

Study of “LONG” Lighting System for Enhanced Motorcycle Conspicuity

Yojiro TSUTSUMI*

Kazuyuki MARUYAMA*

ABSTRACT

The Longitudinal Oriented Normative time Gap compensation (LONG) lighting system is proposed to enhance conspicuity with regards to the evaluation of motorcycle distance and speed. This system positions motorcycle lamps over a wider range in the vertical direction. Conspicuity was evaluated by measuring the critical time gap (CTG) with an oncoming motorcycle in an automobile waiting for a right turn (in left-hand traffic countries). The results showed that a motorcycle equipped with the LONG lighting system can have approximately the equivalent conspicuity as an automobile.

1. Introduction

Reported analysis of motorcycle traffic collisions in the United Kingdom has shown that, at times, it is not easy for other road users to detect motorcycles⁽¹⁾. For this reason, the United States commenced efforts to promote headlamp use in daytime from around the end of the 1960s to enhance motorcycle detectability during the daytime. Japan mandated daytime headlamp use in 1998, and since then the practice has also gained widespread acceptance in Europe. These measures aim to enhance the “detectability” element of conspicuity, and do not have the

main purpose of enhancing the “evaluation of distance and speed,” which is another element. The data for fatal motorcycle traffic collisions (in which an automobile driver is the party at fault) were analyzed from traffic collision statistics for fiscal year 2003⁽²⁾. The results showed that the main causes of traffic collisions are “misperception of distance or speed” and “oversight” of motorcycles on the part of automobile drivers (Fig. 1). In addition, research by Donne indicates that “misperception of distance or speed” also accounts for a relatively high percentage of traffic collisions in the United Kingdom⁽¹⁾. A lighting system that enhances conspicuity with regards to the evaluation of motorcycle distance and speed in order to reduce this misperception has been proposed.

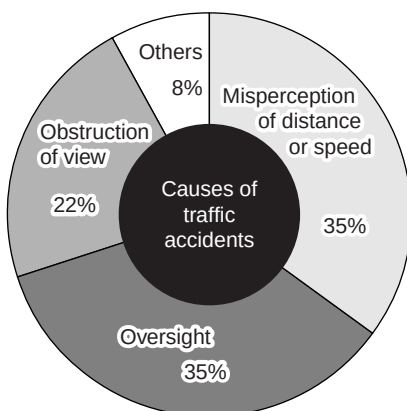


Fig. 1 Analysis of motorcycle traffic accidents in Japan (ITARDA 2003)

2. Fundamental Concept

Previous research showed the possibility of standardizing the conspicuity of various vehicle types using lighting systems⁽³⁾. Some vehicles have high conspicuity, which means that the relative conspicuity of other vehicles may decrease as a result, so this study was conducted to correct this difference. It is thought that the conspicuity of motorcycles should be approximately equal to that of automobiles. However, motorcycles have a more complex body contour than automobiles, which makes it difficult to recognize the vehicle size and shape. Therefore, in particular, the headlamp and front position

* Motorcycle R&D Center

lamps stand out when viewed from the front, and are thought to be used as a reference for recognizing distance and speed.

As the height of an object within the visual field subject to perception separates from the horizon, the object is felt to be closer. This is a type of perspective effect⁽⁴⁾⁻⁽⁶⁾. In addition, evidence supporting the theory that people judge the distance from objects using angular declination by the horizon has also been reported⁽⁷⁾. Ordinary motorcycles have the headlamp and front position lamps in relatively high positions, and there is nothing noticeable near the road surface, so these motorcycles may be perceived as farther away than the actual distance. Therefore, lamps were placed on the lower front fork to emphasize a low position near the road surface. This can be expected to help reduce the effect that motorcycles are felt to be farther away than the actual distance (Figs. 2 and 4).

On the other hand, when a vehicle has a small visual size, the amount by which the image on the retina is magnified as it approaches is also small, making it difficult to sense the speed of approach. Previous research has reported that when an approaching vehicle has a large visual size, the approach speed can be recognized at a farther distance⁽⁸⁾. Most ordinary motorcycles arrange the headlamp and front position lamps within a narrow range that results in a small image on the retina, so it may be difficult to recognize the speed. Ordinary motorcycles have a relatively large body height dimension compared to a small body width dimension. Therefore, lamps are placed in low and high positions on the vehicle body, for example on the lower front fork and the front side of the rear view mirrors, to emphasize the vertical length of the vehicle body. This helps prevent the visual size from being recognized as smaller than the actual size, and makes it easier to recognize the speed (Fig. 3). Furthermore, a large visual size also affects distance recognition, and it has

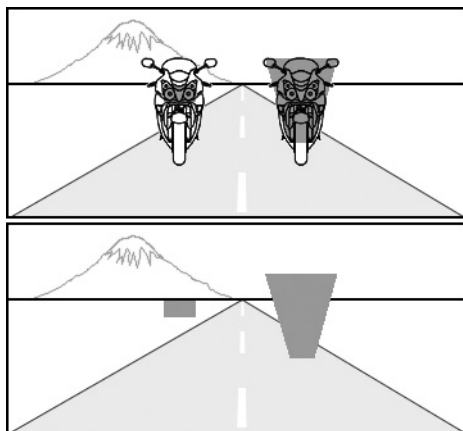


Fig. 2 Principle of enhancing sense of distance

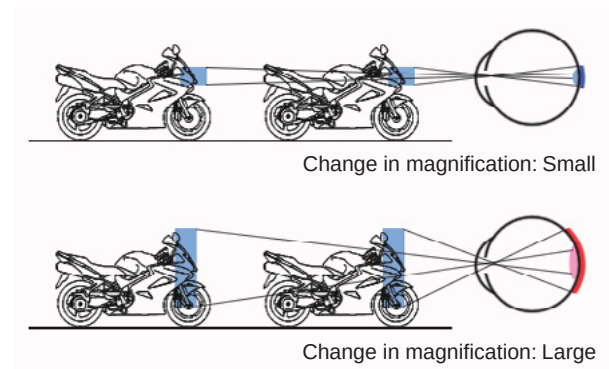


Fig. 3 Principle of enhancing sense of speed, effect of visual size difference projected on retina

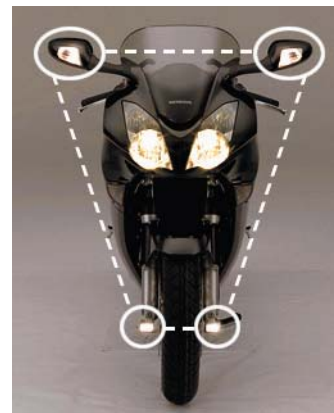


Fig. 4 LONG lighting system

been reported that the distance to objects with a large visual size is felt to be closer⁽⁹⁾ (Fig. 2).

This paper proposes the Longitudinal Oriented Normative time Gap compensation (LONG) lighting system that positions lamps in a reverse trapezoidal shape (Fig. 4). This method makes use of the above-mentioned concepts to enhance conspicuity with regards to the evaluation of motorcycle distance and speed to approximately an equivalent level as that of an automobile.

3. Evaluation Methodology

3.1. Critical Time Gap (CTG)

When making a right turn across traffic (in left-hand traffic countries), the driver is thought to make the decision to start the right turn based on a comprehensive judgment of the distance and speed of approaching oncoming vehicles, the driver's own speed, the road width, and other factors. This series of behaviors is called the gap acceptance behavior in right-turn across path scenario. In addition, the time from when the driver decides not to make the right turn because an oncoming

vehicle is too close until the vehicle passes the right turn start point is called the critical time gap (CTG)⁽¹⁰⁾. Comparing this CTG for various vehicles enables quantitative comparison of the conspicuity of these vehicles with regards to the evaluation of distance and speed. Therefore, the LONG lighting system was quantitatively evaluated by measuring the CTG in the right-turn across path scenario.

Figure 5 shows the vehicle arrangement for CTG measurement. The experimental subjects were instructed that, "You are waiting to make a right turn at an intersection. Press the brake pedal as soon as you judge that you will have to forego the right turn if the approaching oncoming vehicle comes any closer." The speed of the approaching oncoming vehicle used as the stimulus was set at 60 km/h, which is the speed limit on major Japanese roads. In order to regulate the stimulus to the experimental subjects, observation of the stimulus was started when the approaching oncoming vehicle passed the position 150 m from the experimental subject. Specifically, experimental subjects were told to face downward so that they were not looking forward at first, and then to observe the forward direction when they heard the beep from the vehicle passage sensor. In addition, observation was stopped by having experimental subjects face downward again immediately after pressing the brake pedal in order to minimize the learning effect. The vehicle in which the experimental subjects sat had a millimeter wave radar unit installed in the front grill that measured the speed and distance of the stimulus vehicle at a 0.1 s

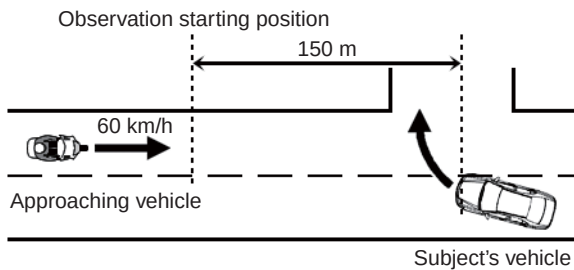


Fig. 5 Schematic plan of right-turn across path scenario, as used in the study

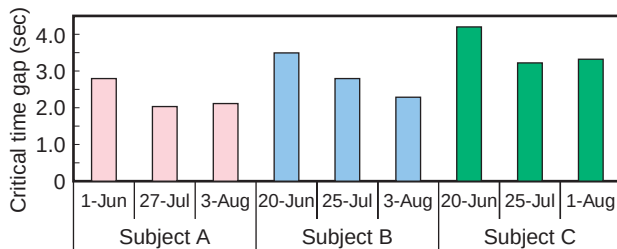


Fig. 6 CTG of ordinary motorcycle in nighttime

cycle. The CTG was calculated from the speed and distance of the stimulus vehicle at the instant the experimental subjects pressed the brake pedal. The CTG was measured five consecutive times for the same stimulus vehicle, and the mean was used as the value for that stimulus vehicle.

3.2. CTG Ratio

Figure 6 shows an example of the CTG measurement results for an ordinary motorcycle in nighttime. This is the data for three people, and shows the values for experiments conducted on three different days using the same motorcycle for each subject. The coefficients of variation were obtained by dividing the standard deviations of the CTG for experimental subjects A, B, and C by each mean, and were 0.25, 0.30, and 0.21, respectively. Even though these results are for the same subject using the same stimulus vehicle, there is variation depending on the measurement day. CTG variation was also indicated in past research⁽¹¹⁾, and it is thought that the CTG lacks sufficient reliability to be employed directly as a variable expressing conspicuity. Therefore, this research focused on the fact that the CTG of automobiles measured on the same day varied in the same manner as that of motorcycles. Figure 7 shows the CTG ratio of motorcycles compared to that of automobiles, which is expressed as a percentage obtained by dividing the motorcycle CTG by the automobile CTG. The coefficients of variation were obtained by dividing the standard deviations of the CTG ratio for experimental subjects A, B, and C by each mean, and were 0.06, 0.02, and 0.10, respectively. This shows a clear decrease in value variation by measurement day. That is to say, variance by measurement day can be suppressed, and conspicuity can be evaluated in a stable manner by using the CTG of an automobile measured on the same day as a reference. The LONG lighting system aims to make the conspicuity of a motorcycle approximately equivalent to that of an automobile, so comparison with automobiles also matches this goal. Therefore, this research used the CTG ratio of an automobile measured on the same day as the variable for evaluating conspicuity with regards to evaluating distance and speed.

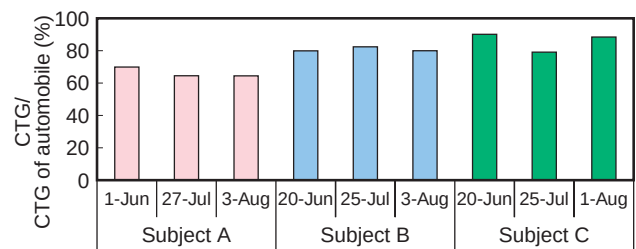


Fig. 7 CTG ratio of ordinary motorcycle compared to automobile

4. Conspicuity Enhancement Effects

4.1. Vehicles Used for Measurement

The conspicuity enhancement effects of the LONG lighting system were evaluated by measuring the CTG using actual vehicles. Figure 8 shows a photograph of the stimulus motorcycle used for measurement. This vehicle is an on-road type motorcycle (Honda XR250 Motard) with a displacement of 250 cm³, and uses 17-inch tires for both the front and rear tires. The LONG lighting system was mounted on the front of this vehicle using stays. In addition, the LONG lighting system used large turn-signal lamps (for the CB1300SF) on the upper side, and small turn-signal lamps (for the XR250) on the lower side. However, the lenses of these lamps were changed from amber to clear in order to emit white light. The lower lamp height (H) was 225 mm, and the distance in the horizontal direction was 300 mm. The upper lamp height was set so that the distance (S) from the lower lamps was 950 mm, and the distance in the horizontal direction was 750 mm. In addition, a pulse width modulation (PWM) dimmer circuit was mounted that enables the maximum luminous intensity of the LONG

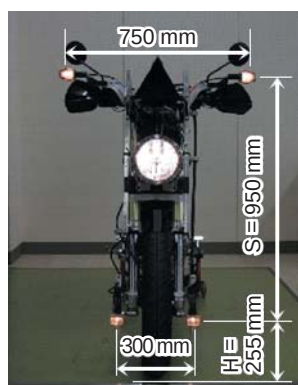


Fig. 8 Motorcycle used for measurement of enhanced conspicuity



Fig. 9 Automobile used for measurement of enhanced conspicuity

lighting system to be freely changed. This motorcycle had special stays that enabled the headlamp and height of various vehicle types on the market to be reproduced, and a single-bulb type multi-reflector headlamp (55/60 W, for the CB1300SF) was mounted at a height of 825 mm. Figure 9 shows a photograph of the stimulus automobile used for measurement. This vehicle is a Japanese minivan type passenger car (Honda STEPWGN) with a displacement of 2 000 m³ and a body color of white. In addition, the vehicle body width is 1 695 mm, the vehicle body height is 1 770 mm, the headlamp height is 800 mm, and the distance between the headlamps is 1 350 mm.

4.2. Enhancement Effects in Nighttime

Figure 10 shows the mean nighttime CTG ratio with an automobile of an ordinary motorcycle (MC) and a motorcycle equipped with the LONG lighting system (LONG MC). The experimental subjects were 21 people (18 men, 3 women, age 23 to 52) who drive an automobile on a daily basis. The error bars show the maximum and minimum values. The maximum luminous intensity of each of the four lamps comprising the LONG lighting system was adjusted to 16 cd. This value is the luminous intensity of ordinary motorcycle position lights. All measured stimulus vehicles were driven with the low-beam headlamps lit at a speed of 60 km/h. In addition, the course over which the measurements were performed was illuminated by streetlights, and the illuminance at the road surface was approximately 6 lx. The MC CTG ratio was 81.8%, which was approximately 18% smaller than that of the automobile. The mean automobile CTG in these measurements was 4.0 s, so this reduction in CTG corresponds to 0.72 s. In addition, the minimum MC CTG ratio was approximately 65%, and this CTG reduction of 35% corresponds to approximately 1.4 s. This showed quantitatively that an ordinary motorcycle may be perceived as being farther away and slower than an automobile in nighttime. In contrast, the LONG MC CTG ratio shows a value of 98.9%, which indicates that the sense of distance and speed is approximately equivalent to that of an automobile.

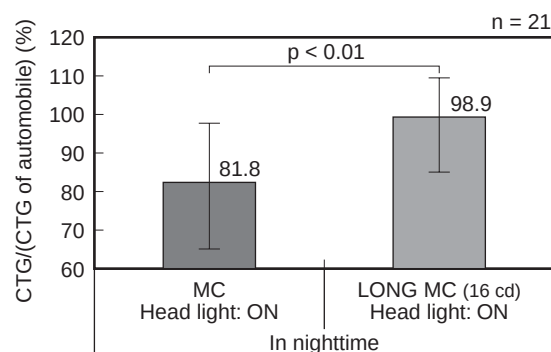


Fig. 10 Enhanced conspicuity in nighttime

4.3. Enhancement Effects in Daytime

Figure 11 shows the mean MC and LONG MC CTG ratios with an automobile for all experimental subjects in daytime. The experimental subjects were 14 people (12 men, 2 women, age 23 to 52) who drive an automobile on a daily basis. The error bars show the maximum and minimum values. The MC CTG was measured under the two conditions with the low-beam headlamp off (Head light: OFF) and on (Head light: ON). In addition, The LONG MC CTG was measured with the headlamp off, and the maximum luminous intensity of each of the four LONG lighting system lamps adjusted to 121 cd. This value is the maximum luminous intensity of ordinary motorcycle turn-signal lamps. All measured stimulus vehicles were driven at the same speed of 60 km/h as the nighttime measurements. The illuminance from the unobstructed sky of the course over which the measurements were performed was 4 410 lx to 33 500 lx. These measurements were performed over a five-day period, so there was variation in the illuminance from the unobstructed sky. The headlamps of the automobile measured to obtain the CTG ratio were off. The MC CTG ratio with the headlamp off was 86.5%, which means that the MC (Head light: OFF) CTG is 13.5% smaller than that of the automobile. This showed quantitatively that even in daytime, an ordinary motorcycle may be perceived as being farther away and slower than an automobile. In contrast, the MC CTG ratio with the headlamp on was 93%, which is an increase of 6.5% over the MC with the headlamp off. This indicates that turning on the headlamp enhances the sense of distance and speed. However, this CTG is still approximately 7% smaller than that of an automobile, which means that the equivalent conspicuity of an automobile for the evaluation of distance and speed cannot be obtained simply by turning on the headlamp. On the other hand, the LONG MC CTG is 99%, which is approximately equivalent to that of an automobile. This showed that even during the daytime, the LONG lighting system can enhance conspicuity with regards to the

evaluation of motorcycle distance and speed to approximately the equivalent level as that of an automobile. For reference, the mean automobile CTG for all experimental subjects during the daytime was 4.0 s, which is approximately equivalent to the nighttime mean of 4.1 s for these same experimental subjects.

5. Dependence on Lamp Layout

5.1. Measurement Conditions

The dependence of the conspicuity enhancement effects in nighttime on the lamp layout was measured. The distance (S) in the vertical direction between the upper lamps and the lower lamps, and the lower lamp height (H) from the ground surface were used as the lamp layout parameters. In addition, the distance in the horizontal direction was fixed at 750 mm between the upper lamps, and at 300 mm between the lower lamps (Fig. 8). The maximum luminous intensity of each of the four lamps was adjusted to 16 cd. All measured stimulus vehicles were driven with the low-beam headlamps lit at a speed of 60 km/h. The course used for the measurements was illuminated by streetlights, and the illuminance at the road surface was approximately 6 lx.

5.2. Dependence on height(H) of lower lamps

Figure 12 shows the CTG ratio dependence on H. The H values used for measurement were the three levels of 125 mm, 225 mm, and 325 mm, and the parameter S was fixed to 950 mm. The experimental subjects were 16 people (14 men, 2 women, age 23 to 52) who drive an automobile on a daily basis. The error bars show the maximum and minimum values. The results show that there was little CTG ratio dependence on H over the measured H range. The mean automobile CTG measured at the same time was 4.0 s, and the mean CTG of a motorcycle equipped with the LONG lighting system was 3.92 s, 3.94 s, and 3.90 s when H was 125 mm, 225 mm, and 335 mm, respectively.

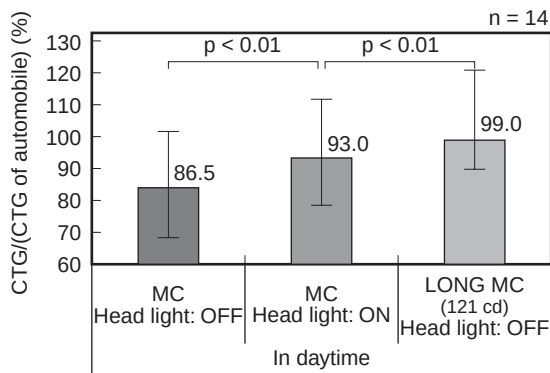


Fig. 11 Enhanced conspicuity in daytime

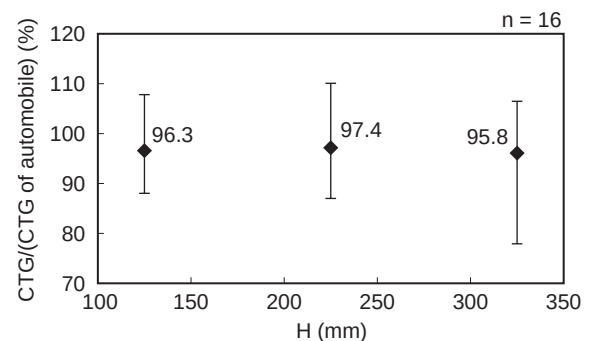


Fig. 12 CTG ratio dependence on height (H) of lower lamps in nighttime

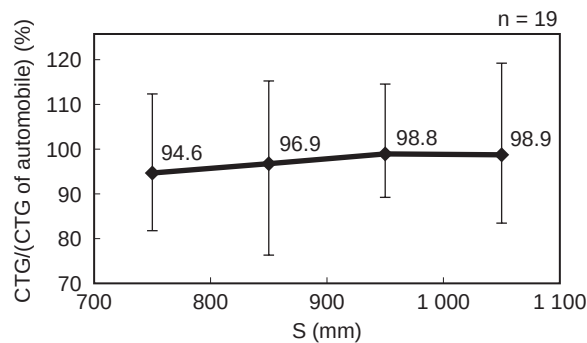


Fig. 13 CGT ratio dependence on space (S) between upper lamps and lower lamps in nighttime

5.3. Dependence on distance(S) between upper lamps and lower lamps

Next, Fig. 13 shows the CTG ratio dependence on S. The S values used for measurement were the four levels of 750 mm, 850 mm, 950 mm, and 1 050 mm, and the parameter H was fixed to 225 mm. The experimental subjects were 19 people (17 men, 2 women, age 23 to 52) who drive an automobile on a daily basis. The error bars show the maximum and minimum values. The results show that the CTG ratio increased with S over the S range from 750 mm to 950 mm. The fundamental concept of the LONG lighting system is that increasing the visual size increases the accuracy of speed and distance evaluation, which is predicted to increase the CTG ratio. The measurement results match this premise.

From these results, it can be inferred that drivers mainly use the size of the noticeable portions of vehicles to evaluate the distance and speed of a single approaching vehicle when making a right turn across traffic.

6. Dependence on Lamp Luminous Intensity

The dependence of the conspicuity enhancement effects in nighttime on the lamp luminous intensity was measured. The lamp layout was set at H = 225 mm and S = 950 mm. The luminous intensities of the lamps used for measurement were the three levels of 16 cd, 34 cd,

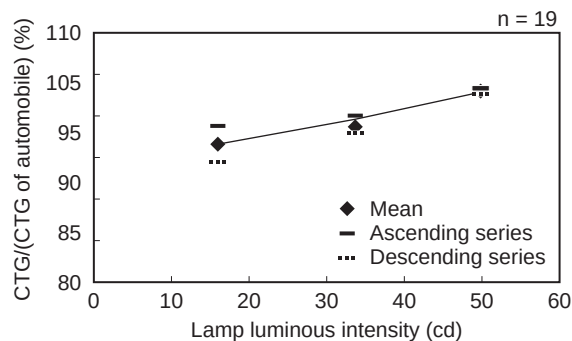


Fig. 14 CTG ratio dependence on lamp luminous intensity in nighttime

and 50 cd. All measured stimulus vehicles were driven with the low-beam headlamps lit at a speed of 60 km/h. The course used for the measurements was illuminated by streetlights, and the illuminance at the road surface was approximately 6 lx. The experimental subjects were 19 people (17 men, 2 women, age 23 to 52) who drive an automobile on a daily basis. Preliminary experiments showed sequential effects with regards to level. Therefore, each experimental subject was measured both in ascending series (16 cd → 34 cd → 50 cd) and descending series (50 cd → 34 cd → 16 cd) of luminous intensity, and the mean of the values for the same levels were used as the typical values in order to minimize these effects. Figure 14 shows the CTG ratio dependence on lamp luminous intensity. These results show that the CTG ratio increases with the lamp luminous intensity. In addition, when the lamp luminous intensity is zero cd in nighttime, the CTG ratio is literally the same as that of a motorcycle that is not equipped with the LONG lighting system, so the CTG ratio in this case is thought to be approximately 81.8% from Fig. 10. In the lamp luminous intensity range below 16 cd, the CTG ratio is presumed to decrease rapidly as the lamp luminous intensity approaches zero cd.

7. Conclusion

The LONG lighting system was proposed as a method of enhancing conspicuity with regards to the evaluation of motorcycle distance and speed to approximately an equivalent level as that of an automobile.

- (1) Experimental results showed that the conspicuity of a motorcycle can be increased to approximately an equivalent level as that of an automobile by making the distance in the vertical direction between the lower and upper lamps 950 mm.
- (2) The lower lamp height has no effect on the enhancement effects, but increasing the distance between the lower lamps and upper lamps increases the enhancement effects in nighttime.
- (3) The enhancement effects increase with the lamp luminous intensity in nighttime.

A remaining issue is the need to research how the effects of lamp layout change when the lamp luminous intensity changes. This and other issues will be further examined and researched in the future.

References

- (1) Donne, G. L.: Research into Motorcycles Conspicuity and its Implementation, Proceedings: International Congress and Exposition, SAE Paper 900749 (1990)
- (2) Annual Traffic Accident Report in 2003, Institute for Traffic Accident Research and Data Analysis of Japan (ITARDA), 403p. (2003)
- (3) Maruyama, K., Uematsu, I., Tsutsumi, Y., Sakamoto, M., Kushida, K.: A Study of New Lighting System for

- Better Conspicuity of Motorcycle, Review of Automotive Engineering, Vol. 27, No. 4, p. 571-577 (2006)
- (4) Gibson, J. J.: The Perception of the Visual World, Houghton Mifflin, 247p. (1950)
 - (5) Dunn, B. E.: Relative height on the picture plane and depth perception, Perceptual and Motor Skills, Vol. 21, p. 227-236 (1965)
 - (6) Epstein, W.: Perceived depth as a function of relative height under three background conditions, Journal of Experimental Psychology, Vol. 72, p. 335-338 (1966)
 - (7) Ooi, T. L., Wo, B., He, Z. J.: Distance determined by the angular declination below the horizon, Nature 414, p. 197-200 (2001)
 - (8) Maruyama, K., Tsutsumi, K., Kushida, K.: A Study of New Lighting System for Better Conspicuity of Motorcycle, Journal of Society of Automotive Engineers of Japan, Vol. 37, No. 5, p. 137-142 (2006)
 - (9) Gogel, W. C.: The absolute and relative size cues to distance, American Journal of Psychology, Vol. 82, p. 228-234 (1969)
 - (10) Miura, T.: A preliminary study of gap acceptance behavior and its perceptual factors, Bulletin of the Faculty of Human Sciences, Osaka University, Vol. 6, p. 37-41 (1980)
 - (11) Ueno, H., Maeda, K., Ochiai, K.: Analysis of Driving Behavior in Right Turns, Journal of Society of Automotive Engineers of Japan, Vol. 46, No. 9 (1992)

■ Author ■



Yojiro TSUTSUMI



Kazuyuki MARUYAMA