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New Concepts in Vehicle Interior Design Using ASPECT

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ABSTRACT

The ASPECT (Automotive Seat and Package Evaluation and Comparison Tools) program developed a new physical manikin for seat measurement and new techniques for integrating the seat measurements into the vehicle design process. This paper presents an overview of new concepts in vehicle interior design that have resulted from the ASPECT program and other studies of vehicle occupant posture and position conducted at UMTRI. The new methods result from an integration of revised versions of the SAE seat position and eyellipse models with the new tools developed in ASPECT. Measures of seat and vehicle interior geometry are input to statistical posture and position prediction tools that can be applied to any specified user population or individual occupant anthropometry.

INTRODUCTION

Automobile interior package design practices have been greatly aided over the past thirty years by the development of a variety of standardized tools to represent the behavior of vehicle occupants, particularly drivers. Committees of the Society of Automotive Engineers (SAE) have developed a set of interrelated physical and statistical tools that define human-centered reference points and capture anthropometric and postural variability in simple equations and design templates.

SAE Recommended Practices provide support for vehicle interior design in three primary areas. First, SAE J826 describes the H-point manikin, a weighted, contoured manikin that defines and measures the H-point, an estimate of human hip joint locations in a seat that is the primary reference point for occupant accommodation assessment. The geometry of the H-point manikin legs and shoes define pedal reference points (Ball of Foot and Accelerator Heel Point) that create the origin for a driver package coordinate system. Second, SAE J1100 defines vehicle dimensions, many of which are defined with reference to the H-point and pedal reference points measured using the H-point manikin. Headroom, legroom, and vision angles are measured with reference to these human-centered points. Third, a number of SAE practices describe task-oriented percentile accommodation models that encapsulate a large amount of human anthropometric and behavioral data in simply formulated equations. The development of these models, beginning in the early 1960s, represented a fundamental change in the way vehicle interiors are designed.

Two current research programs will lead to substantial changes in the SAE practices that underlie the vehicle design process described above. For more than a decade, the American Automobile Manufacturers Association (formerly the Motor Vehicle Manufacturers Association) has supported research at the University of Michigan Transportation Research Institute (UMTRI) leading to the development of new statistical models to predict the distributions of driver-selected seat positions and driver eye locations (1-3).[1] In a separate but related effort, a group of eleven auto companies and seat suppliers has supported the four-year ASPECT program, the goals of which are the development of new vehicle design and measurement tools (4-9). The foremost objective of the ASPECT program has been the development of a new H-point manikin to replace the current SAE J826 manikin.

Both of these research programs are based on extensive investigations of the effects of vehicle and seat design factors on driver and passenger posture and seat position. Both programs have included studies conducted in vehicles and laboratory vehicle mockups (seating bucks). The AAMA-funded research has focussed on seat position and eye location, while the ASPECT studies have emphasized whole-body posture measurement and prediction. The AAMA work has led to the development of two new driver accommodation models for driver seat position and eye location. The ASPECT program has produced a new H-point manikin and associated whole-

1. Numbers in parentheses denote references at the end of the paper.

body posture-prediction models. Together, these new tools have the potential to improve substantially the process of vehicle interior design.

OVERVIEW OF POPULATION-BASED DESIGN TOOLS – Prior to the development of task-oriented percentile accommodation models in the early 1960s, the leading method for designing vehicle interiors could be referred to as the boundary template approach. In-depth studies of the human skeletal articulation in the 1950s by Dempster and others (10, 11) led to the widespread use of two- and three-dimensional mechanical templates illustrating the human form as an articulated linkage of contoured segments. Small and large templates were constructed, typically representing women who are fifth-percentile by stature and men who are ninety-fifth-percentile by stature. The two-dimensional templates were manipulated on full-size, sideview drawings to determine, for example, if the small female template could “see” over the steering wheel and if the knees of the large male template could fit below the instrument panel.

The template approach to vehicle design assumes that anthropometric variability is the key determinant of accommodation. That is, if the physical dimensions of small and large people will fit in the vehicle interior space while preserving the necessary reach envelopes and sight lines, then the population of people with anthropometric dimensions intermediate to the tested templates are assumed to be accommodated.

However, postural variability is nearly as important as anthropometric variability for vehicle occupant accommodation. The strength of task-oriented percentile accommodation models is that they provide a way to include both anthropometric and postural variability in the design process.

The best known example, and the first applied widely in vehicle design, is the eyellipse (12-14). The eyellipse (the word is a contraction of eye and ellipse) was developed in the early 1960s to address the problem of accurately predicting driver eye locations. In a project sponsored by SAE, visitors to Ford Motor Company facilities were invited to sit in one of three convertibles positioned in front of road scenes. Two photographs taken of each person from perpendicular angles were used to determine eye locations relative to the vehicle. A total of 2355 people were measured, each in one of the three cars. Statures of the subjects (with shoes) were measured to the nearest inch. The resulting distributions of stature within gender were judged to be representative of the U.S. driving population.

The vehicles used in the original eyellipse study were different in a number of ways from contemporary vehicles, notably because the seat tracks were shorter and because the seatback angles were fixed at about 25 degrees. Compared to current vehicle seats, the seats used in the original eyellipse study were less contoured and probably lacked substantial lumbar support.

Since the distributions of driver eye locations were approximately multinormal, a statistical method was devised to represent eye locations relative to vehicle landmarks. The eyellipse is a second-order ellipse constructed such that tangents to the ellipse (or planes tangent to the corresponding ellipsoid in three dimensions) separate the spatial distribution of eye locations according to the percentile specification of the ellipse. For example, a tangent to the two-dimensional 95^{th}-percentile eyellipse cuts off five percent of the population eye locations, while the ellipse encloses 74 percent of the eye locations (12).

Because the eyellipse directly predicts the distribution of eye locations for a U.S. driving population, it accounts for variability in eye location due to both anthropometric and postural variability. The eyellipse is therefore a much more useful tool for determining vision requirements than the template-based approach. Following on the success of the eyellipse, other task-oriented percentile models have been developed for head space (J1052), hand reach (J287), and driver-selected seat position (J1517). Each provides a way for designers to consider the distribution of particular, task-oriented postural characteristics with reference to population, rather than individual, anthropometry.

One minor limitation of the task-oriented percentile models is that they are difficult to reconcile with template-based approaches, because there is no information in the eyellipse that specifies the anthropometry of people whose eyes lie in some region of the ellipse. Further, they cannot be readily linked together. SAE J1517, which specifies the distribution of driver-selected seat positions, cannot be used to identify a seat position that corresponds to a particular point in the eyellipse. Thus, the task-oriented percentile models provide no information that can be used for template-based analyses, except broad guidelines bounding the range of reasonable postures.

The major limitation of the current task-oriented percentile models is that they are only applicable to certain well-studied, essentially static characteristics of driver posture. The current models are also formulated in such a way that they apply only to a specific occupant population, namely a U.S. driving population (some of the models provide for variation in the population gender mix). Considerable judgement is required to apply the models to different populations, and the models are not generalizable to other important analyses (e.g., assessing clearances in the shoulder area).

Because of the strengths of the task-oriented percentile models, template-based approaches are now used relatively infrequently for primary vehicle design tasks. However, template-type tools, such as the SAE H-point manikin and the J826 2-D template, have retained an important function in vehicle design. The H-point manikin and its 2-D representation create a standardized, uniform, schematic representation of a vehicle occupant.

Key reference points on the template, such as the H-point, are used to position accommodation models and to measure interior dimensions for comparison across vehicles. For example, clearances measured to the knee of the 2-D template are used in some design guidelines. The knee of the template represents only one knee location within the range of possible occupant knee locations, but the standard installation procedure for the template means that the clearance dimensions can be compared across vehicles.

Task-oriented percentile models, such as the eyellipse, have allowed vehicles to be designed without the need for extensive analysis using multiple template sizes. However, in recent years, the movement of design tasks into the computer environment has created opportunity for new applications of the template-based approaches. The templates are now articulated, three-dimensional human models, or CAD manikins, that can be manipulated to simulate a wide range of tasks within a virtual vehicle mockup. New practices are needed to support accurate use of these new CAD tools within the framework of the existing task-oriented percentile models. Further, the percentile models need to be updated and improved to provide greater accuracy and flexibility.

This paper summarizes the current vehicle design tools defined in SAE recommended practices, then discusses the changes to these practices that are being considered. The development of the new ASPECT H-point manikin provides a natural juncture at which to make these changes, because the current H-point manikin underlies many of the SAE vehicle design practices. Each of the new tools and their interrelations are discussed to illustrate a new framework for vehicle interior design that builds on the existing tools.

OVERVIEW OF CURRENT DESIGN PRACTICES

SAE RECOMMENDED PRACTICES – Although each company has many in-house procedures and guidelines to design and evaluate vehicles and seats, SAE recommended practices form the basis for many common design procedures. Table 1 lists the SAE Practices that are used for vehicle interior packaging (15, 16).

SAE Recommended Practice J182 establishes the fiducial marks necessary to define a vehicle coordinate system that is used to develop package-specific coordinate systems, e.g., for the driver. J287 defines reach envelopes for drivers that are based on laboratory data (17). J826 describes the H-point manikin and usage procedures, as well as the two-dimensional template based in part on the H-point machine geometry. J941 presents the eyellipse, created using data from a large-scale study of driver eye locations conducted in the early 1960s (12). J1052 contains head location contours based on the eyellipse (14). J1100 defines hundreds of motor vehicle dimensions, many of them interior dimensions, and several defined relative to the other practices listed here (e.g., H30 is seat height, defined using the H-point manikin described in J826). J1516 defines the pedal reference points, Ball of Foot and Accelerator Heel Point, used to define measures of package space. J1517 provides equations predicting the distribution of driver fore-aft seat position for a U.S. driver population with an equal gender mix (18). Figure 1 illustrates the accommodation tools defined in these practices.

These practices have considerable interrelation, illustrated in Figure 2. The H-point machine defines and measures the seat H-point. When the seat is located in the design (manufacturer-specified) position, the H-point is known as the Seating Reference Point (SgRP). The manikin leg and shoe geometry are used to define the Ball-of-Foot (BOF) and Accelerator Heel Point (AHP) reference points, which are used as the X and Z coordinates, respectively, of the vehicle package origin. These definitions are codified in J1516, Accommodation Tool Reference Points, and in J1100.

Many dimensions in J1100 are defined relative to this manikin position. Seat height (H30) is the vertical distance between the H-point (SgRP) and heel (AHP). Fore-aft steering wheel position (L11) is the horizontal distance between the center of the steering wheel and the AHP. Headroom (H61) is measured using a probe from the SgRP oriented eight degrees rearward of vertical. In effect, the H-point manikin defines the primary reference points that are used to measure interior dimensions related to occupant accommodation. Some of these dimensions are used to position the driver reach envelopes described in SAE J287. The eyellipse (J941) and head contours (J1052) are positioned with respect to the SgRP, with a recommendation to establish the SgRP using the 95th-percentile population seat position curves defined in SAE J1517. The latter predicts the distribution of driver-selected seat position using second-order functions of seat height (H30). Thus, the SAE J826 H-point manikin is important to all of the other interior design practices.

Table 1. SAE Recommended Practices for Passenger Car Interior Design (15, 16)

Practice	Title
J182	Motor Vehicle Fiducial Marks
J287	Driver Hand Control Reach
J826*	Devices for Use in Defining and Measuring Vehicle Seating Accommodation
J941*	Motor Vehicle Driver's Eye Range
J1052*	Motor Vehicle Driver and Passenger Head Position
J1100*	Motor Vehicle Dimensions
J1516*	Accommodation Tool Reference Point
J1517*	Driver Selected Seat Position

* Revisions anticipated as a result of the research and new tools described in this paper.

A SIMPLIFIED EXAMPLE – The design process will be illustrated using the packaging of a hypothetical vehicle. For this illustration, a seat height of 220 mm and some predefined pedal geometry are assumed. Figure 3 shows the tools on a side view of the package. First, the pedal plane angle is calculated using the equation in J1516, in the process defining the BOF and AHP locations. Next, using the 95th-percentile driver-selected seat position curve, an SgRP location is established. The 2.5th percentile and 97.5th-percentile curves from J1517 are laid in, along with a seat-track (H-point) travel line, to define the seat track travel length necessary to accommodate preferred seat positions of 95 percent of a U.S. driver population with an equal gender mix. With the SgRP and pedal reference points established, the other accommodation models may be positioned. The eyellipse (defined in J941 for a U.S. driving population with an even gender mix) is positioned relative to the SgRP using the design seatback angle (defined in J1100 as L40). Head contours from J1052 are positioned in a similar manner. Positioning the hand-control reach envelopes requires calculation of the "G" factor from a range of vehicle interior dimensions, including H30, L11, and others.

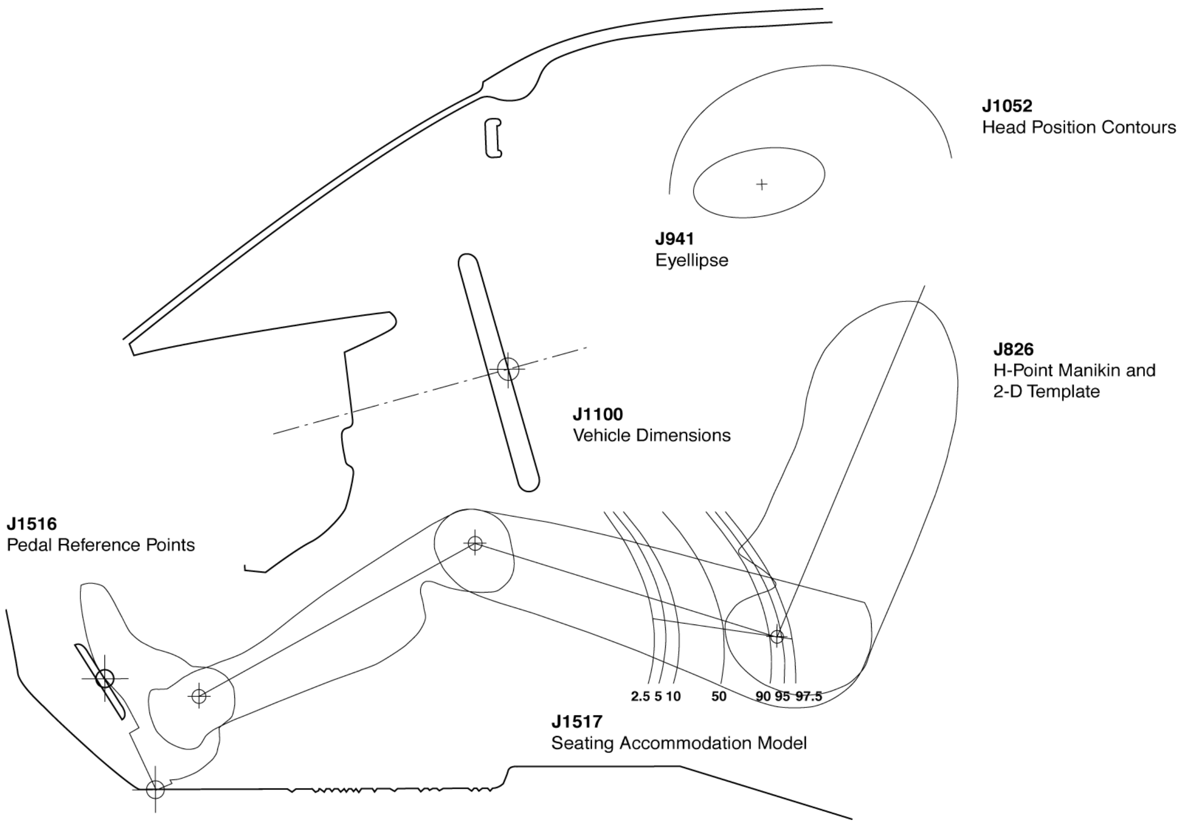


Figure 1. Accommodation tools defined in SAE recommended practices.

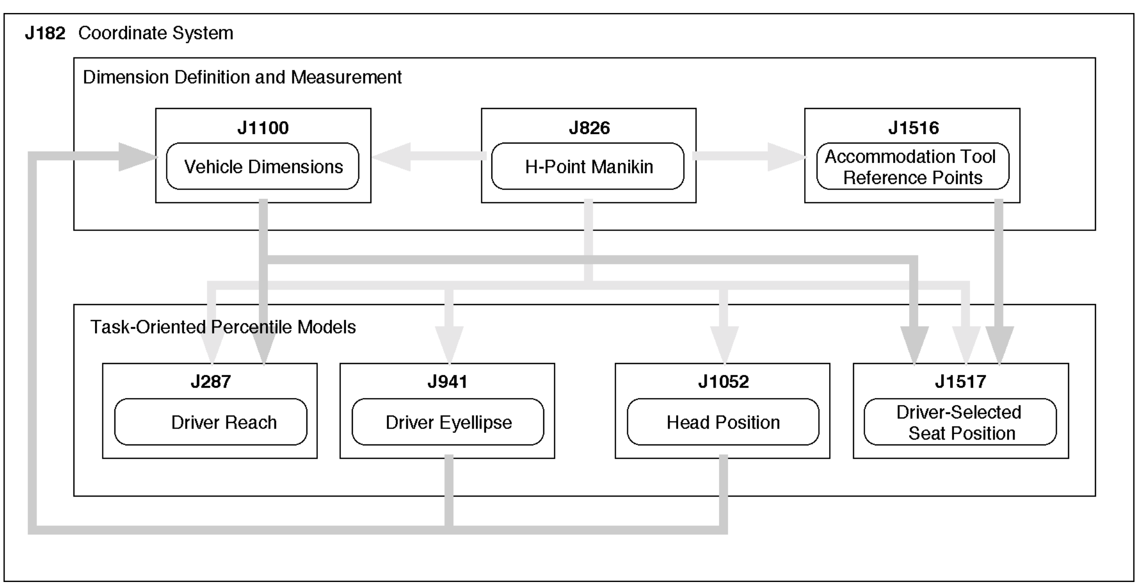


Figure 2. Schematic of relationships among SAE recommended practices.

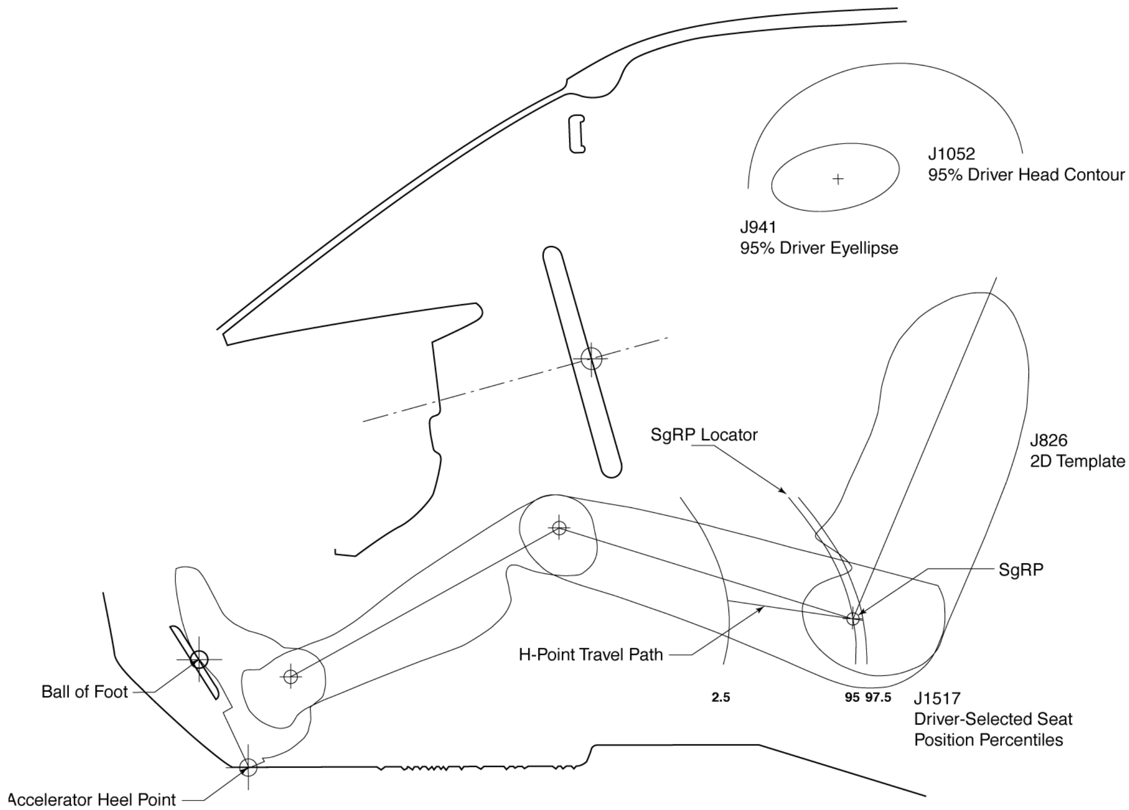


Figure 3. Illustration of hypothetical driver station layout procedure using SAE recommended practices.

The resulting accommodation tool locations can then be used to assess the vehicle interior design. Display locations and steering wheel obscuration can be evaluated using sight lines or planes constructed tangent to the eyellipse. Head clearance can be quantified using procedures defined in J1100 based on translation of the head contours toward the roof. In addition, many other design guidelines developed by individual companies that reference the SAE accommodation models can then be applied.

HUMAN CAD MODELS – In recent years, vehicle interior designers are increasingly turning to computer-aided-design (CAD) manikins to assess prototype layouts (19). These CAD manikins represent a human figure that can be scaled to match a wide range of human anthropometry, and can be positioned in the simulated vehicle to explore a wide range of possible occupant postures. Vision tasks can be evaluated by examining the view from the manikin's eye locations, and reach tasks can be simulated by manipulating the manikin's limbs. In spite of rapid advances in the quality and capability of these models in recent years, their use in the vehicle development process has been hampered by a lack of integration with the now-standard tools described in the SAE practices. The new tools described in this paper include methods for positioning CAD manikins so that their postures and body landmark locations have a quantitatively defined relationship to the population distributions, providing the needed linkage between the population-based task-oriented percentile models and the CAD manikins.

NEW TOOLS FOR VEHICLE INTERIOR DESIGN

OVERVIEW – The research described here and elsewhere (1-9) has led to the development of a set of new design tools that are intended to be more closely integrated than the current practices. Table 2 lists the new tools along with the relevant SAE recommended practices. The following sections discuss the source and application of each tool. Several general principles have guided the development of these tools.

Accuracy – The primary motivation behind the new tools is a desire to improve on the accuracy of the current practices, defined as correspondence between the model predictions or tool measurements and the analogous values for human occupants.

Population Configurability – Many of the current tools are formulated solely for a particular U.S. population, generally one defined using anthropometric data that are decades old. The new tools are designed to be used for any population of interest and can be applied equally well to the U.S. or other populations.

Ease of Use – Some of the current practices and tools, notably the H-point machine, are difficult to use, whether physically or in CAD. Where practical within the constraints imposed by improved accuracy, the application methods have been simplified. The ASPECT manikin, in particular, contains many changes in features and procedures intended to simplify its use.

Continuity with Current Practice – There is a large body of information that has been accumulated over the preceding decades using the current tools. The need to preserve the applicability of these data was considered along with the other primary priorities in creating the new tools. As a result, the changes in the tools are evolutionary, and many of the current dimensions and measurement conventions will remain applicable under the new system.

Table 2. New Vehicle Interior Design Tools

Tool/Model	Relevant SAE Recommended Practice
UMTRI Seating Accommodation Model	J1517
UMTRI Eyellipse Model	J941
Head Contours	J1052
ASPECT Manikin	J826
Pedal Reference Points	J1516
SgRP Definition	J1100
Human Body Reference Forms	*
ASPECT Posture Prediction	*
Application Guidelines for Human Models	*

* No current SAE recommended practice

UMTRI SEATING ACCOMMODATION MODEL – The initial goal of the MVMA/AAMA research conducted at UMTRI was the development of a more accurate model for predicting the distribution of driver-selected seat positions. Beginning in 1985, SAE J1517 provided curves to predict the various percentiles of a fifty-percent male U.S. driver seat position distribution (18). However, data from studies at UMTRI suggested that the curves were substantially in error in some vehicles (1). Seat positions of hundreds of drivers of widely varying anthropometry were measured in 44 vehicles with a wide range of vehicle interior geometry after driving on a local road route. In addition, a detailed laboratory investigation was conducted, in which package geometry was varied over a wide range to determine the effects on seat position. These studies led to a model that predicts the distribution of driver-selected seat positions as a function of seat height, horizontal steering-wheel-to-Ball-of-Foot distance, seat cushion angle, transmission type (clutch/no clutch), and population anthropometry (1, 2).

The new Seating Accommodation Model (SAM) goes beyond adding three new vehicle and seat variables as predictors, however. The most valuable addition to SAM is the use of population anthropometry as input to the model. The current SAE J1517 seat position curves for passenger cars are applicable only to a specific, U.S. driver population. SAM allows the user to specify the anthropometry of the user population, including the gender ratio, average stature for each gender, and the stature variance within gender. This new feature provides considerably greater flexibility for designing seat track layouts. For example, designers of a sports car aimed at a 65-percent-female target market could locate their seat track to accommodate 95 percent of the target population without unnecessarily restricting rear seat legroom.

SAM also provides the ability to predict mean selected seat positions for any specified driver stature. This feature was recently exploited to propose new crash dummy positioning procedures that would place the dummies in positions more representative of similarly sized human occupants than current procedures (20). Another application of this feature of SAM is in positioning CAD manikins for vehicle design.

UMTRI EYELLIPSE MODEL – Along with the new Seating Accommodation Model, the UMTRI research team has developed a new eyellipse model (3). Eye location distributions observed in contemporary vehicles differ in important ways from the SAE eyellipse. Figure 4 compares the UMTRI eyellipse with the SAE eyellipse for one vehicle geometry. The new eyellipse centroid is generally behind and slightly above the current SAE centroid, and the fore-aft axis is longer.

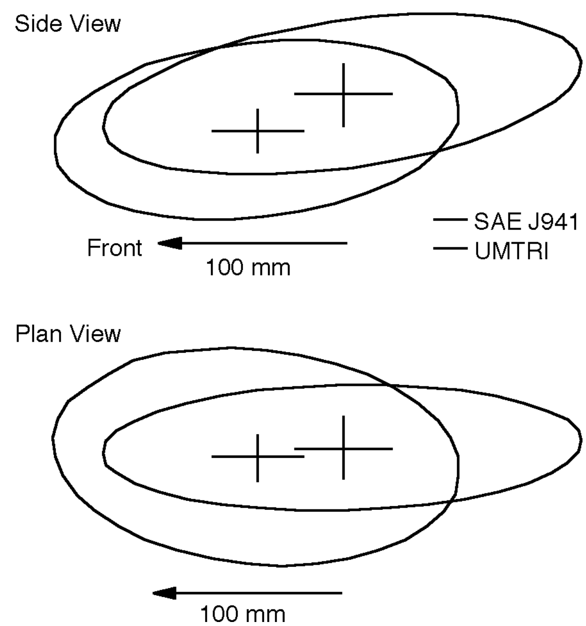


Figure 4. Comparison of SAE J941 and new UMTRI 95^{th}-percentile eyellipses for a typical vehicle geometry and 50-percent-male U.S. driving population.

More important than the shape changes, however, are the changes in the way the eyellipse is positioned in vehicle space. In current SAE practice, the eyellipse is positioned with respect to the SgRP using a function of design (seat) back angle (L40). SAE J941 suggests using the SAE J1517 95^{th}-percentile driver-selected seat position curve to determine the SgRP as a function of seat height. Design back angle is a manufacturer-specified value, usually a value between 21 and 28 degrees, selected to meet a variety of design goals, such as visibility, headroom, and safety performance.

The research conducted to develop SAM demonstrated that the J1517 95th-percentile seat position curves did not consistently predict driver seat positions; consequently, the SgRP defined in that manner does not represent an optimal point from which to reference the eyellipse position (1). The eye position research also demonstrated that design seatback angle is not a good predictor of driver-selected seatback angle or torso posture (3, 20). The new eyellipse model positions the eyellipse centroid with respect to the pedal reference points, rather than with respect to the SgRP, and does not include design seatback angle in the centroid location calculations. As with SAM, the new eyellipse provides the capability of specifying the target driver population anthropometrically. For example, a light truck intended for a population that is taller, on average, than the population used to define the current SAE eyellipse can be designed using an appropriately specified eyellipse.

HEAD SPACE CONTOURS – The current SAE Recommended Practice J1052 presents head space contours created by moving an average-size headform around the perimeter of the SAE J941 eyellipse. These cutoff contours are intended to be used as reference surfaces for determining headroom dimensions. Contours are specified for both fixed seats and those with adjustable seat tracks.

The new eyellipse model provides an opportunity to revise the shape of these contours and to provide a new, more accurate method of positioning them in the vehicle. Using similar procedures, a new ellipsoid model will be developed that provides head space cutoffs for any population of interest. Additionally, new data on head turn kinematics will allow the space required for volitional head movement to be accounted for more fully than is the case in the current J1052 models. As with the eyellipse, the removal of design seatback angle from the head space contour locating procedure for seats with adjustable seatback angles will improve the accuracy of the model.

ASPECT MANIKIN – The new ASPECT manikin is intended to replace the current SAE J826 manikin (4, 9). The manikin, shown in Figure 5, is designed to measure the seat independent of the vehicle package. The new manikin has an articulated lumbar spine that allows the manikin to measure the longitudinal contour of the seatback, expressed as lumbar support prominence. The ASPECT manikin measures an H-point location that can be directly related to the J826 H-point location (9), and simultaneously measures seat cushion angle and seatback angle. The manikin includes supplemental, lightweight legs that can be attached after the manikin is installed in a seat without altering the H-point location, providing the ability to measure the knee and hip angles used in some accommodation assessments. Details of the manikin design and associated application procedures are presented elsewhere (7, 9).

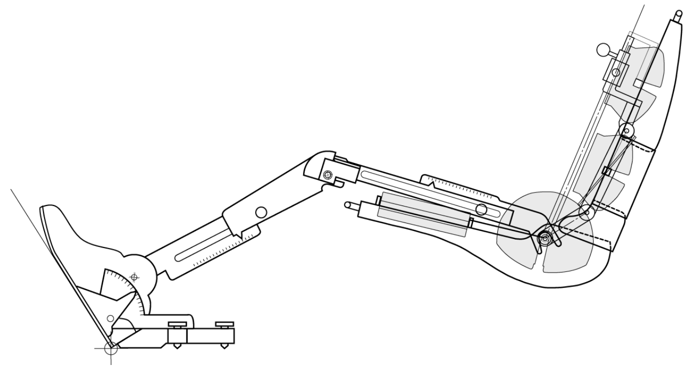


Figure 5. New ASPECT manikin, shown with supplemental thigh, leg, and shoe components (9).

As noted above, the current SAE J826 manikin is closely interwoven into many contemporary design practices, including those described in the SAE recommended practices. These relationships were among the foremost considerations in the design of the ASPECT manikin. The new manikin was created from the start to be integrated into the design process more consistently than the current manikin.

The primary purpose of the H-point manikin, from the vehicle and seat design perspective, is the definition and measurement of the H-point. Yet, in most cases, the physical manikin is not needed until after the interior is designed and the first prototypes are constructed. The H-point, or more specifically, the particular H-point location at the SgRP, is a key starting point for the package layout and seat design. The physical manikin is used only to verify that the seat and package, as constructed, have met the design dimensions.

However, the current J826 manikin geometry is closely tied into the current design process because a two-dimensional template based, in part, on the manikin geometry is widely used in vehicle package development. The template, having the same link lengths and approximately the same profile as the J826 manikin thigh, leg, and shoe, is used with the procedures in J1516 to establish the Ball of Foot and Accelerator Heel point. These points are the reference locations for determining the SgRP position and locating the accommodation tools, such as the eyellipse.

In the current SAE J826, H-point location is intrinsic to the seat, but the SgRP is a specific H-point location, intrinsic to the workspace (15, 16). However, because H-point verification is done with the legs attached, changes in the J826 manikin leg posture can change the H-point location. In contrast, the ASPECT manikin isolates the H-point measurement from the package by using no leg segments for the standard H-point measurement. With the seat cushion and seatback at design attitude, the H-point measurement (relative to the seat) can be made with the seat at any fore-aft seat position, or even without any vehicle components other than the seat.

The ASPECT manikin thereby provides a set of measures of seat geometry that can be used to specify a seat more fully, and to predict the effect that seat geometry will have on occupant posture and position. In addition to the H-point location relative to the seat frame, the vehicle package designer can specify the seat cushion angle, lumbar support prominence, and seatback angle at a particular seat frame orientation. The effects of these parameters on occupant posture can then be accounted for in both the population-based accommodation models (such as SAM) and in the use of CAD manikins. After the seat is constructed, the ASPECT manikin is used to verify compliance with the specifications.

NEW PEDAL REFERENCE POINTS – One of the goals of the ASPECT manikin design was to remove the dependence of the pedal reference points on the manikin linkage geometry. Because the Ball-of-Foot and Accelerator-Heel-Point reference points are related by a pedal plane angle derived from the SAE J826 manikin leg geometry, fixed foot (ankle) angle, and seat height (see J1516), any change in seat height, or SgRP location generally, changes the pedal reference point locations. This is contrary to the results of human posture studies, which suggest that if the pedals do not change, the pedal reference point should also remain fixed. Further, this definition of pedal reference points introduces iteration into the design process, so that a change in SgRP location leads to changes in the positions of all of the design tools located using Ball of Foot or Accelerator Heel Point. Identical pedals in vehicles differing in seat height by 20 mm would have different pedal reference points.

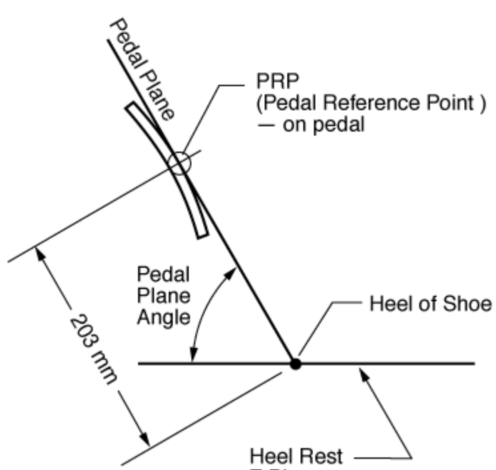


Figure 6. Proposed procedure for locating a pedal reference point (PRP) on the accelerator pedal.

In conjunction with the ASPECT program, a new pedal reference point proposal has been developed that defines a new point, called the Pedal Reference Point (PRP), based only on floor and accelerator pedal geometry. Figure 6 illustrates the proposed procedure for locating the PRP. A tangent to the accelerator pedal is constructed such that it contacts the pedal a distance of 203 mm along the tangent line from the depressed floor surface. For a flat accelerator pedal, the measurement is made along the plane of the pedal. The PRP is always on the pedal, unlike the Ball of Foot point on the current manikin shoe. The floor contact point, called the Initial Heel Point (IHP), defines the Z reference plane for package dimensions, and the PRP defines the X reference plane. The process of determining the PRP location can be readily performed in CAD or on a physical accelerator pedal.

When the ASPECT manikin thigh, leg, and shoe segments are installed, the shoe is oriented using a shoe-plane angle equation, rather than the pedal tangent. The shoe plane angle (α) was obtained from an analysis of driver shoe orientations in a range of vehicle packages, and is given by

$$\alpha = 76 - 0.08\ \mathrm{H30} \qquad (1)$$

where H30 is the height of the SgRP above the heel rest surface (AHP). To make measurements in a vehicle, the manikin shoe is installed so that it rests against the accelerator pedal at the angle specified by equation 1, as depicted in Figure 7. Note that the manikin shoe may contact the pedal anywhere along its length, and not necessarily at the PRP. Compared with the pedal plane angles given by the current J1516 equation, shoe plane angles given by equation 1 are flatter (closer to horizontal), change more slowly with seat height, and better represent actual shoe angles observed in studies of driver posture. Depending on the vehicle design, the resulting AHP may be different from the IHP. However, changes in design practice are expected to result in the two points being coincident. Just as current pedal plane angles are often designed to the J1516 equation, pedals designed to the new shoe plane equation will place the Initial Heel Point and the Accelerator Heel Point at the same location.

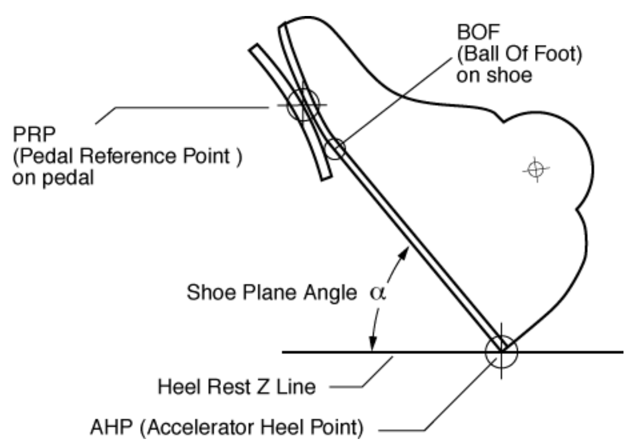


Figure 7. Manikin shoe oriented according to the calculated shoe plane angle (α) on a pedal oriented according to the current SAE J1516 pedal plane angle function.

STANDARDIZED SgRP DEFINITION – One of the notable problems with the current set of SAE practices is that the most important reference point for driver packaging, the Seating Reference Point, is ambiguously defined. Currently, the SgRP is defined in SAE J1100 as the "rearmost normal design driving or riding position." This would seem to specify the most rearward position on the seat track, but such a definition would prevent the SgRP from being used as a standard reference for locating accommodation models, since seat track lengths and locations vary considerably. Recognizing this limitation, SAE J941 recommends, but does not require, that the SgRP position be determined using the 95th-percentile driver-selected seat position curve from SAE J1517. Although discussions among industry representatives suggest that this practice is routinely followed, a standardized, unambiguous definition is needed because of the importance of the SgRP in vehicle design.

One of the problems with changing the SgRP definition (or creating an unambiguous definition that conflicts with current practice) is that there are a large number of dimensions in SAE J1100 that are affected by the SgRP location. These dimensions, many of them also related to the SAE J826 manikin geometry, are routinely used to compare vehicles and to specify interior space. The simplest example is seat height (H30), defined as the height of the SgRP above the heel rest surface (AHP). For a vehicle with an inclined seat track, a change in fore-aft SgRP location would change the seat height, which would in turn affect many other accommodation models, such as the driver-selected seat position curves and the eyellipse locations.

These considerations indicate that a new SgRP definition will be most easily incorporated into the design process if the dimensional changes relative to the old system are small. One possibility for a new definition would be to codify the practice of using the SAE J1517 95th-percentile seat position equation. However, as noted above, plans are underway to revise SAE J1517, replacing the current equations with a more accurate and flexible system (i.e., SAM). Therefore, a proposal for a new SgRP locator equation has been developed that removes the ambiguity of the preceding definition while preserving reasonable continuity with current practice. The newly developed Seating Accommodation Model (SAM), described previously, provides a way to develop such a system.

One of the equations in SAM predicts the mean selected seat position of a single-gender population having a specified mean stature (2). This equation is equally applicable to a diverse population of women or a hypothetical subpopulation of men who are all exactly the same stature. Besides stature, the other inputs to the equation are seat height, steering-wheel-to-Ball-of-Foot distance, and seat cushion angle.

The current practice of using the SAE J1517 95th-percentile seat position equation to establish SgRP makes SgRP location a function of seat height. This is a reasonable approach, since seat height is an important determinant of occupant position. To create a similar relationship in the new system, the SAM equation was reconfigured to express seat position as a function of only seat height and stature. Seat cushion angle and steering wheel position were approximated using regressions of these variables on seat height. An optimization procedure was then used to determine the stature that produced the best agreement (least squared error) between the predicted seat position in 26 vehicles and the seat position given by the 95th-percentile J1517 equation. Figure 8 shows the predicted seat position for drivers 71.1 inches (1806 mm) tall as a function of seat height, compared with the J1517 equation now commonly used to determine SgRP location. The new linear equation,

$$\text{SgRPx} = 1038.2 - 0.3945\ \text{H30} \qquad (2)$$

crosses the J1517 curve at two points within the range of seat heights typical of passenger cars, and differs from the J1517 curve in fore-aft position by a maximum of about 7 mm for seat heights from 180 to 340 mm. For many vehicles, the difference is within the range of one seat track detent. This equation, which predicts fore-aft seat position as a function of seat height for people who are 1806 mm in stature, is suggested as a new SgRP definition.

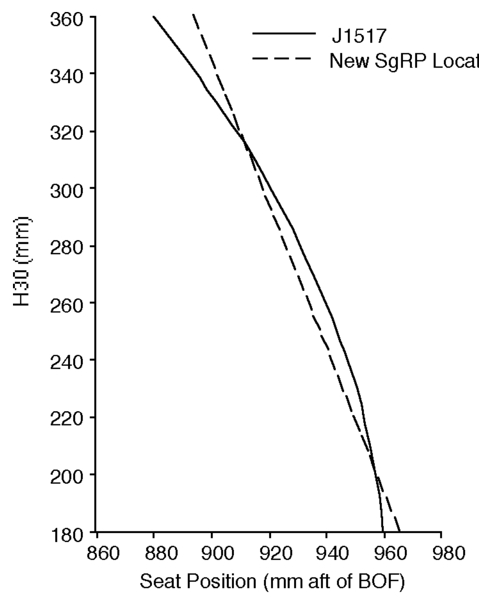


Figure 8. Comparison of proposed SgRP locator function with currently used SAE J1517 95th-percentile driver-selected seat position curve.

The new equation has a number of advantages over standardizing on the current SAE J1517 equation. First, the J1517 equation will be superceded soon by revisions to the practice based on SAM. Second, the J1517 equation was developed for a fifty-percent-male U.S. driving population, using anthropometry that may be out of date. Ideally, the SgRP equation should be population independent, to provide uniform applicability to international populations and consistency over time.

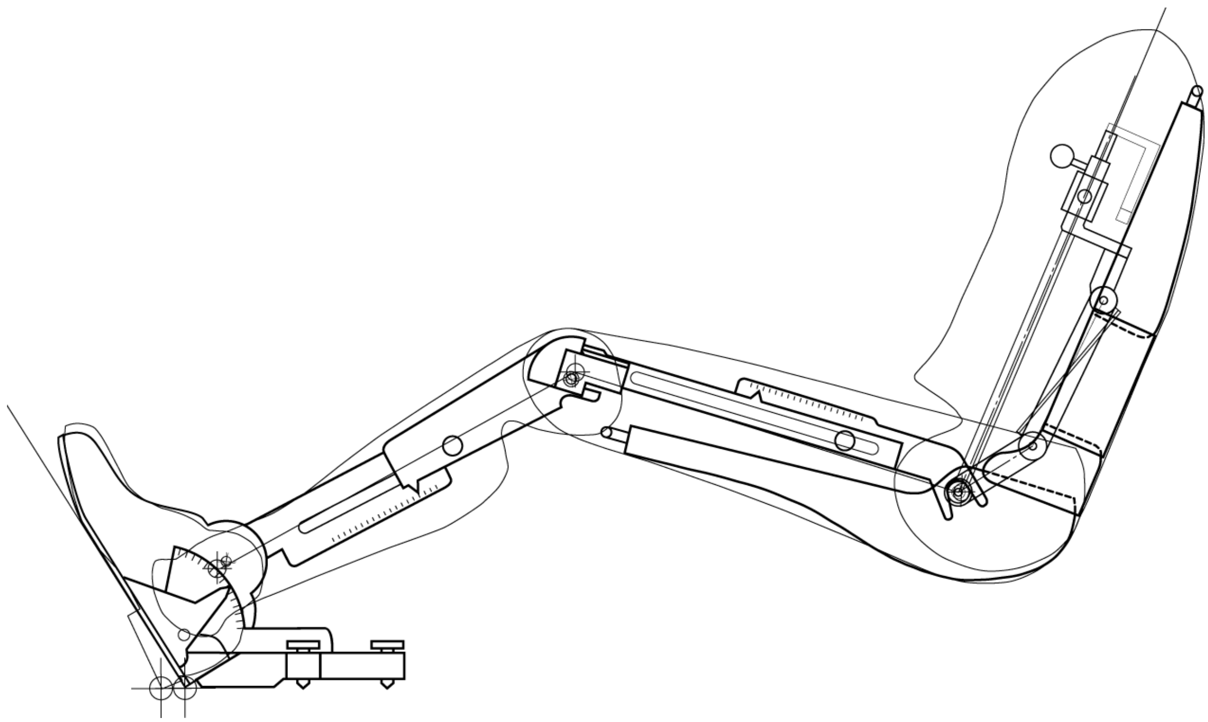


Figure 9. Comparison of current (light lines) and new (ASPECT manikin) packaging practices for a 220-mm seat height.

The proposed new SgRP equation overcomes both of these limitations and also provides an opportunity to create new leg and thigh segment lengths for use with the manikin that are anthropometrically consistent with the SgRP seat position. In current practice, the SgRP location is determined using an estimate of the location of the 95th percentile of the driver-selected seat position distribution. As has been noted before (18), this location does not correspond to the average seated position of people who are 95th percentile on any anthropometric variable, such as stature. Yet, in current practice, the J826 manikin and template are positioned with the H-point on this locator curve and then installed using "95th-pecentile" leg and thigh segment lengths. These segment lengths are based on 95th-percentile values for external leg dimensions from the U.S. HES study, dating from the early 1960s (21). Because both segments are designed to be 95th percentile individually, the combined leg and thigh length is larger than the 95th percentile for the original target population. Thus, the current practice uses a leg length, thigh length, and seat position that are inconsistent from anthropometric perspective. Consequently, the resulting manikin lower extremity posture bears, at best, an unclear relationship to actual human postures.

The new proposal would replace the leg and thigh segment lengths with lengths that are consistent with the SgRP reference stature. Using data from a large-scale anthropometric survey (22), the average knee height and buttock-to-knee lengths for men matching the SgRP reference stature of 1806 mm were calculated. Preserving the same offsets between the knee surface and knee joint, ankle and bottom of shoe, and H-point and the posterior of the buttock/thigh shell, new segment lengths were calculated to match these external dimensions. Table 3 shows the SgRP reference segment lengths, along with the current J826 95th-percentile segment lengths. The proposed thigh length is only slightly smaller than the J826 95th-percentile segment length, but the leg segment is about five percent shorter.

To measure a vehicle package, the ASPECT manikin is installed with the seat positioned such that the manikin H-point lies at the SgRP, as calculated by equation 2. The shoe is installed so that it contacts the accelerator pedal at the orientation given by equation 1. Then, the leg and thigh segments set to the SgRP-reference segment lengths given in Table 3 are installed. The resulting knee and hip angles are generally within one degree of those measured with the current practices. The AHP, however, is generally 5 to 25 mm rearward of the current AHP, because of the flatter foot angle calculated from equation 1. Figure 9 shows a typical vehicle package comparing the current and new systems for locating SgRP, along with the corresponding tools (SAE 2D template and ASPECT manikin) adjusted to the appropriate lower-extremity segment lengths.

Table 3. Comparison of SgRP Reference Segment Lengths with SAE J826 95th-Percentile Segment Lengths (mm)

Segment	SAE J826 95th Percentile	New SgRP Reference
Thigh	456	452
Leg	459	436

* Segment lengths appropriate for male matching the SgRP reference stature of 1806 mm.

Overall, the effects on vehicle package dimensions of the new SgRP proposal are small. Yet, the new proposal would:

- standardize the SgRP definition,
- create a single reference anthropometry for SgRP definition that is independent of any particular population,
- provide consistency with the new Seating Accommodation Model, and
- introduce consistency between manikin segment lengths and SgRP locations.

This proposal remains subject to further discussion and potential modification by the industry through the SAE Design Devices Committee. Assessments of current vehicle packages using the proposed system support the conclusion that most changes will be minor and that the large body of data collected under the current system will remain applicable.

HUMAN BODY REFERENCE FORMS – Industry representatives to the ASPECT program raised the concern that, in current design practice, there are no standard three-dimensional representations of the human body other than the SAE J826 manikin and the crash dummies. The SAE J826 manikin, as noted above, represents an amalgam of dimension percentiles, and crash dummies have been designed primarily for dynamic performance, not for the representational accuracy of their external geometry. Particularly in the shoulder and neck areas, the current standard Hybrid-III crash dummy does not have accurate contours.

Although collecting new whole-body contour data was beyond the scope of the ASPECT program, whole-body contours were available that were based on detailed anthropometric measurements. As part of an effort funded by the National Highway Traffic Safety Administration (NHTSA) to develop anthropometric specifications for a new generation of crash dummies, researchers at UMTRI developed full-size, physical, three-dimensional shells representing the average anthropometry and posture of small-female, midsize-male, and large-male drivers (23). The anthropometric specifications for the subjects were selected based on 5^{th--}, 50th-, and 95th-percentile stature and weight for men and women, based on the 1974 U.S. NHANES study (24).

As part of the ASPECT program, high-resolution surface scan data from the three physical shells were used to fit parametric (splined) surfaces. These three-dimensional figures, shown in Figure 10, can be rendered in CAD environments and manipulated in virtual vehicle mock-ups. These body surface descriptions may be considered for standardization in a new SAE practice.

There are a number of potential uses for these three-dimensional representations in vehicle design. First, they provide a way of visualizing vehicle occupants of three different sizes in a vehicle package. If the representations become part of a recommended practice, companies could use them to make comparative measurements, much as the current SAE J826 manikin and two-dimensional template are used now. Second, the reference forms provide a way of ensuring a degree of consistency in body contour among CAD manikins. Currently, CAD manikins from different companies configured to the same overall anthropometry often have considerably different body contours. This difference complicates use of the CAD manikins to make accommodation assessments. CAD manikins that matched the external surfaces of the reference forms developed in the ASPECT program would provide comparable measurements independent of the software.

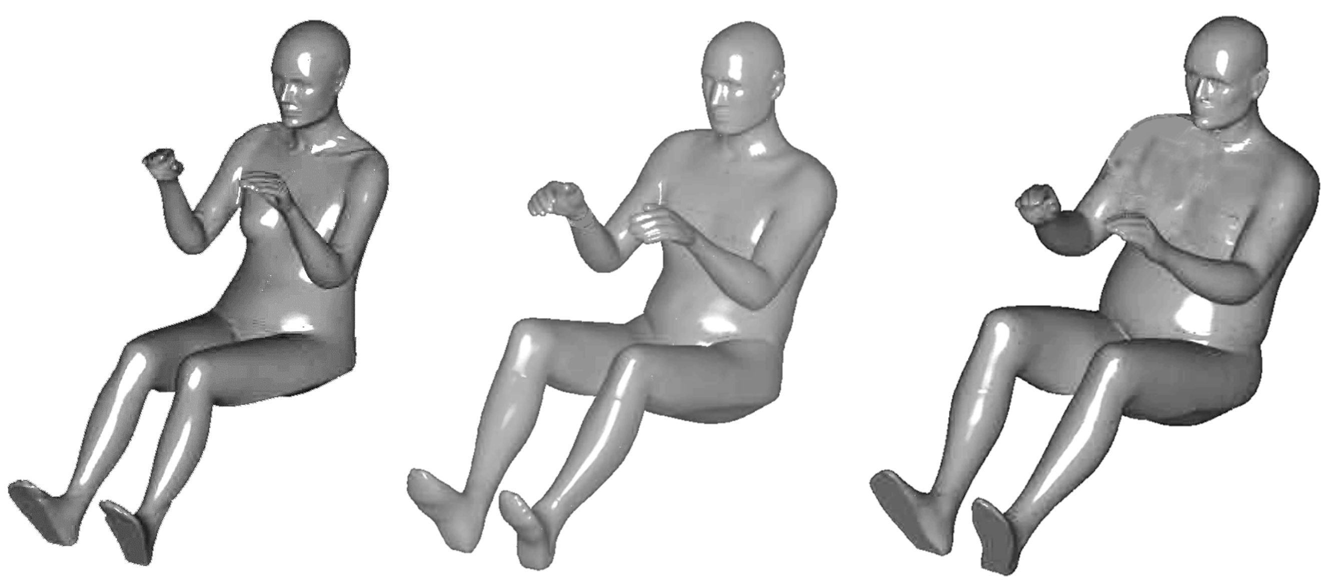


Figure 10. Small female, midsize male, and large male body surface contours for representing humans in CAD environments

Third, the standardized body surfaces would provide three-dimensional tools for conducting some of the analyses that are currently performed using the two-dimensional SAE J826 template. The SAE 2-D template has a torso height and shape that are different from the three-dimensional manikin. The "shoulder" height of the 2-D template is intended to be approximately representative of the 99th-percentile U.S. male shoulder height, and is used for such things as assessing shoulder belt anchorage locations. The new large male 3-D body surface could be used as a reference tool for measuring a number of vehicle interior clearance dimensions. The front torso and leg surfaces of the reference forms may provide more useful steering wheel and knee bolster clearance measures than are provided by the current two-dimensional template.

ASPECT POSTURE PREDICTION – Early in the ASPECT program, the research team solicited extensive input from industry concerning the current and anticipated uses of the ASPECT manikin. One common sentiment was that use of the physical device was expected to diminish as more vehicle design and assessment tasks were conducted in CAD. While it was clear that a physical tool would always be needed to verify that the seat and vehicle were constructed as intended, new tools to facilitate the use of computers in the design process were also desired.

In addition to CAD models of the ASPECT manikin, companies participating in ASPECT indicated that future vehicle designs would make extensive use of computerized human models. These CAD manikins are capable of representing people with widely varying anthropometry and can be manipulated to simulate tasks within the vehicle. A review of existing CAD manikins demonstrated that the biggest impediment to effective use of the models is a lack of accurate posture prediction. While the anthropometric scaling of the available models is sophisticated, the posturing and position of the models is commonly left to the discretion of the vehicle designer. Of the models surveyed for ASPECT in 1995, only RAMSIS contained any posture prediction validated for vehicle occupants (25).

Consequently, a major objective of the ASPECT program was to develop a large database of vehicle occupant postures, covering a wide range of anthropometry, vehicle, and seat geometry. The data were analyzed to determine the effects of these factors on occupant posture and position. The resulting statistical models provide a means of predicting the posture and position of drivers or passengers with a wide range of body dimensions in almost any passenger car geometry. The models have been validated using data from large-scale posture studies conducted in vehicles. Details of the occupant posture research and posture-prediction model development are presented elsewhere (6, 8).

The ASPECT posture prediction models will provide ways of using CAD manikins with known quantitative accuracy. For example, a manikin positioned using the ASPECT techniques has an eye location with a specified accuracy relative to the distribution of eye locations for people who match the manikin anthropometry. The ASPECT posture-prediction models allow CAD manikins to be used to make more accurate assessments of accommodation than were possible using other posture-prediction methods (8).

The ASPECT posture-prediction models also provide a way of ensuring compatibility between different CAD manikins. Ideally, a manikin with a specified anthropometry provided by one software publisher will sit in the vehicle environment in the same way as an identically sized manikin from another software company, that is, in a way that represents the average posture of people matching the specified anthropometry. Any discrepancies can be resolved by reference to the available data and models from the ASPECT program and other studies. Much as SAE J1517 and J941 have provided standardized predictions for population distributions of some postural degrees of freedom, a new SAE practice could be developed that would standardize prediction of a number of postural degrees of freedom for individuals.

CAD MANIKIN USAGE AND POSTURAL VARIABILITY – The analyses of posture data collected in the ASPECT program leading to the development of posture prediction models have emphasized the need to consider carefully the importance of residual postural variability when applying CAD manikins to design analyses. In many ways, the current use of CAD manikins in vehicle design approximates in three virtual dimensions the template-based design practices that preceded the development of the task-oriented percentile models, such as the eyellipse. That is, large and small manikins are selected to represent the occupant population. These manikins are positioned in the simulated vehicle space, and their accommodation is assessed, using vision, reach, and comfort analyses (the latter usually based on joint angles). In the old template-based procedures, the work was performed in two dimensions using physical templates, and the time-consuming manual procedures meant that only a few templates were applied. With CAD manikins, many different occupant sizes can be rapidly evaluated, and the analyses can include full three-dimensional assessment. However, these assessments are still limited by the primary assumption underlying the approach, which is that body dimensions are the primary determinants of occupant accommodation.

The central difficulty in applying physical or CAD manikins to accommodation assessment is that occupant positions are affected both by anthropometric variability and by postural variability that is not related to anthropometry. For example, consider the case of using manikin-based procedures to determine the appropriate range of fore-aft seat track adjustment. Using data from recent studies at UMTRI (1, 2, 20) the mean selected seat position for men who are 95th percentile in the U.S. driver population by stature (1870 mm) is 953.5 mm aft of the Ball-of-Foot reference point for a typical midsize sedan. Figure 11 shows this mean position, which represents the most accurate prediction available for a male driver of this size. However, Figure 11 also depicts the *distribution* of seat positions for male drivers with this stature, approximated by a normal distribution with a standard deviation of 30 mm (20). Because of differences not associated with stature, men who are 1870-mm tall select seat positions over a fairly wide range. Among a hypothetical population of people 1870-mm tall, a fore-aft range 117.6 mm would be required to span 95 percent of their preferred seat positions.

For comparison, consider the mean predicted seat position in the same vehicle for a small woman whose stature is equivalent to the 5th percentile for U.S. women. Figure 11 illustrates the mean predicted seat position for people of this stature, along with the residual variance. (Analyses at UMTRI have shown that men and women of the same stature select the same average seat position.) The residual variance in seat position for small women is approximately the same as for large men (2). The difference in mean selected seat positions between 5th-percentile women and 95th-percentile men (by stature within gender) is 155 mm, only about 37 mm (32 percent) more than the horizontal window containing 95 percent of individuals of either stature.

Suppose that these accurate posture prediction models were used with a family of CAD manikins to determine the necessary range of seat track adjustment. Selecting the 5th-percentile female and 95th-percentile male statures in an attempt to span 95 percent of a 50-percent-male driver distribution, the mean predicted positions for these two body sizes, shown in Figure 11, would define the needed range of seat track travel.

However, such an analysis would neglect the postural variability not accounted for by accurate posture predictions based on anthropometry. In contrast, a task-oriented percentile model for seat position, like that presented in SAE J1517 or the recently developed Seating Accommodation Model (SAM), includes both anthropometric and postural variability in determining accommodation ranges. Figure 11 shows the predicted 2.5th and 97.5th percentiles of the target driver population using SAM, approximated by the 5th percentile of the female distribution and 95th percentile of the male distribution (2). Compared to the manikin-based approach, SAM indicates that an additional 41 mm of seat track travel is needed to accommodate the desired percentage of the population.

Previous studies have demonstrated similar findings, showing that the distance between the mean seat positions of 5th-percentile women and 95th-percentile men is smaller than the range of adjustment needed to accommodate 95 percent of the driving population. These observations formed part of the justification for developing the driver-selected seat position model in SAE J1517 (18). However, the issue of residual variance in posture prediction for individuals has not previously been explored in the context of CAD manikin usage.

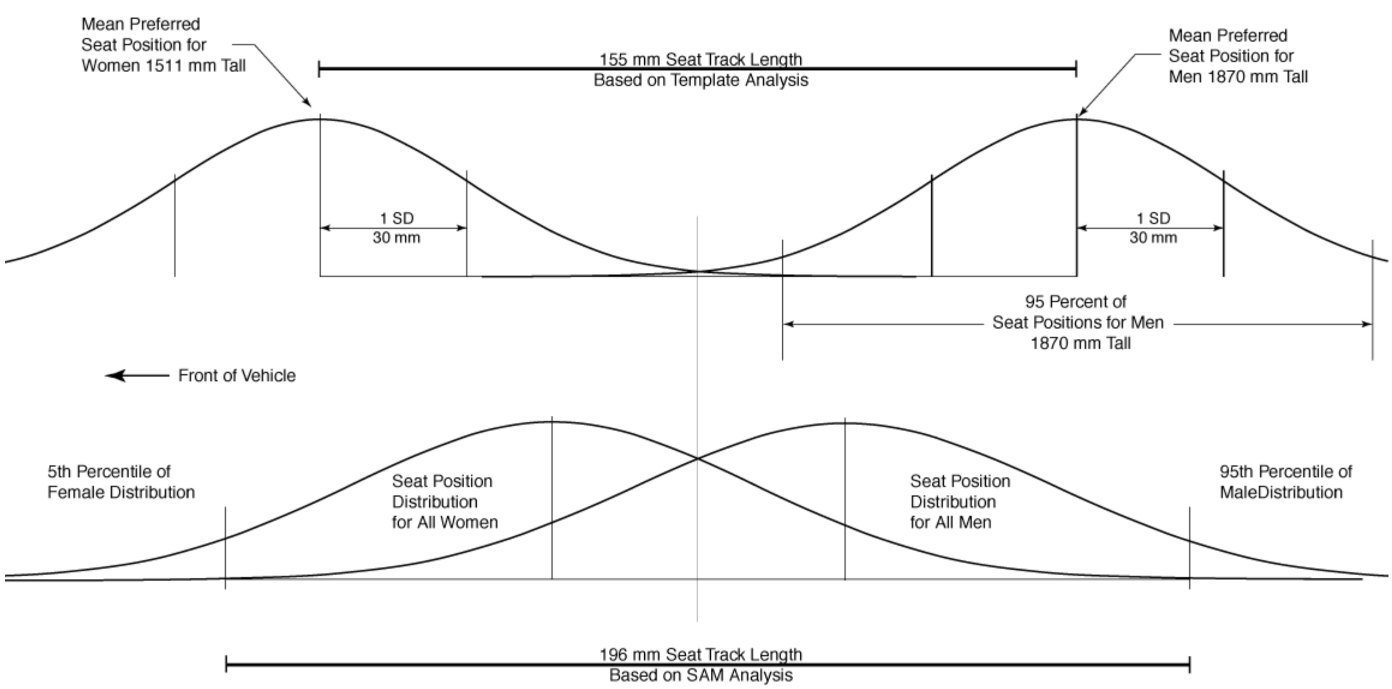


Figure 11. Illustration of seat position distribution. The top curves show predicted seat positions for large men (right) and small women (left). The bottom curves show distributions of seat positions for all men and women, along with the seat track length necessary to accommodate 95 percent of the combined population.

One might expect that the performance of the manikin assessment approach could be improved by specifying anthropometric variables in addition to stature. For example, using the ratio of sitting height to stature (or leg length) as well as stature might improve the prediction of seat position. Four manikins could be used, representing the same two statures, but with a range of leg lengths within stature. The idea could be carried further, sampling a family of manikins to span a wide range on several variables. Unfortunately, this procedure does not substantially improve the performance of the technique, because the use of additional anthropometric variables does not substantially improve the posture prediction.

Accuracy in posture prediction can be defined as agreement between the predictions and the average value for the same measure obtained with a large group of people matching the specified anthropometry, in the specified vehicle conditions. Since it is impossible to sample people who are anthropometrically identical, and it is likewise impossible to manipulate the anthropometry of an individual experimentally, the "true" posture values for a specified anthropometry are determined by statistical analysis of the postures of people who span a range of anthropometry. The experimentally measured postures are analyzed to determine the anthropometric variables that are associated with posture differences, and mathematical models are constructed to determine the average posture for a specified anthropometry (8, 26).

In research conducted for ASPECT, a diverse population of drivers selected their preferred driver seat positions in a vehicle mockup adjusted to a wide range of vehicle package conditions. Stepwise regression analysis demonstrated that about 76 percent of the variance in fore-aft seat position can be accounted for using package and seat variables along with stature (adjusted $R^2 = 0.763$). Adding two other posture variables (the ratio of sitting height to stature, and body mass index, defined as the body mass divided by the stature squared) improves the percentage of variance predicted (adjusted R^2 value) to 0.767. Importantly, the root mean square error, a measure of the residual variance, decreases only from 38.8 to 38.5 mm, indicating that the additional variables have not substantially improved the posture prediction. Using leg length (stature minus sitting height), rather than stature, yields slightly poorer results ($R^2_{adj} = 0.735$, RMSE = 41.0). Similar findings have been reported elsewhere, in work to develop the new Seating Accommodation Model (1, 2)[2].

These analyses indicate that most of the residual postural variance is not related to primary anthropometric variables, such as leg length or weight, that would be useful for positioning manikins. Instead, the residual variance represents the range of driver preference independent of anthropometry. This variance is likely to be essentially unpredictable; that is, the variance is not related to the small number of descriptors, such as gender, stature, and weight, that are useful for describing target vehicle occupant populations.

Although the examples given here use seat position, the general observations apply to any other postural variable. For example, eye location shows a three-dimensional residual variance distribution after taking into account vehicle, seat, and anthropometric factors (8, 26). The resulting uncertainty in posture prediction is important for assessments that are dependent on CAD manikin posture and position, such as reach and vision evaluations.

It is difficult to represent the posture variance not attributable to anthropometry in CAD human models. Yet, these models have important applications in vehicle design. If accurately postured, they can be used to visualize people of a wide range of sizes sitting in the vehicle interior. Often, these visualizations will reveal design problems that were not identified using the standard statistical tools. Dynamic tasks, such as reaches, that are difficult to describe kinematically with task-oriented percentile models, are usefully examined with human models. Further, accommodation dimensions that are limited almost entirely by anthropometry are assessed well using CAD manikins. For example, lateral hip and shoulder room can be usefully studied using an appropriately selected family of manikins. However, the uncertainty regarding the postures and positions of drivers of these sizes must be kept in mind when assessing fit.

The knowledge gained from recent occupant posture research could be used to develop new methods for CAD manikin application that would broaden the applicability of these models for accommodation assessment. In particular, automated procedures could be developed to conduct vehicle evaluations using virtual sampling of a large number of manikins from the target population. In such a procedure, the posture and anthropometry of each CAD manikin instance would include random components accounting for the residual postural variability that cannot be predicted from primary anthropometric factors. Research is now underway to determine the efficacy of this approach for manikin-based accommodation assessments.

DESIGN PROCESS USING THE NEW TOOLS – Table 4 contrasts the current SAE practices with the new methods. The new methods provide considerable continuity with existing practice, but with greater accuracy and generality. The application of the new tools to vehicle interior design can be illustrated using a hypothetical example. As in the preceding illustration, a seat height of 270 mm and some predefined pedal geometry are assumed. Figure 12 shows the new tools on a package layout.

2. The residual variance in this analysis is larger than the variance used in Figure 11, which was taken from SAM calculations. The SAM calculations are based on in-vehicle data, whereas these calculations are based on laboratory data. The smaller variance in the vehicle data may indicate the influence of posture restrictions not present in the laboratory, but the overall effects of anthropometry and other variables are similar in vehicle and laboratory studies (1).

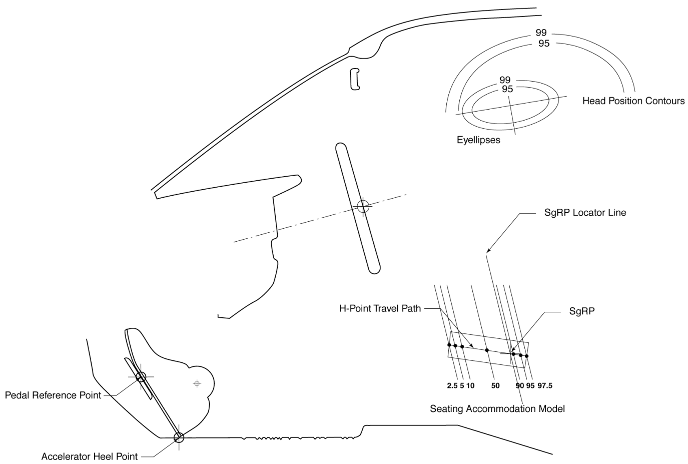
First, the Pedal Reference Point (PRP) location is determined by constructing a plane tangent to the accelerator pedal extending 203 mm from the depressed floor surface. This defines the horizontal (PRP) and vertical (AHP) reference points for laying out the vehicle package. The new SgRP locator line is placed on the drawing, referenced to the PRP and AHP locations. Using the specified seat height, the SgRP location is now defined.

The SAE task-oriented percentile models for eye location and seat position can now be added. The new version of the eyellipse requires information on steering wheel position and the anthropometry of the target population, obtained using in-house procedures. For this illustration, a population matching the general U.S. adult population defined in the 1974 NHANES survey (24), but with a 60-percent-female gender mix, will be used. Note that this type of configurability is not available with the current eyellipse. The eyellipse centroid location is calculated relative to the PRP and AHP reference points, using the fore-aft steering wheel position and seat height. The eyellipse is not positioned relative to the SgRP, as in the old procedure, and design seatback angle is not used. The new head contours can be positioned in the same way as the eyellipse.

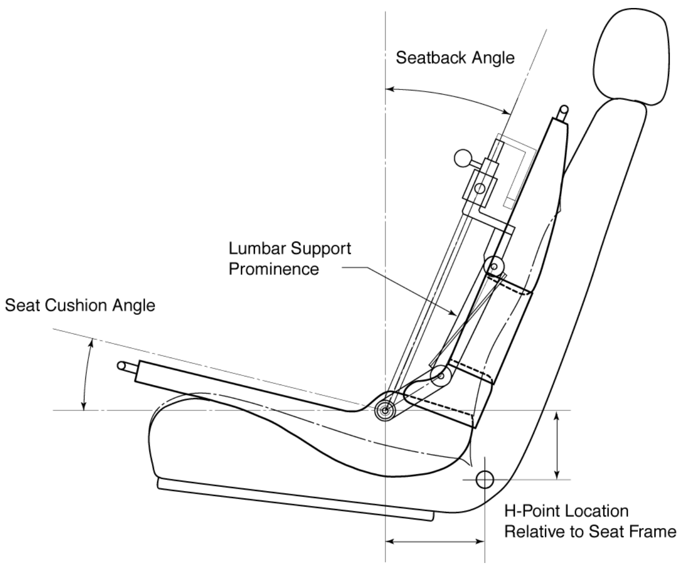
Next, the seat track is laid out using the new Seating Accommodation Model (SAM). In addition to steering wheel position and seat height, seat cushion angle and transmission type are required. For this two-way seat track vehicle, a design cushion angle of 14 degrees is chosen, based on in-house guidelines, and the vehicle is designed for automatic transmission (no clutch). The same population used to define the eyellipse is used to determine the 2.5th and 97.5th percentiles of the driver-selected seat position distribution, defining a seat track adjustment (H-point travel) range that will accommodate 95 percent of drivers in their preferred seat positions. Using the SgRP location and a design seat track angle of six degrees (defined from in-house practice), the H-point travel path is defined. Driver reach envelopes can be added for further design analysis. Although J287 is not directly affected by the new procedures described in this paper, it is currently under review by the SAE Design Devices Committee.

Table 4. Comparison of Current SAE Recommended Practices with New Methods

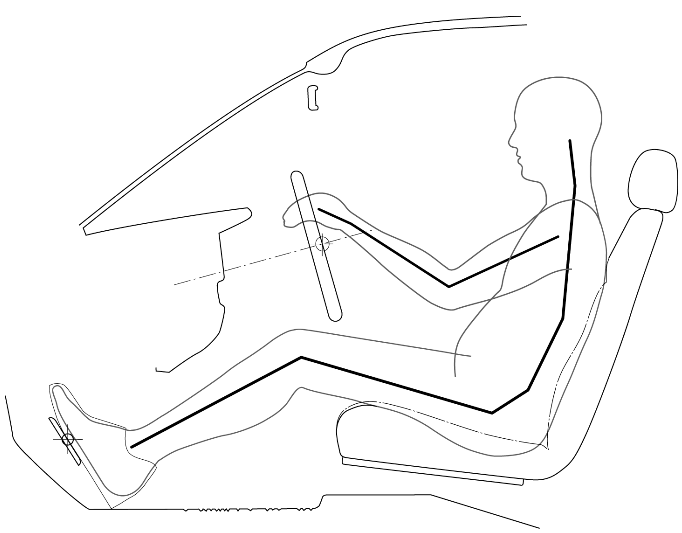
Practice	Topic	Current	New
J1517	Driver Selected Seat Position	U.S. 50%/50% male/female driver population Function of seat height Equations for 7 percentiles	Any population stature and gender mix Function of seat height, steering wheel position, seat cushion angle, and transmission type Solutions for any desired percentile of the distribution
J1516	Accommodation Tool Reference Points	Pedal Plane Angle Theta Ball of Foot Accelerator Heel Point – –	Shoe Plane Angle Alpha Ball of Foot Accelerator Heel Point Pedal Reference Point
J1100	Motor Vehicle Dimensions	Ambiguous SgRP Definition Many dimensions relative to H-point manikin	New SgRP Definition Revised definitions relative to ASPECT manikin
J826	Devices for Use in Defining and Measuring Vehicle Seating Accommodation	H-point manikin 2-D template – –	ASPECT manikin CAD ASPECT Manikin 3-D CAD human reference forms
J941	Driver's Eye Range	U.S. 50%/50% male/female population Function of SgRP location and design seatback angle 95th- and 99th-percentile cutoff ellipses – –	Any population stature and gender mix Function of seat height and steering wheel position Solutions for any desired percentile ellipse New eyellipse shape
J1052	Driver and Passenger Head Position	U.S. 50%/50% male/female population Function of SgRP location and design seatback angle 95th- and 99th-percentile cutoff ellipses No head turn	Any population stature and gender mix Function of seat height and steering wheel position Solutions for any desired percentile ellipse Includes space for head turn



Package Layout



Seat Design Specification using ASPECT Manikin



Design Assessment with CAD Manikins

Figure 12. Illustration of hypothetical driver station design procedure using the new methods.

The ASPECT manikin is not directly used in the design process up to this point. However, there are a number of assessments that are currently made using the SAE 2D template that may be carried over. For example, knee clearances are sometimes assessed using the 2D template knee and shin locations. To facilitate this type of analysis, a 3D CAD version of the ASPECT manikin can be installed in the new design, placing the H-point at the SgRP. The shoe is placed on the accelerator pedal and oriented according to the specified seat height, using the alpha equation defined above. The leg and thigh segments, adjusted to the SgRP reference length, complete the installation. Note that it is not necessary to include the entire ASPECT manikin for this application. Only the geometry of the thigh, leg, and shoe segments are needed.

When the vehicle designer begins to consider seat design, the ASPECT manikin measures of the seat can be used as specifications. For example, the location of the H-point relative to the seat frame, the seat cushion angle, seatback angle, and lumbar support prominence can be specified for a particular seat frame orientation. This information, along with other dimensional guidelines, can be forwarded to the seat supplier to guide the seat design. When a seat prototype is available, the seat can be tested using the ASPECT manikin for conformance with these specifications without having to install the seat in a vehicle mockup. Only the correct seat frame attitude with respect to vertical is required.

For additional design assessments, CAD manikins can be used with posture prediction models developed in ASPECT. Inputs to the posture prediction models include basic package dimensions such as seat height and steering wheel position, but also include ASPECT manikin seat measures, such as seat cushion angle, lumbar support prominence, and (for fixed seatbacks) seatback angle. The posture prediction models include the appropriate offsets between the manikin hip joint and seat H-point as a function of anthropometric, seat, and package variables. The standard human body reference forms (small female, midsize male, and large male) can also be used to make interior assessments. Using appropriate posture prediction, the three-dimensional CAD forms can be placed in the vehicle interior for visualization or to make comparative clearance measures.

DISCUSSION

The SAE recommended practices for vehicle interior design represent a substantial body of knowledge concerning vehicle occupant posture and position. These tools, developed and modified over several decades with contributions from many people in the auto industry, have been very successful in providing uniform methods for designing, evaluating, and comparing vehicles. The new methods described in this paper represent only evolutionary changes to the current vehicle design practices, and provide considerable continuity with respect to measurement definitions and applications techniques. Yet, the new tools will provide vehicle designers with better accuracy, consistency, and flexibility. Seat position and eye location distributions can be customized for the specific vehicle occupant population of interest. The new ASPECT posture prediction models, combined with a quantitative understanding of postural variability, can be used to improve the effectiveness and validity of analyses with CAD manikins. Finally, the ASPECT H-point manikin provides new measures of the seat that will allow more complete specification of seats to meet comfort and performance goals.

The research leading to the development of these new tools has been conducted in close cooperation with industry, including the participation of many people from the corresponding SAE committees. This cooperation ensures that the tools are likely to meet the requirements of industry, but there will be additional opportunities for feedback as the committees prepare the revisions to the recommended practices. Evaluations of these tools are currently underway at a number of companies.

The implications of changes in the current recommended practices are broader than can be addressed in this paper. Notably, several of the practices and definitions are cited in vehicle safety standards, such as the U.S. Federal Motor Vehicle Safety Standards. The H-point manikin is used in dummy positioning procedures, and the eyellipse and associated points are used in vision standards. The SAE practices have also been cited and adapted for a number of international standards. Changes to these other practices, if necessary, will require additional actions by the associated committees and governing bodies. However, the considerable effort required to change the current practices should not dissuade the industry from moving ahead with improvements that will result in better-designed, more comfortable, and safer automobiles.

While the previous task-oriented percentile models were limited to descriptions of a particular U.S. driver population, the new models can be configured to represent any population of interest. The ASPECT manikin and the new SgRP locating procedure have been developed using anthropometric reference standards so that they can be applied equally well for any particular population. However, the extension of the task-based models to non-U.S. populations is based solely on anthropometry. These models do not take into account the potential for other sources of difference between populations in vehicle occupant posture.

The research leading to the development of these tools has clarified the complicated issues regarding anthropometric and postural variance. While both sources of variability in vehicle occupant positioning are addressed by the task-oriented percentile models, current CAD manikin procedures address only the anthropometrically related variance. New application procedures will be necessary to integrate them fully into the vehicle design process.

CONCLUSIONS

A new set of tools has been developed that improves on the current SAE recommended practices for vehicle interior design, including new versions of:

- H-point manikin (J826),
- driver-selected seat position model (J1517),
- driver eyellipse (J941),
- pedal reference points (J1516),
- seating reference point definition (J1100), and
- vehicle interior dimensions (J1100).

New methods and models have also been developed for:

- three-dimensional human body surface definition, and
- whole-body posture prediction.

Through the activities of the associated SAE committees, these new methods will be considered in revising the current SAE recommended practices. Continued participation of industry representatives throughout the process will ensure that the resulting practices are appropriate for current and future needs.

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