

Driver Preference for Fore-Aft Steering Wheel Location

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ABSTRACT

The fore-aft location of the steering wheel relative to the pedals is a critical determinant of driving posture and comfort. Current SAE practices lack quantitative guidance on steering wheel positioning. This paper presents a model of subjective preference for fore-aft steering wheel position across a range of seat heights. Sixty-eight men and women evaluated the steering wheel positions in a total of 9 package conditions differentiated by seat height and fore-aft steering wheel position. Numerical responses were given on a 7-point scale anchored with the words “Too Close”, “Just Right”, and “Too Far”. A statistical analysis of the results demonstrated that the preferred fore-aft steering wheel position was affected by seat height and driver stature. An ordinal logistic regression model was created that predicts the distribution of subjective responses to steering wheel location. The model can be used to calculate the preferred steering wheel position for individuals or populations. The results were compared to distributions of steering wheel locations in 86 vehicles.

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INTRODUCTION

The comfort and safety of drivers is strongly influenced by the layout of the primary controls in relation to the seat adjustment range and the vehicle structure. The steering wheel location relative to the pedals usually has a much smaller adjustment range than the seat position, and hence the steering wheel position is a major determinant of how the driving “package” feels to the driver.

The standards and recommended practices for vehicle interior packaging developed by the Society of Automotive Engineers (now SAE International) measure driver workstation dimensions from reference points defined near the accelerator pedal. The accelerator heel point (AHP) is a point on the depressed carpet surface near the accelerator pedal that is used as the original for vertical measurements of seat height (SAE H30) and steering wheel height (SAE H17). Many fore-aft dimensions are referenced to the ball-of-foot reference point (BOFRP), which is a point near or on the surface of the accelerator pedal. The procedures for locating and using these points are described in detail in SAE J4002, J4003, and J4004. Prior to the development of these practices, pedal reference points were defined in SAE J1516 (J1516 now applies only to Class-B vehicles, i.e., heavy trucks and buses).

SAE L6 is the fore-aft location of the steering wheel center relative to the BOFRP (see SAE J1100). SAE standards and recommended practices provide quantitative

guidance on designing seat track adjustment ranges (SAE J4004), but do not provide information on the steering wheel locations that drivers prefer. To address this issue, subjective ratings of steering wheel fore-aft position were obtained from participants in a laboratory study of driving posture. The results were analyzed to predict the distribution of subjective responses. The resulting model can be used to predict the preferred steering wheel position.

METHODS

As part of a larger laboratory study [1], sixty-eight men and women with a wide range of body size, ranging from less than 5th-percentile female to greater than 95th-percentile male stature relative to the U.S. population, evaluated the fore-aft steering wheel positions in each of 9 packages. [Table 1](#) lists the packages. In each condition, the participant selected his or her preferred seat position on an unrestricted fore-aft track and adjusted the seat back angle (no seat height or seat cushion angle adjustment) prior to providing a numerical rating on the scale shown in [Figure 1](#). The entire sitting period prior to rating was less than five minutes in each condition. Drivers were directed toward a horizontal vision target but no driving simulation was performed. Drivers did not conduct any reach or secondary tasks prior to rating.

Table 1. Package Conditions

Package	H30	L6 (mm)
1	180	650
2	180	550
3	270	650
4	270	600
5	270	550
6	270	500
7	270	450
8	360	550
9	360	450

Too Close			Just Right	Too Far		
1	2	3	4	5	6	7

Figure 1. Rating scale for steering wheel position.

A statistical analysis using ordinal logistic regression was conducted to predict the distribution of subjective responses as a function of steering wheel position (L6), other package dimensions, such as seat height (H30), and driver attributes. Due to relatively few responses at the extremes of the scale, responses 1, 2, and 3 were counted as “too close”, response 4 as “just right”, and responses 5, 6, and 7 as “too far”. Using the resulting models, the predicted most-preferred steering wheel position for 86 vehicles was compared to the measured position.

RESULTS

Statistical Analysis of Driver Ratings

Stature, L6, seat height (H30), and seat height squared were significantly related to subjective response. [Table 2](#) shows the ordinal logistic model.

Table 2. Ordinal Logistic Model

Whole Model Test

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	160.42181	4	320.8436	<.0001*
Full	743.40932			
Reduced	903.83114			
RSquare (U)*	0.1775			
AICc*	1498.91			
BIC*	1527.74			
Observations	916			

Table 2 (cont). Ordinal Logistic Model

Parameter Estimates				
Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Intercept[-1]	-6.1239	1.8453	11.01	0.0009*
Intercept[0]	-2.7026	1.8279	2.19	0.1393
H30	-0.01854	0.009809	3.57	0.0587
H30^2	0.00004958	1.7962e-5	7.62	0.0058*
Stature	-0.003441	0.0005738	35.96	<.0001*
L6	0.021182	0.001398	229.28	<.0001*

* The RSquare value is a measure of goodness of fit. RSquare values are generally much lower in logistic regression models than in traditional linear models with continuous dependent measures. AIC is the Akake Information Criterion, a measure of goodness of fit. BIC is the Bayesian Information Criterion, which penalizes additional parameters more than the AIC.

The implementation of the model is as follows. The linear portion of the logistic model is given by $\phi = -0.003441 \text{ Stature} + 0.02118 \text{ L6} - 0.01854 \text{ H30} + 0.00004958 \text{ H30}^2$ for driver stature and H30 in mm. The cumulative probability of “too close” is given by

$$P_{-1} = \frac{1}{1 + e^{-(6.1239) - \phi}}$$

And the probability of “just right” or “too close” is given by:

$$P_0 = \frac{1}{1 + e^{-(2.7026) - \phi}}$$

Then $P_{\text{too_close}} = P_{-1}$, $P_{\text{just_right}} = P_0 - P_{-1}$, and $P_{\text{too_far}} = 1 - P_0$.

[Figure 2](#) shows the effect of L6 on the rating probabilities for stature of 1750 mm (approximately median U.S. male) and H30 of 270 mm (typical of a midsize sedan). For this seat height, the largest proportion of “just right” evaluations (70%) occurs with an L6 value of 558 mm.

[Figure 3](#) demonstrates that the ratings are somewhat affected by driver stature, but the effect is relatively small. The largest effects are in the “too close” and “too far” categories, with the expected trends. At an H30 value of 270 mm, an L6 value of 550 mm is much more likely to be judged as “too close” by shorter-statured drivers than by taller-stature drivers.

The H30 effect in [Figure 4](#) shows nonlinearity and generally a much weaker effect than expected. The percentage of drivers rating an L6 value as “just right” is predicted to be approximately the same through a large range of H30 values. Only above H30 = 325 mm does the fraction of predicted “just right” responses drop appreciably.

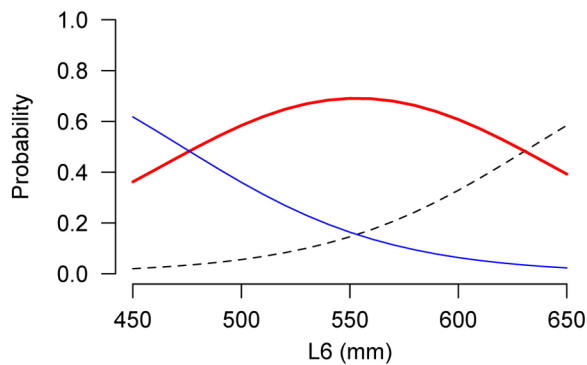


Figure 2. Effects of L6 on driver rating of steering wheel location for drivers 1750 mm tall at an H30 of 270 mm. Thick (red) line is the probability of rating the steering wheel location as “just right”, the thin (blue) line is the probability of rating “too far” and the dashed line is the probability of rating “too close”.

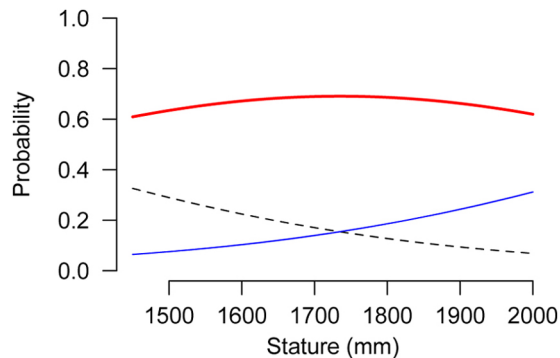


Figure 3. Effects of stature on driver rating of steering wheel location for L6 = 550 mm and H30 = 270 mm. Thick (red) line is the probability of rating the steering wheel location as “just right”, the thin (blue) line is the probability of rating “too far” and the dashed line is the probability of rating “too close”.

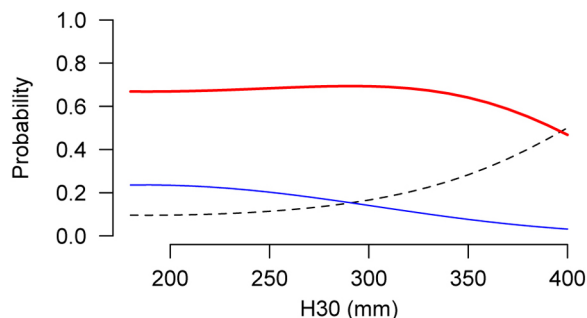


Figure 4. Effects of H30 on driver rating of steering wheel location for L6 = 550 mm and stature = 1750 mm. Thick (red) line is the probability of rating the steering wheel location as “just right”, the thin (blue) line is the probability of rating “too far” and the dashed line is the probability of rating “too close”.

Comparison with Vehicle Data

In a separate study, the dimensions of a large number of vehicles were measured. No driver testing was performed in these vehicles. Figure 5 shows H30 and L6 from 86 passenger cars, light trucks, SUVs, and minivans listed in Appendix A. Pedal reference points and Seating Reference Point (SgRP) were found using J4003-2004 procedures. For the range of seat heights, the optimal L6 was computed using the logistic regression model for a mean population stature of 1692 mm, approximately the mean of the U.S. adult population (see <http://www.cdc.gov/nchs/nhanes.htm>). Figure 5 shows the resulting curve. In addition, the fraction of the U.S. adult population predicted to rate the fore-aft steering wheel position as “just right” was computed for each vehicle. For 40 vehicles (47%), the fraction predicted as rating the steering wheel position as “just right” was between 0.68 and 0.7, essentially the maximum possible for this model. Only 6 vehicles had predicted “just right” fractions below 0.6. The lowest predicted “just right” fraction was 0.38 for the outlying vehicle to the right in Figure 5.

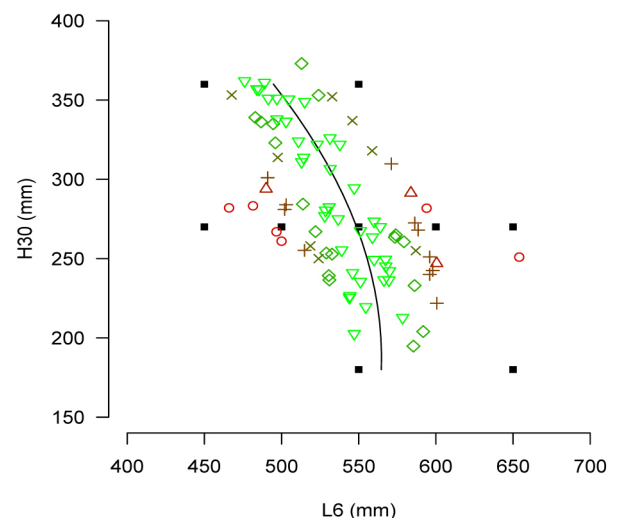


Figure 5. H30 and L6 for 86 vehicles measured at UMTRI. Optimal L6 as a function of H30 based on the current analysis is shown as a curve. Test conditions from the driver response data are shown as filled squares. Vehicle symbols and colors show the predicted fraction of “just right” ratings from 0.68 to 0.7 (inverted triangles), 0.66 to 0.68 (diamonds), 0.64 to 0.66 (x), 0.62 to 0.64 (+), 0.6 to 0.62 (triangles) to less than 0.6 (circles).

DISCUSSION

These results are the first available to quantify drivers' preferred steering wheel positions using subjective responses. The results are broadly consistent with a large sample of current vehicles; in only a few vehicles is the fore-aft