

Field Experimental Analysis of the Behavior Improvement Effect Using Roadside Devices to Notify Approaching-Vehicle for Cyclists

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Abstract: The accident rate of vehicles approaching from narrow streets, and bicycles approaching from the left side on a sidewalk is high at small intersections along arterial roads. Drivers tend to gaze to the right side. On the other hand, at intersections with bad visibility, cyclist's safety confirmation and ability to slowdown greatly differs from that of an intersection with good visibility. Thus, bicycles on a sidewalk are at risk of colliding with vehicles travelling along narrow streets. In this study, we focused on notifying the cyclist of a the vehicle's approach from a narrow street as one of the countermeasures for supporting safe running of bicycles. The effectiveness of this system was verified by public-road experiment. It was found that cyclists' behavior of safety confirmation improved, cyclists tended to slow-down and there was a subsequent increase in cyclists' safety.

Keywords: Small Intersections along Arterial Roads, Vehicle-Bicycle Accident Prevention, Mirror Device, Dynamic Flashing Light Device, Cyclists' Safety Confirmation Behavior, Bicycle's Speed

1. INTRODUCTION

1.1 Background of Vehicle-Bicycle Accidents

In Japan, bicycle related accidents account for about 20% of total traffic accidents. This ratio is increasing as use of bicycles increases. About 60% of bicycle related accidents are crossing collisions. In particular, at small intersections running along arterial roads, it is noted that the incidence rate of collision-type accidents with motor vehicles (hereafter called as VNS) which are approaching from a narrow street, and bicycles(hereafter called as BLS) which are approaching from left side to VNS is high (Minoshima et al., 2010; Ito et al., 2011).

The following factors are pointed out from previous studies. At small intersections along arterial roads where crossing collision accidents occur frequently, about 70% of VNS tend to neglect stopping in front of an intersection (Mitani et al., 2011). Drivers tend to pay attention only to vehicles which are coming from the right side (Summala et al., 1996). The rate of safety confirmation of drivers to the left side is low compared with that of the right side. The rate changes depending on good and bad of a visibility of intersectional corner (Kiyota et al., 2001). Therefore, drivers tend to delay noticing cyclists of BLS. Meanwhile, bicycles' behavior of slowdown is also related to occurrence of accidents (Watanabe et al., 2010).

1.2 Possible Countermeasures

According to the occurrence factor, improvement of a VNS's driver's behavior is important. Under present circumstances, countermeasures, such as roads with reflecting mirrors installed for mutual visual confirmation improvement and stop regulation, need to be established. Moreover, new countermeasures (Mitani et al., 2011; etc.) which offer stopping assistance to a driver are devised. However, they have not yet been applied for common use as road infrastructure at small intersections. Therefore, examination of countermeasures from a viewpoint of BLS is also necessary.

According to the above mentioned study, BLS accidents are related not only to a driver's safety confirmation behavior but also to a cyclist's behavior. It is suggested that these relationships are affected by the influence of the visibility characteristic at an intersection. However, such correlations have not yet been clarified.

Therefore, the authors analyzed the relationship between the visual field characteristic of both corners of an intersection, and number of accident. Drivers' safety confirmation behavior was analyzed by video survey at intersections with different visibility features. Furthermore, cyclist behavior of the BLS was analyzed.

In previous research, the following points were clarified (Wang, Mitani and Yamanaka, 2012). On intersections which have bad visibility at the left corner, compared with the right corner, crossing collision accidents occur at a high rate. The rate of safety confirmation of the VNS's driver to left side is about 20% lower than that of the right side. At intersections which have bad visibility at the left corner, compared with the right corner, safety confirmation behavior to the left side of a VNS's driver begins and ends a little earlier than that of intersections which have poor visibility at the right corner compared with the left corner, and an intersection which has bad visibility at both sides. Hence, the driver does not pay attention to left side just before entering an intersection. Therefore, the cyclist of the BLS is difficult to be noticed by the driver. The risk is even higher when visibility of the left corner from VNS is inferior to that of the right corner.

On the other hand, at intersection with "a little bad visibility", safety confirmation frequency of BLS's cyclist to the VNS and slowdown action increases compared with that of intersections having good visibility. However, at intersections with "completely bad visibility", neither safety confirmation behavior to VNS nor slowdown action increases. The behavior of cyclists at intersections with "a completely bad visibility" is almost equivalent to that of intersections with "a good visibility." Accordingly at intersections with "completely bad visibility", a BLS cyclist will notice the VNS which is approaching just before the intersection.

As mentioned above, especially at intersections without visibility near the left corner of a narrow street, the BLS cyclist is exposed to risk of a collision due to a delay in noticing the VNS driver. As a countermeasure to the VNS, complete stop before an intersection and paying attention to the left corner of a narrow street near the intersections are necessary. Meanwhile, as a countermeasure for the BLS, it is important that the BLS cyclist can notice the VNS beforehand. Under such conditions, a cyclist can avoid a collision even if the VNS is a dangerous vehicle.

1.3 Aim of this Study

This study aims to propose bicycle safety measures based on the problem of transportation behavior at small intersections along arterial roads. Since studies related to countermeasure to the BLS are rare, here we consider a method of running assistance for the BLS in the

intersection which has a left corner with bad visibility. In this study, we employ a method of gaining a cyclist's attention by notification of the existence of approaching VNS.

We also aim to understand the influence on BLS behavior by using the notification method, in order to verify its effectiveness as a countermeasure for the BLS. With cost-effectiveness and simplicity in mind, we assume using this countermeasure at intersections which have a high rate of vehicle-bicycle accidents. A road facility is considered to be a notification device. Its influence was estimated based on behavior observed in a public-road experiment using an actual notification device. A conceptual illustration of an experiment is shown in figure 1.

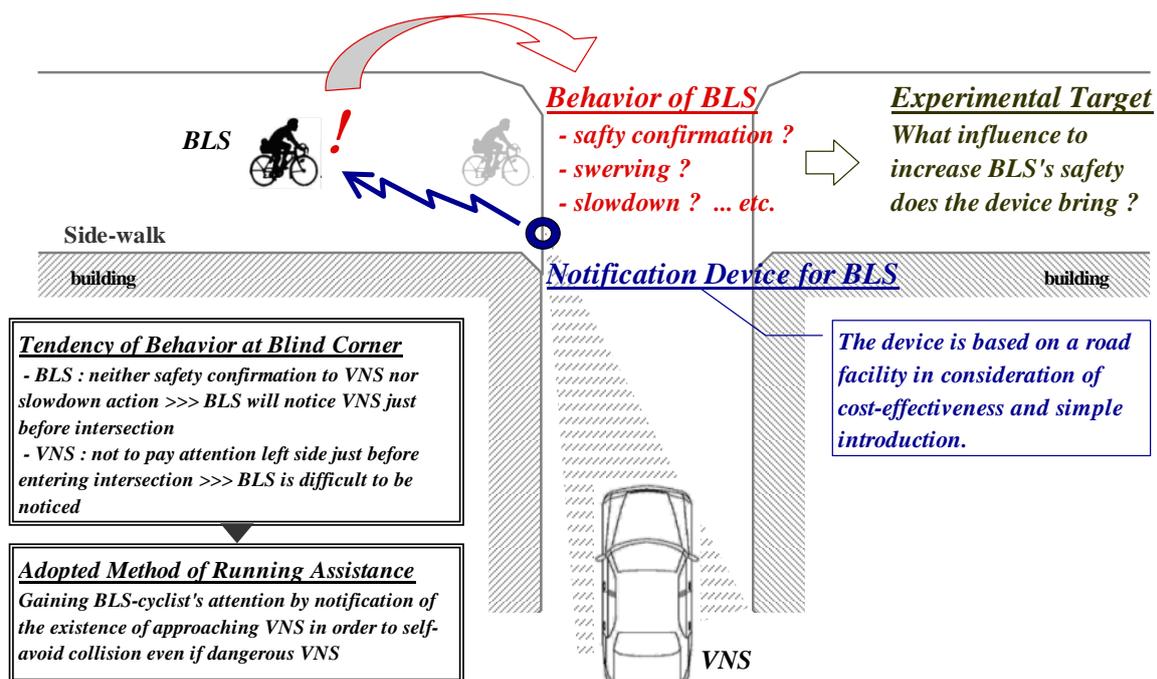


Figure 1. Conceptual Illustration of Experiment

2. Field Experiment

2.1 Outline of Experiment

BLS traffic behavior was observed by way of a public-road experiment for each case without the notification device, and with the notification device at intersections with bad visibility at the left corner of a narrow street. Traffic behavior data was obtained by the analysis of video footage recorded on the road. The experiment was conducted over a period of five days January 17, 2011. The weather was fine or cloudy. Video observation was carried out during the daytime (from 07:00 to 17:00).

The location of an experimental intersection is shown in figure 2. The outline and the view on the road of the intersection are shown in figure 3. This intersection was selected as it was also used in the authors' previous study (Wang, Mitani and Yamanaka, 2012) in consideration of visibility conditions and a traffic volume. The left corner of the intersection is completely obstructed by a building. There is a high volume of commuting bicycle traffic to the station in the morning and bicycle traffic for shopping around the station's front in the daytime. The estimated value of VNS traffic volume based on observed traffic volume is about 500 vehicles per 12 hours.



Figure 2. Location of Experiment Site

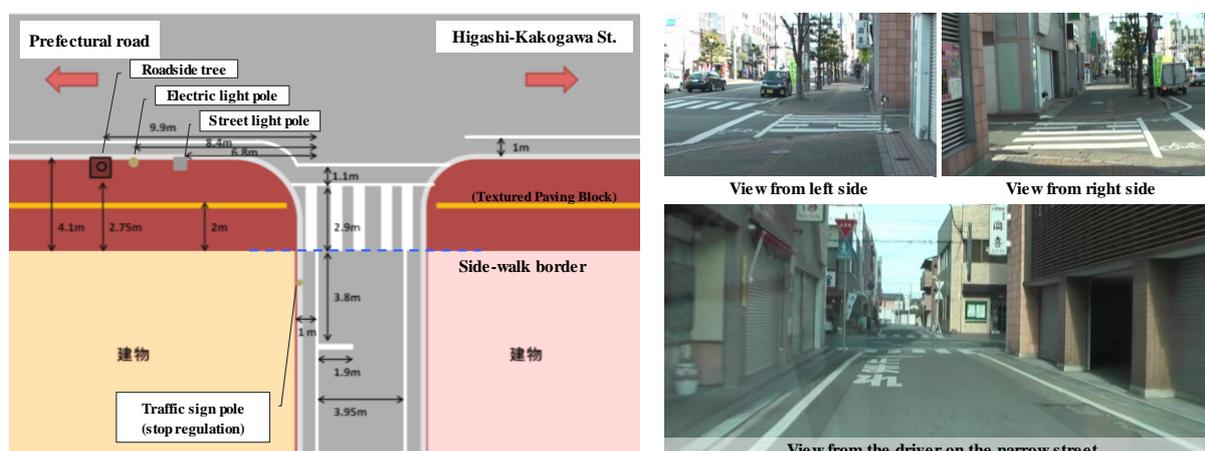


Figure 3. Outline and the view on the road of an experiment intersection

2.2 Notification Devices

In this study, two kinds of devices were used as notification methods for BLS.

2.2.1 Mirror Device

One of them is a mirror installed on a road as a simple and easy device (hereafter called as the mirror device). Although a mirror assists with visibility, in addition to it, this device also aims at the effect of gaining attention with the reflected VNS image in the mirror for the cyclist. The mirror device is installed on the left corner of the bad visibility point of a narrow street so that the BLS cyclist can confirm the VNS visually.

The appearance and installation condition of the mirror device are shown in figure 4. Since this device is installed in a narrow space on an intersection, compactness of the device is necessary. Location and direction of the mirror are adjusted so that the VNS may be reflected in a wide range depending on where the cyclist is looking. The device was made by a road infrastructure manufacturer (SEKISUI JUSHI Corp.), based on the requirements for installation. As for other parts, over the counter products were used.



Figure 4. Mirror Device

2.2.2 Flashing LED and Mirror Device

Another device used is the flashing LED and mirror device. This device detects the approaching VNS. And the device notifies a BLS cyclist of the VNS existence by way of a flashing light. The VNS is reflected in the mirror at the same time. This device aims at gaining attention to the VNS by leading the cyclist's gaze to the intersection's left corner, and showing the reflected VNS image in the mirror.

With regard to the flashing LED and mirror device, the appearance and installation conditions are shown in figure 5. The installation method of this device is the same as that of the mirror device. The LED light is installed facing the direction of the side walk for the BLS. It was confirmed on site that this LED light has a sufficient illumination angle to the side walk.

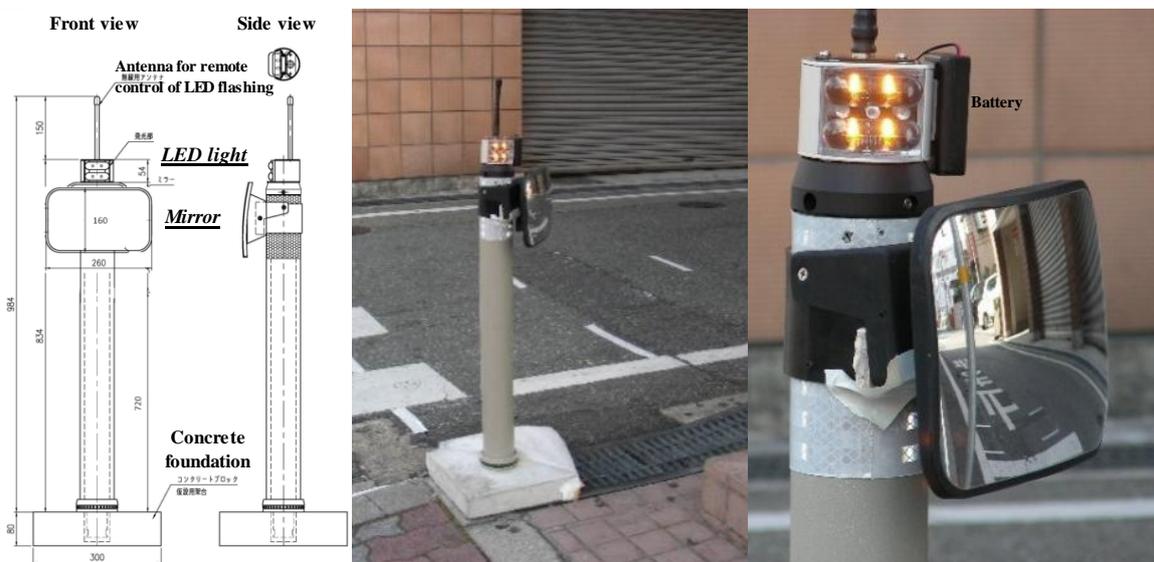


Figure 5. Flashing LED and Mirror Device

2.3 Video Observation

Video observation was carried out under various conditions as follows; without the notification device, with the mirror device, and with the flashing LED and mirror device. The

installation position of a video camera is shown in figure 5. Two sets of video cameras were installed. One video camera recorded behavior of the BLS from the right side of a narrow street (C1). The other video camera recorded the visual conditions of the notification device and the VNS from a cyclist's eyes (C2).

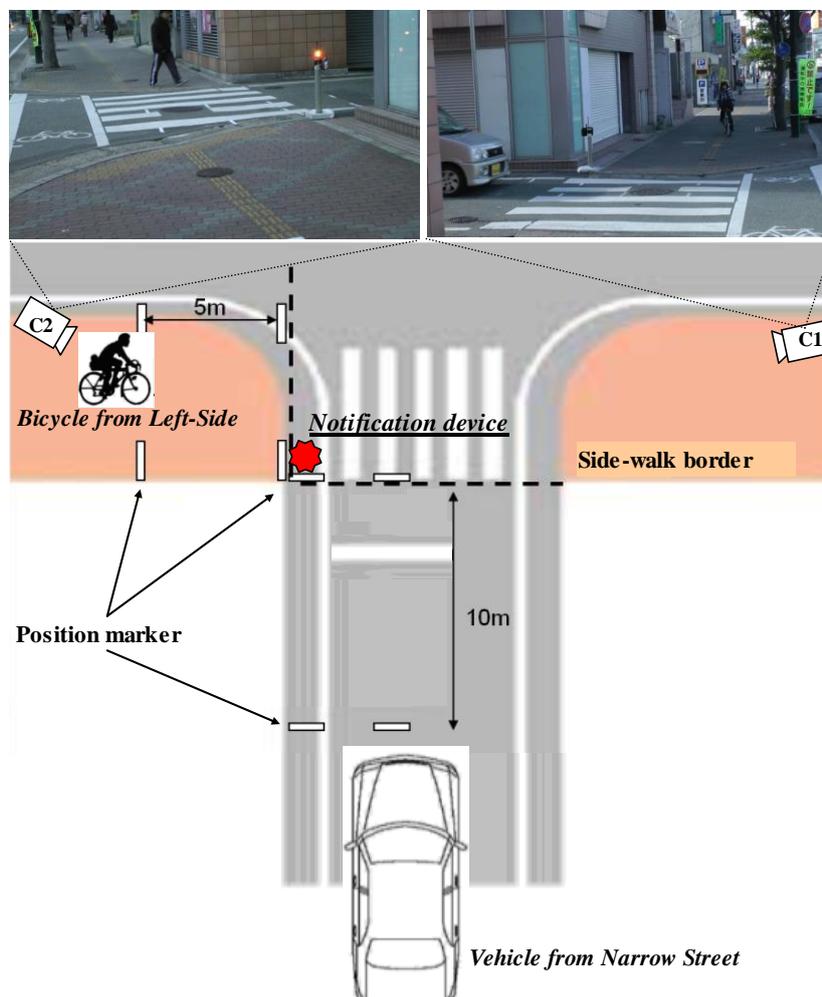


Figure 6. Configuration of video camera

3. Results of Analysis

3.1 Outline of Behavior Analysis

3.1.1 Behavior Indices

In order to estimate the influence of a notification device, the following six items of BLS were analyzed from the video footage. Bicycle's position was estimated with the wheel contact point and the position marker of the road surface.

- (1) Existence of safety confirmation : the direction of a cyclist's face was estimated.
- (2) Position of first safety confirmation : was estimated by whether the subject is closer than a 5-m position from the side-walk border.
- (3) Frequency of safety confirmation : the number of times until the BLS arrives at a side-walk border was estimated.

- (4) Existence of swerving : it was assumed that the BLS swerves suddenly.
- (5) Existence of slowdown : action of stopping, brake operation, etc. was estimated.
- (6) Passage speed : average velocity of the section from a 5-m position to a side-walk border was calculated.

3.1.2 The BLS Under Analysis

While the BLS is approaching an intersection, the notification device informs the cyclist about existence of the VNS. Influence of the notification device is reflected in the behavior of the BLS until he/she arrives at the side-walk border after being informed.

This study assumed the case where the BLS met with the VNS just near a sidewalk border, in order to analyze the influence of behavior improvement in a dangerous approach condition from a viewpoint of an accident prevention. Therefore, in this study, when the VNS arrived at a sidewalk border, BLS which was in less than 5 m from a side-walk border was analyzed. When more than one BLSs were approaching, the head BLS which arrives at a sidewalk border first was analyzed. In addition, the BLS which mingles with an opposite bicycle or a pedestrian before the arrival to a sidewalk border was exempted in consideration of the influence on their behavior.

For influence analysis of the notification device, BLS of 50 samples was selected at random based on images recorded by the video camera (C2) in the case without a device, the case with the mirror device, and the case with the flashing LED and mirror, respectively. Each BLS behavior was analyzed using the image recorded on the video camera (C1) according to behavior indices.

3.2 Influence on BLS Behavior

Table 1 shows the actual condition of BLS behavior observed for each of the experimental cases. Analysis output of the behavior indices of cases (1), (2), (3), (4), and (5) is shown by the sample number of BLS. The behavior index of (6) is shown by the mean value of the entire BLS for each case. As an overall behavior index for a cyclist's safety, the existence of either behavior of safety confirmation, swerving, and slowdown was observed. The significance level of the difference between "With device" and "Without device" is also shown in Table 1.

In the following, the influence on BLS behavior for each device is considered with regard to significance of behavior difference between the case without the device, and the case with the device.

Table 1. Actual condition of the BLS' behavior

Behavior Indices			Experiment case			Total	
			Without device	With MIRROR	With Flashing LED & MIRROR		
Safety confirmation	(1) Existence	non-observed	35 (70%)	30 (60%)	21 (42%)	86 (57%)	
		observed	15 (30%)	* 20 (40%)	** 29 (58%)	64 (43%)	
	(2) First position	non-observed	35 (70%)	30 (60%)	21 (42%)	86 (57%)	
		observed					
		within 5m pos.	6 (12%)	' 6 (12%)	** 12 (24%)	24 (16%)	
		beyond 5m pos.	9 (18%)	* 14 (28%)	** 17 (34%)	40 (27%)	
	(3) Frequency	non-observed	zero	35 (70%)	30 (60%)	21 (42%)	86 (57%)
observed		once	14 (28%)	' 16 (32%)	' 18 (36%)	48 (32%)	
		twice	1 (02%)	** 4 (08%)	** 11 (22%)	16 (11%)	
Approaching Behavior	(4) Existence of swerving	non-observed	37 (74%)	37 (74%)	34 (68%)	108 (72%)	
		observed	13 (26%)	' 13 (26%)	' 16 (32%)	42 (28%)	
	(5) Existence of slowdown	non-observed	49 (98%)	40 (80%)	36 (72%)	125 (83%)	
		observed	1 (02%)	** 10 (20%)	** 14 (28%)	25 (17%)	
	(6) Passage speed	ave. of passage time [sec.]	1.35	1.77	1.72	1.61	
		standard deviation of passage time	0.51	0.65	0.60	0.62	
		ave. of speed [m/s]	3.70	** 2.82	** 2.91	3.11	
		ave. of speed [km/h]	13.3	** 10.2	** 10.5	11.2	
	Behavior for Cyclist's safety	Neither of the behaviors was observed		32 (64%)	27 (54%)	18 (36%)	77 (51%)
		At least one behavior was observed		18 (36%)	* 23 (46%)	** 32 (64%)	73 (49%)
# of total			50	50	50	150	

The ratio of number of samples to "# of total" is in "()".

Significance level of the difference between "With case" and "Without case" : ** p-value of less than 5%; * p-value of 5%-10%; ' p-value of more than 10%

The p-value of (1)(2)(3)(4)(5)(7) was estimated by Binominal test. The (6) was estimated by t test.

3.2.1 Safety Confirmation

In the case of with the device, the ratio of safety confirmation is high compared with that of the case without a device.

In the case of with the mirror device, the difference in the ratio of safety confirmation existence is significant on a 10% level. The difference of "first" safety confirmation of within 5 m is not significant. The difference of "first" safety confirmation of more than 5 m is significant on a 10% level. The difference of "twice" safety confirmation is significant on a 5% level. However, the ratio is low.

On the other hand, in a case with the flashing LED and mirror device, the difference among all items with the exception of "once" safety confirmation is significant on a 5% level.

3.2.2 Approaching Behavior

In the case with the device, the ratio of swerving or slowdown is high compared with the case without the device. The average of passage speed is low at about 25%.

The difference of the rate of "swerving approach" is not significant in either of the cases. The difference of "slowdown" is significant on a 5% level in every case. Moreover, the difference in the average of passage speed is significant on a 5% level in every case.

3.2.3 Behavior for Cyclist's Safety

The ratio of behavior improvement in the case of with the device is high at about 10%-20%

compared with the case without the device.

In the case with the mirror device, difference of the ratio of behavior is significant on a 10% level. In the case with the flashing LED and mirror device, the difference of the ratio of behavior is significant on a 5% level.

3.3 Effectiveness of Devices

3.3.1 The Mirror Device

The mirror device prompts slowdown just before an intersection. It is clear that such slowdown decreases the possibility of collision even when a dangerous VNS is encountered.

Since hearing response of the cyclist was not taken into account, the factor of this behavior change is unknown. However, although cyclists did not move their face, they can recognize the mirror device in their peripheral vision. It is apparent that attention turned to the intersection corner by cognition results in the slowdown behavior.

3.3.2 The flashing LED and mirror device

On the other hand, the flashing LED and mirror device has a significant effect on all behaviors with the exception of "swerving". The "twice" safety confirmation is increased by this device. The "first" safety confirmation located in a position of over 5m from an intersection is increased. The "first" safety confirmation located in the position of within 5 m from an intersection is also increased. The passage speed in front of an intersection is reduced.

The BLS cyclist seems to detect the dangerous BNS a little earlier due to these behavior improvements. In addition, it is apparent that slowdown improves the possibility of collision avoidance with the detected dangerous VNS.

The factor of these behavior changes was not confirmed from the cyclist. However, a cyclist's attention was strongly attracted on the intersection square by the direct flashing light. It is most likely that this caused the behavior change.

4. Conclusions

This study examined countermeasures for accident prevention of vehicles approaching a narrow street, and bicycles which are approaching from the left on a sidewalk at small intersection along an arterial road. At small intersections of the public roads which have bad visibility at the left corner, the positive effect of the notification device of vehicles approaching for a cyclist was verified. Bicycles' behavior of 50 experimental cases was analyzed from video footage for each of the case the case without the device, and with the mirror device, and with the flashing LED & mirror device. The conditions of a cyclist's safety confirmation and approaching behavior to the intersection were analyzed.

As a result, it was shown clearly that, in the case with the device present, a bicycle slowed down just before the intersection. Cycling speed was about 20% lower compared with the case without the device. In particular, in the case with the flashing LED and mirror device, it was shown clearly that the frequency of a cyclist's safety confirmation increased in addition to the slowdown effect. Moreover, the ratio of the bicycle which shows some safety-related behavior is more than 60% of the total. This ratio is about 1.8 times that of the case without the device.

It is concluded that the notification device of approaching vehicles is effective as a

running assistance device for the safety improvement to the bicycle on a sidewalk. Notifying directly by flashing light increases the effect furthermore. Moreover, it was found that the accident-prevention effect increases by combining a countermeasure on a priority side (for a bicycle) such as this device and a countermeasure on a non priority side (for a vehicle running along a narrow street).

However, the accident reduction effect was not clarified by this study. Evaluation of collision-danger based on behavior and evaluation of accident number by long-term trial experiment of the device in a public road is necessary. Moreover, analysis of actual accident characteristics would be helpful for improvement of the device.

In addition, the device of this study is a prototype. For practical use, examination about factors, such as power source, housing, a mirror device, and a flashing light device, is needed. For practical installation, it is necessary to develop a device which can be used continuously over a long period of time. It is a future aim to obtain long-term accident data and behavior data also.

Since the corner of this experiment intersection was completely bad visibility, the device was exactly installed at the corner. At an intersection with a corner cut, separation of a vehicles detection sensor and a flashing light device is necessary. Effective installation method corresponding to intersectional visibility conditions should be examined in future research.

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