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16. Abstract

Information about the locations of headlamps and driver eye positions is important in estimating the performance of a variety of traffic-safety equipment, such as retroreflective traffic signs and markings, rearview mirrors, and headlamps. Driver eye height is also an important factor in determining safe sight distances on vertical curves. However, no comprehensive database concerning the locations of headlamps and driver eye positions exists for the current U.S. fleet. The present study was designed to obtain such information for vehicles currently sold in the U.S. The information was derived from the 15 best-selling cars and the 15 best-selling light trucks and vans. These 30 vehicles represent 52% of all vehicles sold in the U.S. in 1995.

For headlamp locations, actual vehicle measurements were made. For driver eye positions, dimensional information provided by vehicle manufacturers was used to estimate the location of the driver seating reference point. An UMTRI-developed computer model that predicts the relationship of the driver eye position to the driver seating reference point was then used to calculate driver eye positions. The obtained information includes sales-weighted mean dimensions for the locations of headlamps and driver eye positions, calculated separately for cars and for light trucks and vans.

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Contents

Introduction

Information about the locations of headlamps and driver eye positions is important in estimating the performance of a variety of traffic-safety equipment, such as retroreflective traffic signs and markings, rearview mirrors, and headlamps. Driver eye height is also an important factor in determining safe sight distances on vertical curves.

Let us consider, for example, retroreflective traffic signs. The efficiency of retroreflective materials is an inverse function of observation angle, the angle formed by the light source (the headlamp), the material (the sign), and the eyes of the observer (the driver) (Sivak, Flannagan, and Gellatly, 1993). Consequently, the locations of the headlamps and driver eye positions are critical in estimating the efficiency of the retroreflective materials. However, no comprehensive database concerning the locations of headlamps and driver eye positions exists for the current U.S. fleet. Because of this state of affairs, different studies and computer models have assumed different values for these locations, with the consequence that the findings across studies are not directly comparable. As an example, Table 1 lists the locations of headlamps and driver eye positions in several recent publications related to retroreflective traffic signs.

The present study was designed to obtain information about the locations of headlamps and driver eye positions in vehicles currently sold in the U.S. The information was derived from the 15 best-selling cars and 15 best-selling light trucks and vans. For headlamp locations, actual vehicle measurements were made. For driver eye positions, dimensional information provided by vehicle manufacturers was used to estimate the location of the driver seating reference point. An UMTRI-developed computer model that predicts the relationship between the driver eye position and the driver seating reference point was then used to predict driver eye positions.

Table 1
The assumed locations of headlamps and driver eye positions in previous publications.

Vehicle type	Distance (m)				
	1	2	3	4	5
Car (CIE, 1988)	0.65		1.20		2.00
Car (Paniati and Mace, 1993)	0.61	0.61	1.07	0.46	1.37
Car (Sivak et al., 1993)	0.62	0.57	1.14	0.42	2.06
Car (CEN, 1994)	0.65	0.50	1.20	0.30	2.00
Car (Szczech and Chrysler, 1994)	0.68	0.61	1.16	0.41	2.08
Car (Stimsonite, 1996)	0.66	0.52	1.13	0.33	2.06
Light truck (Sivak et al., 1993)	0.76	0.65	1.63	0.47	2.06
Light truck/small bus (CIE, 1988)	0.86		1.68		1.20
Bus/truck (CEN, 1994)	0.80	0.90	2.20	0.70	0.95
Heavy truck (CIE, 1988)	0.81		2.29		0.97
Heavy truck (Sivak et al., 1993)	0.85	0.99	2.33	0.69	1.52
Large bus (CIE, 1988)	0.85		2.17		0.92
Motorcycle (CEN, 1994)	0.80	0.00	1.00	0.00	0.50
Motorcycle (CIE, 1988)	0.80		1.00		0.50

1: Vertical distance from headlamp center to ground.
2: Lateral distance from headlamp center to vehicle centerline.
3: Vertical distance of driver eye location to ground.
4: Lateral distance from driver eye location to vehicle centerline.
5: Longitudinal distance between headlamp and driver eye location.

Note: The entries for headlamp mounting height and driver eye height in Sivak et al. (1993) were computed using raw data from Cobb (1990).

Method

Location of headlamps

Information about the location of headlamps was based on actual measurements made on 1996 model vehicles. The measurements were performed on the 15 best-selling cars and the 15 best-selling light trucks and vans in the U.S. for calendar year 1995 (Wards Automotive Reports, 1996). The 30 vehicles represented 52% of all vehicles sold: the 15 cars constituted 41% of all cars sold, while the corresponding percentage for the 15 light trucks and vans was 67% (Wards Automotive Reports, 1996). The 30 vehicles were manufactured by six companies (Chrysler, Ford, GM, Honda, Nissan, and Toyota).

Three measurements were taken to identify the position of the low-beam headlamps of each vehicle: vertical distance of a headlamp from the ground (center-to-ground mounting height), lateral distance between the headlamps (center-to-center separation), and longitudinal distance from the bumper to the headlamp lens (see Figure 1). (Lateral distance to the centerline of the vehicle was obtained by dividing lateral distance between headlamps by 2.)

The measurements for all but one vehicle model were taken in car dealerships. (One vehicle model was no longer available in car dealerships. Consequently, the measurements for this vehicle model were made in a car rental agency.) No occupants were in the vehicles at the time of the measurements. Fuel levels and tire pressures were not monitored or adjusted.

At least two samples of each vehicle model were measured, and these measurements were then averaged. These average measurements for each vehicle model were then, in turn, weighted by the corresponding 1995 sales numbers to obtain grand means for cars and light trucks, respectively.

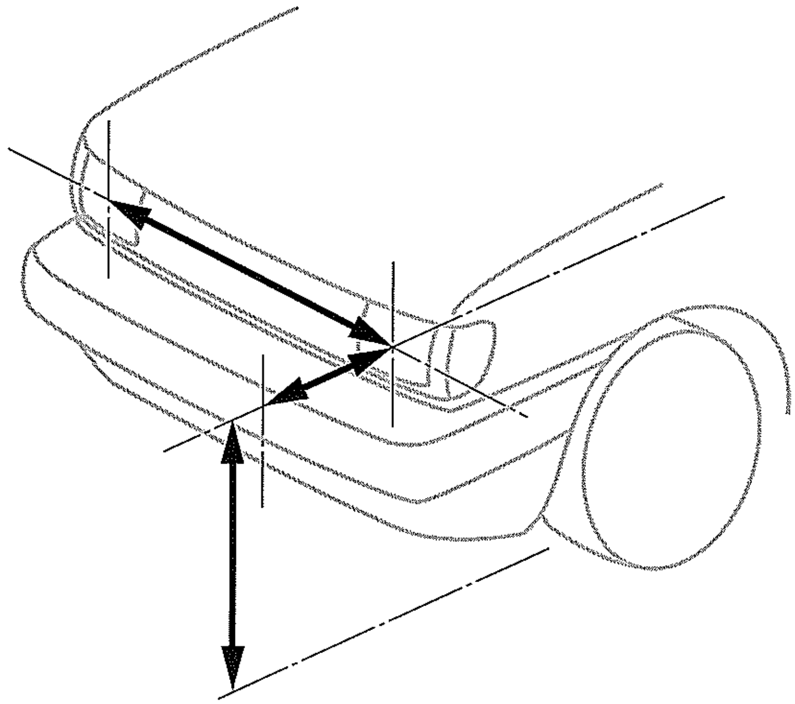

Figure 1. Schematic diagram of the three headlamp measurements taken for each vehicle.

Location of driver eye positions

Estimated locations of driver eye positions were derived in a two-part process (see Figure 2). First, the coordinates of the SAE seating reference point (SgRP) were calculated using SAE dimensions H5, W20, L104, and L114 (defined in SAE Recommended Practice J1100 [Society of Automotive Engineers, 1996]). The actual values were provided by vehicle manufacturers. Second, using a model developed at UMTRI, the SgRP coordinates were used to predict the coordinates of the average driver eye position (as the centroid of an eyellipse).

The SgRP is a vehicle interior reference point, defined in SAE Recommended Practice J1100 and measured according to SAE Standard J826 (Society of Automotive Engineers, 1996). The SgRP corresponds to the predicted location of the hip-joint center of a driver seated at the 95th percentile seat position. The vertical component of the distance from the SgRP to the accelerator heel point (SAE dimension H30) is an important predictor of driver eye locations.

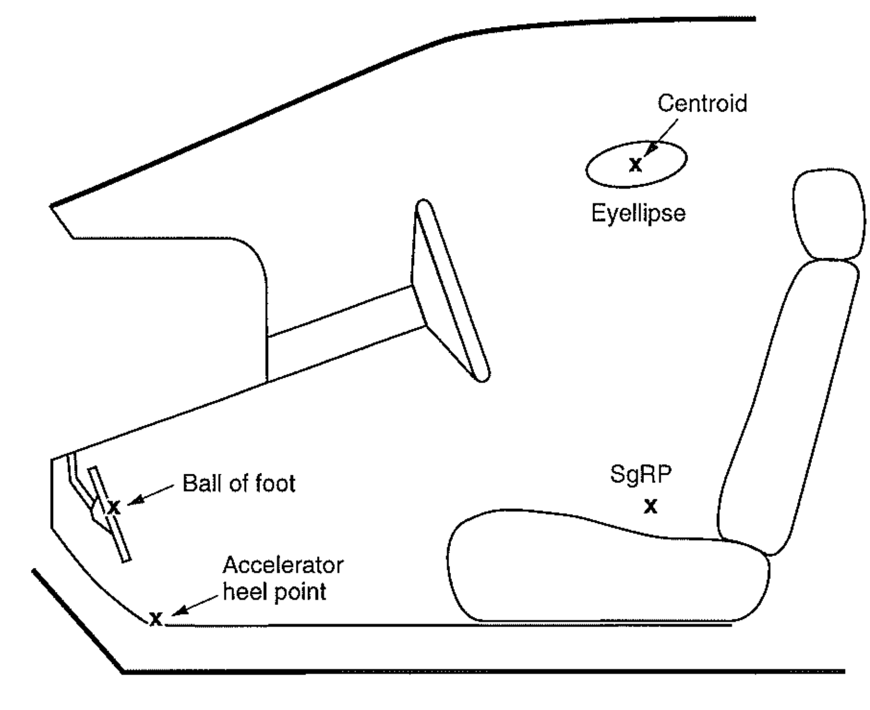

Figure 2. Schematic diagram of the relationship between the driver seating reference point (SgRP) and the mean driver eye position (the centroid of the eyellipse).

Design specifications were requested from the respective vehicle manufacturers for 1996 model vehicles. (Specifications were not available for the 1996 model year for three vehicles. Therefore, the specifications that were used for these three vehicles were for the 1995 model year.)

The centroid of the eyellipse for each vehicle was derived using the UMTRI model to predict eye location. The UMTRI model was developed from eye-position data for 55 to 100 subjects in each of 13 vehicles and 7 buck conditions (Schneider, Manary, and Flannagan, 1995). An empirical eyellipse was determined for each of the vehicles and buck conditions, and separate regression equations were generated to predict each of the nine parameters of the eyellipses (three centroid coordinates, three axis lengths, and angles of offset in three planes). The equations for the longitudinal and vertical components of the centroid accounted for 90% and 98% of the variance, respectively. The lateral location of the eyellipse centroid was predicted to lie on the seat centerline in all vehicles.

For each vehicle, SAE dimension H30 was used as input to the UMTRI eyellipse model, and the predicted eyellipse centroid was determined. The centroid coordinates were originally derived as distances to standard vehicle interior landmarks: ball-of-foot point for the longitudinal coordinate, accelerator heel point for the vertical coordinate, and driver's seat centerline for the lateral component. These were then translated into distances to bumper (longitudinal), ground (vertical), and vehicle centerline (lateral) using additional SAE design specifications provided by vehicle manufacturers (H5, W20, L53[1], L104, and L114). Finally, averages of these dimensions for cars and light trucks were obtained by weighting the individual vehicle dimensions by the corresponding 1995 sales figures.

[1]L53 was not available for four vehicles. For these four vehicles, L53 was estimated from pedal plane angle and the 95th percentile selected seat position, given H30, in accordance with SAE Recommended Practice J1516 (Society of Automotive Engineers, 1996).

Results

Location of headlamps

The means and standard deviations of the sales-weighted distributions of the measured headlamp locations are listed in Table 2.

Table 2
Locations of the low-beam headlamps. The main entries are the sales-weighted means; the entries in parentheses are the standard deviations of the sales-weighted distributions.

Dimension	Distance (m)	
	Cars	Light trucks and vans
Vertical to ground[1]	0.62 (0.02)	0.83 (0.08)
Lateral to the centerline of the vehicle[1]	0.56 (0.06)	0.65 (0.09)
Longitudinal to the front of the bumper[2]	0.20 (0.04)	0.18 (0.04)

[1]Measured from the center of the headlamp.
[2]Measured to the lens of the headlamp.

Location of the seating reference point (SgRP)

The means and standard deviations of the sales-weighted distributions of the calculated locations for the driver seating reference point are listed in Table 3.

Table 3
Locations of the driver seating reference point (SgRP). The main entries are the sales-weighted means; the entries in parentheses are the standard deviations of the sales-weighted distributions.

Dimension	Distance (m)	
	Cars	Light trucks and vans
Vertical to ground[1]	0.47 (0.02)	0.78 (0.08)
Lateral to the center of the vehicle[2]	0.35 (0.02)	0.42 (0.05)
Longitudinal to the front of the bumper[3]	2.36 (0.10)	2.30 (0.12)

[1]SAE dimension H5.

[2]SAE dimension W20.

[3]Calculated by adding SAE dimensions L104 and L114. For ten vehicles, L114 was not available directly. For six of these ten vehicles, L114 was derived by subtracting L128 from L31. For four of the ten vehicles, L114 was derived as a sum of the longitudinal distance from ball-of-foot to front axle and x_{95} (the 95th percentile selected seat position). (Dimensions L31, L104, L114, and L128 are defined in SAE Recommended Practice J1100; x_{95} was computed given the method in SAE Recommended Practice J1517 [Society of Automotive Engineers, 1996].)

Location of the driver eye positions

The means and standard deviations of the sales-weighted distributions of the predicted driver eye locations are shown in Table 4.

Table 4
Locations of the centroid of the driver eye positions. The main entries are the sales-weighted means; the entries in parentheses are the standard deviations of the sales-weighted distributions.

Dimension	Distance (m)	
	Cars	Light trucks and vans
Vertical to ground	1.11 (0.02)	1.42 (0.08)
Lateral to the center of the vehicle	0.35 (0.02)	0.42 (0.05)
Longitudinal to the front of the bumper	2.34 (0.09)	2.26 (0.12)

Comparisons with other databases

This study provides 3-D information about the locations of headlamps and driver eye positions in vehicles currently sold in the U.S. We are aware of relevant prior U.S. databases only for the vertical component of the driver eye position—the driver eye height (e.g., Stonex, 1958, Stonex, 1960; Lee, 1960; Meldrum, 1965; Boyd, Littleton, Boenau, and Pilkinton, 1978; Cunagin and Abrahamson, 1979; MVMA, 1979; Lee and Scott, 1981; Farber, 1982; Olson, Cleveland, Fancher, Kostyniuk, and Schneider, 1984). The most recent of these studies (Olson et al., 1984) analytically derived driver eye heights for the 1981 model cars. The data of Olson et al. indicate that 1.09 m (43 in) corresponds to the 44th percentile, and 1.12 m (44 in) to the 64th percentile. Interpolating from this information, it appears that about 1.10 m would correspond to the 50th percentile. This compares well with the mean value for cars in the present study (1.11 m). Thus, it appears that driver eye heights in the U.S. have remained relatively stable during the past 15 years.

The mean driver eye height for cars in this study (1.11 m) is somewhat lower than the mean of the U.K. data of Cobb (1990) (1.14 m) calculated by Sivak et al. (1993) from Cobb's raw data. The value obtained in the present study for light trucks and vans (1.42 m) is substantially lower than that for Cobb's data (1.63 m).

Interestingly, Cobb's mean driver eye height for cars (1.14 m) is identical to that found in an earlier U.K. study (Haslegrave, 1979), suggesting no changes in driver eye height in the U.K. during the time period between the data collections for these two studies (1976-1989).

Cobb's U.K. data also include the only prior published information that we know of on headlamp mounting heights. The mean value for cars (again calculated by Sivak et al., 1993 from Cobb's raw data) was the same as in the present study—0.62 m. The corresponding mean values for light trucks and vans were 0.76 m in Cobb and 0.83 m in the present study.

In conclusion, the current mean vertical component of the location of driver eye positions for cars in the U.S. appears to be relatively unchanged over the past 15 years, and it is about 3 cm lower than in the U.K. The mean vertical component of the location of headlamps on cars is currently the same in the U.S. and the U.K. On the other hand, because of the absence of other relevant databases, no similar time-trend or cross-sectional comparisons can be made for the obtained lateral and longitudinal components of the locations of either driver eye positions or headlamps.

References

Boyd, M.W., Littleton, A.C., Boenau, R.E., and Pilkington, G.B. (1978). *Determination of motor vehicle eye height for highway design* (Report No. FHWA-RD-78-66). Washington, D.C.: Department of Transportation.

CEN (Comité Européen de Normalisation). (1994). *Proposal for R' requirement for retroreflective signs* (Note to CEN/TC226 WG3 Group of Experts). Brussels, Belgium: Author.

CIE (Commission Internationale de l'Eclairage). (1988). *Visual aspects of road markings* (Publication CIE No. 73). Vienna, Austria: Author.

Cobb, J. (1990). *Roadside survey of vehicle lighting 1989* (Research Report 290). Crowthorne, UK: Transport and Road Research Laboratory.

Cunnagin, W. and Abrahamson, T. (1979). Driver eye height: A field study. *ITE Journal*, *49*, 34-36.

Farber, E.I. (1982). Driver eye-height trends and sight distance on vertical curves. *Transportation Research Record*, *855*, 27-33.

Haslegrave, C.M. (1979). *Measurement of the eye heights of British car drivers above the road surface* (Supplementary Report 494). Crowthorne, UK: Transport and Road Research Laboratory.

Lee, C.E. (1960). *Driver eye height and related highway design features.* Paper presented at the 39th Annual Meeting of the Highway Research Board, Washington, D.C.

Lee, R.L. and Scott, C.P. (1981). *Driver eye height and vehicle sales trends (1969 - 1979).* Washington, D.C.: Federal Highway Administration.

Meldrum, J.F. (1965). *Automobile driver eye position* (Report No. 650464). New York: Society of Automotive Engineers.

MVMA (Motor Vehicle Manufacturers Association). (1979). *Driver height comparison for 1976 and 1978.* Detroit, MI: Author.

Olson, P.L., Cleveland, D.E., Fancher, P.S., Kostiniuk, L.P., and Schneider, L.W. (1984). *Parameters affecting stopping sight distance* (NCHRP Report No. 270). Washington, D.C.: Transportation Research Board.

Paniati, J.F. and Mace, D.J. (1993). *Minimum retroreflectivity requirements for traffic signs* (Report No. FHWA-RD-93-077). McLean, VA: Federal Highway Administration.

Schneider, L., Manary, M., and Flannagan, C. (1995). *Human factors of driver seating and control packaging. Phase 2: Ellipses, headroom, and pedal reference point* (AAMA second quarterly report). Ann Arbor, MI: The University of Michigan Transportation Research Institute.

Sczcech, T.J. and Chrysler, S.T. (1994). Proposal for standard U.S. headlamp beam pattern for evaluation of retroreflection. *Transportation Research Record, 1456*, 91-98.

Sivak, M., Flannagan, M.J., and Gellatly, A.W. (1993). Influence of truck driver eye position on effectiveness of retroreflective traffic signs. *Lighting Research and Technology, 25*, 31-36.

Society of Automotive Engineers. (1996). *1996 SAE Handbook, Vol 3: On-highway vehicles and off-highway machinery.* Warrendale, PA: Author.

Stimsonite Corp. (1996). *ERGO Program documentation.* Niles, IL: Author.

Stonex, K.A. (1956). Driver eye height and vehicle performance in relation to crest sight distance and length of no-passing zone. I. Vehicle data.. *Highway Research Board Bulletin, 195*, 1-4.

Stonex, K.A. (1960). *Review of vehicle dimensions and performance characteristics.* Paper presented at the 39th Annual Meeting of the Highway Research Board, Washington, D.C.

Ward's Automotive Reports. (1996, January 8). Southfield, MI: Author.