Chapter 2. Population Characteristics

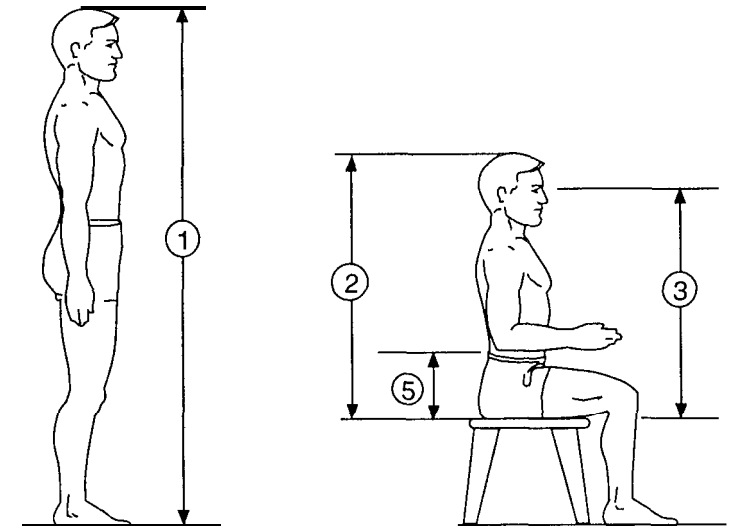
As stated in volume I, part I of the handbook, human factors ". . . is concerned with . . . the design of systems . . . to match the capabilities and limitations of the human user." Thus, at the outset, it is important to know what are those capabilities and limitations so the system design can be tailored to the needs of its users. Table 3 is presents information about the intended automated highway system user population for key variables. This information should be treated as boundary conditions for the design of the AHS, and used where appropriate in the design process.

Table 3. Selected characteristics of the automated highway system user population.

Characteristic	Population Data	Comment
Age: legal driving age	≥16 years	
SIZES		
Males, Ages 17 to 51[8,9]		
Standing height (figure 2, ¿)	• Street clothes: 186 4 cm (73 4 in). • Winter clothes: 191.5 cm (75.4 in).	All data for males, ages 17 to 51 are 95th percentile, and are adjusted for clothing and slump.
Seated height (figure 2, ¡)	• Street clothes: 93.8 cm (36.9 in). • Winter clothes: 99.3 cm (39.1 in).	
Seated eye height (figure 2, ¬)	• Street clothes: 81.4 cm (32.0 in). • Winter clothes: 87.0 cm (34.2 in).	
Seated midshoulder height (figure 2, √)	• Street clothes: 69.2 cm (27.2 in). • Winter clothes: 72.7 cm (28.6 in).	
Seated elbow rest height (figure 2, *f*)	• Street clothes: 28.9 cm (11.4 in). • Winter clothes: 32.5 cm (12.8 in).	
Males, Ages ≥70[9,10]		
Standing height (figure 2, ¿)	• Street clothes· 176.3 cm (69.4 in). • Winter clothes. 181.4 cm (71.4 in).	All data for males, ages ≥70 are 95th percentile, and are adjusted for clothing and slump
Seated height (figurc 2, ¡)	• Street clothes: 89.8 cm (35.4 in). • Winter clothes: 95.4 cm (37.6 in).	
Seated midshoulder height (figure 2, √)	• Street clothes: 70.6 cm (27.8 in) • Winter clothes: 74.2 cm (29.2 in).	
Seated elbow rest height (figure 2, *f*)	• Street clothes: 28.4 cm (11.2 in). • Winter clothes: 32.0 cm (12.6 in).	*(Table continued on next page.)*

Table 3. Selected characteristics of the automated highway system user population (continued).

Characteristic	Population Data	Comment
SIZES (continued)		
Females, Ages 17 to 51[8,9]		
Standing height (figure 2, ¿)	• Street clothes· 153 3 cm (60.4 in). • Winter clothes. 160.4 cm (63.2 in).	All data for females, ages 17 to 51 are 5th percentile, and are adjusted for clothing and slump.
Seated height (figure 2, ¡)	• Street clothes: 76.9 cm (30.3 in). • Winter clothes: 83.5 cm (32.9 in).	
Seated eye height (figure 2, ¬)	• Street clothes: 65.8 cm (25.9 in). • Winter clothes: 72.4 cm (28.5 in).	
Seated midshoulder height (figure 2, √)	• Street clothes: 54.8 cm (21.6 in). • Winter clothes: 57.1 cm (22.5 in).	
Seated elbow rest height (figure 2, *f*)	• Street clothes 18.5 cm (7.3 in). • Winter clothes: 20.8 cm (8.2 in).	
Females, Ages ≥70[9,10]		
Standing height (figure 2, ¿)	• Street clothes: 141.0 cm (55.5 in). • Winter clothes. 148.1 cm (58.3 in).	All data for females, ages ≥70 are 5th percentile, and are adjusted for clothing and slump.
Seated height (figure 2, ¡)	• Street clothes: 68.7 cm (27.1 in) • Winter clothes: 75.3 cm (29.7 in).	
Seated elbow rest height (figure 2, *f*)	• Street clothes: 17.1 cm (6.8 in). • Winter clothes 19.4 cm (7.7 in).	*(Table continued on second page following.)*



1. Standing height
2. Seated height
3. Seated eye height
4. Seated midshoulder height
5. Elbow rest height

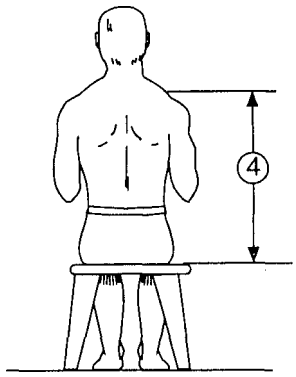


Figure 2. Reference figures for user population sizes.

Table 3. Selected characteristics of the automated highway system user population (continued).

Characteristic	Population Data	Comment
AUDITION[11]		
Males		
Hearing threshold level (as compared with audiometric zero) • 500 Hz • 1,000 Hz • 2,000 Hz • 3,000 Hz • 4,000 Hz • 6,000 Hz	 • ≥26 dB (5.0 percent) • ≥26 dB (5.8 percent) • ≥46 dB (5.2 percent) • ≥66 dB (4.5 percent) • ≥76 dB (3.8 percent) • ≥76 dB (7.4 percent)	Data are for the worse of the left and right ears. Data in the reference report are shown as percentages of the sample with hearing threshold levels in each of several ranges (e.g., 26 to 35 dB) compared with audiometric zero, for each ear separately. The nearest datum to a 5th percentile was chosen for each ear. The data provided here are for the worse ear at each frequency. Where the hearing threshold levels are the same for the two ears, the datum shown is for the sample percentage closer to 5 percent. The numbers in parentheses are the percentage of the sample with the hearing threshold levels shown. These data were used because they are from a sample where people were not rejected on the basis of otological disease or other such criteria, they covered an appropriate frequency range (based on the recommended range for nonspeech auditory displays), and they represented a reasonable age range (18 to 79).
Females		
Hearing threshold level (as compared with audiometric zero) • 500 Hz • 1,000 Hz • 2,000 Hz • 3,000 Hz • 4,000 Hz • 6,000 Hz	 • ≥26 dB (5.2 percent) • ≥26 dB (5.0 percent) • ≥36 dB (4.6 percent) • ≥46 dB (4.5 percent) • ≥56 dB (3.5 percent) • ≥56 dB (7.6 percent)	Data are for the worse of the left and right ears. Data in the reference report are shown as percentages of the sample with hearing threshold levels in each of several ranges (e.g., 26 to 35 dB) compared with audiometric zero, for each ear separately The nearest datum to a 5th percentile was chosen for each ear. The data provided here are for the worse ear at each frequency. Where the hearing threshold levels are the same for the two ears, the datum shown is for the sample percentage closer to 5 percent The numbers in parentheses are the percentage of the sample with the hearing threshold levels shown. *(Table continued on next page.)*

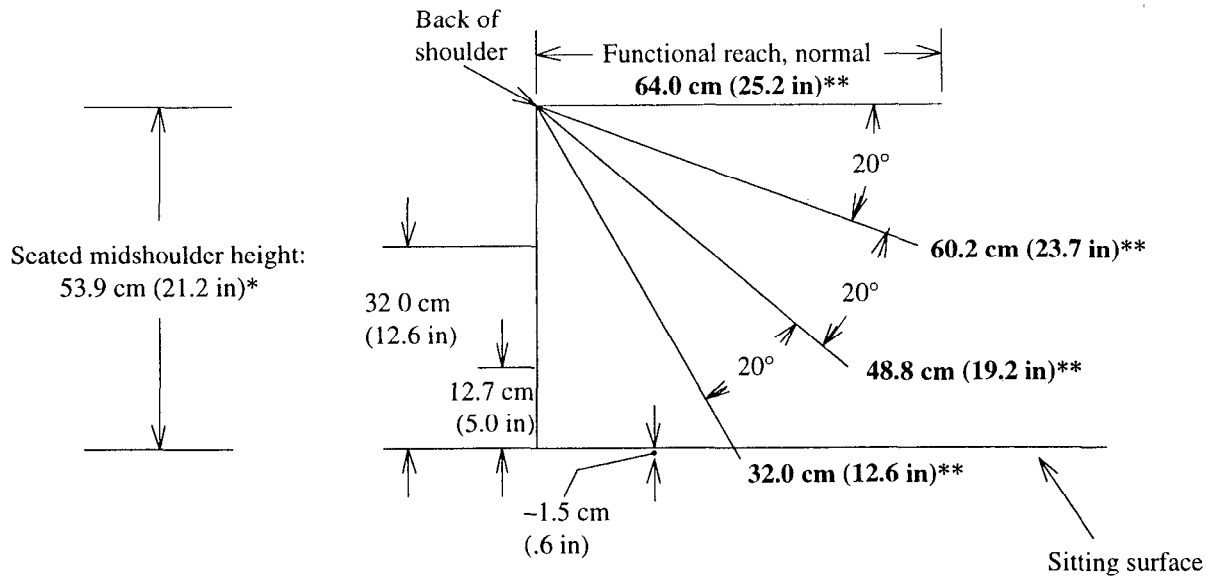
Table 3. Selected characteristics of the automated highway system user population (continued).

Characteristic	Population Data	Comment
AUDITION (continued)		
Females (continued)		
		These data were used because they are from a sample where people were not rejected on the basis of otological disease or other such criteria, they covered an appropriate frequency range (based on the recommended range for nonspeech auditory displays), and they represented a reasonable age range (18 to 79).
VISION (See references 12,13,14,15,16.)		
Static acuity (Snellen)	20/40 will allow unrestricted driving in all States.	A person with a Snellen acuity of 20/20 can read a target (e.g., state what letter it is) that subtends 1 min of arc at a distance of 6.1 m (20 ft). At 6.1 m (20 ft), a person with a Snellen acuity of 20/40 can read only a target that subtends 1 min of arc at 12.2 m (40 ft). The latter target subtends 2 min of arc at 6.1 m (20 ft).[12]
Horizontal movements • Eye rotation only, around a line straight ahead. • Head rotation only, around a line straight ahead. • Head plus eyes, around a line straight ahead.	• Optimal: ±15°. • Maximum: ±35°. • Easy: ±45°. • Maximum: ±60°. • Easy: ±60°. • Maximum: ±95°.	
Vertical movements • Eye rotation only, around the horizontal • Head rotation only, around the horizontal. • Head plus eyes, around the horizontal.	• Optimal: Horizontal to 30° below horizontal. • Maximum: 25° above horizontal to 35° below horizontal. • Easy: ±30°. • Maximum: ±50°. • Easy: ±45°. • Maximum: 95° above horizontal to 115° below horizontal.	
Binocular fields of view • Around a line straight ahead. • Around the horizontal.	• Right eye: 90° to the right, 60° to the left. • Left eye: 90° to the left, 60° to the right. • Both eyes together: ±60°. • 50° to 55° above horizontal. • 60° to 70° below horizontal.	*(Table continued on next page.)*

Table 3. Selected characteristics of the automated highway system user population (continued).

Characteristic	Population Data	Comment
REACH[17][1]		
Functional reach, normal (furthest extent of the reach envelope, driver sitting upright, seat back upright, without moving from against the seat back)	64.0 cm (25.2 in)	This is measured from the back of the right shoulder to the tip of the right thumb, with the tip of the index finger touching the pad of the thumb; both shoulders are held against the wall. The datum is for the 5th percentile female.
Functional reach, extended (furthest extent of the reach envelope, driver sitting upright, seat back upright, moving one shoulder while keeping the other shoulder in contact with the seat back)	73.4 cm (28.9 in)	This is measured from the back of the right shoulder to the tip of the right thumb, with the tip of the index finger touching the pad of the thumb; the left shoulder is against the wall, the right shoulder is extended as far as possible. The datum is for the 5th percentile female.
Elbow to grip length (normal grip radius for frequently used, precise-adjustment controls)	29.5 cm (11.6 in)	This is measured from the tip of the elbow to the center of the hand, with the upper arm vertical and a 90° angle at the elbow. The datum is for the 5th percentile female.
Functional reach, normal, as a function of height above the sitting surface	See figure 3 below	
Change in functional reach as a function of change in seat back angle	See table 4 below.	
STRENGTH[19]		
Two handed rotational force applied to a steering wheel	• Moving vehicle, surprise loss of power assistance. 76.1 N (17.1 lbf) • Moving vehicle, forewarned loss of power assistance: 86.8 N (19.5 lbf)	Data are for the 5th percentile female.
Foot push (brake pedal)	• Moving vehicle, surprise loss of power assistance: 287.5 N (64.6 lbf) • Moving vehicle, forewarned loss of power assistance. 368.9 N (82.9 lbf)	Data are for the 5th percentile female *(Table continued on second page following.)*

[1] Context-specific reach data depend to a large extent on the specific geometry of the vehicle being considered as the workspace for a particular design. Such factors as vehicle body type (e.g., sports car, station wagon, light truck), seat position (i.e., location along its track), seat back angle, seat elevation, and so on, have a significant impact on reach in relation to a fixed reference point in the vehicle. Providing reach data for all combinations of those factors seemed unreasonable, as did trying to select combinations that were representative of the population of geometries. The Society of Automotive Engineers provides reach data based on vehicle cockpit geometries and a methodology for using the data.[16]



* Taken from the same source as used for functional reach, normal This is ***not*** the source used for midshoulder height elsewhere in table 3.

** Forward reach at the height indicated above the sitting surface.

Figure 3. Functional reach as a function of height above the sitting surface.

Table 4. Change in reach as a function of change in seat back angle.[18]

Direction of Arm Reach (0° = straight ahead; 90° = arm to the right)	Approximate Change in Reach for Each 1° Change in Seat Back Angle (as the seat back moves away from the vertical, reach decreases by the amount shown, as the seat back moves towards the vertical, reach increases by the amount shown)
0°	1.02 cm (.40 in)
15°	1.27 cm (.50 in)
30°	1.14 cm (.45 in)
45°	.94 cm (.37 in)
60°	.66 cm (.26 in)
75°	.36 cm (.14 in)
90°	.25 cm (.10 in)

Table 3. Selected characteristics of the automated highway system user population (continued).

Characteristic	Population Data	Comment
FOOT REACTION TIMES[20,21]		
Braking, simple reaction time • Auditory stimulus • Visual stimulus	• 879 ms • 1,314ms	Simple reaction time was in response to a forewarned auditory stimulus (simple tone) or visual stimulus (red light). The foot was on the accelerator at the time the stimulus was presented. Data shown are combined 95th percentile primary secondary reaction times. Primary reaction time is the interval between stimulus onset and removal of the foot from the accelerator. Secondary reaction time is the interval between removal of the foot from the accelerator and operation of the brake.
Braking, choice reaction time • Auditory stimulus • Visual stimulus	• 1,359 ms • 1,575 ms	Choice reaction time was in response to an auditory stimulus (simple tone) or visual stimulus (red light) presented randomly among four stimulus types total: the red light, the tone, and left- and right-pointing arrows. The arrows required the driver to turn in the indicated direction, not to brake. Data shown are combined 95th percentile primary secondary reaction times. Primary reaction time is the interval between stimulus onset and removal of the foot from the accelerator. Secondary reaction time is the interval between removal of the foot from the accelerator and operation of the brake.
Braking, perception-reaction time • Mean (standard deviation). • 85th percentile.* • Longest observed out of 116 subjects. • American Association of State Highway and Transportation Officials design standard.	• 1.5 s (.4 s) • 1 9 s • 2 5 4 s • 2.5 s**	Perception-reaction time is the time it takes to perceive a stimulus, interpret it, decide what response to make, and initiate that response. In this study, the stimulus was the unannounced, sudden appearance of an object rolling toward the roadway. *(Table continued on next page.)*

* The 85th percentile perception-reaction time is ". . . often used for developing highway design values."(20,p. 208)

** It is recommended that the 2.5 s perception-reaction time be used.

Table 3. Selected characteristics of the automated highway system user population (continued).

Characteristic	Population Data	Comment
HAND REACTION TIME [21]		
Steering, simple reaction time	498 ms	Simple reaction time was the time to start turning the steering wheel in response to a forewarned visual stimulus (directional arrow). The datum is the worse of the 95th percentile left- or right-arrow responses.
Steering, choice reaction time	1,203 ms	Choice reaction time was in response to a visual stimulus (directional arrow) presented randomly The datum is the worse of the 95th percentile left- or right-arrow responses.