

# Headlamp Levelness and Glare: Preliminary Analyses Based on Field Data

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## ABSTRACT

Vehicle headlamps are essential for driver safety at night, and technological evolution of headlamps over several decades has brought substantial improvements to driver visibility and comfort. Nonetheless, glare remains an important concern among many in the driving public, perhaps even more so in North America, where requirements for headlamps differ from those in much of the rest of the world. In most of the world, headlamps producing higher luminous flux are required to have automatic leveling and cleaning systems, thought to help reduce glare. The arrival of headlamp systems in the worldwide marketplace with luminous flux values just below those triggering requirements for leveling and cleaning systems will bring new questions about the causes of and countermeasures for glare. In the present paper, preliminary relationships are described among headlamp and vehicle related factors, particularly headlamp levelness, and the negative consequences of glare, using field data from real-world vehicles and conditions. A better understanding of these relationships could lead to improved strategies for countermeasures to prevent glare, which can be applied to regulatory contexts throughout the world.

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## INTRODUCTION

Vehicle headlamps are essential for driver safety at night, and technological evolution of headlamps over several decades has brought substantial improvements to driver visibility and comfort. Nonetheless, glare remains an important concern among many in the driving public, perhaps even more so in North America, where requirements for headlamps differ from those in much of the rest of the world. For example, North American headlamp requirements make no distinctions among systems with greater or lesser lamp luminous flux. In most of the world, headlamps using light sources that produce luminous flux values higher than 2000 lm are required to have automatic leveling and cleaning systems, thought to help reduce glare. Recently available light sources for forward lighting systems in the worldwide marketplace have luminous flux values just below those triggering the requirements for leveling and cleaning systems. Questions about whether the 2000-lm limit is predictive of the actual need to have automatic leveling and cleaning systems have arisen [1]. It is clear that empirical data illustrating the relationships among headlamp and vehicle-related factors and the negative consequences of glare, can be useful in understanding whether new light sources for low-beam headlamp systems might be problematic for glare, and

whether luminous flux ought to be one of the criteria for determining whether headlamp systems might require special glare-control measures.

The present paper describes field measurements and preliminary analyses for vehicles in the U.S. that can be used to assist with the need for empirical data described above.

## FIELD ASSESSMENT OF HEADLAMP LEVELNESS AND MOUNTING HEIGHT

Bullough et al. [2] described an automated field apparatus to simultaneously measure real-world headlamp mounting heights, vertical aim, and vertical illuminances toward the location of oncoming drivers' eyes. It consisted of a camera used to take an image of an oncoming headlamp when the vehicle reached a specific distance from the camera. The image was compared to an image of a calibration grid taken with the identical measurement geometry to provide an estimate of the mounting height of the headlamp. In addition, vertical arrays of photopically calibrated light sensors were positioned 2° from the center of the oncoming vehicle's traveling lane, toward the passenger side of the measured vehicles. This allowed reliable estimation of the height of the

right-side vertical cutoff of the headlamp beam distribution by locating the height of the maximum gradient between sensor locations. From the estimates of mounting height and the right-side cutoff (and assuming most headlamps to be low-beams with visually optically aimable-right [VOR] types of headlamps as reported by Schoettle et al. [3]) it was possible to obtain estimates of the in-service levelness of the headlamps on the measured vehicles.

At the same time, a photopically-calibrated illuminance meter was positioned at the same angular location as the eyes of an oncoming driver located 30 m away, based on estimates of driver eye location provided by Sivak et al. [4]. Illuminance measurements were recorded at the same time as the mounting height and vertical cutoff data in order to estimate the impact of these parameters on headlamp glare, with illuminance serving as a surrogate measure for glare.

This apparatus was used to measure vehicles during nighttime data collection sessions in the City of Watervliet, in the New York capital region at a tee intersection [5]. The distribution of measured mounting heights followed an approximately lognormal distribution and had a mean value of 67 cm. Figure 1 shows this distribution, with the relative proportion shown as a function of headlamp mounting heights.

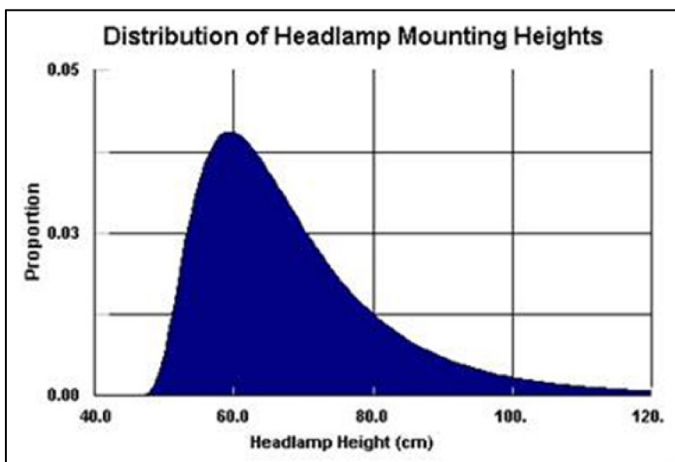


**Figure 1. Distribution of headlamp mounting heights measured by Bullough et al. [5].**

Bullough et al. [5] also reported the distribution of the measured vertical cutoff heights, from which the estimates of headlamp levelness or aim were calculated. The headlamp levelness values (in degrees above or below horizontal) were found to exhibit an approximately normal distribution. Figure 2 shows this distribution with the relative proportion of measured headlamps shown as a function of the range of vertical aim values measured. On average, headlamps measured by Bullough et al. [5] were aimed slightly downward. These data are consistent with a separate survey of vehicle headlamp aim from the same geographic region of New York [6].

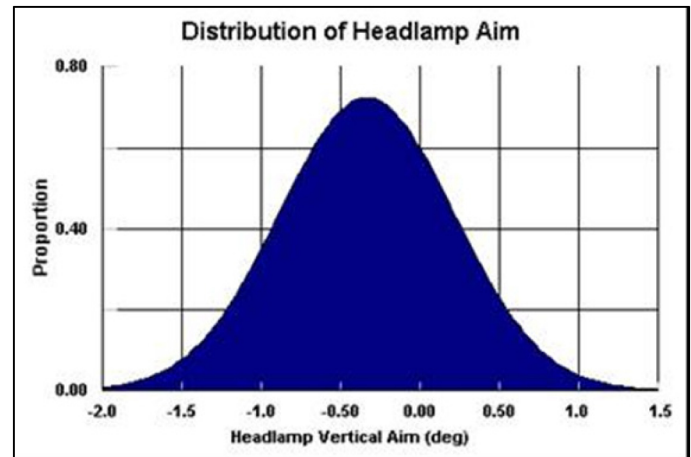


**Figure 2. Distribution of headlamp levelness values (vertical aim) measured by Bullough et al. [5].**

## REAL-WORLD INFLUENCE OF LEVELNESS AND HEIGHT ON HEADLAMP GLARE

As described above, Bullough et al. [5] measured the oncoming illuminance from the same vehicles for which they measured headlamp mounting height and vertical cutoff, in order to determine whether these factors influenced glare, as defined by the illuminance from vehicle headlamps at the location of an oncoming driver's eyes.

As reported by Bullough et al. [5], there was only a weak relationship (Pearson  $r < +0.01$ ) between the illuminance at oncoming drivers' eyes and the mounting height of oncoming headlamps, but there was a moderate but statistically reliable (Pearson  $r = +0.58$ ) relationship between headlamp levelness and (vertical aim) and the oncoming illuminance. Accounting for both of these factors yielded the following relationship among headlamp mounting height ( $H$ , in cm), levelness or vertical aim ( $A$ , in degrees), and oncoming illuminance ( $E$ , in lx) from a distance of 50 m in front of the vehicle:

$$E = 1.83/(1.18 - 0.54A) + 1.58 \log H - 3.55 \quad (1)$$

This relationship between the predicted and measured oncoming illuminance values using Eq. 1 was stronger (Pearson  $r = +0.70$ ) than the relationships for either mounting height or headlamp levelness alone. The solid lines in Figure 3 show the predictions from Eq. 1 as a function of mounting height for three different headlamp levelness values. The solid lines in Figure 4 show the predictions from Eq. 1 as a function of headlamp levelness for three different mounting heights.

In order to better understand the predictive ability (and limitations) of Eq. 1, a simulation was conducted. Using the distributions of mounting height and of headlamp levelness values illustrated in Figures 1 and 2, randomized data for 100 vehicles having those distributions were generated. When the