Comments on Proposed NIOSH Study of Truck Driver Anthropometry

University of Michigan Transportation Research Institute
April 16, 2006

CONTEXT

NIOSH should be commended for initiating research in this important area. Improved data and methods applicable to the design of commercial vehicle cabs are needed. Some aspects of the context for this work are:

- Reliable data on the anthropometric characteristics of U.S. commercial drivers are not publicly available. Summary statistics are available from studies conducted in the 1970s, but those data are widely believed to be poorly representative of current drivers due to anthropometric and demographic changes in the driver population.

- The SAE Recommended Practices relating to driver packaging are not readily applied to current vehicles because (1) the body dimensions distributions of the underlying driver populations are out of date, and (2) the models do not account for the component adjustability in modern cabs, such as steering wheel tilt/telescope and seat height adjustment.

- Digital human models, such as Jack and RAMSIS, are increasingly used for vehicle design and assessment. These software tools will provide one of the primary application contexts for any new anthropometric data on truck drivers, so the data requirements specific to digital human models should be taken into account.

NEEDS AND PRIORITIES

The current context provides many opportunities to improve the state of the art. However, it is valuable to prioritize these needs, in particularly because of dependencies among them.

1. The foremost need is for **distributional data on basic anthropometric and demographic data on commercial vehicle drivers.** That is, what are the stature, weight, sitting height, age, etc. of drivers of various vehicle classes in various parts of the country? The other components of this research have substantially limited utility without this information. The distributional data must be obtained from a relatively large sample (probably thousands) of drivers, because of the need to estimate tail percentiles of these dimensions by geographic region, ethnicity, gender, and vehicle category. However, detailed information, such as a body scan, is not needed. Only perhaps 10 or 15 variables that will capture the basic information are needed from this large sample. Gathering these data should be the primary objective of any new effort in truck driver anthropometry.

2. The second highest priority is **detailed driver posture data gathered in vehicles driven on-road** using both typical and minimally constraining vehicle packages. This information, from a dozen or more carefully selected vehicles with 30 or more drivers per vehicle, is a necessary precursor to the establishment of new SAE practices for cab layout. Mockup data alone are not sufficient to produce models that can be confidently and accurately applied to cab design. The recent experience of updates to the SAE Class-A (passenger car and light truck) eyellipse and seating accommodation model provide a good guide for the combination of laboratory and in-vehicle data that are needed to create a valid model.

3. The third highest priority is a set of **high-quality body surface models generated from body scan data** from a diverse population that includes a substantial number of "anthropometrically interesting" individuals, i.e., those whose dimensions place them near the design limits for various seat and cab dimensions. Several hundred of these body scan models are needed. The subject pool should be stratified to oversample people in the tails of the distributions of stature and body mass index. Members of minority groups who represent significant fractions of vehicle design populations (particularly African-Americans and Mexican-Americans) should also be oversampled to ensure adequate availability of body shape data for these groups. For each subject, six or more scans should be conducted to capture the changes in body shape with posture and to facilitate the fitting of kinematic linkages within the body. Because the shoulders and torso (particularly abdomen) contours are of particularly concern for modeling commercial vehicle drivers, the scan postures should include a wide range of torso and shoulder postures. The scan data should be processed by fitting a uniform body surface mesh to each scan so that each scan is represented by the same number of vertices in a "watertight" mesh. A large number of standard anthropometric dimensions should be gathered for each scanning subject. In addition, a large number of body landmarks are needed to accurately identify skeletal structures. In particular, landmarks on the torso that are useful for identifying pelvis and spine structures in each of the scans are needed.

4. The fourth priority is **detailed driver posture and preference data from a laboratory (mockup) study**. Such a study should address two basic questions: How do drivers respond posturally and subjectively to particular combinations of component locations and adjustment ranges? And what component locations and adjustment ranges are preferred? Data from 60 to 100 drivers from a stratified sample are needed in a large number of test conditions. The Sanders study from the 1980s provides a good starting point, but the design problems are considerably more complex now because of the larger adjustment ranges that are commonly in use. Because all manufacturers currently have their own tools to simulate driver postural responses and preferences, a new mockup study will need to be particularly well conducted to provide additional benefit.

DISCUSSION OF NEEDS AND PRIORITIES

The draft test plan distributed by NIOSH addresses some but not all of the priorities discussed above. As the draft plan is modified, some of the lessons learned in previous anthropometric studies, and in applying the data from those studies, are worth revisiting.

Body Scanning and Data Processing

Data collection for body-scan and mockup studies takes a large amount of the participant's time and requires participants who are willing to change clothes and to endure scrutiny and probing of their anatomy. Such a protocol will not attract a representative sample of drivers. Hence, it is both necessary and desirable to stratify the sample. Given that the sample will be none representative, it make sense to oversample people whose body dimensions cause them to be near accommodation limits, such as people who are very tall or very short, unusually heavy for their stature, and who have unusual body proportions. It is also critical to sample for minority participants with appropriate stratification for body dimensions within these populations.

Relative to the total test time, the time to set up and scan one posture is small. Consequently, once a subject has been readied for scanning, including taking standard anthropometric data and marking landmarks, many scans should be taken. The scanned postures should include both standing and seated conditions with a wide range of body postures, including seated postures with realistic arm and torso postures. Coverage of the whole body need not be achieved with all postures, because a model fitting procedure will be used to ensure whole-body data are produced in all postures.

Given that the primary application context for the body scan data is digital human models, the requirements of the human model developers should be given consideration in the development of the study plan. Experience with previous body scan studies, such as CAESAR, has shown that the raw data files produced by the scanners are very difficult to use. Time-consuming data processing is required to use the data for cab design problems. Rather than requiring each partner to take on this task themselves, NIOSH should include the preparation of high-quality scan models as part of the project. The processing should include fitting a high-resolution polygon mesh to each body scan, preserving the relationship between particular surface nodes and landmarks in the body scan data. For example, the acromion landmark should lie at the same node on the model mesh for each scan of each participant. A uniform, water-tight, high-resolution mesh, along with appropriate surface landmarks, will greatly facilitate the application of the body scan data to digital human models. Note that it is not necessary that particular mesh chosen match any particular software manikin. In fact, a much higher resolution mesh than is typically used for interactive manikins would be desirable. Given a polygon mesh with appropriate landmarks, RAMSIS or Jack manikins can be fit automatically.

Taking more scans per subject, and processing the scan data to a form readily usable in digital human models, will increase the amount of effort required per subject. However, it would be desirable to reduce the number of subjects scanned, if necessary, rather than to reduce the data quality per subject to get a larger sample size. With CAESAR, most partners used only a relative handful of the thousands of scans, choosing anthropometrically interesting individuals based on standard anthropometric measures (by reference to population distributional data from other studies). A new body-scan study will be more useful if more-complete and better-quality data are gathered from a smaller, more carefully chosen set of participants. NIOSH should take into account these lessons learned from previous studies in planning for a new study.

Challenges and Limitations of Mockup Studies

Mockup-based studies of driver postures are difficult to conduct well. Mockups are best for assessing the independent and interactive effects of component factors, such as steering wheel position and seat height. They are less valuable for obtaining estimates of mean outcomes, such as eye location, because drivers often sit differently in vehicles than in mockups. Previous research has suggested that these differences are systematic in trucks, such that average postures in trucks driven on-road are different from those measured in laboratory studies.

The large study of truck driver postures conducted by Sanders in the early 1980s provides some valuable lessons. The Sanders study was better designed and conducted than one might assume from the limitations of the SAE practices derived from the study. For example, data were gathered in conditions with driver-adjusted seat height, but those data were not used in the formulation of SAE J1517 or J941. Unfortunately, the data from the Sanders study have been lost.

The approach used for specifying test conditions in the earlier study is insufficient to gather data applicable to modern vehicles. The steering wheel and seat in most vehicles is now adjustable over a relatively large range. Consequently, conditions with fixed steering wheel locations do not provide readily applicable information. Mockup studies should focus on (1) preferred component locations, (2) postural adjustments to constraints in component adjustment ranges, and (3) subjective assessments of component locations and adjustment ranges. For example, how do drivers respond when they run out of rearward seat track travel? Can they compensate by sitting higher? Is it possible to achieve the same overall level of accommodation by limiting rearward track travel but increasing steering wheel adjustability?

These issues are difficult to study in real vehicles, making them ideal for laboratory studies. However, data from a subset of laboratory conditions presented in vehicles driven on-road are essential for the development of valid models. As noted above, the development of new SAE practices for eyellipse and seating accommodation models will require validation data from appropriately (not representatively) sampled populations of drivers operating vehicles in realistic on-road conditions.

Population Distributional Data on Basic Dimensions Are Critical

Returning to the first priority, only small improvements in the state of the art in cab design can be made without accurate distributional data. The selection of manikins for use in CAD assessments, for example, is made by reference to data on the distribution of stature, body weight, sitting height, etc. for the target population. New SAE practices will be configurable for population body dimensions, so that they can be reliably applied to different types of vehicles, but they will have little utility unless the required distributional data are available. The single most important thing that NIOSH could do to improve cab design would be to gather a reliable sample of basic anthropometric data. A body scan study will provide little additional benefit without these basic data.