Good Headlamp
- Engineer or Driver’s Perspective?

A Presentation to NHTSA Workshop

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I. What Is a “Good” Headlamp?
II. Evaluations by Engineers vs. Drivers
III. Who Is Right?
IV. What Can Be Done Better?
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What Is a “Good” Headlamp

Top of the List …
What Is a “Good” Headlamp

Good Headlamp: what vehicle makers say?

- Should think about vehicle buyers

Female

Nissan

Male

Toyota

Lighting Spec

GM

Young

Honda

Old

Ford
What Is a “Good” Headlamp

Vehicle Makers Believes
(besides the lamps should look good or cool)

- Good headlamp beam that has:
  - Wide Spread
  - A lot of foreground light
  - Uniform light distribution (no streaks or spots on the road surface)
  - Cutoff line (gradient) should not be too sharp

- Good headlamp should also:
  - Project enough light onto the road and overhead sign, but
  - No glare to oncoming vehicle drivers

😊 (make sense)
What Is a “Good” Headlamp

Good Headlamp: what human factor experts say?

- Think about drivers
  - Safety: visibility, seeing distance, …
  - Drivers comfort: distraction, fatigue, stability, …
What Is a “Good” Headlamp

Human Factor Experts Believe:

- **Safety** (primarily means driver’s visibility) should be a high priority
  - **Seeing distance**: When driving on a highway, driver’s seeing distance should be longer than vehicles’ stopping distance.
  - **Headlamp light projection distance**: When driving on a highway at night, low-beam should provide sufficient down-the-road light that reaches to the seeing distance.

😊 (sounds logical)
What Is a “Good” Headlamp

Good Headlamp: what lighting engineers do?

- Design and make lamp to achieve performance of:
  - Beam pattern brightness (total lumen)
  - Down-the-road visibility (hotspot candela value)
  - Beam width (spread)
  - Light on the road (uniformity, foreground light, …)
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Evaluation of a Headlamp

Vehicle Makers Evaluation (example)

- **Visibility range**
  - Lx value at 65 m?
  - How far is 3 lx line?

- **Beam width**
  - 40 m half-width 5 lx line?
  - 20 m width 5 lx line?

- **Foreground light**
  - Lx value between 10 – 20 m?
Evaluation of a Headlamp

Human Factor Experts Evaluation

- Safe seeing distance
  - 100 m on a highway
  - Minimum 3 lx level up to 100 m

- Typical US low-beam pattern (UMTRI)
  - In 2001, 50th percentile of US top 20 selling passenger vehicles, the 3 lx lines reaches less than 90 m
Evaluation of a Headlamp

Lighting Engineers Evaluation

- **Performance – Lighting Spec**
  - Safety
  - Comfort

- **Design restrictions:**
  - Type of light sources
  - Type of optics
  - Lamp package size

### Safety:
- Seeing Distance

### Comfort:
- Foreground
- Spread
- Uniformity
- Glare
Evaluation of a Headlamp

Headlamp Evaluation Example

- **Desired low beam photometry performance**
  - Total lumen inside beam pattern: > 400 lm
  - Maximum intensity: 30,000 cd
  - Sharpness of cutoff: G > 0.15

- **Best design results**
  - In order to project higher than 3 lx to 100 m (near 1.5 m right), light intensity at 0.6D-1.3R should be greater than 16,000 cd
Headlamp Evaluation Example (cont.)

- Look closely to the beam pattern

![Diagram showing beam pattern with points labeled 0.5U-1R, 0.5U-3R, 0.6D-1.3R, and 1.5D-2R]
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Who Is Right?

Should Everyone be Happy?

- Lighting engineers have done their job as good as they can …
Who Is Right?

What Happened to “Perfectly Designed” Headlamps?

- Customers are complaining!
  - Glare
  - Glare
  - Glare

- NHTSA has concerns!
  - Glare
  - Glare
  - Glare

[Image: A car with bright headlights, indicating glare.]
Who Is Right?

What Could be Wrong?

- **For lighting engineers**
  - Headlamps have best photometry performance for a stationary situation

- **For drivers**
  - Not so “stable” and inconsistent “use” of headlamps in a real driving environment
Who Is Right?

Unstable and Inconsistent Use of Headlamps

- **Aiming**
  - Not perfectly aimed on the vehicle
  - Even headlamps are perfectly aimed during vehicle assembly, vehicle is not leveled when driving
  - Roads are never leveled

- **Mounting height**
  - Regulations permits large variation for lamp mounting heights

- **Headlamp lens**
  - Dust accumulation
  - Rain and snow
  - Haze
Who Is Right?

Aiming Effect

- Vehicle load vs. headlamp leveling

<table>
<thead>
<tr>
<th>Vehicle Load</th>
<th>Angle (α) change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver</td>
<td>0.000 degrees</td>
</tr>
<tr>
<td>Driver + 1 front passenger</td>
<td>-0.098 degrees</td>
</tr>
<tr>
<td>Driver + 1 front &amp; 1 rear passenger</td>
<td>0.745 degrees</td>
</tr>
<tr>
<td>Driver + 1 front &amp; 2 rear passengers</td>
<td>0.919 degrees</td>
</tr>
<tr>
<td>Driver + 1 front &amp; 2 rear passenger + load in trunk</td>
<td>1.322 degrees</td>
</tr>
<tr>
<td>Driver + load in trunk</td>
<td>2.515 degrees</td>
</tr>
</tbody>
</table>

- Vehicle acceleration & deceleration
Who Is Right?

Part of Reasons for Complains

- **Lamp design intend**
  - >16,000 cd at 0.6 degrees down
  - > 30,000 cd at 1.5 degrees down

- **Misaim in reality**
  - Headlamp can be aimed 2.5 degrees higher!
  - The brightest part of the beam could be directly aimed toward on-coming vehicle drivers
Who Is Right?

Mounting Height

- **Regulation & Industry Standards**
  - NHTSA Regulation for upper limit: 1.37 m
  - SAE Recommendation for upper limit: 0.9 m

- **In reality (UMTRI)**
  - Average US vehicle $H = 0.62$ m for cars, $H = 0.83$ m for SUVs, pickup trucks and vans
  - Average passenger car driver’s eye heights = 1.01–1.14 m
  - Rearview mirror reflected light intensity could increase 300 – 500% if it is followed by a high mounted headlamp vehicle
Who Is Right?

Headlamp Lens Effects

- Dust effect
  - Refer to UMTRI Reports
  - Automotive Lighting, SAE Paper 2004-01-0666

- Haze effect
  - Refer to UMTRI Reports
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What Can Be Done Better?

Rational from Engineers – Aiming

- **Headlamp vertical aim sensitivity**
  - Glare is largely contributed by headlamp misaim (unconsciously)
  - Greater the headlamp performance $\rightarrow$ higher glare sensitive

- **Maintain headlamp proper aim**
  - Headlamp leveling system
What Can Be Done Better?

Rational from Engineers – Aiming (cont.)

- Studies on headlamp leveling systems
  - Koito studies
  - Automotive Lighting studies

![Graph showing deviation from basic aiming with and without leveling.](image)
What Can Be Done Better?

Rational from Engineers – Mounting Heights

- **Headlamp mounting height dependability**
  - Higher the headlamp mounted → better projection distance for the driver
  - Higher the headlamp mounted → greater glare for the front vehicle driver’s rear view mirror

- **Mounting height upper limit**
  - Should regulation and standard be more stringent?
Rational from Engineers – Lens Effects

- Headlamp lens effect
  - Less lens transmission → less seeing distance
  - Less lens transmission → higher glare

- Maintain lens transmission
  - Headlamp cleaning system
Summary

What Do We Know So Far?

- **Good headlamp**
  - A good headlamp should be safer, more comfortable, and less glare for drivers. However,
  - A good headlamp can easily cause more glare

- **Good headlamp on the road**
  - A good headlamp needs to be used properly on the road, e.g.,
  - Level (aiming) needs to be maintained
  - Mounting height needs no to be too high
  - Lens needs to be clean
The End
Thank You!