STUDY ON THE IMPROVEMET OF PEDESTRIAN'S VISIBILITY BY GEOMETRIC PATTERNS PROJECTION LIGHTING

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Japan

Paper Number 23-0063

ABSTRACT

A growing proportion of traffic accidents with pedestrian fatalities are occurring at night. With conventional lighting technology, using stronger illumination to increase the visibility of pedestrians contrarily causes the issue of increasing glare.

The present research therefore devised geometric pattern projection lighting that is aimed at extending the distance at which drivers can detect pedestrians while at the same time reducing glare for pedestrians. Test subject verification regarding visibility of pedestrians by drivers was performed and the effectiveness of the devised lighting was made clear.

1. INTRODUCTION: ISSUE AND AIMS

Accidents with pedestrian fatalities make up 36% of traffic accidents in Japan. By road status, 35% of such accidents are on straight roads. Looking at time of day, 29% of such accidents occur during the day and 71% at night, so more accidents with pedestrian fatalities on straight roads occur at night (Fig. 1).

As current nighttime lighting technology, there is the auto high-beam (AHB) system that detects whether or not there are vehicles in the surrounding area and automatically switches between low beam and driving beam. Development is underway of variable light distribution-type headlight systems (adaptive driving beam (ADB)) that detect the location of vehicles in the surrounding area and mask the lights so as not to expose them to glare. These conventional systems have an issue, which is that because they try to prevent glare for pedestrians, they do not adequately illuminate pedestrians.

Geometric pattern projection lighting was therefore devised and its effectiveness was made clear.

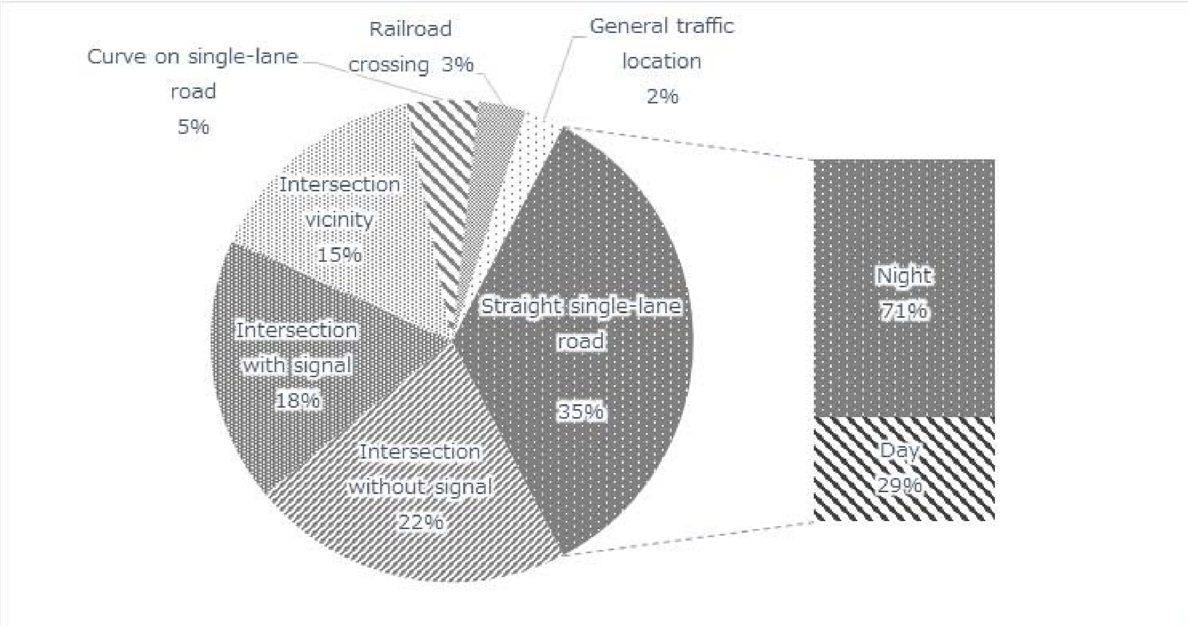

Figure 1. Pedestrian fatalities in Japan in 2021 in percentages by road state and in percentages of pedestrian fatalities on straight roads by day and night [1]

2. PROPOSAL: LIGHTING WITH GEOMETRIC PATTERNS

The present research made use of projection technology, which has made evolutionary advances in recent years, to study how projecting illumination with geometric patterns could enhance visibility of pedestrians while at the same time acting to reduce glare for pedestrians. Advance study was made regarding geometric patterns and illuminated area.

First, regarding geometric patterns, the following three patterns were studied.

The first pattern, as shown in Fig. 2, illuminates with vertically banded light in order to reduce glare.

When pedestrians cross through an area that is illuminated with vertically banded light, the light in the bright lines in the banding is a powerful stimulus, whereas the stimulus of light in the dark lines is weakened. It was confirmed that movement is made more conspicuous by this variation in light stimulus. Since the bright lines in the vertical banding are emphasized, however, it was found that pedestrians appear like sticks and are not easily recognized as pedestrians.

Therefore the second pattern studied as a way to enhance the visibility of pedestrians was a grid pattern, as shown in Fig. 3, that adds horizontal bands to the first pattern. It was confirmed that the visibility of pedestrians was enhanced over the first pattern because the light is in a grid pattern. However, depending on the body type of the pedestrian, this pattern ends up continuing to shine the powerful light into the pedestrian's eyes with the horizontal bands, so it was found that this pattern was not able to reduce the glare.

The third pattern studied as a way of enhancing the visibility of pedestrians, therefore, was the diamond-shaped pattern made up of diagonal lines shown in Fig. 4. This would reduce the amount of light on pedestrians regardless of differences in their body type. As a result, it was found that this could emphasize the movement of pedestrians, enhance the visibility of pedestrians, and reduce the glare on pedestrians, as shown in Fig. 5.

This diamond-shaped illumination pattern was used in the testing of subjects to confirm its effectiveness.

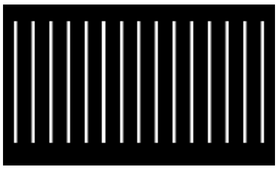

Figure 2. Vertically banded pattern

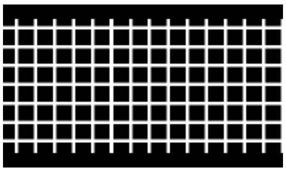

Figure 3. Grid pattern

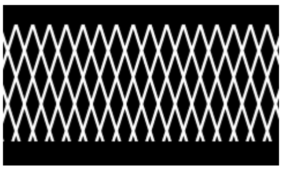

Figure 4. Diamond-shaped pattern

Figure 5. How pedestrians appear

The area illuminated by this diamond-shaped pattern is shown in Fig. 6. Assuming that a driver driving a vehicle at a speed of 40 to 60 km/h finds a pedestrian trying to cross the road and stops, we decided to illuminate the sidewalk of 40 to 80 m. As shown in Fig. 7, we decided to illuminate the pedestrian's whole body with the diamond-shaped pattern.

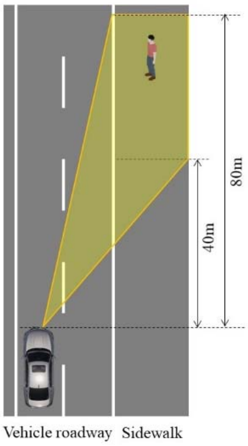

Figure 6. Illuminated area

Figure7. Conceptual image of illumination

3. CONTENT OF TEST

3.1. Evaluation Method

The distance on a straight road at which a driver using geometric pattern projection lighting will notice a pedestrian was determined by testing with human research subjects.

For convenience, the geometric pattern projection lighting will be referred to in the following as projection lighting.

3.2. Human Research Subjects and Informed Consent

There were 40 human research subjects aged 20–60 years. They were selected randomly by an in-house call for applications.

The human research subjects participated of their own free will. The parties responsible for the testing gave them full spoken and written explanations in advance of the purpose of this research, its content, and the right of participation, and their written consent was obtained.

This testing was conducted with approval (98HM-076H) from the Bioethics Committee of Honda R&D Co., Ltd.

3.3. Status of Vehicle Lighting

The following two patterns were determined for the lighting modes.

(1) Low-beam lighting

(2) Low-beam lighting and projection lighting

3.4. Pedestrian Clothing

The object of visibility in this research is defined as pedestrians crossing the road. The pedestrians crossing the road are defined as wearing upper and lower clothing that is black. Testing was conducted with this reduced visibility condition.

Figure 8. Pedestrians crossing the road wearing black upper and lower clothing

3.5. Test Environment and Procedure

The test location was an outdoor test course. Testing was conducted in clear weather in an environment without nighttime lighting.

The test used a 200-m-long section of straight road with one lane on each side. The test layout had the positional relationship shown in Fig. 9.

For the test procedure, the test vehicle was positioned at a sufficient distance from the pedestrian. The human research subjects were instructed to board the test vehicle and look toward the front to simulate ordinary driving. The test vehicle was driven forward and the distance at which the human research subjects perceived the pedestrian was measured. The test vehicle was driven at a speed of 6 km/h or lower. The pedestrian that was the object of perception walked back and forth on the sidewalk at a normal walking pace (1 m/sec).

After the distance at which the subject of perception recognized the pedestrian was measured, the test vehicle was positioned at a location 43 m away from the pedestrian and sensory evaluation of the visibility of the pedestrian was conducted. The distance of 43 m is the stopping distance envisioned for a vehicle at the speed of 40 km/h decelerating at 4 m/s^2. The sensory evaluation was scored on a five-point scale with the following criteria.

5	Clearly saw that it was a person
4	Though hard to see, it was visibly a person
3	Though not certain, there was an impression of seeing a person
2	There was an impression of seeing an object of some kind
1	Nothing was visible

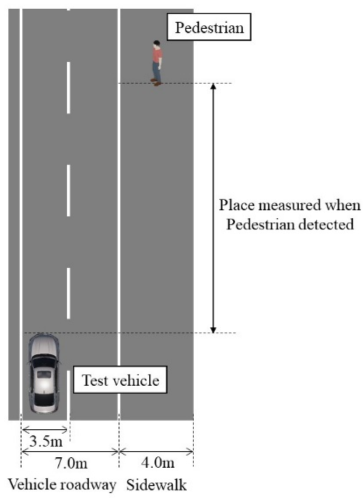

Figure 9. Test layout

4. TEST RESULTS

Average values were calculated for the results from measurement of the distance at which the human research subjects perceived a pedestrian. The results are shown in Fig. 10.

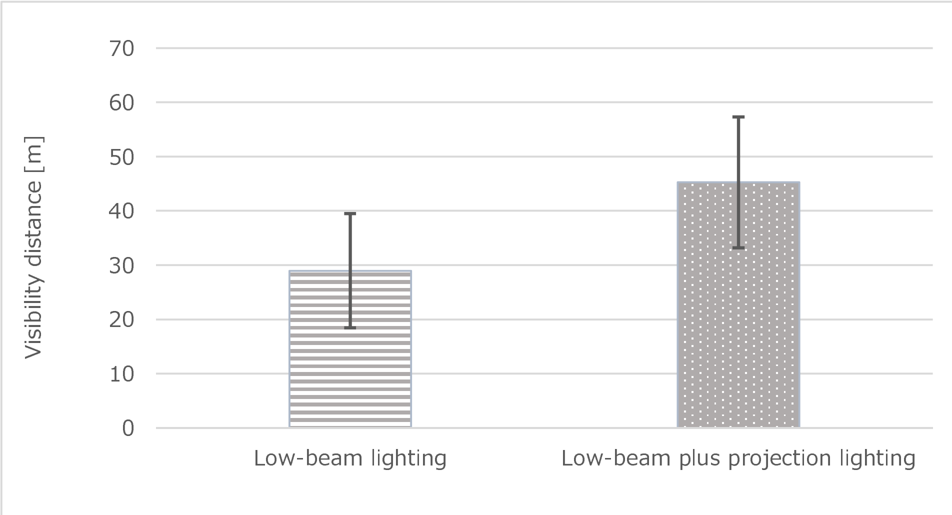

Figure 10. Average value of pedestrian perception distance on straight road

It is apparent from Fig. 10 that where the average distance with low beam is 28.9 m, the average distance with projection lighting is 45.2 m. The perception distance was extended by 16.3 m. No difference by age of the human research subjects was observed in the results. These results were recognized as showing a significant difference as determined by significance testing (t test).

Figure 11 shows the results of sensory evaluation.

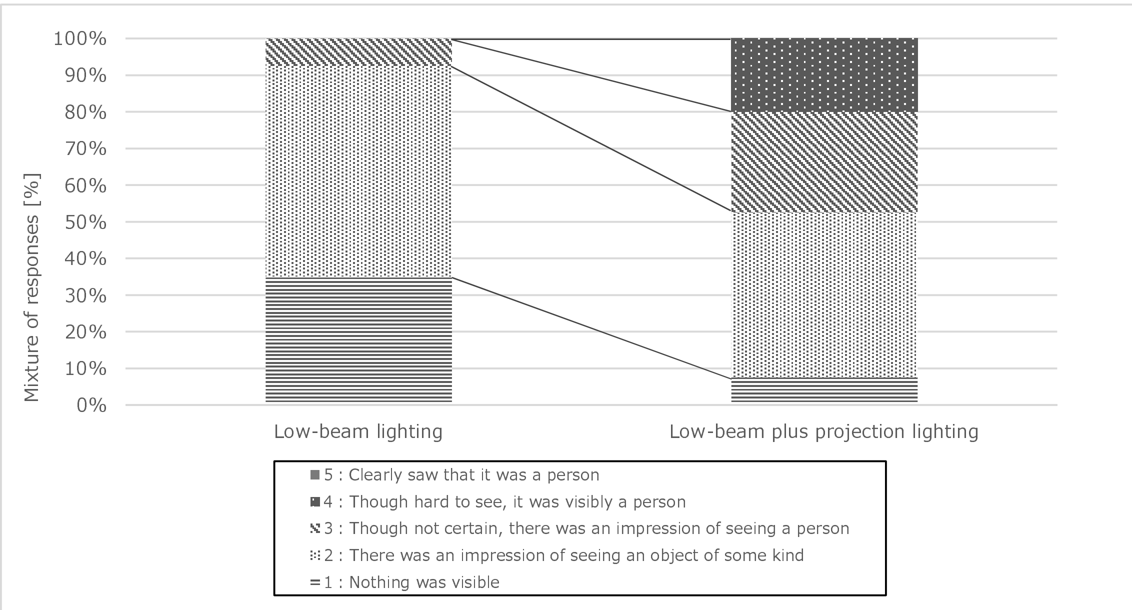

Figure 11. Sensory evaluation of pedestrian visibility on straight road

Responses of “There was an impression of seeing an object of some kind” or higher can be expected to have an accident reduction effect. These responses amounted to 65% of the total with the low-beam lighting and 93% with the projection lighting, an enhancement of 28 percentage points. No difference by age of the human research subjects was observed in the results.

5. DISCUSSION

Pedestrian accidents on straight roads at night are thought to be caused by drivers overlooking crossing pedestrians and delay in detecting them. In the road environment in Japan in particular, where vehicles are driven on the left side of the road, accidents involving pedestrians crossing from the right side at night make up a larger percentage.

The test results showed that where the average perception distance at which drivers detected the pedestrian crossing from the right was 28.9 m with the low-beam lighting, with the projection lighting the average perception distance was 45.2 m, a 16.3-m extension of the perception distance. Envisioning deceleration at 4 m/s^2 from the point where the crossing pedestrian was detected, the distance with the low-beam lighting corresponds to the stopping distance at a speed of 35 km/h, whereas the distance with the patterning beam corresponds to the stopping distance at a speed of 45 km/h. This suggests that an accident reduction effect can be expected up to a higher speed range.

Similar testing was also conducted in a scenario of a vehicle waiting to turn right (i.e., across traffic) at an intersection, with the pedestrian crossing from the same side. Those results confirmed that with the projection lighting, drivers perceived pedestrians crossing from the same side at a point on average 2.9 m before perception with the low-beam lighting. This suggests that projection lighting has an effect even in the area that is in the driver’s peripheral vision. When the pedestrian is walking at a pace of 1 m/s, the driver is able to perceive the pedestrian approximately 3 seconds sooner. This can be expected to help keep drivers from starting to move forward when they have overlooked the approaching pedestrian.

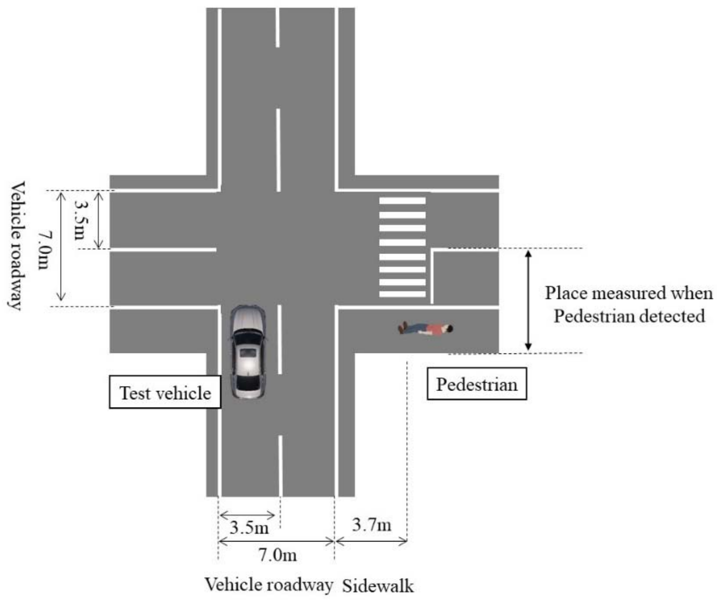

Figure 12. Layout of test at intersection

6. CONCLUSION

In this research, geometric pattern projection lighting was devised with the aim of extending the distance at which drivers detect pedestrians while reducing the glare for pedestrians. Verification of the test subjects conducted with respect to visibility of pedestrians by drivers made clear the effectiveness of the lighting.

As a result, the following results were obtained.

(1) Where the pedestrian perception distance on a straight road was an average of 28.9 m with the low-beam lighting, it was an average of 45.2 m with the projection lighting, a 16.3-m extension of the perception distance.

(2) In sensory evaluation of the visibility of pedestrians on a straight road, responses of “There was an impression of seeing an object of some kind” or higher amounted to 65% of the total with the low-beam lighting, whereas it was 93% with the projection lighting, an enhancement of 28 percentage points.

(3) It was confirmed that the pedestrian perception distance in a scenario of right turn at an intersection with projection lighting was on average at a point 2.9 m before detection with the low-beam lighting.

It was found from these results that it is possible for the proposed projection lighting to extend the distance at which drivers perceive pedestrians beyond the distance with low-beam lighting while also reducing the glare for pedestrians.

Going forward, efforts will be made to clarify the effectiveness of increasing the visibility of automobiles as seen by pedestrians, and to conduct an evaluation of the reduction of glare felt by pedestrians.

7. **REFERECE**

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