Glare and visibility by headlight for pedestrian and elderly driver

22 October 2018
National Traffic Safety and Environment Laboratory
The traffic accident numbers in Japan have been declining around 2001. However, the accident number by aged drivers has risen about 2.2 times from 15 years before.

We researched the accidents of the aged driver. It became clear that the accidents have a high percentage of pedestrian accidents in the night as the result.

The pedestrian accident tends to lead to a fatal accident in particular, so the measure is needed.

(a) Non-aged drivers (Daytime)  (b) Aged drivers (Daytime)
(c) Non-aged drivers (Nighttime)  (d) Aged drivers (Nighttime)

The pedestrian accident tends to lead to the fatal accident in particular, so the measure is needed.
The reason which the aged driver often causes pedestrian accident in night

- Decline of the visual ability of the aged driver
  - Decline of the vision of the night: The risk which will overlook pedestrian rises for driver.
  - Rise of the glare sensitivity: Influence of an oncoming vehicle headlight rises (Evaporative phenomenon of pedestrian).
The purpose of study

For reduction in further traffic accident, reduction of night pedestrian accident by the aged driver is important.

- Analysis about the night visual characteristics of the aged driver
  → Change in how to be seen by headlight and aging

  **We have developed a simulator with a name as “ASSESS” which can analyze road safety based on the data.**

- Simulation analysis of change of pedestrian accident number by headlight and aging
- The Safety effect evaluation of the new headlight (ADB)
Overview of ASSESS

ASSESS
A Survey Simulator to Evaluate Safety Systems
The recognition algorithm for pedestrian (driver model)

The driver model calculates the pedestrian’s contrast ratio $\varepsilon_l$ to judge whether a pedestrian can be recognized or not by the following equation.

$$\varepsilon_l = \frac{P_l - B_l}{P_l + EV_l}$$

$P_l$ : Pedestrian luminance
$B_l$ : Background luminance
$EV_l$ : Equivalent Veiling luminance

The driver model can detect a pedestrian, when this contrast ratio exceeds the contrast threshold value.
Equivalent Veiling luminance

There is a case that the driver cannot be to detect a pedestrian by the influence of the glare which is caused by the headlight of the oncoming vehicle.

Pedestrian’s contrast ratio is influenced by glare which changes with the scattering particles size and density in driver’s eyeball.

- Equivalent veiling luminance is the value which reflects this influence to the driver by glare headlight.

\[ \varepsilon_l(↓) = \frac{P_l - B_l}{P_l + EV_l(↑)} \]

- \( P_l \) : Pedestrian luminance
- \( B_l \) : Background luminance
- \( EV_l \) : Equivalent Veiling luminance
- \( \varepsilon_l \) : Pedestrian's contrast ratio

When glare occurs, the pedestrian's contrast ratio decreases.
**Equivalent Veiling luminance**

**ASSESS** can simulate the change of glare with the aging on the basis of medical data.

- Simulation examples of glare based on the medical data of the eyeball state

![Non-aged driver](image1.png) ![Aged driver](image2.png)

**Fig.3** Light scattered analysis flow chart in crystalline lens
Equivalent Veiling luminance

\[ \varepsilon_l(\downarrow) = \frac{P_l - B_l}{P_l + EV_l(\uparrow)} \]

- \( P_l \): Pedestrian luminance
- \( B_l \): Background luminance
- \( EV_l \): Equivalent Veiling luminance
- \( \varepsilon_l \): Pedestrian’s contrast ratio

\[ \varepsilon_l < \varepsilon_{lt} \] (Contrast threshold of pedestrian)

→ Driver can't visually recognize pedestrian.

This contrast threshold of pedestrian also change by aging.
We researched this contrast threshold by a subjective experiment in the darkroom.
Subjects observe the imitation pedestrian image projected by projector light on the screen and conduct visibility evaluation.

- Subjects: 30 drivers (15 non-aged drivers and 15 aged drivers)
- Average eyesight: Non-aged drivers (left:0.98, right:0.98) Aged drivers (left:0.98, right:0.90)
○ Change in a contrast threshold by aging

○ Contrast threshold changes with aging and background luminance.

○ The aged drivers reduce visibility for the pedestrian with reduction of background luminance than non-aged driver and raise the contrast threshold.

<table>
<thead>
<tr>
<th>Background luminance</th>
<th>0.14cd/m²</th>
<th>0.33cd/m²</th>
<th>0.96cd/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance between vehicle and pedestrian (m)</td>
<td>0.01</td>
<td>0.10</td>
<td>1.00</td>
</tr>
</tbody>
</table>

- □ Aged
- ■ Young

Contrast threshold

Distance between vehicle and pedestrian (m)
(Contrast threshold of pedestrian)

【Non-aged driver (30-years-old)】

\[ \log_{10}(\varepsilon_{lt}) = -0.971 + 0.00293 \times R - 0.400 \times B_l \]

【Aged driver (70-years-old)】

\[ \log_{10}(\varepsilon_{lt}) = -0.869 + 0.00271 \times R - 0.480 \times B_l \]

\( \varepsilon_{lt} \) : Contrast Threshold value of pedestrian

\( B_l \) : Background luminance of the pedestrian

\( R \) : Distance between the pedestrian and the vehicle
Pedestrian model

(Simulate the crossing a street)

The following judgment equation of crossing a street which change depends on the type of an approaching vehicle’s headlights and pedestrian’s position for this vehicle is set based on the analysis of the subject experiment data in nighttime.

【Low-Beam, Left-side pedestrian】
\[ y = 0.71x + 24.8 \]

【Low-Beam, Right-side pedestrian】
\[ y = 0.74x + 30.3 \]

【High-Beam, Left-side pedestrian】
\[ y = 0.45x + 36.4 \]

【High-Beam, Right-side pedestrian】
\[ y = 0.57x + 38.7 \]

\( x \) : vehicle speed [km/h]
\( y \) : distance between vehicle and pedestrian by which crossing is possible [m]

When \( y \) is shorter than the distance to an approaching vehicle, the pedestrian model judges not to cross a street.
The situation of the evaluation

【Headlight type】
High beam, ADB, Low beam

Headlight type

<table>
<thead>
<tr>
<th>Own vehicle</th>
<th>Oncoming vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>High beam</td>
<td>High beam</td>
</tr>
<tr>
<td>High beam</td>
<td>ADB</td>
</tr>
<tr>
<td>High beam</td>
<td>Low beam</td>
</tr>
<tr>
<td>ADB</td>
<td>High beam</td>
</tr>
<tr>
<td>ADB</td>
<td>ADB</td>
</tr>
<tr>
<td>ADB</td>
<td>Low beam</td>
</tr>
<tr>
<td>Low beam</td>
<td>High beam</td>
</tr>
<tr>
<td>Low beam</td>
<td>ADB</td>
</tr>
<tr>
<td>Low beam</td>
<td>Low beam</td>
</tr>
</tbody>
</table>

The Example of simulation
Adaptive driving beam (ADB)

- High beam area
- Low beam area (40 cm)
- High beam area

High beam area
- Horizontal axis [°]
- Luminosity of High beam [cd]

Low beam area
- Vertical axis [°]
- Horizontal axis [°]
- Luminosity of Low beam [cd]

- Graphic showing high beam and low beam areas with luminosity levels.
- Text indicating distances and beam characteristics.
○ Case which pedestrian accident doesn’t occur by ADB.

○ Case which pedestrian accident occurs by low beam.
The conditions of evaluation

- **Velocity of the pedestrian**: 7.2 km/h, 5.4 km/h, 3.6 km/h
- **Age of Driver (influence of glare)**: Young people (30-years-old), Elderly person (70-years-old)
- **Judgment of crossing a street**: y intercept of the judgment equation: Average, ±σ, ±2σ
Table 2. Number of collisions and near-miss incidents in the case of the driver’s age 30

<table>
<thead>
<tr>
<th>Headlight type</th>
<th>The velocity of a pedestrian</th>
<th>5.4 [km/h]</th>
<th>3.6 [km/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collision</td>
<td>Near-miss</td>
<td>Collision</td>
</tr>
<tr>
<td></td>
<td>own vehicle</td>
<td>oncoming</td>
<td>own vehicle</td>
</tr>
<tr>
<td>ADB High beam</td>
<td>270</td>
<td>0</td>
<td>613</td>
</tr>
<tr>
<td>ADB ADB</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ADB Low beam</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Low beam High beam</td>
<td>510</td>
<td>0</td>
<td>1,275</td>
</tr>
<tr>
<td>Low beam ADB</td>
<td>510</td>
<td>0</td>
<td>1,122</td>
</tr>
<tr>
<td>Low beam Low beam</td>
<td>570</td>
<td>0</td>
<td>1,254</td>
</tr>
<tr>
<td>High beam High beam</td>
<td>201</td>
<td>0</td>
<td>615</td>
</tr>
<tr>
<td>High beam ADB</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>High beam Low beam</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Fig. Areas for judging collision and near-miss incident
Table 4. Number of collisions and near-miss incidents in the case of the driver’s age 70

<table>
<thead>
<tr>
<th>Headlight type</th>
<th>The velocity of a pedestrian</th>
<th>5.4 [km/h]</th>
<th>3.6 [km/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collision</td>
<td>Near-miss</td>
<td>Collision</td>
</tr>
<tr>
<td></td>
<td>own vehicle</td>
<td>oncoming</td>
<td>own vehicle</td>
</tr>
<tr>
<td>ADB</td>
<td>High beam</td>
<td>1,240</td>
<td>0</td>
</tr>
<tr>
<td>ADB</td>
<td>ADB</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ADB</td>
<td>Low beam</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Low beam</td>
<td>High beam</td>
<td>1,650</td>
<td>0</td>
</tr>
<tr>
<td>Low beam</td>
<td>ADB</td>
<td>1,575</td>
<td>0</td>
</tr>
<tr>
<td>Low beam</td>
<td>Low beam</td>
<td>1,638</td>
<td>0</td>
</tr>
<tr>
<td>High beam</td>
<td>High beam</td>
<td>1,166</td>
<td>0</td>
</tr>
<tr>
<td>High beam</td>
<td>ADB</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>High beam</td>
<td>Low beam</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

There is a possibility that the pedestrian accident night of the aged driver decreases remarkably by the spread of ADB.
Summary

1. The aged drivers are raised the contrast threshold so that background luminance becomes low compared with non-aged driver. The aged driver has high dangerous degree on a dark road surface in particular.

2. The number of the collision and the near miss for night pedestrian were analyzed by ASSESS. It became clear that the case for which 2 vehicles which pass each other use ADB together has the lowest dangerous degree of the night pedestrian. It became clear that the spread of ADB is able to expect the reduction effect of the accident.
Future research task

(1) The safety evaluation according to the ADB performance （Because it was analyzed in ADB with the ideal performance this time）

(2) Consideration of glare control to pedestrian as well as an oncoming car

→ The percentage of the pedestrian who feels dangerous is quite large when headlight is glare.

Fig.3 Questionnaire result of the pedestrian safety by a headlight （Q About a headlight of a close vehicle at night.）
Thank you for listening

e-mail : aoki@ntsel.go.jp