研究結果報告書　（英文）

A Study on Unsignalized Crossing Facilities with Rectangular Flashing Beacons for Increasing Drivers Yielding to Pedestrians

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Abstract

We conducted an experiment to assess the effectiveness of Rectangular Rapid Flashing Beacons (RRFB), a measure implemented in the United States to enhance pedestrian right-of-way law at crosswalks. The results of the verification conducted in Sendai City showed that after four months of operation with RRFB installed, the rate of drivers yielding increased by 15.2 points compared to the period when RRFB was not installed. However, due to the low actuation, it cannot be stated that the flashing lights significantly improved drivers yielding.

1. Aim of Research

Yielding to pedestrians at unsignalized crosswalks become a major concern in Japan. Although some local communities have been requesting the traffic signals to ensure that pedestrians have the opportunity to cross safely, fewer are not being equipped with traffic signals. As background, declining population has been changed traffic conditions and the country's financial difficulties have led to a policy of reducing traffic signals in Japan, so Japanese traffic authorities discuss about sustainable traffic safety crosswalks facilities alternative to traffic signals.

Generally, crosswalks consist of signs and markings. Additionally, overhead crosswalk signs, colored pavement, and warning signs, have been installed over time. Focusing at crossing facilities in the U.S., they employ Rectangular Rapid Flashing Beacons (referred to as "RRFB") alternative to signals. Specifically, flashing lights can be attached to the pole of crosswalk signs to alert drivers. However, the effectiveness of flashing lights in crossings has not been established in Japan. Therefore, the aim of this study is to investigate whether RRFB has an effect in improving pedestrian right-of-way law.

2. Method of Research & Progression

2-1 Specifications of the RRFB

The equipment used in the experiment was the push-button RRFB manufactured by Tapco in the U. S.. As shown in Figure 1, the light bar was mounted under the crosswalk sign. Power was supplied independently via a solar panel which charged a battery. Additionally, a communication feature was set up so that pressing the button on the upstream side would simultaneously activate the downstream side RRFB. The flashing pattern followed the Wig-Wag + Simultaneous method, with the Federal Highway Administration (FHWA) specifying an 800ms cycle for left-right alternating and simultaneous flashing(Figure 2).

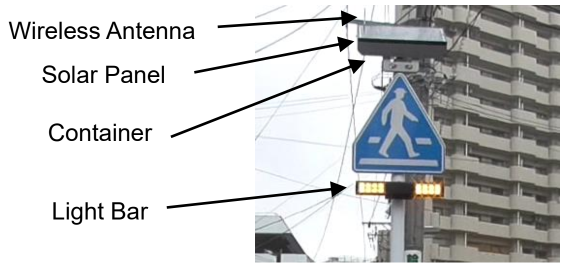

FIGURE 1：The Components of RRFB

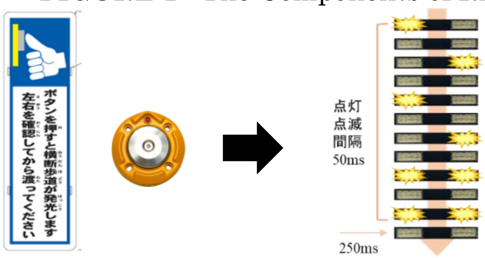

FIGURE 2：Push Button and Flashing Pattern

2-2 Notification Method

We installed RRFB before the start of the experiment, and the experimental period was set for four months from April 4th to August 8th. In order to inform RRFB, we attached four notice boards as shown in Figure 3(a) to roadside facilities indicated by the blue rectangles in Figure 4 until the end of the experiment. We also installed the notice boards for drivers at the positions indicated by the red rectangles in Figure 4 as showed in Figure 3(b). However, the notice boards for drivers were removed one week after the experiment started.

(a)For Pedestrians (b)For Drivers

FIGURE 3 : Notice Board

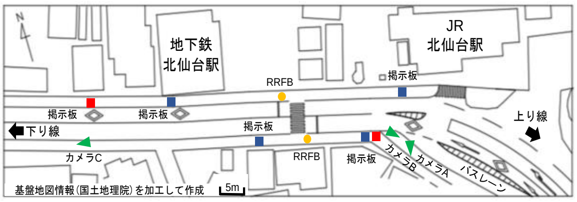

FIGURE 4 : Experimental Site Plan

2-3 Survey Overview

The survey was conducted once before the installation of RRFB, and one month and four months after installation. The survey took place over five weekdays with a total of seven hours of observation each day. The observation method was the use of a total of three elevated video camera devices known as 'viewpoles,' each recording at 30 frames per second (fps). The vehicles included in the analysis were those traveling in the eastward direction. Additionally, pedestrians waiting positions were categorized as 'near-side' for the left side when viewed from the drivers, 'far-side' for the right side, and 'both sides' representing pedestrians positions on both sides of the road.

3. Results of Research

3-1 Yielding Rate and Actuation Rate

Figure 5 illustrates the changes in yielding rates at the experiment site. Using the pre-installation yielding rate of 34.7% as a baseline, the yielding rate increased by 15.2 percent point fout months after installation. However, the percentage of pedestrians using RRFB was quite low, standing at 6.4% one month into its operation and dropping slightly to 6.2% after four months of operation. As shown in Figure 6, the yielding rate was higher when RRFB was flashing compared to when they were not, but due to significant sample size imbalances, it was difficult to evaluate the effectiveness of flashing lights and driveres yielding behavior.

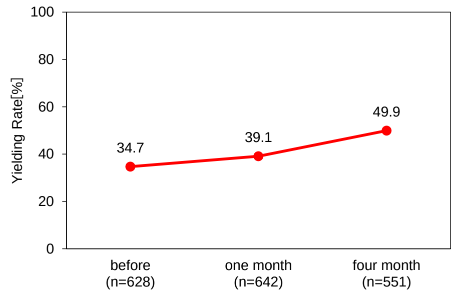

FIGURE 5 : Yielding Rate Trend

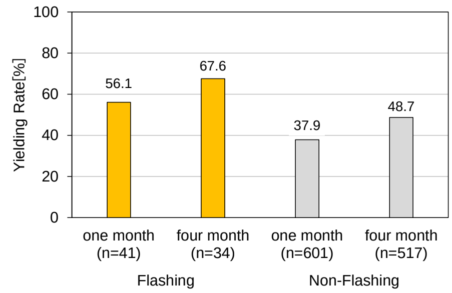

FIGURE 6 : Yielding Rate by Presence of Flashing

3-2 Staged Pedestrian Protocol

Based on the first month observations, we conducted an experiment in which the investigators themselves activated RRFB (refered to as Staged Pedestrian Protocol). The method involved two signalers initially stationed on the sidewalk for communicating the estimated arrival time to staged pedestrians who push button via wireless devices. The staged pedestrians, in turn, approached the pushbutton for activating the RRFB according to the specified time.

3-3 Vehicle Types and Yeilding Behaviors

The ratios of observed vehicles categorized into six vehicle types showed that regular passenger cars were the most prevalent, accounting for over 60%, followed by taxis. Figure 7 illustrates the changes in the yielding rates of the six vehicle types, divided into groups with and without flashing lights. In cases without flashing lights, there was an increasing trend for the five vehicle types (excluding motorcycles) compared to their pre-installation rates. In cases with flashing, the proportion of four-wheeled vehicles (excluding compact delivery trucks) exceeded the yielding rates four months after the event compared to the group without flashing lights.

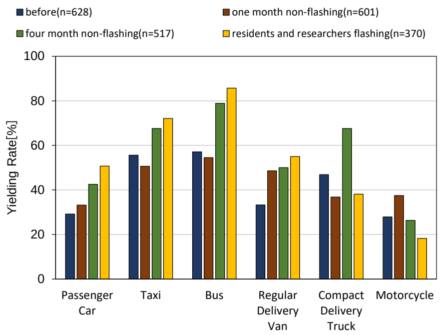

FIGURE 7 : 6 Vehicle Categories

3-4 Crossing Locations and Yeilding Rate

Figure 8 depicts the yielding rate for pedestrians crossing locations on sidewalks such as near-side and far-side, excluding both sides, divided into groups with and without flashing lights for different survey periods. As a result, in all four groups, the yielding rate on the near side was higher than that on the far side, indicating a tendency for pedestrians on the far side to be less likely to be yielded to by drivers.

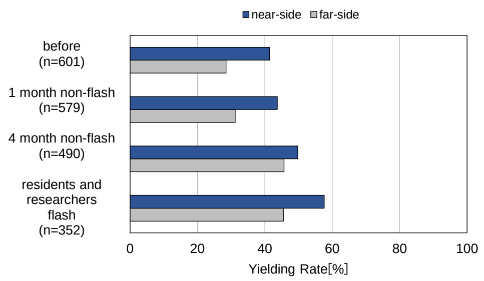

FIGURE 8 : Crossing Locations

3-5 Dtiving Section and Yeilding Behavior

We analyzed whether the yielding rate differed based on the distance to the crosswalk, when pedestrians entered the waiting area for crossing or the onset of a flashing of the RRFB. The survey method involved dividing the area from the end of the crosswalk markings upstream to 30 meters into segments of 5 meters to establish travel segments. Figure 9 presents the yielding rate for different travel segments. The results indicated that all four groups approached the crosswalk, the yielding rate decreased. When comparing the three groups without flashing, the ratios for the operation four months increased except for the 0-5m segment. In the group with flashing, the effectiveness of yielding due to a flash of RRFB was highest at 63.1% when flashing lights started at 30 meters or more.

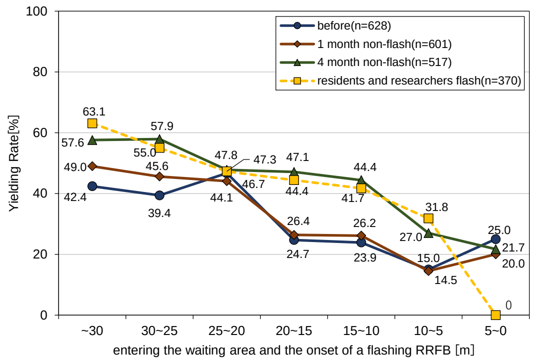

FIGURE 9 : Travel Segment

3-6 Vehicle Speed and Yeilding Behavior

We conducted an analysis of vehicles with a travel distance of 30 meters or more at the time of the flashing to examine whether there is a difference in yielding rates based on the vehicle speed when the flashing occurred. Figure 10 presents the results of yielding rates, categorized into groups with and without flashing lights, with speed classes in 5 km/h increments. The mode speed for all four groups was 30-35 km/h. The yielding rates in all four groups tended to decrease as vehicle speed increased. When comparing the groups without flashing lights, the yielding rates were higher after 4 months of operation than they were before the operation and one month into the operation, with the exception of some sections. However, there were no significant differences in the trends between the groups without flashing lights and the groups with flashing lights after four months.

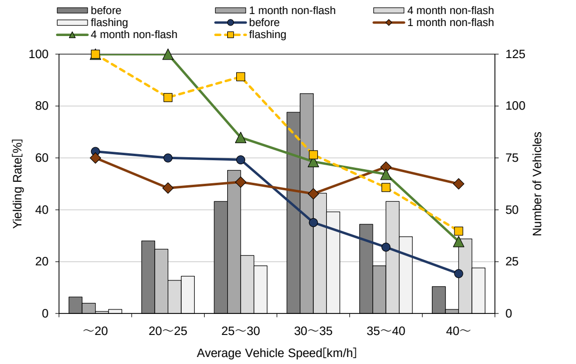

FIGURE 10 Yielding Rate by Vehicle Speed

3-7 Factor Analysis of Drivers Yielding

To assess the factors influencing drivers yielding behavior in response to RRFB flashing, an analysis is conducted using binomial logistic regression. In the binomial logistic regression model, Equation (1) represents the probability (denoted as Py) of a drivers response variable, which indicates whether they yield when flashing is present or not.

$$P_y = \frac{1}{1 + exp\{-(b_0 + b_1 x_1 + b_2 x_2 + \cdots + b_k x_k)\}} \quad (1)$$

Table 1 shows the results of the logistic regression analysis. Regarding the relationship between pedestrian characteristic and yielding influenced by RRFB, it indicated that when there were more pedestrians, the presence of flashing had a more significant impact on yielding behavior, especially when there were "multiple" pedestrians compared to "solo" pedestrians. When it comes to the crossing position, pedestrians who activated the RRFB on the 'far-side' relative to the 'near-side' demonstrated a slightly lower impact, although no significant difference was observed. In terms of vehicle driving conditions, the results showed that the impact of flashing lights was less pronounced and statistically significant when the partial regression coefficients were negative for scenarios involving 'motorcycles,' 'platooning,' and 'increased vehicle speed.'

Next, regarding the flashing start interval with positive and significant coefficients, it was observed that the further the vehicle's position from the crosswalk at the onset of flashing, the more likely it was to encourage yielding behavior, as indicated by the parameter ratios.

Table 1 : Logistic Regression Model

Independent Variable	Partial Regression Coefficient
Crossing Position Dummy (far-side : 1, near-side : 0)	-0.33
Numeber of Pedestrian Dummy (Multiple : 1, Solo : 0)	1.59**
On-Street Parking Dummy (Yes : 1, No : 0)	-0.87
Vehicle Type Dummy (Motorcycle : 1, Four-Wheel Vehicle : 0)	-2.91*
Driving Condition Dummy (Platooning : 1, Non-Platooning : 0)	-1.04*
Flashing Onset Interval Dummy [20~10m] (Upstream 20～10m : 1, Otherwise : 0)	1.33*
Flashing Onset Interval Dummy [30~20m] (Upstream 30～20m : 1, Otherwise : 0)	2.37***
Flashing Onset Interval Dummy [~30m] (Upstream more than 30m : 1, Otherwise : 0)	3.22***
Average Vehicle speed at the Onset of Flash [km/h] (Average Speed over a 5-meter Interval)	-0.13***
Intercept	2.00
McFadden's Pseudo R-Squared	0.217
Accuracy Rate[%]	71.72
Sample Size	343
χ^2 (df)	159 (1)***

*: P<0.05, **: P<0.01, ***: P<0.001

4. Future Area to Take Note of, and Going Forward

Based on the analysis results, it has been determined that installing at pedestrian crossings has the potential to enhance the yielding rate of vehicles, making it an effective traffic safety feature. However, the difference between when it was flashing and when it wasn't flashing was not significantly large, which led to the conclusion that there was no clear effect of flashing on the yielding behavior of vehicles. As a future task, it is necessary to conduct an assessment during nighttime. Furthermore, it is essential to accumulate empirical research in different road traffic environments. This will help clarify the effectiveness of RRFB safety measures in various road traffic settings.

5. Means of Official Announcement of Research Results

The results of this study were presented at the 43rd Transportation Engineering Research Presentation Meeting on August 9, 2023.