Headlamp Light Performance Evaluation

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Outline

- Lighting and safety
- Vertical aim, visibility, glare
- Vertical aim and headlight evaluations
- Low-beam, high-beam and adaptive driving beam headlights
- Outlook
Lighting and safety

- Most roads (in the U.S.) are not illuminated (NHTSA 2007) so vehicle headlights are critical

- Visual performance from roadway lighting is directly correlated with nighttime crash reductions associated with lighting (Bullough et al. 2013)
Safety impacts of vehicle lighting are also strongly correlated with visual effectiveness (Bullough 2011)

- Low-beam headlights are 4.3 times more conspicuous during dusk/dawn than during the daytime
- Using headlights during rainy weather is 4.2 times more likely to prevent a fatal multi-vehicle crash during dusk/dawn than during the daytime

(Bullough 2011, 2012)
Importance of glare

- Glare directly impacts visibility, especially near the line of sight (Fry 1954)

- Glare is a major concern of drivers and of vehicle lighting regulators

- What factor(s) influence glare from headlights?
Sensitivity analyses have consistently shown (Perel 1985; Sivak et al. 1998; Akashi et al. 2008) that vertical aim is the most critical parameter associated with visibility and glare from headlamps.

Real-world measurements (Skinner et al. 2010; Bullough et al. 2010; Flannagan 2011) have demonstrated that many vehicles have misaimed headlamps, including brand-new vehicles.

(Skinner et al. 2010)
Influence of vertical aim on visibility

(Akashi et al. 2008)
Vertical aim (vs. mounting height) and glare

(Bullough 2013)
Vertical aim (vs. mounting height) and glare

(Bullough 2013)
Influence of glare on driving behavior

(Van Derlofske and Bullough 2005)
Headlight evaluation ratings

- Not all headlight evaluation and rating systems control for vertical aim (e.g., Insurance Institute for Highway Safety – IIHS)
- In the IIHS system, illuminance levels at target and oncoming driver eye locations are measured without adjusting headlight aim
- Headlights are penalized if they fail to illuminate targets or if they exceed limits toward driver eye locations
- Recall that a substantial proportion of new automobiles have misaimed headlights

(Skinner et al. 2010)
“Demerit” scores and categories are shown for 64 headlight sets, neglecting bonuses for swiveling lights and automatic high beams.

Headlights with the greatest misaim (too low or too high) tended to be rated most poorly.

If headlights had been aimed properly, twice as many headlights could have been labeled as acceptable or good.
Why the emphasis on vertical aim?

- Low beam headlights have sharp vertical cutoffs
- High beams don’t, but...
High beam use

- Driver don’t often use their high beam headlights
- Even though overall visibility might be improved if everyone used high beams, discomfort glare would increase

Data replotted from Mefford et al. (2006)

Flannagan et al. (2000)
Adaptive driving beam (ADB) headlights

Adaptive driving beam (ADB) systems might reduce visibility-related nighttime crashes by 6%-7% based on visual performance improvement (Bullough 2014).

De Boer Rating Scale

9  Unnoticeable glare
8  Satisfactory
7  Just permissible
6  Disturbing
5  Unbearable
4  Unbearable
3  Disturbing
2  Just permissible
1  Satisfactory
0  Unnoticeable glare

From Bullough et al. (2016)
Evaluating ADB/dynamic headlight performance

- Field tests of an ADB vehicle were made along a flat, straight road using draft procedures for SAE J3069
- Measurements were feasible and repeatable
Possibility of self-adjusting/self-calibrating ADB headlight systems

- ADB headlights work in conjunction with a camera to interpret the scene in front of a vehicle
- A “matrix” type of ADB system can control small individual portions of the beam pattern
- A calibration routine to match matrix beam elements with angular locations within the camera image (sequentially) could be developed
  - This could ensure that variations in headlight vertical aim do not increase glare or reduce forward visibility
Traditionally there has been a “trade-off” between visibility/glare.

(Akashi et al. 2008)
Outlook (cont’d.)

- Because of the visibility/glare trade-off, vertical aim has been critical to control
- ADB headlight systems can offer a way to break through this trade-off
  > Dynamic, whole-vehicle field measurement is feasible and repeatable
- In the near-term, more rational headlight evaluation procedures are needed that account for headlight performance, not vertical misaim
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