STUDY ON IMPROVING TWO-WHEELED VEHICLE CONSPICUITY

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ABSTRACT

This study was conducted to clarify the effects of automatic headlamp on (AHO) and position lamps on improving the conspicuity of two-wheeled vehicles in the daytime and at dawn/dusk. The following two items were covered:

(1) Effect of AHO on reducing injury-causing accidents
The data was taken from 1990 to 2001 on traffic accidents in Japan involving two-wheeled vehicles. Specific accident configurations closely associated with the conspicuity of two-wheeled vehicles (collision while turning right, right-angle collision, head-on collision) were selected and analyzed.
The findings are as follows:
AHO was confirmed to be effective in reducing the number of specific accidents closely associated with the conspicuity of two-wheeled vehicles in the daytime and at dawn/dusk. As the percentage of AHO-equipped vehicles in the total number of two-wheeled vehicles rose from 0% in 1990 to 71% in 2001, it was calculated that AHO's reduction of specific accidents in the daytime and at dawn/dusk amounted to 12,124 cases (16.0%).
(2) Effect of AHO and position lamps on improving two-wheeled vehicle conspicuity
Twelve subjects observed the approach of an oncoming motorcycle followed by a passenger car (30 m behind) with its passing beams on.
Instructions were given to indicate the motorcycle's conspicuity when it arrived at a point 100 m ahead of their eyepoint.
Eight motorcycle lighting conditions were observed.
The findings are as follows.
AHO has an improvement effect on two-wheeled vehicle conspicuity in the daytime and at dawn/dusk. To further improve the conspicuity, it is effective to combine amber position lamps with AHO. The effect of position lamps can be increased by optimizing their color, luminous intensity and distance from the headlamp.

INTRODUCTION

Daytime use of the headlamp and position lamps has been considered as a measure for improving the conspicuity of two-wheeled vehicles. Starting from 1991, Japan progressively introduced AHO for two-wheeled vehicles. AHO, whereby the headlamp automatically turns on when the engine is running, was made mandatory in 1997 for new two-wheeled vehicles. By 2001, over 70% of Japan's two-wheeled vehicles were equipped with AHO (See Figure 1).

With the introduction of AHO in European and North American countries, it appeared necessary to evaluate the actual effectiveness of AHO in reducing accidents involving two-wheeled vehicles.
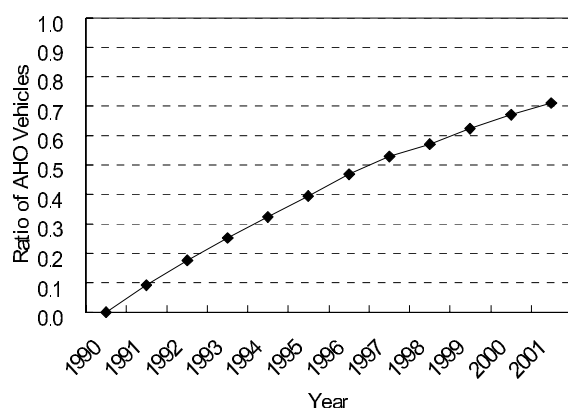
Figure 1.   Ratio of AHO vehicles

Several European countries (mainly Scandinavian) and Canada have made daytime running lights (DRL) mandatory for four-wheeled vehicles [1].

As DRL proposals have been discussed in the United Nation's Working Party on Lighting and Light-Signaling (GRE) and in the European Union [2][3], it will be possible to introduce mandatory use of DRL in international regulations in the near future.

Considering the large number of two-wheeled vehicles in Japan (13.2 million in 2005), there are rising concerns that four-wheeled vehicles' DRL will impair the conspicuity of two-wheeled vehicles [4].

Therefore, this study was conducted to analyze the number of accidents in situations closely associated with the conspicuity of two-wheeled vehicles (collision while turning right, right-angle collision, head-on collision) according to the time of day (daytime, dawn/dusk, nighttime), in order to verify the effectiveness of AHO in reducing the number of accidents involving two-wheeled vehicles. Furthermore, to cope with the introduction of four-wheeled vehicles' DRL, this study was also conducted to examine the effectiveness of AHO and the position lamps in improving the conspicuity of two-wheeled vehicles followed by a passenger car with passing beams on in the daytime and at dawn/dusk.

SURVEY ON THE EFFECT OF TWO-WHEELED VEHICLES' AUTOMATIC HEADLAMP ON FOR TRAFFIC ACCIDENT REDUCTION

Objective

The objective of this research item was to verify the effectiveness of AHO in reducing accidents. Statistical analysis was conducted on the number of accidents involving two-wheeled vehicles in situations closely associated with the conspicuity of two-wheeled vehicles according to the time of day, in order to determine the relationship between the ratio of AHO vehicles and the accident reduction.

Method

Analysis was conducted on traffic accident data compiled by the Institute for Traffic Accident Research and Data Analysis (ITARDA) according to two-wheeled vehicle class, accident configuration, region, month and hour (every 15 minutes). In this analysis, Japan was divided into nine regions according to longitude, and the injury-causing accidents in each region were analyzed according to month and hour (daytime, 2 hours at dawn + 2 hours at dusk = 4 hours, nighttime).

Specific second-party accident configurations closely associated with the conspicuity of motorcycles were selected (collision while turning right, right-angle collision, head-on collision). These specific second-party accident configurations (hereafter defined as "specific accident") were analyzed.

Results

As an indicator of the effectiveness of AHO, the ratio of the number of daytime accidents to the number of nighttime accidents for the specific accident ("day-night accident ratio") was employed.

AHO would be considered effective in reducing accidents if the day-night accident ratio declined while the number of AHO two-wheeled vehicles in use increased. The underlying assumption was that AHO improved the conspicuity of two-wheeled vehicle only in the daytime or at dawn/dusk, but not at night.

Number of Specific Accidents – The number of specific accidents was calculated according to the time of day (See Table 1 and Figure 2). The number of daytime specific accidents in 1990 was 45,977. The number of daytime specific accidents in 2001 was 47,157, slightly larger than in 1990 (a difference of 1,180). The number of dawn/dusk specific accidents in 1990 was 15,319. The number of dawn/dusk specific accidents in 2001 was 15,314, nearly equal to that in 1990 (a difference of 5). The number of nighttime specific accidents in 1990 was 14,493. The number of nighttime specific accidents in 2001 was 17,141, larger than in 1990 (a difference of 2,648).

Figure 3.   Ratio of daytime and dawn/dusk accidents to nighttime accidents

Table 1.
Number of specific accidents

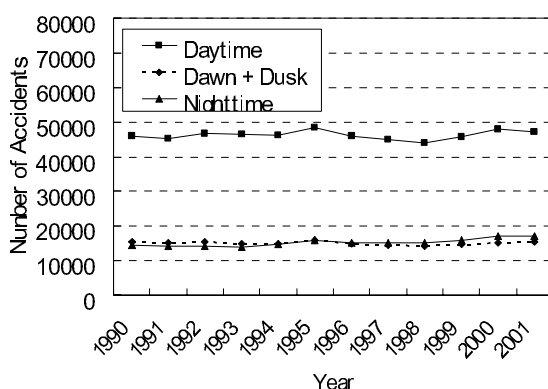| Number of Accidents	Year											
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Daytime	45977	45156	46758	46520	46183	48460	46088	45091	44100	45777	47970	47157
Dawn + Dusk	15319	15146	15451	14959	14898	15893	14968	14535	14107	14603	15151	15314
Nighttime	14493	14207	14290	14016	14614	15831	15219	15243	15271	15857	17168	17141

Figure 2.   Number of specific accidents

Day/Night Specific Accident Ratio – The day-night accident ratio in daytime and at dawn/dusk (number of daytime accidents / number of nighttime accidents or number of dawn/dusk accidents / number of nighttime accidents) declined (See Figure 3).
For daytime accidents, the day-night accident ratio was 3.17 in 1990 and 2.75 in 2001.
For dawn/dusk accidents, the day-night accident ratio was 1.06 in 1990 and 0.89 in 2001.
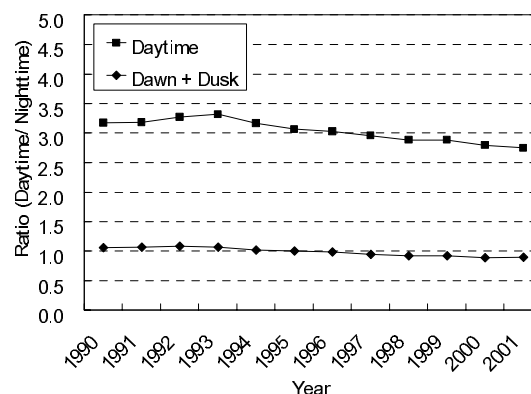
Change in Relative Ratio of Daytime and Dawn/Dusk Accident Ratio - The day-night accident ratio clearly declined from 1990 to 2000 (See Figure 4). For the daytime specific accidents, the day-night accident ratio in 2001 was 87% of that in 1990, exhibiting a significant difference ($p < .01$) between the 1990 and 2001 rates.
For the dawn/dusk specific accidents, the day-night accident ratio was 85% of the 1990 ratio, also exhibiting a significant difference ($p < 0.01$). So, it was possible to judge that AHO has the effect of reducing specific accidents in the daytime and at dawn/dusk.
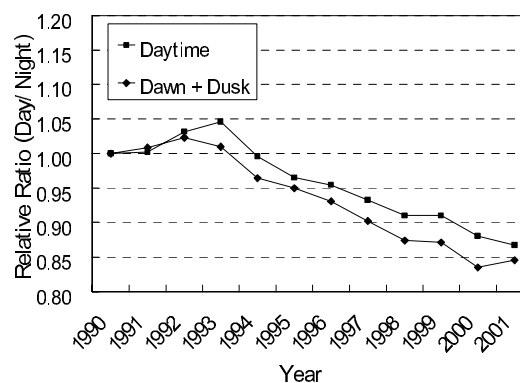

Figure 4.   Change in relative ratio of daytime and dawn/dusk accidents to nighttime accidents (Reference year : 1990)

Estimation of Effect of AHO on Reduction of Specific Accidents - To estimate the reduction effect of AHO on specific accidents, two assumptions were adopted:
a) AHO is effective in reducing accidents in the daytime and at dawn/dusk, but not at night;
b) The day-night accident ratio for specific accidents between 1990 and 2001 depended on the ratio of AHO-equipped vehicles to the total number of two-wheeled vehicles (the ratio corresponding to the regression line in Figure 5). As the ratio rose from 0% in 1990 to 71% in 2001, it was calculated that AHO's reduction of specific accidents amounted to 8,591 cases in the daytime and 3,533 cases at dawn/dusk for a total of 12,124 cases from 1990 to 2001. Accordingly, it was concluded that AHO is effective in reducing the number of accidents involving two-wheeled vehicles in the daytime and at dawn/dusk.

The calculation procedure was as follows:
(1) Regression line for daytime   (Equation 1)

$$y = -0.222x + 1.047 \ (r = 0.888) \qquad (1).$$

(2) Regression line for dawn/dusk   (Equation 2)

$$y = -0.275x + 1.045 \ (r = 0.946) \qquad (2).$$

(3) If the day/night ratio corresponds to the regression line, the number of daytime specific accidents in 2001 is as follows: 17,141 (number of nighttime accidents in 2001) × 0.889 (day/night ratio in 2001: y = −0.222 × 0.71 + 1.047 = 0.889) × 3.172 (day/night ratio in 1990) = 48,336.
If the day/night ratio does not change, the number of daytime specific accidents in 2001 is as follows: 17,141 (number of nighttime accidents in 2001) × 1.047 (the day/night ratio in 2001: y = −0.222 × 0 + 1.047 = 1.047) × 3.172(day/night ratio in 1990) = 56,927.
The difference between the two cases is 8591, 15.1% of the total number of specific accidents.
(4) Using the same calculation procedure, if the day/night ratio corresponds to the regression line, the number of dawn/dusk specific accidents in 2001 is 15,400.
If the day/night ratio does not change, the number of dawn/dusk specific accidents in 2001 is 18,933.
The difference between the two cases is 3,533, 18.7% of the total number of specific accidents.

(5) AHO's reduction of specific accidents amounted to 8,591 cases in the daytime and 3,533 cases at dawn/dusk for a total of 12,124 cases (16.0%) in 2001.
AHO's reduction of specific accidents (12,124 cases) was 5.9% of the total number of two-wheeled vehicle accidents (204,645 cases) in 2001.
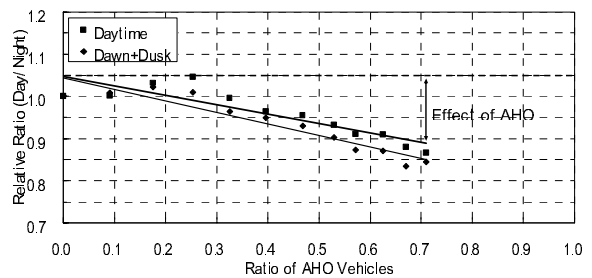

Figure 5. **Change in relative ratio of daytime and dawn/dusk accidents to nighttime accidents as a function of AHO vehicle' ratio (Reference year: 1990)**

A modified regression line (b = 1.0) is shown in Figure 6.
It is possible to easily estimate the accident reduction effect at any ratio of AHO vehicles by using Figure 6.

The regression line for daytime (Equation 3)

$$y = -0.212x + 1.0 \qquad\qquad (3).$$

The regression line for dawn/dusk   (Equation 4)

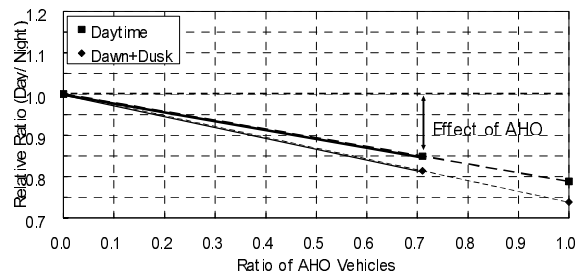$$y = -0.262x + 1.0 \qquad\qquad (4).$$

Figure 6. **Change in relative ratio of daytime and dawn/dusk accidents to nighttime accidents as a function of AHO vehicle' ratio (Reference year: 1990, b=1.0)**

**STUDY ON EFFECTIVENESS
OF AHO AND POSITION LAMPS ON
TWO-WHEELED VEHICLE
CONSPICUITY**

Objective

The objective of this research item was to examine the effectiveness of AHO and the position lamps in improving the conspicuity of two-wheeled vehicles followed by a passenger car with its passing beams on, in the daytime and at dawn/dusk.

Method

Subjects observed the approach of an oncoming motorcycle followed by a passenger car with its passing beams on, and were instructed to indicate the motorcycle's conspicuity.

　Test Vehicles -Three motorcycles and a passenger car were employed.

　Lighting Conditions for Test Motorcycle - The following eight lighting conditions were adopted for test motorcycles, where candela values indicate the maximum luminous intensity of lamps and millimeter values indicate the distance between position lamp and headlamp as measured from the innermost point of the position lamp to the outermost point of the headlamp. Examples of lighting conditions are shown in Figure 7.

(1) No lamps on
(2) Headlamp passing beam on
(3) White position lamps on (30 cd, 75 mm)
(4) White position lamps on (30 cd, 150 mm)
(5) Amber position lamps on (30 cd, 75 mm)
(6) Amber position lamps on (30 cd, 150 mm)
(7) Amber position lamps on (80 cd, 75 mm)
(8) Amber position lamps on (80 cd, 150 mm)

Regarding the position lamps used in the test motorcycle, the light source, shape and area are as follows, where area refers to the area of the lens:
(1) White position lamp 30 cd – incandescent, round (diameter: 60 mm), 28 cm^2
(2) Amber position lamp 30 cd – incandescent, round (diameter: 60 mm), 28 cm^2
(3) Amber position lamp 80 cd – LED, rectangular (45 mm H, 150 mm W), 68 cm^2
(4) Position lamp height from ground – 830 mm
(5) Headlamp height from ground – 860 mm

(1) No lamps on

(2) Passing beam on (AHO)

(4) White position lamps (30cd, 150mm) on + AHO

(6) Amber position lamps (30cd, 150mm) on + AHO

(8) Amber position lamps (80cd, 150mm) on + AHO

Figure 7.   Lighting conditions of test motorcycles

Lighting Conditions for Test Passenger Car - In the case of the test passenger car, the corresponding height of the headlamp was 650 mm from the ground and the separation was 1,230 mm as measured between the centers of the two headlamps.

Test Course - A private road with a 3.5m-wide lane on each side was used as the test course.

Subject Location and Oncoming Vehicle Operation - The location of the subjects and the operation setup for the test motorcycle are shown in Figure 8. The subjects were seated on three rows of benches with different seat heights. The eyepoints of the subjects were approximately 1.0 m high from the ground for the front row (nearest to the motorcycle), 1.2 m high for the center row, and 1.4 m high for the back row. The eyepoint location of the subject second from the innermost person in the second row was equivalent to the eyepoint location of the theoretical driver of a passenger car running along the center of the same lane (hereafter "eyepoint").
The test motorcycle was trailed by the test car at a distance of 30 m. Maintaining this condition, both vehicles cruised and passed the eyepoint at a constant speed of 60 km/h.
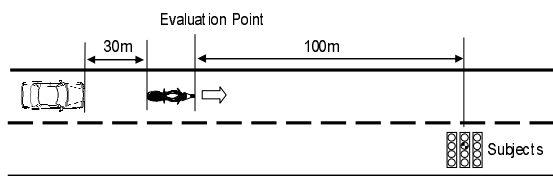

Figure 8.   Subjects and oncoming motorcycle followed by car

Motorcycle Conspicuity Evaluation - To evaluate the conspicuity of motorcycles, the subjects were instructed to observe an oncoming motorcycle in the opposite lane trailed by a passenger car at a distance of about 30 m. (See Figure 9). The subjects were asked to imagine being a driver trying to make a right turn at an intersection. When the oncoming motorcycle reached the point 100 m ahead of the eyepoint, a signal sounded for 1 second whereupon the subjects recorded how the motorcycle appeared, using the conspicuity evaluation scale.

Figure 9.   Experiment situation (Test motorcycle followed by car)

Conspicuity Evaluation Scale - Motorcycle conspicuity was evaluated on the following scale:

1 : Inadequate
2 : Somewhat inadequate
3 : Just acceptable
4 : Somewhat adequate
5 : Adequate

A value of 3.0 is the "just acceptable" level, so 3.0 or higher means an acceptable or adequate level of conspicuity.

Experimental Conditions - The conspicuity evaluation routine was repeated about 20 times for each of the 8 motorcycle lighting conditions under various levels of sky illuminance. Separate experiments were conducted during daytime, dusk and nighttime hours (sky illuminance level was under 20,000 lx).

Subjects - A total of 12 subjects ranging in age from 27 to 58 (average 43) participated in the experiment. All of them were lamp experts.

Results

The average conspicuity evaluation values rated by the 12 subjects are shown in Figure 10, in relation to sky illuminance. A value of 3.0 is the "just acceptable" level, so 3.0 or higher means an acceptable or adequate level of conspicuity.

The test results are summarized as follows:
(1) The conspicuity evaluation value declined with a drop in sky illuminance.
(2) The conspicuity evaluation value proved to be the lowest when none of the motorcycle lamps were on. The value rose with the headlamp on and the position lamps on, in that order.
(3) In the case of position lamps + AHO, the conspicuity evaluation value was higher with amber position lamps compared to white lamps. (For example, when the luminous intensity was 30 cd and the separation was 150 mm, the difference in conspicuity evaluation value was around 0.4).
(4) Between position lamps of lower and higher luminous intensity, the more luminous ones gave a higher conspicuity evaluation value compared to the less luminous ones.
(5) The conspicuity evaluation value was higher when the position lamps were more widely separated from the headlamp.
(6) When the sky illuminance was between 10,000 and 20,000 lx, the headlamp on had a conspicuity improving effect (the difference in conspicuity evaluation value between headlamp on and off was around 0.7). Furthermore, the position lamps had a greater conspicuity improving effect (the difference in conspicuity evaluation value between position lamps + headlamp and no lamps was around 1.2).
(7) Under the no lamps condition, the conspicuity evaluation value declined below the acceptable borderline of 3.0 when sky illuminance was less than 5,000 lx. Accordingly, if sky illuminance is less than 5,000 lx (corresponding to 30 minutes before sunset on a clear day), it is preferable to turn on the headlamp in order to obtain adequate conspicuity.
Under the headlamp condition, the conspicuity evaluation value dropped below 3.0 when sky illuminance was less than 1,000 lx. However, when the position lamps were turned on in addition to the headlamp, conspicuity was improved.
Accordingly, if sky illuminance is less than 1,000 lx (corresponding to 5 minutes before sunset on a clear day), it is preferable to turn on both the headlamp and position lamps in order to obtain adequate conspicuity.
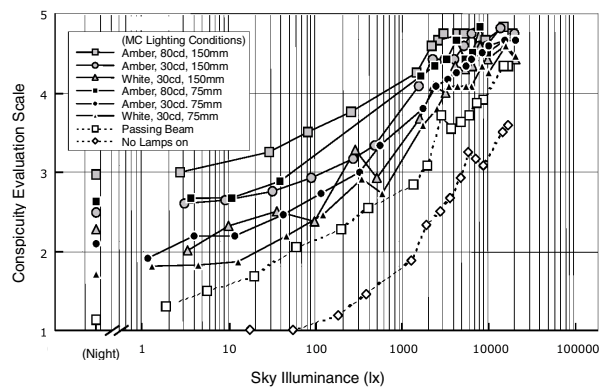

Figure 10.   Conspicuity evaluation on motorcycle followed by car

CONCLUSION

(1) As AHO was confirmed to be effective in improving the conspicuity of two-wheeled vehicles and reducing the number of accidents involving two-wheeled vehicles, the use of AHO should be introduced in more countries and regions.
(2) To cope with the introduction of four-wheeled vehicles' DRL, amber position lamps should be combined with AHO for further improvement of two-wheeled vehicle conspicuity.
(3) To further improve the conspicuity of two-wheeled vehicles, it would be advantageous to re-examine the color of position lamps (amber), their luminous intensity (higher intensity) and their separation distance from the headlamp (longer distance).

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[3] TRANS/WP.29/GRE/56. 2006. "Report of the Working Party on Lighting and Light-Signaling (GRE) on its Fifty-Sixth Session", 9-10.

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