

## Study on the Effects of the Daytime Running Lights of Four-wheeled Vehicles on Their Discernibility (and on the Impairment of Conspicuity of Motorcycles) - Report No. 2

To obtain discussion materials on the suitability of lighting the passing beams or other lamps on four-wheeled vehicles daytime, the Government of Japan commissioned a three-year research project to JARI through JASIC. The interim report was released in September 2003, regarding the effects of lighting the passing beams or other lamps of four-wheeled vehicles (hereafter "Daytime Running Lights - DRL") on their discernibility and on the impairment of conspicuity of motorcycles during the daytime and sunset hours of a cloudy day (51st GRE Informal document No. 10).

This second report pertains to 1) a comparison of similar effects between passenger cars and trucks, the latter having a nearly vertical and large front shape, and 2) the range of DRL luminous intensity effective in improving discernibility under various sky illuminance conditions.

### 1. Summary of the 2003 Study

The 2003 study was conducted concerning the effects of DRL on the discernibility of four-wheeled vehicles and the impairing effects of the four-wheeled vehicle's lighting of these lamps on the conspicuity of motorcycles running ahead with the headlamp on during the daytime and sunset hours of a cloudy day. The conclusions were as follows (Table 1):

- (1) From the standpoint of passenger cars' discernibility, it is preferable to light their DRL when the sky illuminance is not more than 1,000 lx (equivalent to 5 minutes before sunset on a fine day). When the sky illuminance is between 1,000 and 10,000 lx, DRL improve the discernibility of cars to a certain extent. When the sky illuminance is over 10,000 lx, DRL are not effective since the passenger cars themselves are sufficiently discernible.
- (2) Regarding the visual obtrusiveness of DRL and the discernibility of motorcycles, the preferable luminous intensity of DRL is about 200 cd or less when the sky illuminance is not more than 1,000 lx. If the luminous intensity reaches 400 cd, some of the drivers around start complaining of visual discomfort.

**Table 1 Discernibility of cars, obtrusiveness of DRL and the impairment of conspicuity of motorcycles (2003 study)**

Sky illuminance	Evaluation item	Lighting condition							
		No light on	Passing beam	12.5cd	25cd	50cd	100cd	200cd	400cd
10,000 lx	Car discernibility	4.3	4.8	4.6	4.7	4.7	4.7	4.7	4.8
	DRL obtrusiveness	No	4.4	4.9	4.9	4.7	4.5	4.3	3.8
	MC discernibility	4.9	4.6	4.9	4.9	4.9	4.7	4.6	4.2
5,000 lx	Car discernibility	3.9	4.7	4.2	4.4	4.5	4.5	4.5	4.6
	DRL obtrusiveness	No	4.3	4.9	4.8	4.7	4.4	4.0	3.4
	MC discernibility	4.8	4.3	4.8	4.7	4.7	4.7	4.7	4.3
2,000 lx	Car discernibility	3.6	4.8	3.9	4.1	4.4	4.5	4.7	4.7
	DRL obtrusiveness	No	4.2	4.7	4.7	4.5	4.4	3.6	3.0
	MC discernibility	4.5	3.2	4.3	4.1	4.0	4.0	3.6	3.3
1,000 lx	Car discernibility	3.1	4.6	3.7	4.1	4.3	4.5	4.6	4.7
	DRL obtrusiveness	No	4.2	4.6	4.6	4.6	4.2	3.5	2.7
	MC discernibility	4.2	2.5	3.9	3.7	3.7	3.5	3.3	2.8

Note: Rating below acceptable level (less than 3.0).

Rating within the acceptable range.

## **2. The 2004 Study and Its Results**

### **2.1. Purpose**

The present 2004 study was conducted to 1) compare the effects of DRL between passenger cars and trucks, the latter having a nearly vertical front shape to more easily produce a shadow from the sun, and 2) determine the effective range of DRL luminous intensity in improving discernibility under various sky illuminance conditions. Further, as an addition to the 2003 study, the conspicuity and obtrusiveness of DRL under the sky illuminance of 20,000 lx on a cloudy day were examined.

### **2.2. Method**

A truck or a passenger car with DRL was driven alone during the daytime and sunset hours of a fine day to evaluate the discernibility of four-wheeled vehicles and the visual conspicuity/obtrusiveness of DRL.

The 10 subjects employed were each seated on a bench corresponding to a driver's seat position in an intersection area and observed the oncoming test vehicle approaching at a speed of 40 km/h. When the vehicle reached a point 100m ahead of the subject's eyepoint, a signal sounded for one second and the subject rated how the vehicle looked concerning its discernibility and the conspicuity/obtrusiveness of its DRL.

The rating by the subjects was done according to the following scale, whereby an average point of 3.0 or higher was considered to be satisfactory or within an acceptable range:

- \* Discernibility of four-wheeled vehicles  
1 (Deficient), 2 (Somewhat deficient), 3 (Just acceptable), 4 (Somewhat sufficient), 5 (Sufficient)
- \* Conspicuity of DRL  
1 (Vehicle more conspicuous), 2 (Vehicle somewhat more conspicuous), 3 (Vehicle and DRL equally conspicuous), 4 (DRL somewhat more conspicuous), 5 (DRL more conspicuous)
- \* Visual obtrusiveness of DRL (Impairment by DRL)  
1 (Obtrusive), 2 (Somewhat obtrusive), 3 (Barely non- obtrusive), 4 (Not obtrusive), 5 (Not obtrusive at all)

The following 12 DRL conditions were applied: No lamps on, passing beams on, other lamps on (with the central luminous intensity of 12.5 cd, 25 cd, 50 cd, 100 cd, 200 cd, 400 cd, 800 cd, 1,600 cd, 3,200 cd, and 6,400 cd). Lamps of a specific luminous intensity were employed in the range of 12.5 to 400 cd, while a single pair of headlamps was used to produce luminous intensities ranging between 800 and 6,400 cd by applying filters over the driving beams.

This feeling test was conducted in the daytime or sunset hours of a fine day in May and July 2004 under a reverse light condition where the sun was behind the test vehicle (Figures 1 & 2).

The test site was situated in a suburb of Tokyo at latitude 36 degrees north, which is below the latitudes of most European countries and nearly equal to Athens at latitude 37 degrees north.



**Fig. 1 Test scene (truck)**



**Fig. 2 Test scene (car)**

### **2.3. Results**

The average value of the rating points given by the 10 subjects was adopted as the representative value for each of the test conditions.

#### **2.3.1. Truck-Car Discernibility and DRL Conspicuity/Obtrusiveness**

When the sun was shining from behind the vehicle, there was no significant difference between the test truck and the test car in their discernibility and the conspicuity or obtrusiveness of their DRL. Given below are the data on the test car, while the data on the test results are omitted in this report.

#### **2.3.2. Car Discernibility and DRL Conspicuity (Table 2)**

##### **(1) Evaluation of Discernibility**

The discernibility of the test car with its DRL was rated within the acceptable range under all the test conditions. The lowest rating was 3.6, recorded at a sky illuminance of 1,000 lx under the no-lamps-on condition. DRL had practically no discernibility improving effects when the sky illuminance was between 10,000 and 100,000 lx, but the discernibility rating was high when the passing beams or other lamps were lighted when the sky illuminance was 1,000 lx.

##### **(2) Conspicuity of DRL**

The conspicuity of DRL went up with an increase in DRL luminous intensity.

##### **(3) Visual Obtrusiveness of DRL**

As their luminous intensity rose, DRL were rated as being more obtrusive (the evaluation point declined). As the sky illuminance rose, DRL were rated as being less obtrusive to the eyes of surrounding drivers.

##### **(4) DRL Conditions Where DRL More Conspicuous Than Vehicle (Point 3.0 or More) and Obtrusiveness in Acceptable Range**

- \* Sky illuminance 1,000 lx: The lighting of passing beams or other lamps 50-200 cd in luminous intensity.
- \* Sky illuminance 2,000 lx: The lighting of passing beams or other lamps 200 cd.
- \* Sky illuminance 5,000 lx: The lighting of lamps 400-800 cd.
- \* Sky illuminance 10,000 lx: The lighting of lamps 800 cd (passing beams and 400-cd lamps not effective) (Note: 800-cd lamps on the truck were rated non-acceptable in conspicuity.)

- \* Sky illuminance 20,000 lx: The lighting of lamps 1,600 cd (Note: 1,600-cd lamps on the truck were rated to be barely non-obtrusive.)
- \* Sky illuminance 50,000 lx: The lighting of lamps 1,600-3,200 cd (Note: 3,200-cd lamps on the truck were rated non- acceptable in obtrusiveness.)
- \* Sky illuminance 100,000 lx: The lighting of lamps 1,600- 6,400 cd (Note: 6,400-cd lamps on the truck were rated non- acceptable in obtrusiveness.)

### 2.3.3. DRL Conspicuity and Obtrusiveness by Weather (Table 2)

The luminous intensity that would make the DRL more conspicuous than the vehicle while keeping the DRL obtrusiveness within an acceptable range varied widely according to sky illuminance which is affected by fine, cloudy and other weather conditions as well. The DRL of the same luminous intensity were more conspicuous on a cloudy than a fine day.

For example, the passing beams were rated more conspicuous than the vehicle at a sky illuminance of 20,000 lx on a cloudy day, but a similar relationship was obtained only under a sky illuminance below 5,000 lx when the weather was fine (Table 2).

However, the influence of weather conditions was small on the obtrusiveness of DRL.

**Table 2 DRL Conspicuity and Obtrusiveness by Weather (Car)**

Sky illuminance	Evaluation item	Lighting condition												
		No light on	Passing beam	12.5cd	25cd	50cd	100cd	200cd	400cd	800cd	1600cd	3200cd	6400cd	
100,000 lx Fine	Car discernibility	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
	DRL conspicuity	No	2.0	1.0	1.0	1.0	1.2	1.6	1.8	2.7	3.6	4.3	4.6	
	DRL obtrusiveness	No	4.9	5.0	5.0	5.0	5.0	4.9	4.9	4.7	4.2	3.6	3.1	
50,000 lx Fine	Car discernibility	4.9	5.0	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
	DRL conspicuity	/	2.1	1.0	1.0	1.1	1.3	1.6	1.8	2.7	3.5	4.2	4.5	
	DRL obtrusiveness	/	4.6	5.0	5.0	4.9	4.8	4.6	4.4	4.2	3.7	3.1	2.6	
20,000 lx Fine	Car discernibility	4.8	5.0	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
	DRL conspicuity	/	2.1	1.0	1.0	1.2	1.4	1.5	1.9	2.7	3.4	4.1	4.4	
	DRL obtrusiveness	/	4.3	5.0	5.0	4.8	4.5	4.2	3.8	3.6	3.0	2.4	2.0	
20,000 lx Cloudy	DRL conspicuity	/	4.0	1.0	1.0	1.4	1.8	2.6	3.3	3.5	4.4	4.7	4.8	
	DRL obtrusiveness	/	4.0	5.0	5.0	4.9	4.8	4.7	4.4	4.3	3.3	2.5	1.8	
	Car discernibility	4.7	5.0	4.9	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
10,000 lx Fine	DRL conspicuity	/	2.4	1.0	1.3	1.3	1.7	2.0	2.7	3.2	3.7	4.3	4.7	
	DRL obtrusiveness	/	4.2	5.0	4.9	4.8	4.3	4.0	3.5	3.5	2.7	2.0	1.7	
	DRL conspicuity	/	4.3	1.0	1.3	1.9	2.5	3.1	3.7	4.1	4.6	4.7	4.8	
10,000 lx Cloudy	DRL obtrusiveness	/	4.0	5.0	5.0	4.9	4.7	4.4	3.9	3.9	2.6	2.2	1.6	
	Car discernibility	4.6	4.9	4.7	4.7	4.8	4.9	4.9	4.9	4.9	4.9	4.9	4.9	
	DRL conspicuity	/	2.8	1.2	1.7	1.7	2.2	2.7	3.1	3.5	4.1	4.6	4.7	
5,000 lx Fine	DRL obtrusiveness	/	4.1	5.0	4.8	4.7	4.1	3.7	3.3	3.2	2.4	1.8	1.6	
	DRL conspicuity	/	4.5	1.3	1.6	2.2	2.8	3.6	4.1	4.3	4.6	4.7	4.8	
	DRL obtrusiveness	/	3.4	5.0	5.0	4.9	4.5	4.2	3.7	3.7	2.6	2.1	1.3	
2,000 lx Fine	Car discernibility	4.0	4.8	4.3	4.4	4.6	4.7	4.8	4.8	4.8	5.0	/	/	
	DRL conspicuity	/	3.7	1.8	2.4	2.6	2.8	3.4	3.6	3.9	4.4	/	/	
	DRL obtrusiveness	/	4.1	4.9	4.6	4.5	3.9	3.3	3.0	2.8	2.1	/	/	
2,000 lx Cloudy	DRL conspicuity	/	4.7	1.8	2.2	2.7	3.4	3.9	4.4	4.4	4.6	4.9	5.0	
	DRL obtrusiveness	/	3.7	5.0	5.0	4.4	4.2	4.0	3.3	2.5	2.4	1.6	1.1	
	Car discernibility	3.6	4.8	4.0	4.1	4.4	4.5	4.6	4.6	4.6	4.6	/	/	
1,000 lx Fine	DRL conspicuity	/	4.2	2.3	2.9	3.3	3.5	4.0	4.2	4.5	4.7	/	/	
	DRL obtrusiveness	/	4.1	4.9	4.5	4.3	3.8	3.1	2.5	2.7	1.9	/	/	
	DRL conspicuity	/	4.7	2.4	2.8	3.2	3.8	4.2	4.4	4.5	4.7	4.9	5.0	
1,000 lx Cloudy	DRL obtrusiveness	/	3.6	4.9	4.7	4.6	4.1	3.7	2.8	2.9	1.8	1.2	1	

Note: Rating below acceptable level (less than 3.0).

DRL more conspicuous than vehicle while its obtrusiveness within acceptable range.

#### 4. Summary

The results of the 2003 study (Table 1) and the 2004 study (Table 2) can be generalized as follows:

- (1) In fine weather conditions, there is no significant difference in discernibility between trucks and cars, although trucks have a large vertical front shape.
- (2) The luminous intensity that makes the DRL more conspicuous than the vehicle varies widely according to weather and sky illuminance. Under the same sky illuminance, DRL are more conspicuous on a cloudy day than on a fine day (due probably to the effects of shadows cast by buildings and trees around).
- (3) The visual obtrusiveness of DRL varies widely according to sky illuminance, but only slightly according to weather conditions.
- (4) From the standpoint of passenger cars' discernibility, it is preferable to light their DRL when the sky illuminance is not more than 1,000 lx (equivalent to 5 minutes before sunset on a fine day). When the sky illuminance is between 1,000 and 10,000 lx, DRL improve the discernibility of cars to a certain extent. When the sky illuminance is above 10,000 lx, DRL are not effective since the passenger cars themselves are sufficiently discernible even on a cloudy day.
- (5) Regarding the visual obtrusiveness of DRL and the impairment of conspicuity of motorcycles, the preferable luminous intensity of DRL is about 200 cd or less when the sky illuminance is no more than 1,000 lx. If the luminous intensity of DRL reaches 400 cd or higher, some of the drivers around start complaining of the DRL being obtrusive.
- (6) Consequently the luminous intensity of DRL needs to be adjusted to weather and sky illuminance conditions in order to obtain DRL that are more conspicuous than the vehicle while their obtrusiveness is within an acceptable range.

#### 5. Conclusions

- (1) When the sky illuminance is over 10,000 lx, there is little need to light DRL even on a cloudy day since the vehicle itself is sufficiently discernibility.
- (2) In view of a) the discernibility of four-wheeled vehicles, b) the relative discernibility of motorcycles and c) the visual obtrusiveness of DRL, the preferable luminous intensity of DRL is around 200 cd for the following reasons:
  - \* DRL under 200 cd can be more conspicuous than the vehicle when the sky illuminance is below 10,000 lx on a cloudy and below 5,000 lx on a fine day.
  - \* DRL under 200 cd can preclude adverse effects on the discernibility of motorcycles and visual obtrusiveness to oncoming drivers even when the sky illuminance is 1,000 lx or less.

Note: The lighting of passing beams is effective in enhancing the discernibility of the vehicle, when the sky illuminance is below 20,000 lx on a cloudy day and below 5,000 lx on a fine day.

- (3) If DRL are to be always more conspicuous than the vehicle itself in all conditions so as to enhance the vehicle's discernibility while keeping from adversely affecting motorcycles and oncoming drivers, it is more appropriate to select DRL capable of adjusting their luminous intensity according to sky illuminance. Considering weather variations, such DRL should be capable of automatic luminous intensity switching as follows:

- \* DRL switched to about 200 cd under sky illuminance up to 2,000 lx.
- \* DRL switched to about 400 cd under sky illuminance between 2,000 and 5,000 lx.
- \* DRL switched to 400-800 cd under sky illuminance between 5,000 and 10,000 lx. (In fine weather conditions, passing beams as DRL are less conspicuous than the vehicle while the vehicle itself is sufficiently discernible.)
- \* DRL switched to 800-1,600 cd under sky illuminance between 10,000 and 20,000 lx. (In fine weather conditions, passing beams as DRL are less conspicuous than the vehicle while the vehicle itself is sufficiently discernible.)
- \* DRL switched to 1,600-3,200 cd under a sky illuminance of about 50,000 lx. (The vehicle itself is sufficiently discernible. DRL exceeding a 6,400 cd luminous intensity are outside of the acceptable obtrusiveness range.)
- \* DRL switched to 1,600-3,200 cd at a sky illuminance of about 100,000 lx.

## REFERENCE

Appearance under a 100,000 lx Sky Illuminance

DRLs of 800 cd and passing beams cannot be conspicuous.

DRLs can be conspicuous if their luminous intensity is raised to 1,600 cd or higher.

