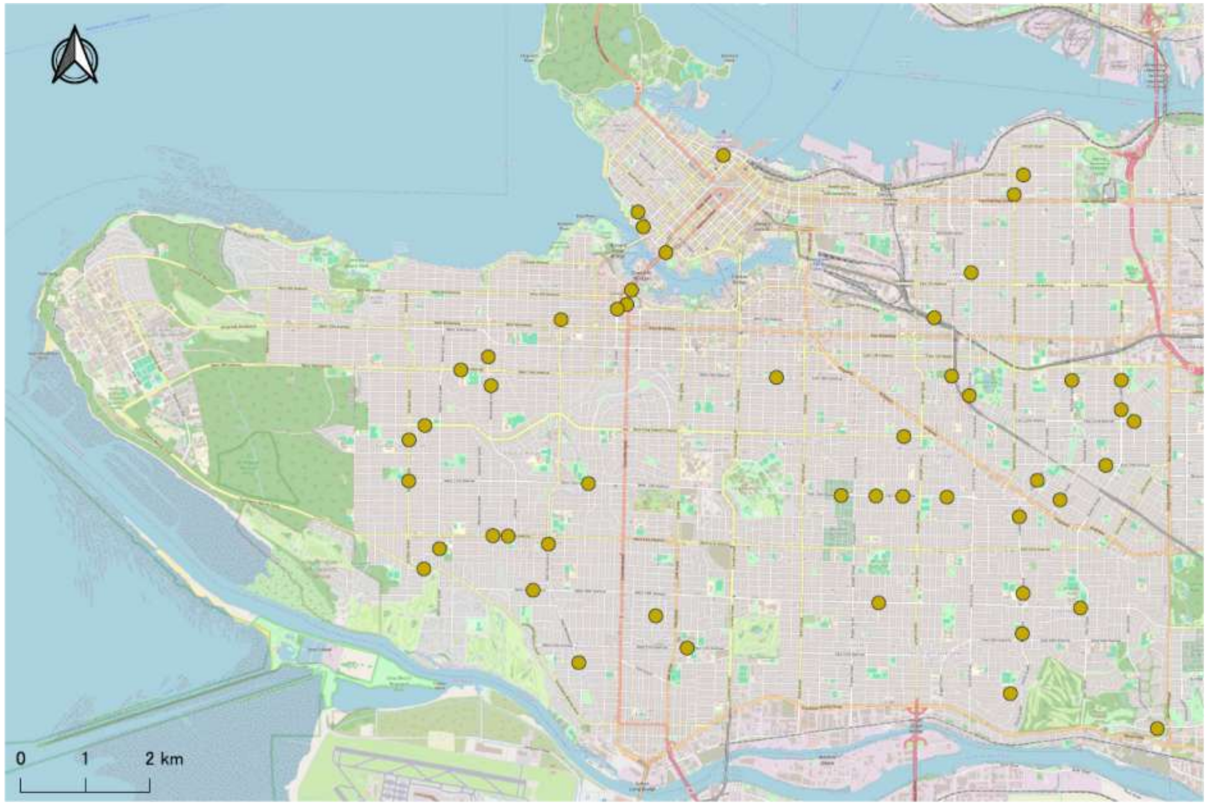
Rectangular Rapid Flashing Beacons (RRFB) have been introduced overseas to alert drivers with flashing lights.

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

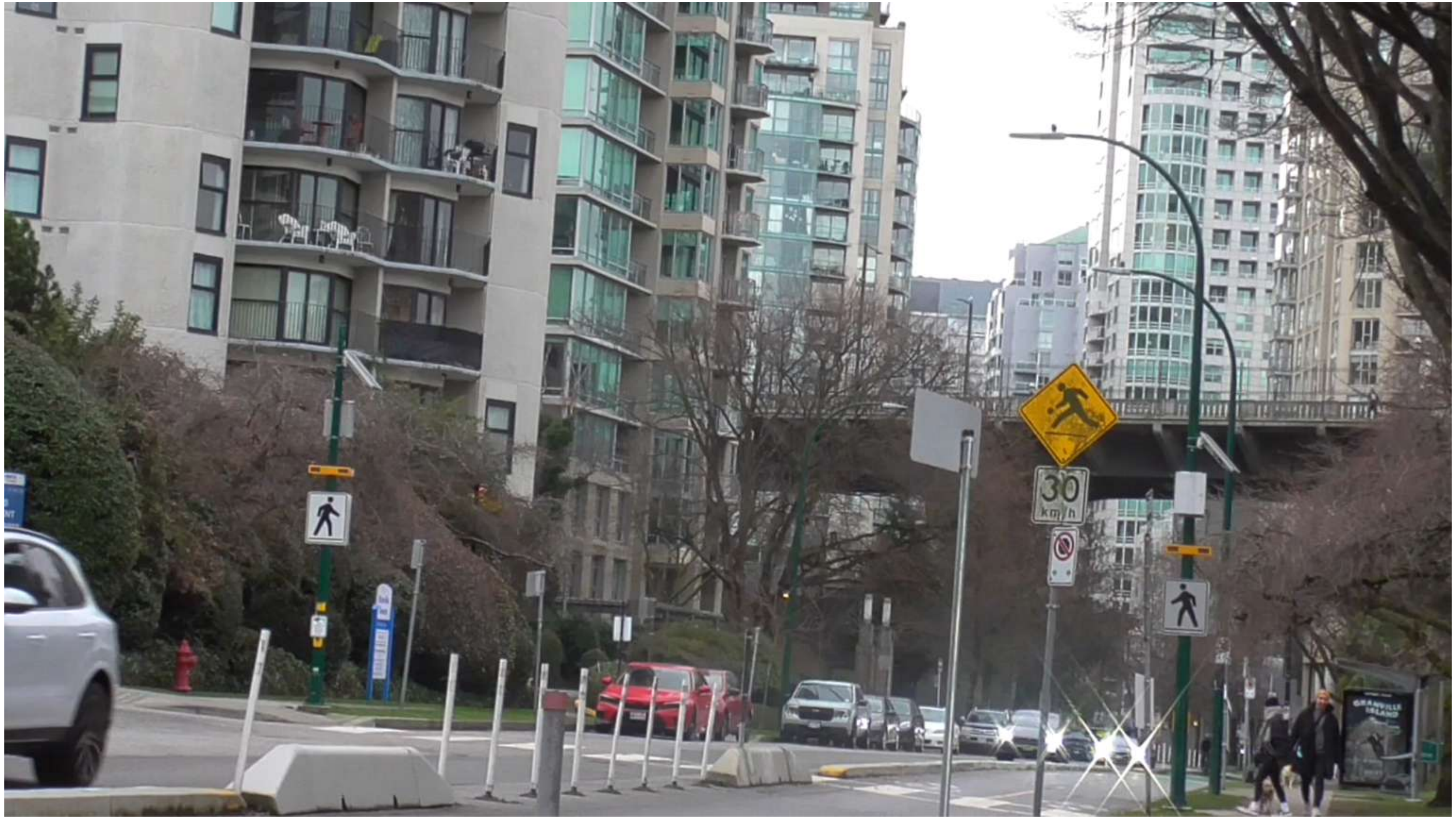
Arterial Road	Secondary Road	Collector	Residential Road	Total
14 locations	23 locations	11 locations	2 locations	50 locations

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

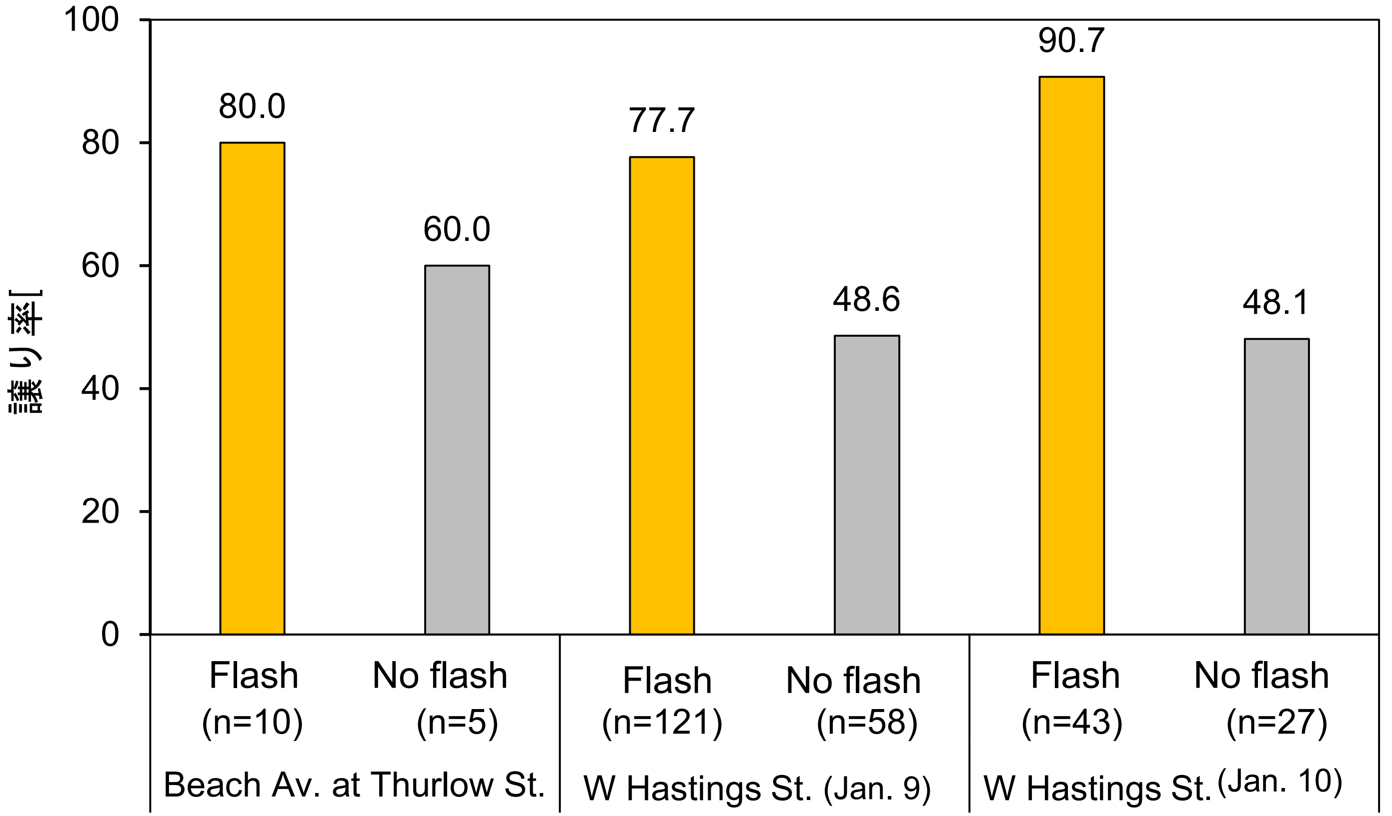


Status of RRFB implementation

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)

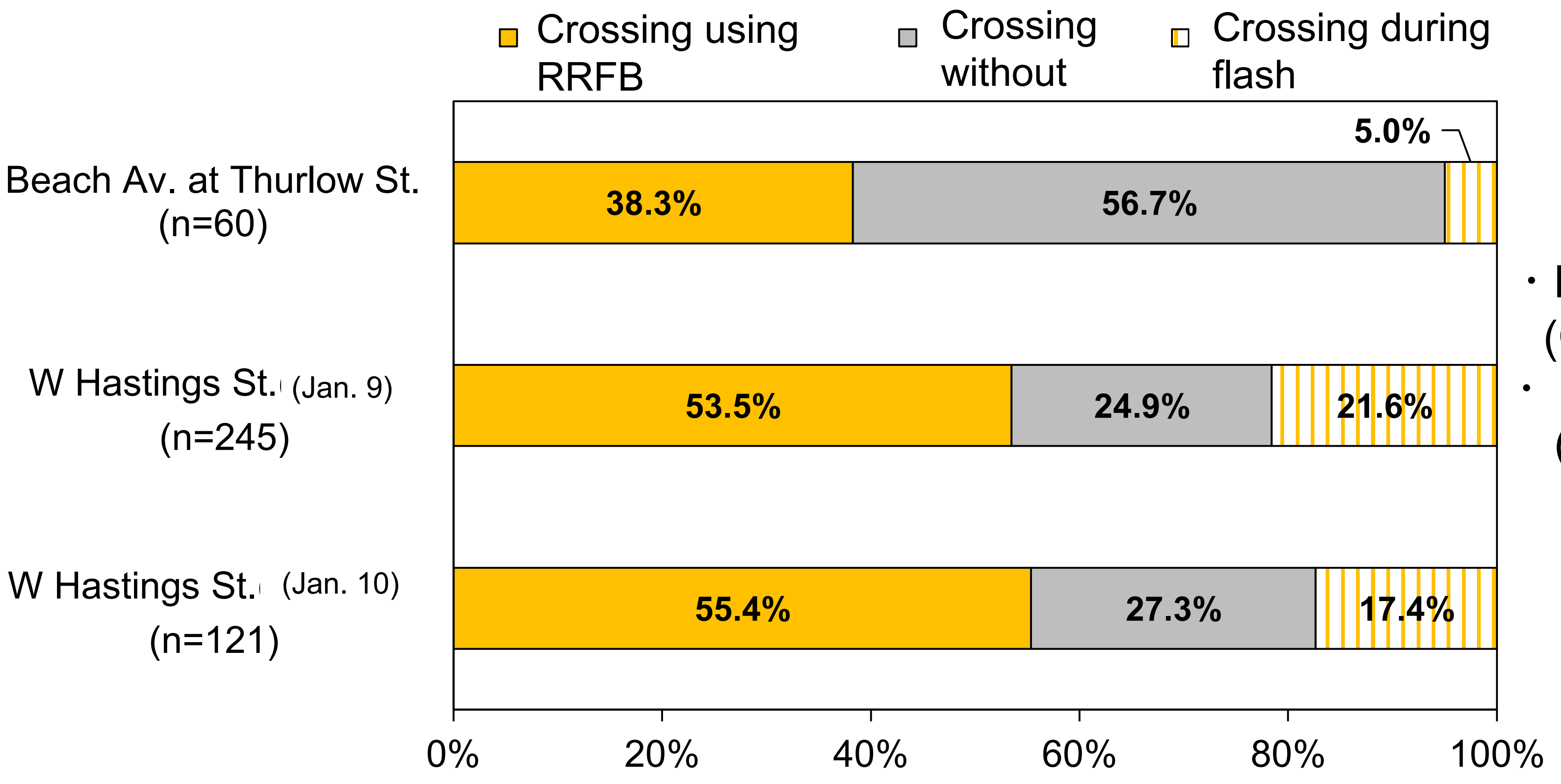
・ W Hastings St. 15 sec.
(Crossing distance: approx. 8 m)

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

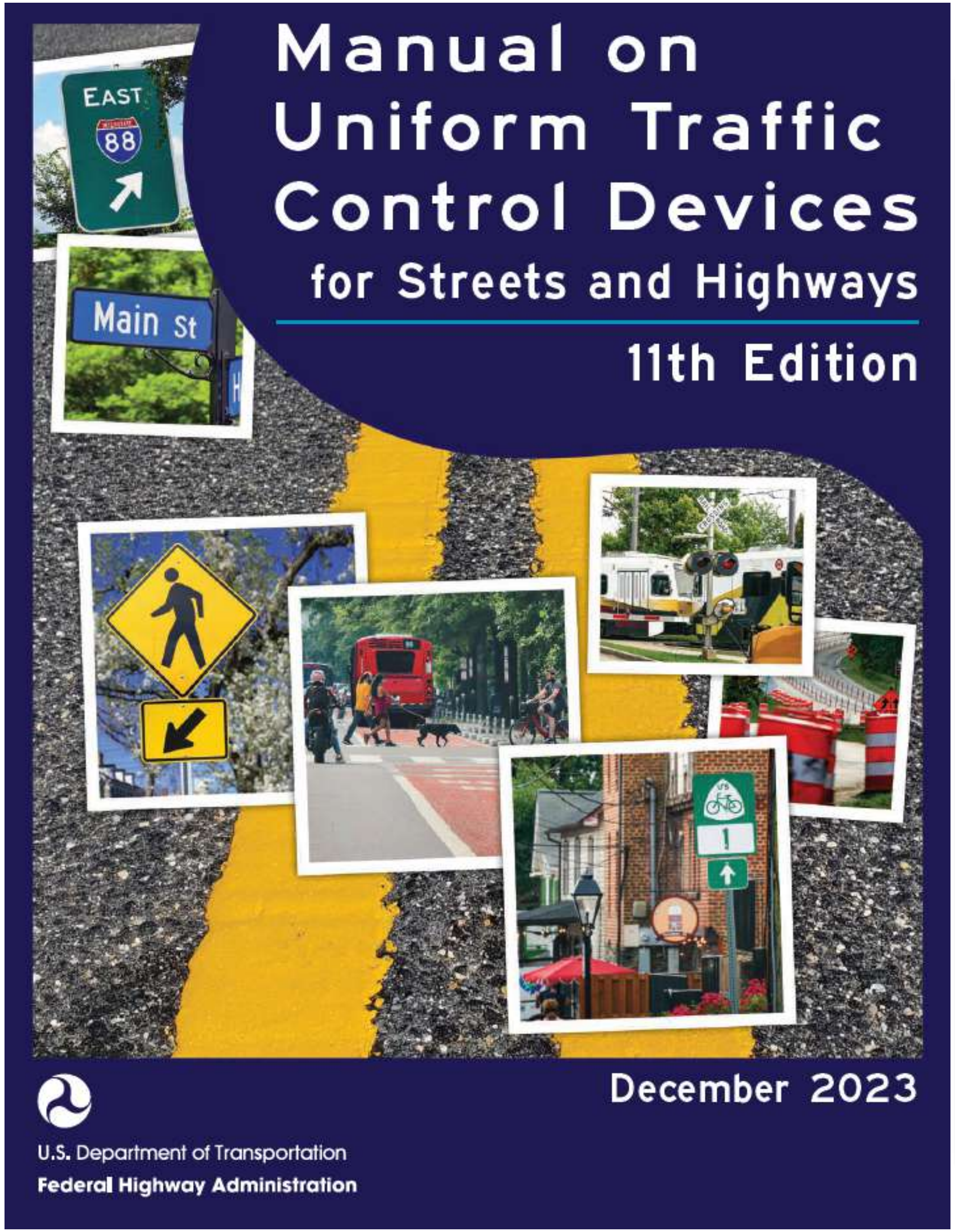
- Beach Av. at Thurlow St. 17 sec.
  (Crossing distance: approx. 11 m)
- W Hastings St. 15 sec.
  (Crossing distance: approx. 8 m)

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.



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

carmanah®

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RRFB Selection Matrix

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

Legend

- Engineering judgment = RRFBs are not recommended but are an optional enhancement with or following engineering judgment
- Consider = RRFBs are a candidate treatment to improving crossing safety on this roadway
- Recommended = RRFBs are an ideal treatment for this roadway

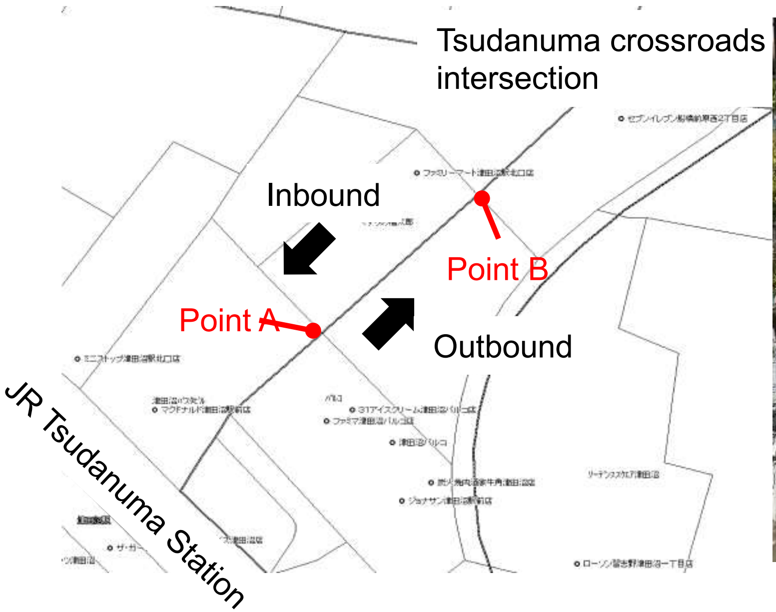
Crossing distance (e.g. number of lanes)	Median presence	Posted Speed Limit (mph) and Annual Average Daily Traffic (AADT)								
		< 9,000 AADT			9,000 – 15,000 AADT			> 15,000 AADT		
		SPEED LIMIT ≤30	SPEED LIMIT 35	SPEED LIMIT 40	SPEED LIMIT ≤30	SPEED LIMIT 35	SPEED LIMIT 40	SPEED LIMIT ≤30	SPEED LIMIT 35	SPEED LIMIT 40
2 lanes (1 lane in each direction)	-	Engineering judgment	Consider	Recommended	Engineering judgment	Consider	Recommended	Consider	Consider	✕
3 lanes (1 lane in each direction with two-way left-turn lane)	Yes	Engineering judgment	Consider	Recommended	Consider	Recommended	Recommended	Consider	Recommended	✕
	No	Consider	Consider	✕	Consider	Recommended	✕	Consider	✕	✕
4+ lanes (2 or more in each direction)	Yes	Consider	Consider	✕	Consider	Recommended	✕	Recommended	✕	✕
	No	Consider	Consider	✕	Consider	Recommended	✕	Recommended	✕	✕

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

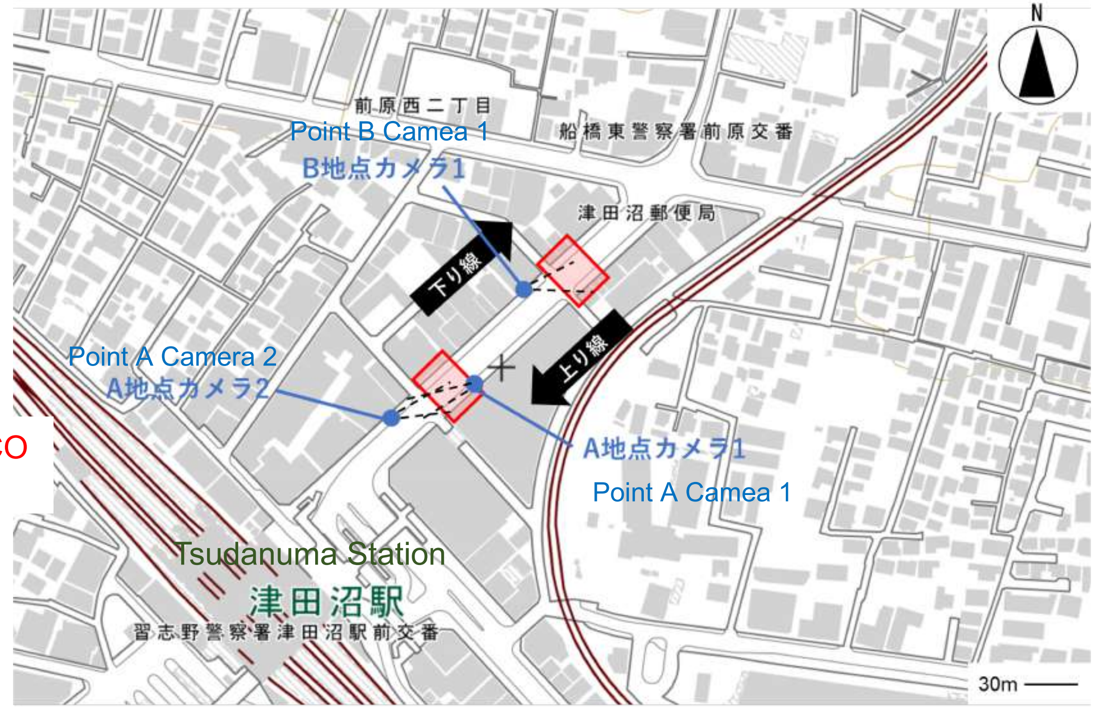
Observation Method

Tsudanuma crossroads intersection

Tsudanuma crossroads intersection

Point B camera 1

JR Tsudanuma Station



*Created by processing Geographical Survey Institute maps

Former PARCO (Now Viit)

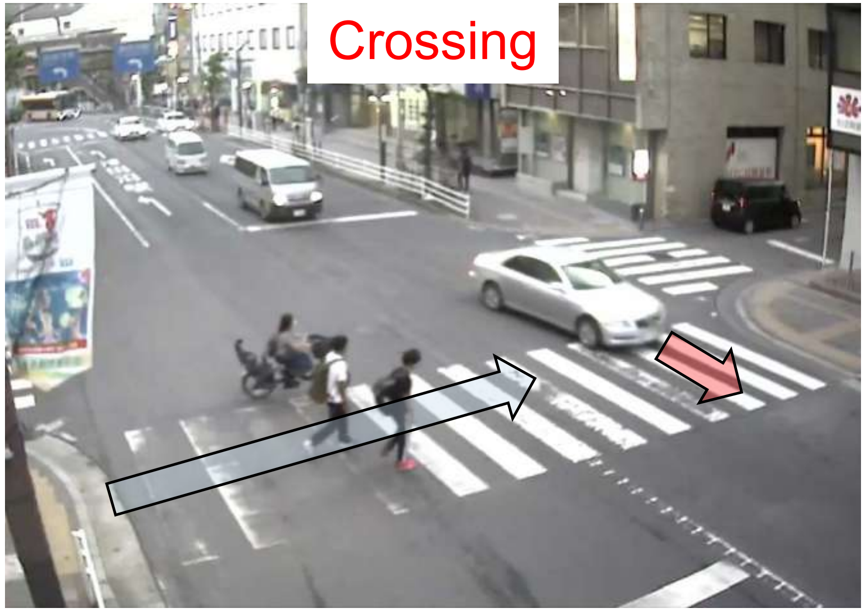
Former PARCO (now Viit)

Point A Camera 2

JR Tsudanuma Station

Point A Camera 1

Determination of yielding behavior based on pedestrian crossing patterns



Observation results： Vehicle type and pedestrian (Point A)

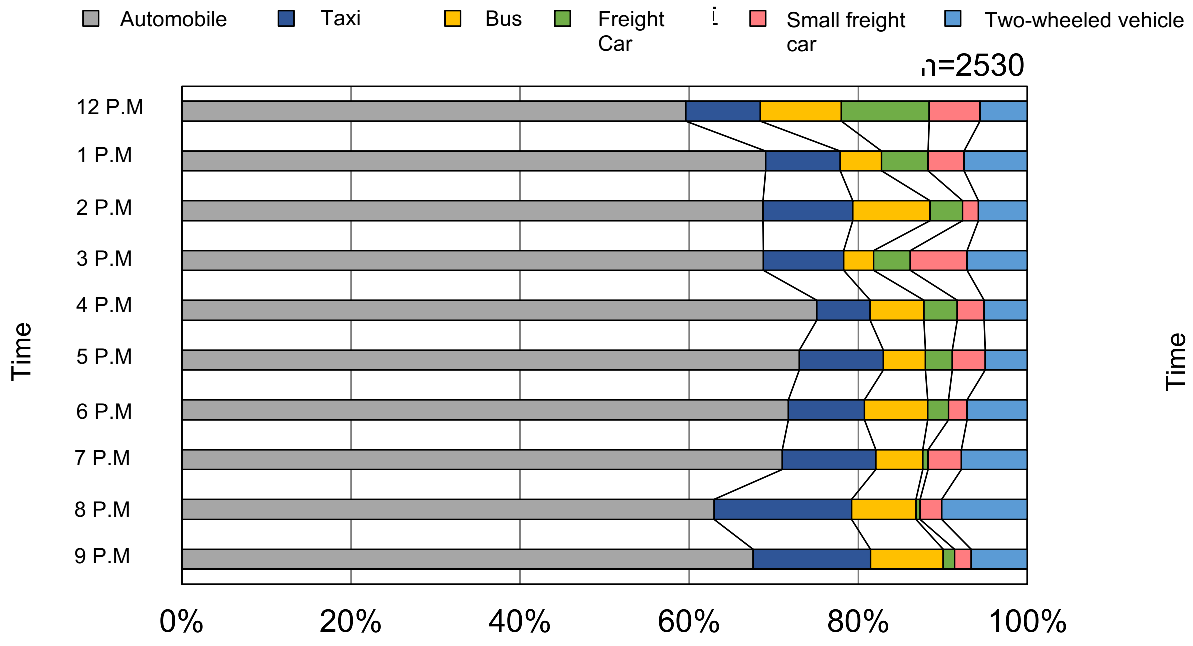
Sample size

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

Sample size

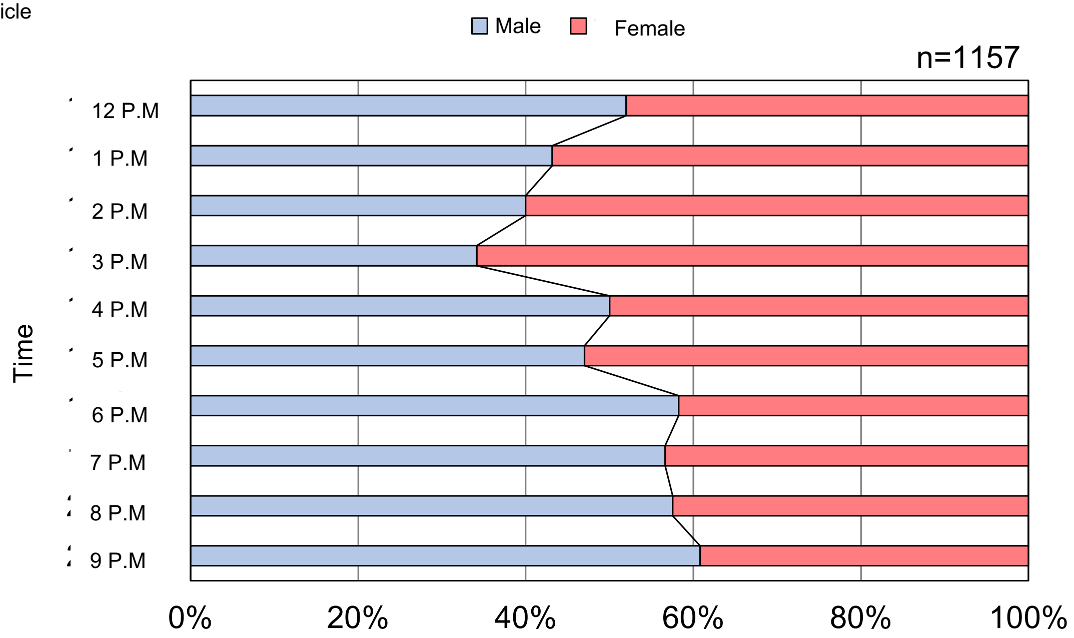
Gender (n)[%].			
Male	Female	Unknown	Total
571 [49.4]	583 [50.3]	3 [0.3]	1157 [100]

Composition by time



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

Composition by time

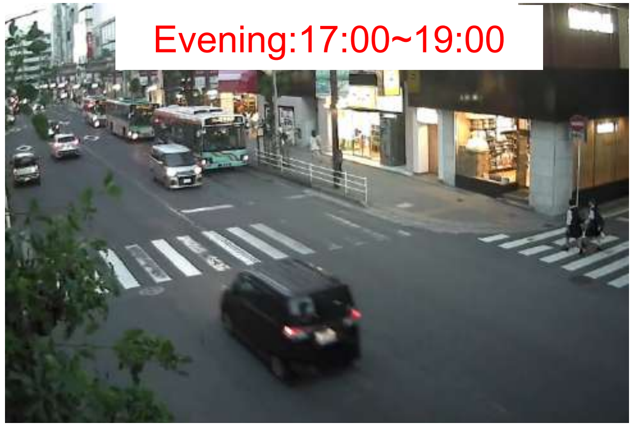


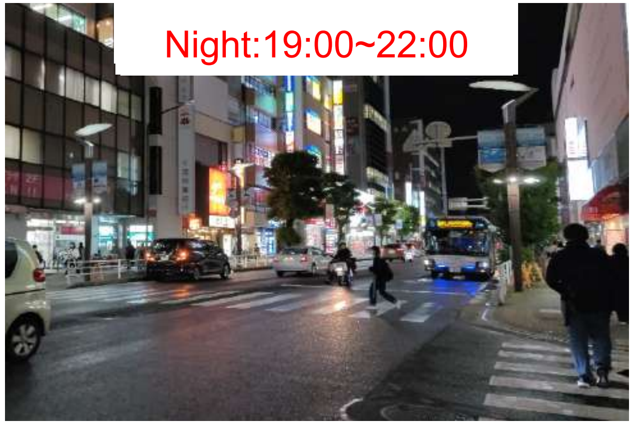
*Even if multiple vehicles pass through per 1 pedestrian at the crossing, it is counted as one in terms of the number of pedestrians per event.

Observations Yield Rate (Actual Situation of Pedestrian Priority)

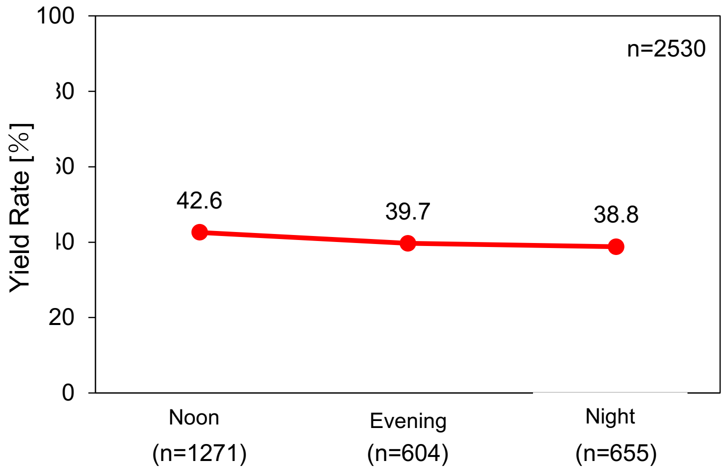
Yield rate at 2 pedestrian crossings in front of JR Tsudanuma Station (3-day total)
Location A (n=2530) 40.9% Location B (n=1829) 40.9 %

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

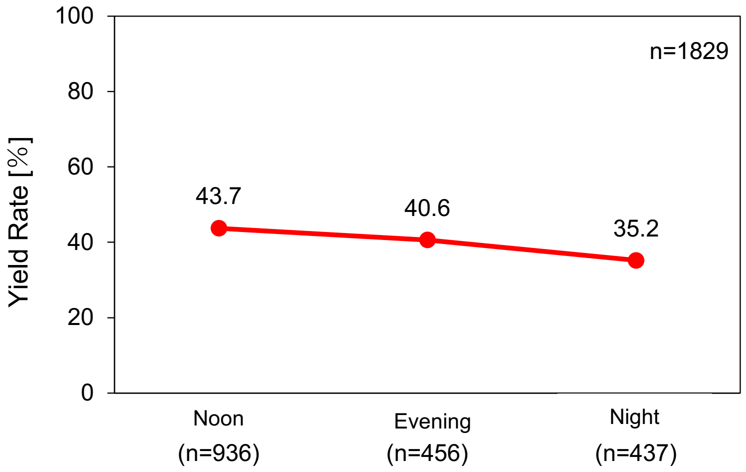




Yield Rate at Point A throughout the day



Yield Rate at Point B throughout the day



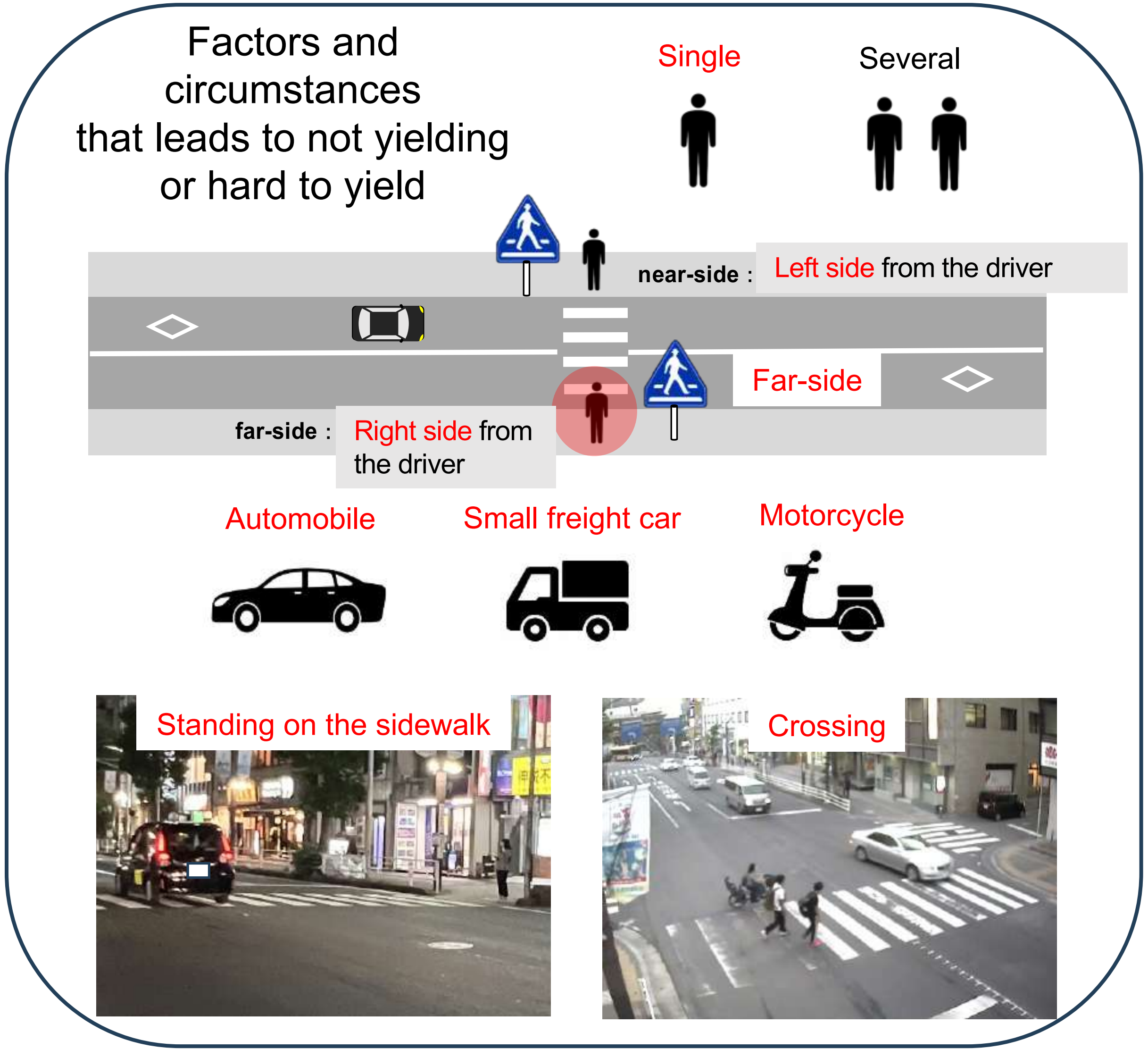
- No significant difference in yield rates when broken down by time of day

Factors Affecting Yield

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

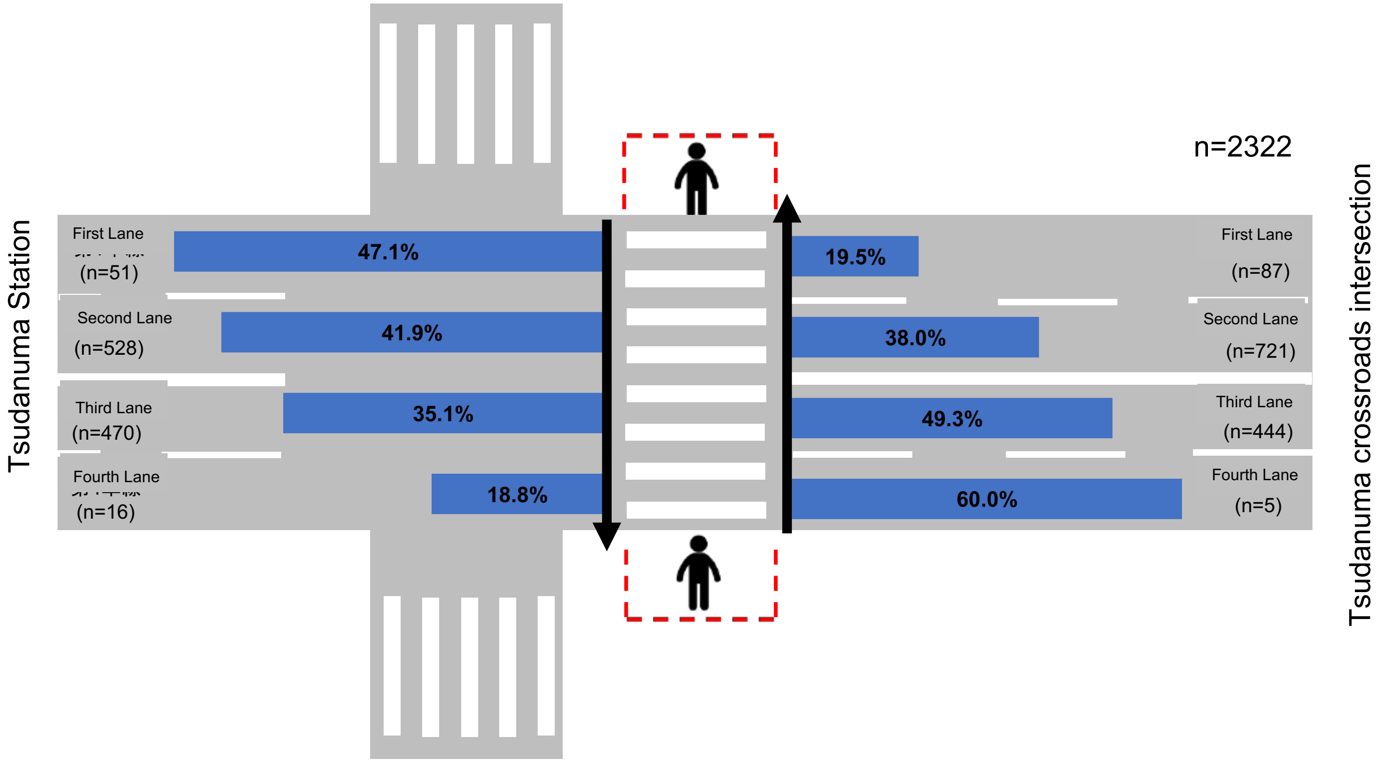
		Number of vehicles (N=2530) Yielded. (n=1036)	intransigent (n=1494)	P-value
Number of pedestrians	Single	681[37.6].	1131[62.4].	<0.001**
(n)[%].	Several	355[49.4]	363[50.6].	
Pedestrian crossing position	Near-side	467 [45.4].	561[54.6].	<0.001**
	Far-side	459 [35.5].	835[64.5].	
(n)[%].	Both sides	110 [52.9].	98 [47.1].	
Vehicle Type	Automobile	674[38.5].	1075[61.5].	<0.001**
(n)[%].	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	Standing at the sidewalk	130 [29.7].	308[70.3]	<0.001**
(n)[%].	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	Day	542[42.6].	729[57.4].	0.21
(n)[%].	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.

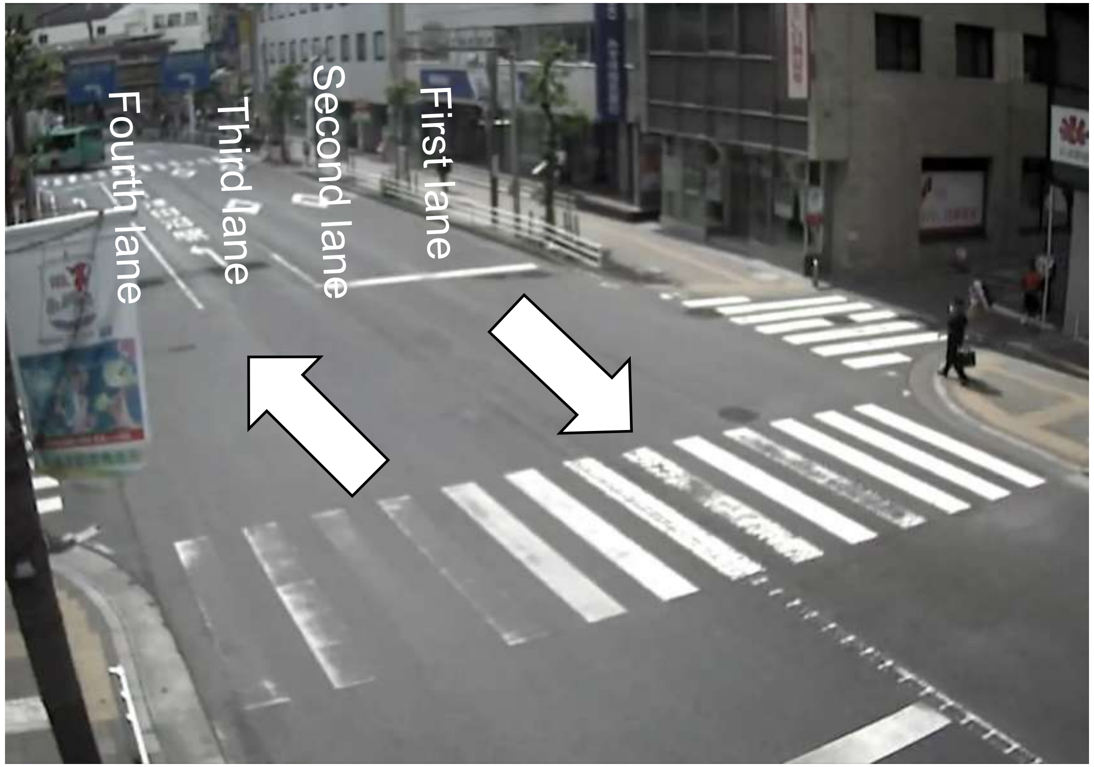


Yield Rate Results by Lane (Point A)

Yield rate by lane (location A)



On-site Situation

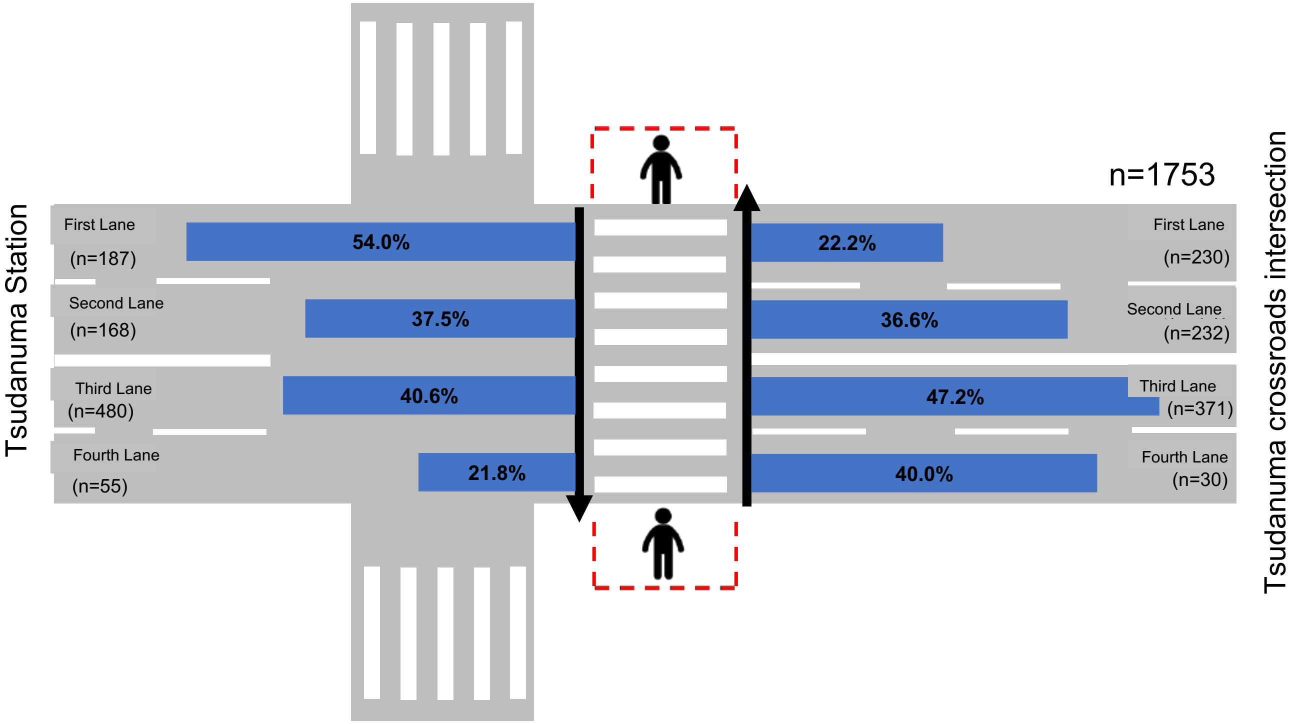


Analysis based on near-side and far-side data, excluding both sides with single and multiple pedestrians.

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

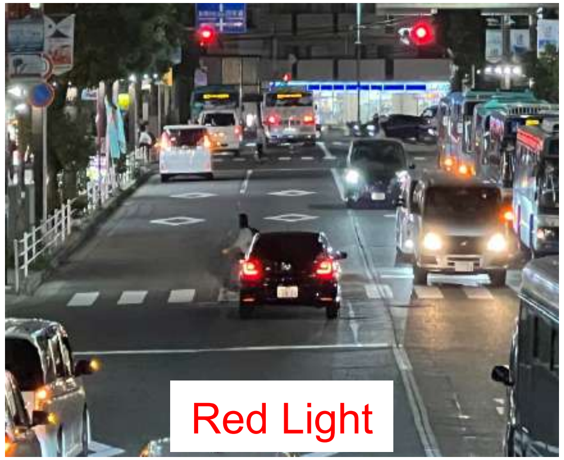
Yield Rate Results by Lane (Point B)

Yield rate by lane (Position B)



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

Comparison of yield rates by signal light color



Investigation result

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

- 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,

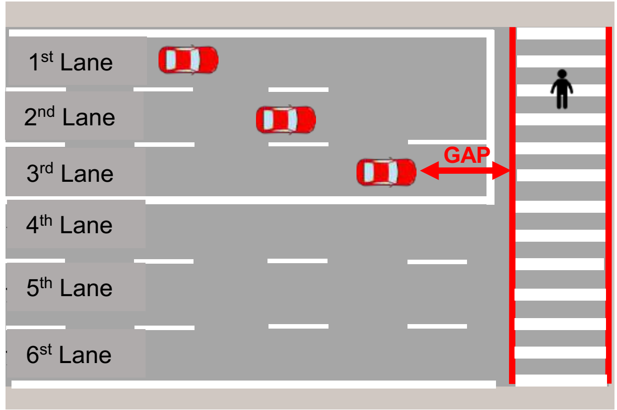
↓

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

Previous studies on Pedestrian Road Crossing Behavior

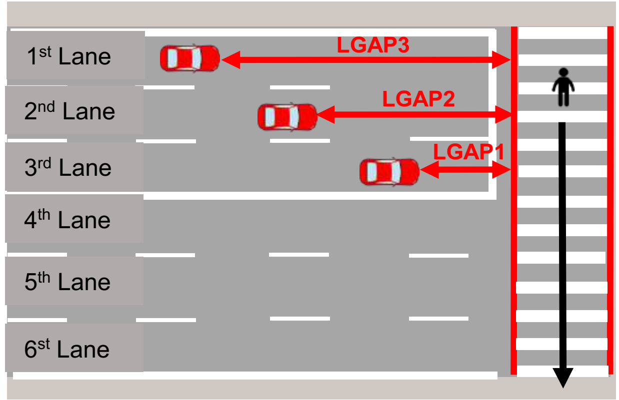
Pedestrian Decisions (Human Factors)	Psychophysics-based Gap Acceptance (PGA Model)
Tendency to make crossing decisions based on vehicle arrival time rather than distance from vehicle Petzoldt (2014)	・Model that incorporates vehicle arrival time as a crossing decision ・ Analysis based on representative 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

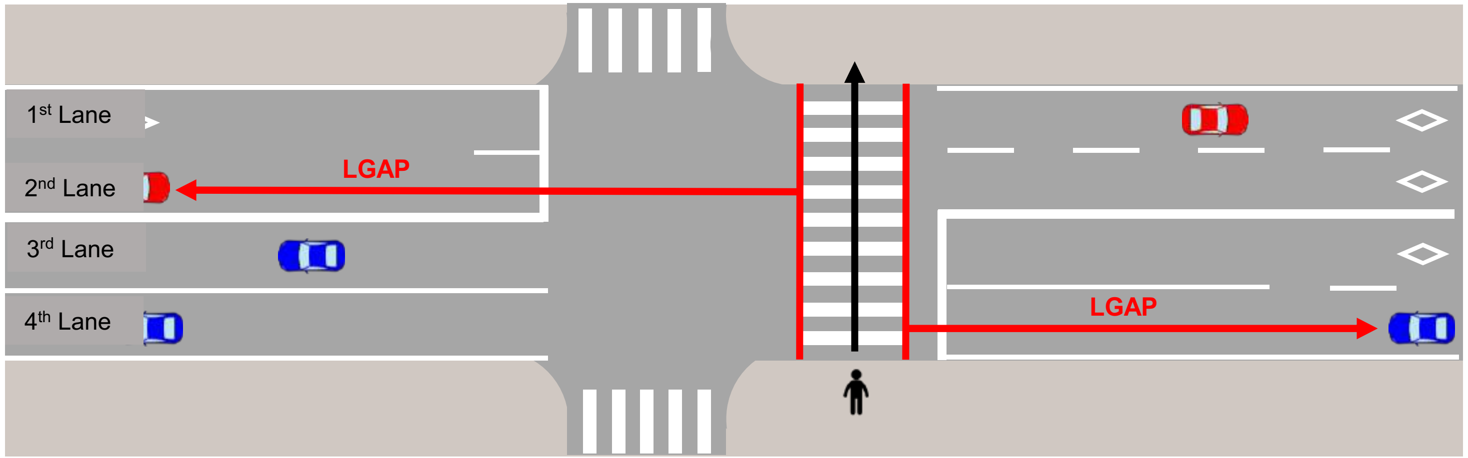
LGAP of lanes 1 and 2 are long, so lane 3, through which the vehicle passes, is judged to be crossable.
Characteristic: Analysis considering subsequent gaps (1st and 2nd) is possible.

Pedestrians' choice of crossing method
1. Single Crossing, 2. Two-Stage Crossing, 3. Rolling Gap Crossing

LGAP and Crossing Method 1

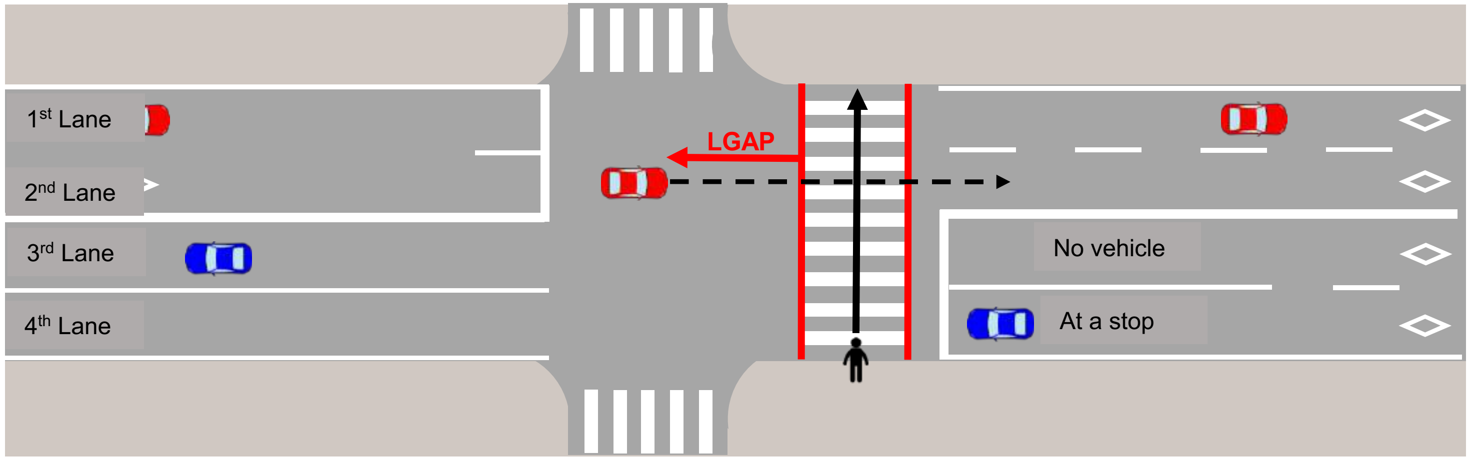
Typical gap value = time [s] (distance/velocity)
Gap value in this investigation= distance from vehicle [m] (surveyed every 5 m)

Single Crossing



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

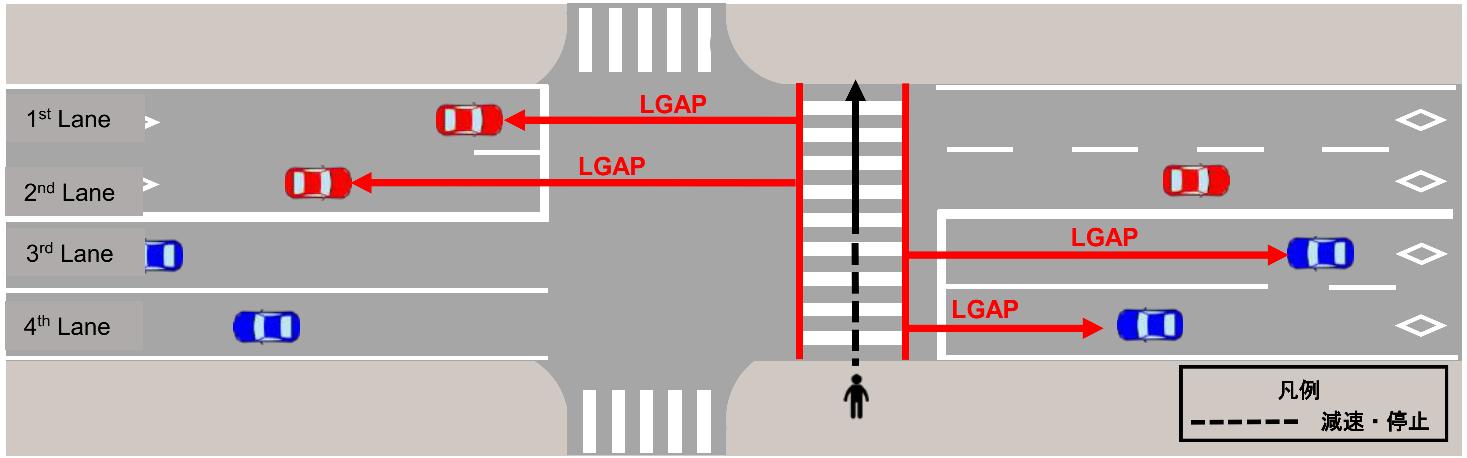
Two-Stage Crossing



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

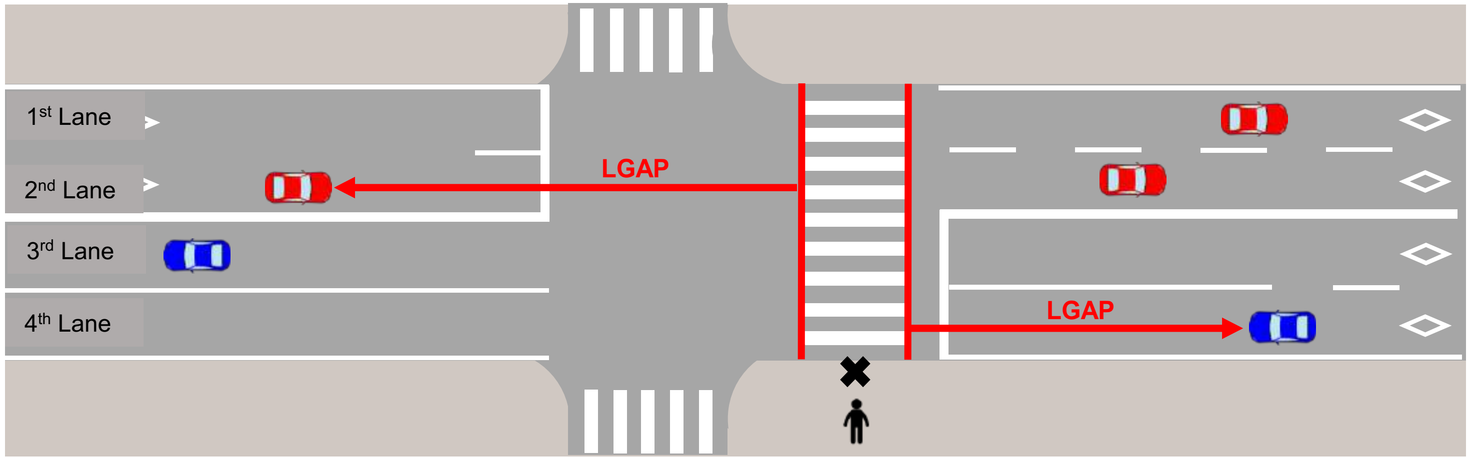
LGAP and Crossing Method 2

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.

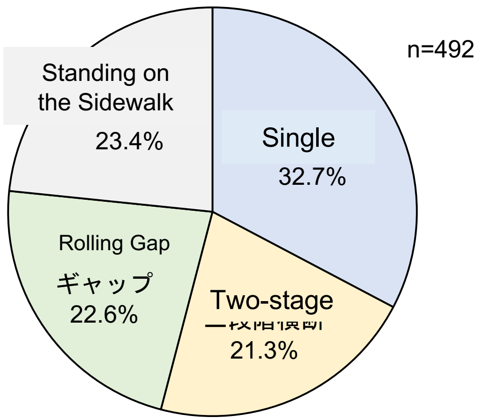
Standing on the Sidewalk

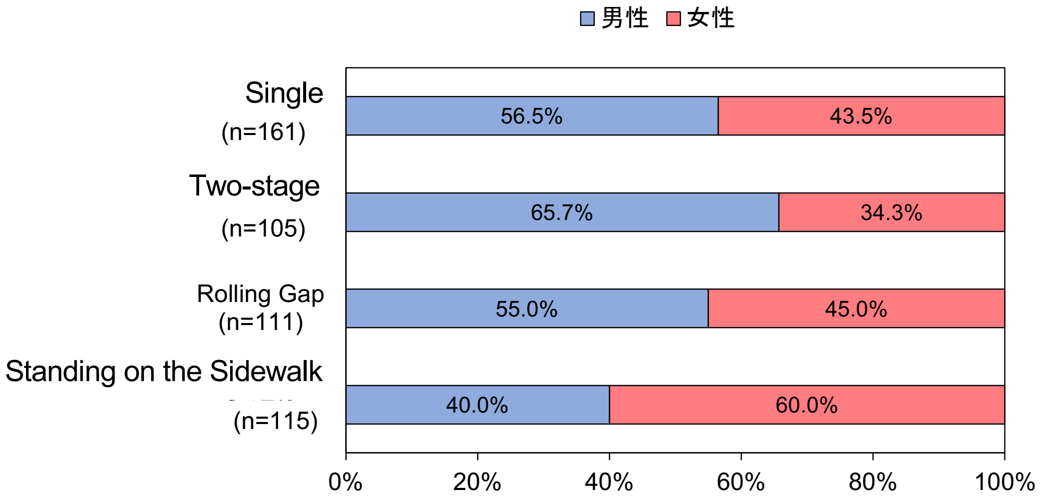


1 Situation where a pedestrian stops on the sidewalk while a vehicle is approaching
2 A situation where a vehicle has started to cross the street after stopping or passing through a pedestrian crossing.

*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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