

An Eyellipse for Rear Seats with Fixed Seat Back Angles

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ABSTRACT

This paper describes the development of the fixed seat eyellipse in the October 2008 revision of SAE Recommended Practice J941. The eye locations of 23 men and women with a wide range of stature were recorded as they sat in each of three second-row bench seats in a laboratory mockup. Testing was conducted at 19-, 23-, and 27-degree seat back angles. Regression analysis demonstrated that passenger eye location was significantly affected by stature and by seat back angle. The regression results were used to develop an elliptical approximation of the distribution of adult passenger eye locations, applying a methodology previously used to develop the driver eyellipse in SAE J941-2002.

INTRODUCTION

The eyellipse is a statistical construct that represents the distribution of vehicle occupants' eye locations as an ellipse, or ellipsoid in three dimensions (1, 2). The eyellipse was introduced by Meldrum (3), who observed that the distribution of a large number of measured driver eye locations was similar to a three-dimensional multivariate normal distribution. A bivariate normal distribution is frequently depicted using an ellipsoid centered on the mean of the distribution. The ellipsoid can be computed to enclose a specified percentage of the distribution density, for example, 95%. Meldrum exploited the "cutoff" characteristic of the density ellipsoid to obtain a result more useful for vision analysis. Tangents to any bivariate normal density ellipse divide the distribution into a constant fraction. Equivalently, as shown in Figure 1, a "cutoff" ellipse can be constructed such that all tangents to the ellipse divide the distribution into constant fractions.

The cutoff ellipse provides greater utility for vision analyses than does the density ellipse. Consider a design criterion to ensure a minimum upward vision angle for drivers. Using a 95% cutoff ellipse, Figure 1 shows a schematic side-view analysis of upvision angle. The figure shows that 95% of drivers have an upvision angle at least as large as the angle of the tangent.

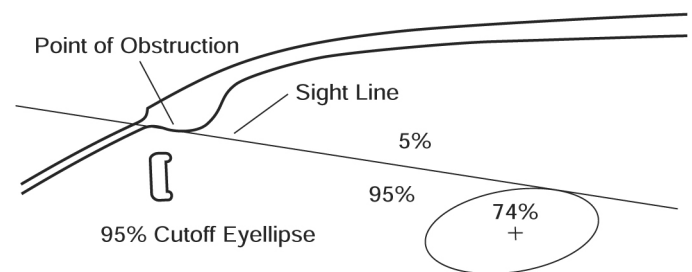


Figure 1. Conducting an upward vision analysis with a side-view 95% cutoff driver eyellipse. The eyellipse encloses approximately 74% of driver's eyes in side view, but 95% of driver's eyes lie below the tangent to point of obstruction.

SAE Recommended Practice J941 presents eyellipses for drivers in passenger cars and light trucks (SAE Class A vehicles) as well as heavy trucks (Class B vehicles). The original eyellipse (3), which applied only to Class A vehicles, was based on eye locations measured statically using stereo-photogrammetry. The eyellipse was enhanced with other data to provide for greater seat track adjustability and head turn (2). Yet, among other limitations, the original eyellipse was based on data obtained using fixed seat back angles and did not provide configurability for population anthropometry.

In 2002, a new edition of J941 was adopted that introduced an entirely new eyellipse model based on driver eye locations from 33 vehicles (4). The model allows specification of single-gender stature distributions and gender mix and takes into account the effect of steering wheel position (see J941, Appendix A).

Because the earlier version of J941 used seat back angle as an input, the model was frequently used to estimate driver eye and head locations in rear seats with fixed seat back angles. However, the model was neither developed nor validated for this purpose.

Both the driver and fixed-seat eyellipses in J941 have been used to create head contours for use in evaluating headroom. The contours, described in SAE J1052, were computed as ellipsoidal approximations to the head distributions associated with the eyellipse.

The current paper describes the development of the rear-seat eyellipse model included in Appendices B and C of the October 2008 revision of J941. The practice refers to a “fixed-seat” eyellipse, since the model is applicable to seats without adjustments. Since these seats are typically available only in the second and more-rearward rows of passenger vehicles, the model is also referred to as a rear-seat eyellipse.

METHODS

As part of a larger study of rear-seat accommodation, the postures of 13 women and 10 men were measured in a laboratory mockup. The subjects ranged in stature from 1470 to 1924 mm. The median body mass index was 26.3 kg/m². The test conditions are described in Reed et al. (7). The second-row seats of three vehicles (two passenger cars and one minivan) were mocked up in the laboratory such that the back angles could be manipulated. The seat height (H30) was 270 mm. Testing was conducted with back angles (SAE J1100 dimension A40, measured with the SAE J826 H-point machine) of 19, 23, and 27 degrees. A FARO Arm coordinate digitizer was used to record the three-dimensional locations of body landmarks. The eye location was estimated in sideview from the X (fore-aft) coordinate of the infraorbitale landmark and the Z (vertical) coordinate of the ectocanthus (corner of eye) landmark.

A regression analysis was conducted to predict eye location with respect to seat H-point as a function of stature and seat back angle (SAE A-40). For ease of modeling, eye location was predicted as the length and angle with respect to vertical of a sideview vector from H-point to eye. Following Manary et al. (4), the residual variance from the regressions was retained for use in modeling.

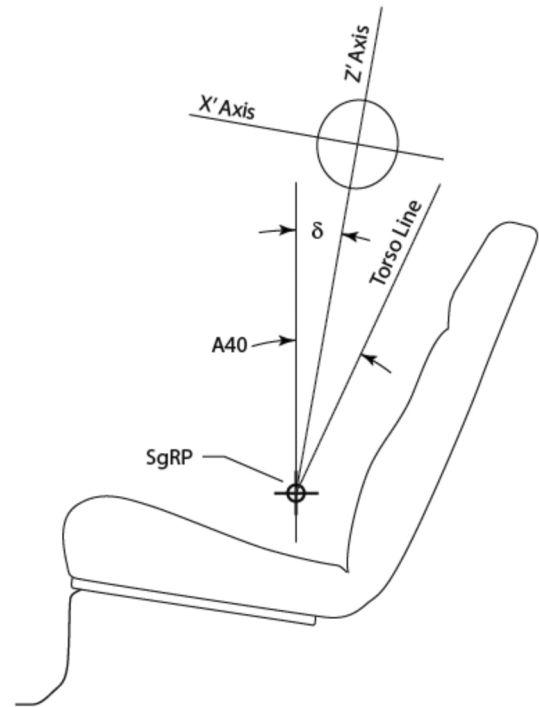


Figure 2. Schematic of fixed-seat eyellipse.

RESULTS

REGRESSION ANALYSIS

The side-view angle of the H-point-to-eye vector was given by the regression equation:

$$\delta = 0.698*(A40) - 9.09,$$

$$R^2 = 0.43, RMSE = 2.63$$

[1]

where δ is the vector angle and A40 is the seat back angle (see Figure 2). The root mean square error (RMSE) is the standard deviation of the residual variance from the regressions. The height of the eye above the H-point along the vector was given by:

$$h = 67.0 + 0.351*S - 1.613*(A40),$$

$$R^2 = 0.83, RMSE = 19.6$$

[2]

where h is the vector distance and S is stature, both in mm. Note that the H-point-to-eye distance is slightly smaller with increased seat back angle.

MODEL DEVELOPMENT

Flannagan et al. (5) introduced a methodology for conducting accommodation analyses that exploits the observations that stature is approximately normally distributed within large single-gender adult populations, many functional anthropometric measures of interest are linearly related to