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16. Abstract

In a survey conducted over 34 years ago, Hare and Hemion (1968) found that United States drivers underuse their high beams in circumstances in which their use is recommended. High-beam use was also found to be inversely related to traffic density. Since that time, changes in beam pattern design, dimming controls, and perhaps driver awareness of the hazards of limited visibility may have sufficiently altered the situation to warrant a follow-up investigation. A survey of high-beam headlamp use was conducted on three unlit local roadways in the Ann Arbor area. Observers judged whether vehicles that were clear of both oncoming and preceding traffic had their high or low beams turned on. Illuminance measures at approximate beam pattern locations were also recorded to support beam judgments. In addition, traffic density was estimated over 15-minute intervals so that the relationship between beam use and traffic density could be examined. The results suggest that the pattern of high-beam underuse is similar to that observed in the late 1960s.

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Introduction

Over thirty-four years ago, Hare and Hemion (1968) conducted an extensive survey of high-beam headlamp use across several regions of the United States. In that study, they found clear evidence that drivers frequently do not use their high-beam headlamps in situations where such use is strongly recommended. Although there were regional differences in high-beam use (for example, drivers in the Southeast used high beams about 40 percent of the time, while drivers in the Northwest used them only 10 percent of the time), some degree of underuse was present everywhere.

High-beam use also declined as average traffic density increased. One would expect high-beam use to decline as traffic density increases, because the average distance between drivers also declines with increasing traffic density. Consequently, drivers *ought* to refrain from using their high beams to reduce glare for nearby drivers. Such situations, however, are excluded from this evaluation. As described more fully below, only the beam use of vehicles *clear* of other roadway traffic is considered here. In this context, higher density traffic implies only an increased likelihood of encountering another vehicle. Thus, as the number of potential roadway encounters increased, drivers appeared less inclined to use their high beams. There may be several reasons for this. Drivers may consider it a nuisance to switch frequently between low and high beams. If the frequency of switching exceeds a particular level, some drivers may even simply stop switching between beams. Drivers may also forget to switch back to high beams for some time after encountering an oncoming vehicle.

Although high traffic density appears to reduce high-beam use, even at the lowest traffic densities there appears to be a substantial degree of high-beam underuse. For example, Schwab and Hemion (1972) report that high beam use does not reach 50 percent (in their data) until traffic density drops below 30 vehicles per hour. It seems likely that a driver's choice to switch to high beams is influenced by more than traffic density. For example, drivers may not be aware of the extent to which they are visually impaired when driving with low beams (Owens & Tyrrell, 1999). They may perceive the difference in light intensity between low and high beams to be small (Rumar, 2000) and perhaps not worth the effort involved in switching and monitoring the state of their lamps. Drivers may also be concerned about forgetting to dim the high beam at an appropriate time, or may even be unacquainted with the operation of the vehicle's dimming controls.

Since 1968, there have been many changes in vehicle lighting and in the driving environment. In particular, the rise in the use of tungsten halogen (TH) sources since 1968 (Moore, 1998) has generally increased headlamp illumination levels. It is plausible that these developments have altered patterns of beam use. For example, drivers may consider the stronger illumination provided by current TH low beams more adequate for their driving needs and therefore may be less inclined to use high beams.

Since 1968, annual vehicle miles traveled (VMT) has increased while expansion of roadway infrastructure has leveled off, raising the density of traffic on most roadways. In rural areas, where fixed roadway illumination is uncommon, the VMT per lane-mile has changed from 103,000 in 1980 to 172,000 in 2000 (Bureau of Transportation Statistics, 2002)—a 67 percent increase over a 20-year period. Because higher traffic density appears to discourage high-beam use, perhaps the general habit of use has also been affected. That is, drivers who would have routinely used their high beams find fewer occasions to do so because of the higher likelihood of encountering other road users. When such an occasion presents itself, drivers may be slow either to recognize it or to take action. On the other hand, we should also recognize that lamp dimming controls have become more convenient to use. In 1968, lamp dimming was controlled with a foot-activated toggle switch, while now it typically involves a conveniently located stalk-mounted switch (Rumar, 2000). The added convenience may encourage beam switching, which may result in greater use of high beams.

Given the changes that have occurred since Hare and Hemion's original study, it is of interest to reexamine high-beam use to determine if there is evidence that the relevance of the original study has eroded.

Method

Roadway Selection

Observations of headlamp use were made on three different roadways in Washtenaw County, Michigan. They were selected using the following criteria: All roadways were two-lane, free of fixed illumination, situated in rural areas, and approximately level and straight along the 1500 to 2400 m observation area. All roadways were free of major connectors, restricted passing areas, restricted speed areas, and warning signs within the observation area. Finally, roadways were selected so that estimates of the average nighttime traffic density ranged between 20 and 300 vehicles per hour, similar to the range used by Hare and Hemion. (The *actual* nighttime traffic densities on the observed roads fell within the desired range and are presented later with the results.)

Procedure

Observations began approximately one hour past civil twilight to ensure light levels were sufficiently low to warrant headlamp use. Ambient illumination measured at the start of the observation sessions was less than .04 lux.

Two observers were located at the roadside, approximately 2-3 m off the shoulder. They observed vehicles from both directions. For each vehicle observed, a judgment was first made whether the target vehicle's passage was *clear* of other vehicles. A *clear* vehicle was defined as one that is: unopposed by any approaching traffic in the opposite lane within visible distance, not following a leading vehicle, and not followed by another vehicle. In general, the criteria applied here are slightly more conservative than those used by Hare and Hemion (1968). Their "open road" definition stipulated "no opposing vehicle in [the] test site and no leading vehicle within 600 ft." It seems clear from the detailed instructions to their observers that they meant no opposing vehicles in the *sight distance* of their test area (independent of the actual placement of their test equipment). This is effectively the same criterion regarding opposing traffic used in the present study. However, the criteria for clear traffic used in this study also excluded vehicles in both leading and following configurations. At short intervehicle distances, leading and following vehicles can each obtain some visibility benefit from the other vehicle's forward illumination, perhaps discouraging high beam use. In addition, a following driver might be discouraged from using high beams by concern about causing rearview-mirror glare for the lead driver. While these potential influences between lead and following vehicles are likely to diminish as the distance between the two vehicles increases, they probably persist to some degree as long as drivers are in sight of each other. To avoid this ambiguity, neither lead or following vehicles were counted as clear in this sample. Thus, there is no ambiguity in the clear circumstance, as it was defined in this experiment, about the appropriateness of high-beam use.

For clear vehicles, observers judged whether the vehicle entered the observational area with high beams activated. All vehicles passing through the observation area were tallied for each 15-minute interval in each three-hour nightly session to produce an empirical measure of traffic density over time. There were four observational sessions for each of the three roadways. Thus, the data were collected from a total of 36 hours of observation.

Roadside photometric measurements were also recorded at a distance of 100 m forward of the clear approaching vehicle, at a height of 1.52 m, 7.5 m to the left side of the roadway (see Figure 1). This was done to provide an objective supplement to the observational data. The measurement location was selected, using market-weighted high- and low-beam photometry (Schoettle, Sivak, & Flannagan, 2001) for guidance, to maximize discrimination between low and high beams. (The selected location lies approximately at 4.3 degrees left and 0.6 degrees up, relative to the center of the beam pattern of correctly aimed headlamps.) Even factoring in the large expected variations in light output as a consequence of differences in beam design, headlamp aim, vehicle yaw and pitch angle, and lens dirt, this location afforded a good opportunity to distinguish high- and low-beam use. Figure 1 shows the isolux curves at a height of 1.5 m for the 25th and 75th percentile high- and low-beam output from Schoettle et al. (2001).

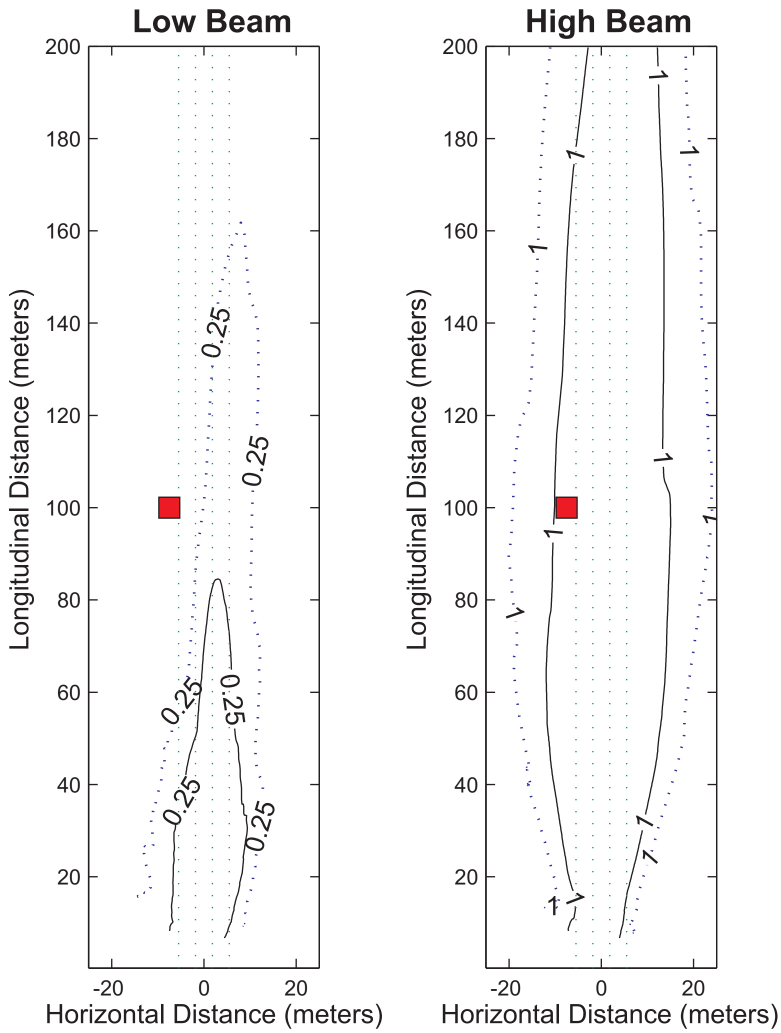

Figure 1. Low- and high-beam isolux curves at a height of 1.52 m above the ground. The roadside observation location is indicated by the dark square (100 m forward, 1.52 m high, 7.5 m left of center). The solid curves show the 25th percentile lamp output and the dashed curves show the 75th percentile output. The low-beam curves are for 0.25 lux, and the high-beam curves are for 1.0 lux. For reference, the straight dotted lines correspond to the boundaries of 3.7 m lanes.

A 1.05 lux criterion was used to distinguish low and high beam activation in the photometric data. Measurements at or exceeding 1.05 lux were judged to be high beams, and measurements below 1.05 lux were judged as low beams. (As explained in the results section, 1.05 lux was chosen to give the best possible discrimination between high and low beams based on photometry at a single point.) Because illuminance measures were taken for only one direction of traffic flow, there are fewer illuminance measurements than observer judgments (403 vs. 968).

Traffic Density

Traffic density on each roadway was measured for 15-minute intervals, although we report it as an equivalent hourly rate. Average density varied among the three roads: The lightest traveled roadway averaged 36 vehicles per hour, the middle roadway averaged 58 vehicles per hour, and the busiest roadway averaged 131 vehicles per hour. Across the three roadways and all 15-minute intervals, density ranged from 4 to 236 vehicles per hour.

The number of clear vehicle observations also varied with traffic density. In periods of light traffic, there were fewer opportunities to observe clear vehicles (or any vehicles at all). In periods of heavy traffic density, there were also fewer opportunities to observe clear vehicles because much of the roadway was shared by oncoming or following vehicles. Consequently, the number of observations of clear vehicles at both the upper and lower extremes of traffic density levels is small. This is shown in the distribution of clear observations (on which illuminance measures were made) by traffic density in Figure 2. This figure combines data from the three different roadways on which observations were made. It should be noted that it is not a homogeneous mixture: 33 percent of the observations came from the lightest traveled roadway, 17 percent came from the roadway with medium traffic density, and 50 percent came from the highest density roadway.

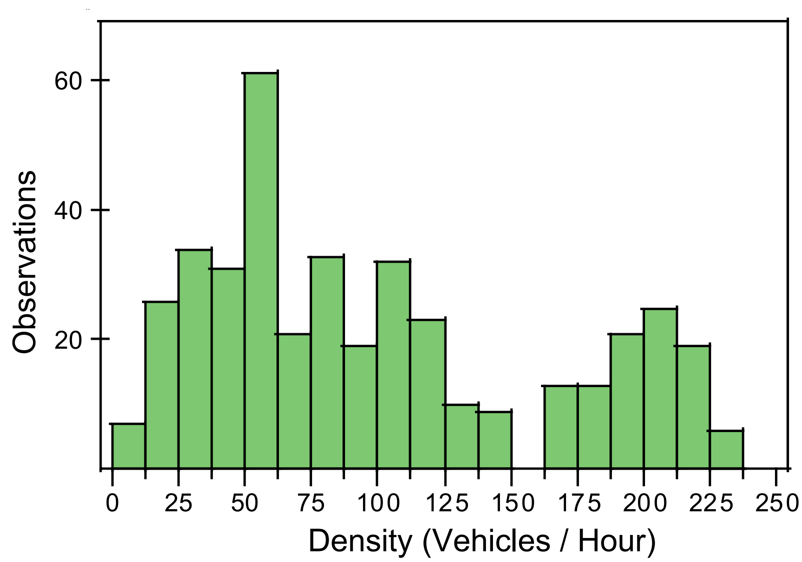

Figure 2. Distribution of observations of clear vehicles by traffic density in vehicles per hour. The histogram combines observations taken from three different roadways over four nightly sessions. Total number of clear vehicles observed was 403.

Results

A total of 1,740 vehicles were observed on the selected roadways. Of these, 975 were clear of oncoming or following traffic. Subjective ratings were made for 968 of these vehicles; illuminance measures were recorded for 403.

Figure 3 presents the distribution of illuminance measures taken at the roadside observation point with the 1.05-lux criterion line drawn to divide high beam from low beam. There is clearly no sharp dividing line between low-beam and high-beam output in the recorded data. Instead, it is likely that there is overlap in the measured illuminance for high and low beams as a consequence of variations in aim, dirt on the lens, and vehicle orientation. The reference line was selected to maximize the agreement between the subjective ratings of each observer and the objective illuminance measure. This was done by selecting a range of lux criteria to divide low beam from high beam and comparing the overlap between each rater's beam judgments with those made using each criterion. Judgment overlap peaked for one observer at 93 percent at a criterion of 1.1 lux, and for a second observer at 85 percent at a criterion of 1.0 lux. Agreement between observers was good—82.2 percent of their judgments were the same.

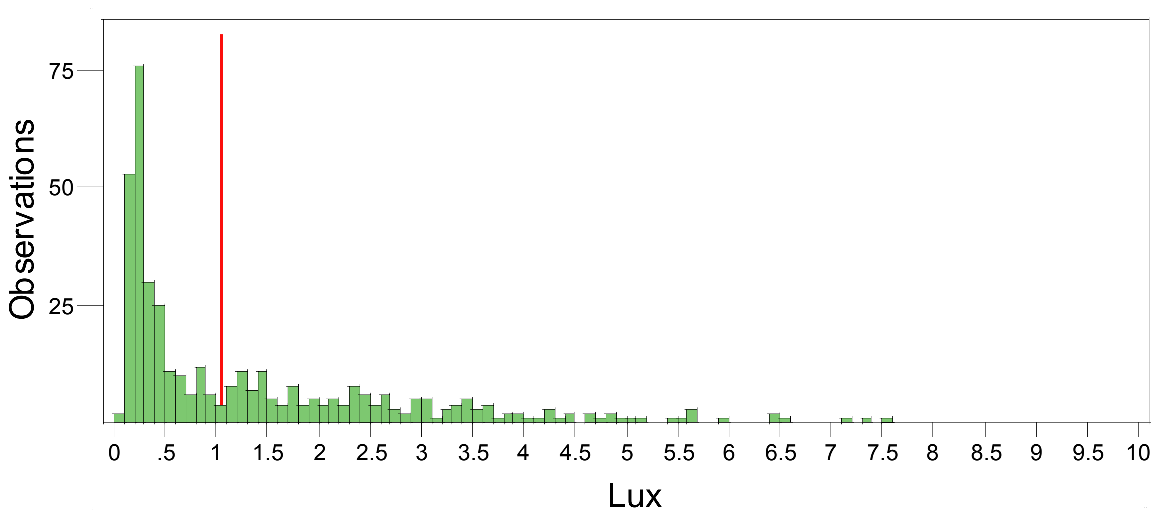

Figure 3. Distribution of illuminance measures recorded at the roadside observation point. The vertical line at 1.05 lux identifies the adopted dividing line between low- and high-beam usage.

Based on the illuminance criterion of 1.05 lux, drivers appeared to use high beams 42 percent of the time under clear conditions. Based on the data from observer judgment—which included traffic from both roadway directions—high beams were used 50 percent of the time. Although this is somewhat higher than the average high-beam usage found by Hare and Hemion (1968) at two sites in Michigan (27 and 24 percent), it is clear that drivers do not use their high beams as often as would be prudent. Of course, a raw comparison like this does not adequately take into account the mixture of traffic density and its effect on high-beam use. A clearer picture is obtained by plotting the percentage of high-beam use against traffic density, and comparing it to that found by Hare and Hemion. Following Hare and Hemion, a linear fit was made between log percent usage and traffic density weighted by the overall number of observations for both the usage data based on observer judgment (Figure 4), and the usage data based the illuminance measurements (Figure 5). The fits are very similar to each other, and neither is very different from the fit to Hare and Hemion's data presented in Schwab and Hemion (1972). Each fit line extrapolates to the ordinate, the projected level of zero density, at between 60 to 70 percent. This suggests that even at the lowest possible level of traffic density drivers are unlikely to use their high beams as much as they should. Both graphs also show a decline in high-beam use with traffic density, similar to the pattern described by Schwab and Hemion (1972) although the asymptote is 10 to 20 percent higher in the new data.

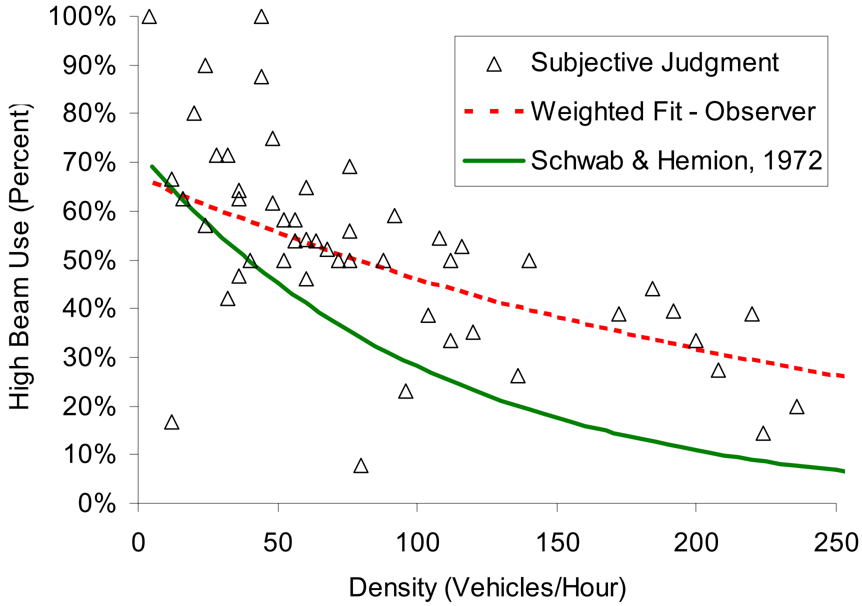

Figure 4. Percent use of high beams declines with traffic density. The data above are based on the judgments of high-beam use by an observer.

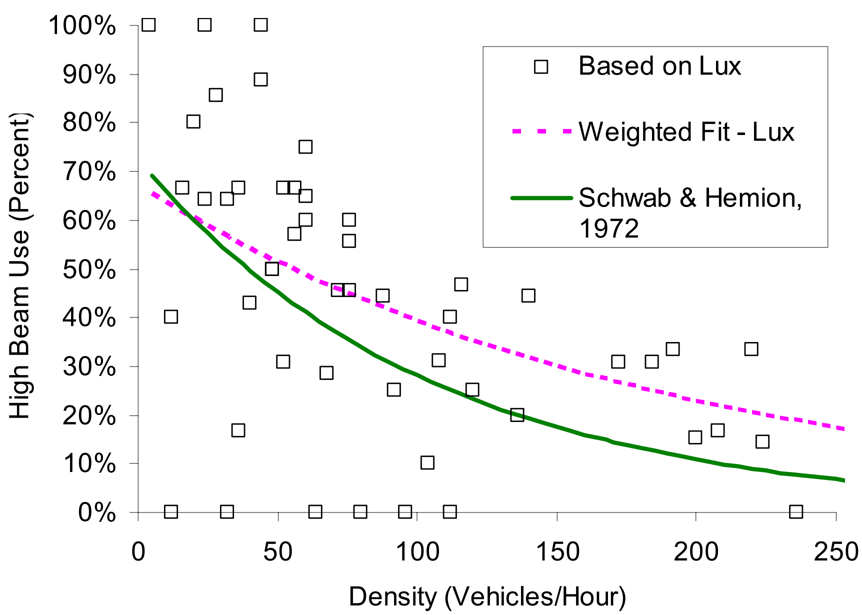

Figure 5. Percent use of high beams declines with traffic density. The data above are based on a partitioning rule that classified a beam as high if it reached or exceeded 1.05 lux at the test location and otherwise as low.

Discussion and Conclusion

The key result of this study is that little appears to have changed with respect to drivers' use of high beams since 1968. Drivers continue to underuse their high beams in situations in which it is reasonable and clearly advisable to do so. And high-beam use appears to decrease with traffic density. Although average high-beam use on the Michigan roadways in this study was twice as high as was previously reported by Hare and Hemion (1968), a meaningful comparison cannot be made without more detail about how Hare and Hemion's observations in Michigan were distributed across traffic densities.

Although traffic density seems to discourage drivers from using their high beams, it is unlikely that traffic density completely accounts for high-beam underuse. Even at the lowest levels of traffic density (extrapolated from these data), high-beam use never exceeds 70 percent. This suggests that other reasons beyond switching convenience are responsible for the relative lack of high-beam use. Assuming that switching is more convenient now than in 1968, perhaps an argument could be made that the higher asymptote at high traffic density in the current data is a consequence of this added convenience. However, before such a case can be made, the roads sampled in the two studies need to be better equated. (It is more likely that these sampling differences are chiefly responsible for these differences.)

A fruitful line of future inquiry might be to investigate the specific circumstances that make drivers decide to use high beams. This might help to better understand why some drivers apparently never make that decision.

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