SUITABILITY OF VEHICLES FOR OLDER DRIVERS
ACCESSIBILITY MEASUREMENTS

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Suitability of Vehicles for Older Drivers - Accessibility Measurements

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Abstract

This report is associated with a research project that will develop criteria for assessing the suitability of vehicles for use by aged drivers, taking into account safety and usability issues. One category of assessment is the accessibility of the vehicle for aged/frail drivers and passengers - primarily the ease of ingress and egress and the operation of driving controls. This report sets out the results of research on vehicle accessibility, the development of a test method and provisional assessment of several sample vehicles.

Key dimensional measurements are identified and rating criteria are recommended. These are subject to further review once more data on a range of vehicles become available.

Keywords

PASSENGER VEHICLE, OCCUPANT, ACCESSIBILITY, HUMAN FACTORS, ERGONOMICS, VEHICLE DESIGN, OLDER DRIVER

Disclaimer

CONTENTS

Introduction

This report is associated with a research project that will develop criteria for assessing the suitability of production vehicles (without modifications) for use by aged drivers, taking into account safety and usability issues. Planned outputs from the project include a protocol for assessing vehicles, a magazine article about choosing a vehicle and the results of assessments of a range of popular vehicles.

One category of assessment is the accessibility of the vehicle for aged/frail drivers and passengers - primarily the ease of ingress and egress and the operation of driving controls. The project has been scoped so that it can ultimately cover other types of vehicle users such as wheelchair users but the initial phase is confined to able-bodied users.

Review of sources of data

A review of the automotive engineering publications revealed few sources of objective recommendations on the ideal dimensions associated with getting in out of a vehicle or operating pedals and other controls. Woodson (c1970) provides "ingress and egress clearances" and an "optimized driver station profile" with recommended dimensions but the values suggest that they are not optimal for aged frail occupants.

Herriotts (2005) undertook an extensive questionnaire survey of older UK drivers aged between 60 – 79 years to identify the type and nature of problems associated with domestic vehicle design. 1,110 completed questionnaires were returned from the sample group of volunteers who were part of the "Thousand Elders" research volunteer group. The researchers found that ingress and egress, placing and retrieving items from the car boot, turning around to look out of the rear window and ease of use of radio controls were the main difficulties drivers identified. These design features were also associated with personal mobility and sensory functional limitations identified by questionnaire respondents.

Bodenmiller and others (2002) describe the results of a study of vehicle ingress and egress by older drivers. Young drivers were also included in the study to provide a contrast. A total of 36 people participated with at least eight people in each of four groups: young female, young male, old female, old male. Three vehicles were chosen for the tests: a mid-size sedan, a mini-van (people-mover) and a pickup truck (work utility). Numerous vehicle dimensions were recorded but the authors only commented on two key measurements: door sill height above ground and seat height (H-point) above ground.

Key Dimensions of Tested Vehicles

Parameter	Sedan	Minivan	Pickup
Sill Height	380mm	420mm	533mm
Seat Height	521mm	686mm	890mm

They found that the mini-van was clearly the best vehicle for the older drivers. This was on the basis of observations and time trials and through interview. Ingress and egress was found to be difficult with the pickup. Aged drivers had difficulty getting out of the sedan due to its relatively low seat height - for ingress they tended to drop into the seat. The authors concluded that vehicles with sill and seat height close to that of the minivan were best for older drivers. They also noted that running boards (for foot placement) might assist use of high vehicles like the pickup and that the contour of bucket seats sometimes hindered ingress and egress.

Petzall (1988) provides a diagram with recommended dimensions for vehicles used by aged and disabled people. The author notes that "the results of experiments show that the same entrance measurements are required by people confined to wheelchairs and people with walking impairments. The reasons for these measurements sometimes differ, however." Petzall recommends:

- Door opening width 800-900mm
- Door height (cant rail) above ground 1330-1380mm (more preferred for standing users)
- Door sill height above floor 40-90mm
- Door sill height above ground 360-400mm
- Seat to A-pillar (longitudinal) 350-450mm
- Door opening angle 70 degrees (or 90 degrees for assistance) with a mechanism to hold it open
- Seat height (H-point) above ground 630-680mm
- Seat should be adjusted so that the seat back is not rearward of the B-pillar

Bradtmiller and Gross (2000) outline a method of designing truck cabins. They caution that applying percentile values (eg designing for 95th% male) can have unexpected outcomes due to the variation in combinations of human dimensions. They propose a multivariate approach to optimise cabin design (combining parameters for the purpose of assessment). However, this is not directly applicable to the assessment of vehicles for aged drivers.

A similar study is reported by Bove and others (2006) where occupant size and vehicle characteristics are compared with injury outcomes. This study is useful for understanding dimensional variations in the population but is not directly applicable to the assessment of vehicles for aged drivers

Dufour and Wang (2005) describe advanced computer modelling of people getting into and out of a car. They are developing a method of rating "discomfort" during these manoeuvres. They found that there was more discomfort during egress, compared with ingress.

Barrett (1999) provides advice on choosing a car for people with disabilities but does not give specific recommendations about vehicle dimensions. In essence, the author recommends "try before you buy".

Parenteau and others (2000) evaluate the benefits of having adjustable pedals. A range of pedal dimensions is provided but no firm recommendations are given. An adjustment range of about 115mm seems to be desirable to cater for most drivers.

Nakahama and others (2000) researched retired Nissan employees. 63 were surveyed and 16 took part in usability trials. They found that handholds were a key factor. Recommendations are given for seat height and sill height but the description is ambiguous and difficult to apply to other vehicles.

Recommended dimensions

Seating reference point

Manufacturers and crash test organisations use special machines to simulate the geometry and mass of people when setting up vehicles for crash tests and other engineering tasks. According to Diffrient, Tilley & Harman (1981) the 'H Point' which represents the hip pivot point on the human body, is used to establish seating criteria and therefore it is also referred to as the 'Seat Index Point' or SIP. This reference point is incorporated in the "H-Point machine" as defined in SAE J826 for this purpose.

All vehicle accessibility measurements are intended to be undertaken with the H-point machine.

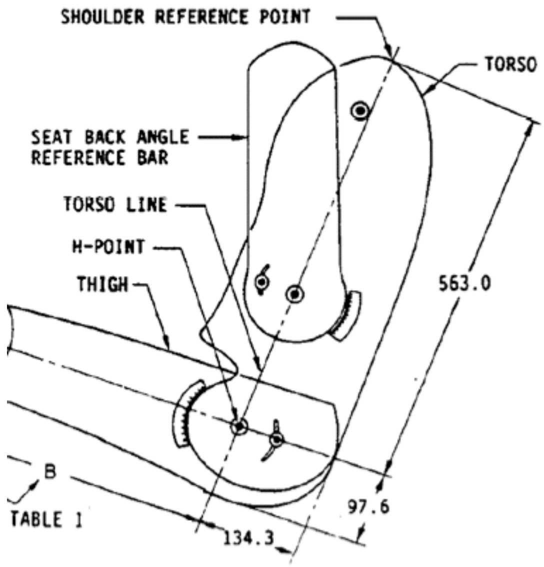

Figure 1. H-point manikin from SAE J826
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Experiments were conducted to determine if valid measurements could be made using a simple template instead of using the H-point manikin. However the manikin weighs about 70kg compared with the simple template (fabricated from dense plastic) weight of 2kg. Seat cushion deflection and vehicle suspension movement resulted in the H-point height reducing by between 25 and 40mm, depending on the vehicle. It was found that the difference between the manikin and the simple template was not predictable and it was concluded that the H-point manikin is necessary for fair and repeatable measurements.

Typical suspension movement of 20mm has been taken into account in the criteria for minimum seat (H-point) height from the ground. This is because the vehicle is not carrying the full weight of the occupant at the critical times of ingress and egress.

Seat position

For all measurements the seat fore-aft adjustment should normally be set at the position that is specified by Euro NCAP for the frontal offset crash test. This is mid-way between the foremost travel and the 95th% male position (normally the rearmost position). However, a frail person might be unlikely to move the seat further rearward than the B-pillar, to avoid the B-pillar interfering with ingress and egress. Therefore, the seat should not be located further rearward than a point where the H-point is in line with the forward edge of the B-pillar (Petzall 1988).

Euro NCAP requires the seat to be in its lowest position. However, for the purpose of assessing ingress and egress this policy would penalise cars with ehight adjustable seats and discourage this desirable feature. Therefore for the seat should be set at mid-height for this assessment. The steps for setting the seat position are:

1. Apply tape to the seat and mark it with height and longitudinal reference lines.
2. Apply tape to the sill so that is in a suitable position for recording the extreme fore and aft movement of the seat.
3. If applicable, drop the seat to its lowest height setting
4. Set any cushion tilt adjustment to its lowest (flattest) position
5. Slide the seat fully rearward (or to 95% position, if this position is provided by the manufacturer) and mark the position on the sill tape.
6. Slide the seat fully forward and mark the position on the sill tape.
7. Determine a point halfway between the rear and front marks and mark this point on the sill tape.
8. Slide the seat until the reference line is aligned with the mid-point on the sill tape
9. If height-adjustable:
    a. measure the height of the seat in its lowest position, using the reference line on the seat.
    b. raise the seat to its highest position and measure the height of the reference line
    c. Determine the mid-point height and adjust the height of the seat to this position. The seat should *not* be adjusted horizontally even though the longitudinal reference line may no longer align with the sill tape mark.
10. Install the H-point manikin in accordance with the manufacturer's instructions.

Key dimensions for rating

On the basis that the rating system is primarily intended for an average-size elderly driver or passenger (the groups typically assessed for the references in the previous section), the following key dimensions and ratings are recommended.

All linear measurements are to be rounded to the nearest 5mm, unless indicated.

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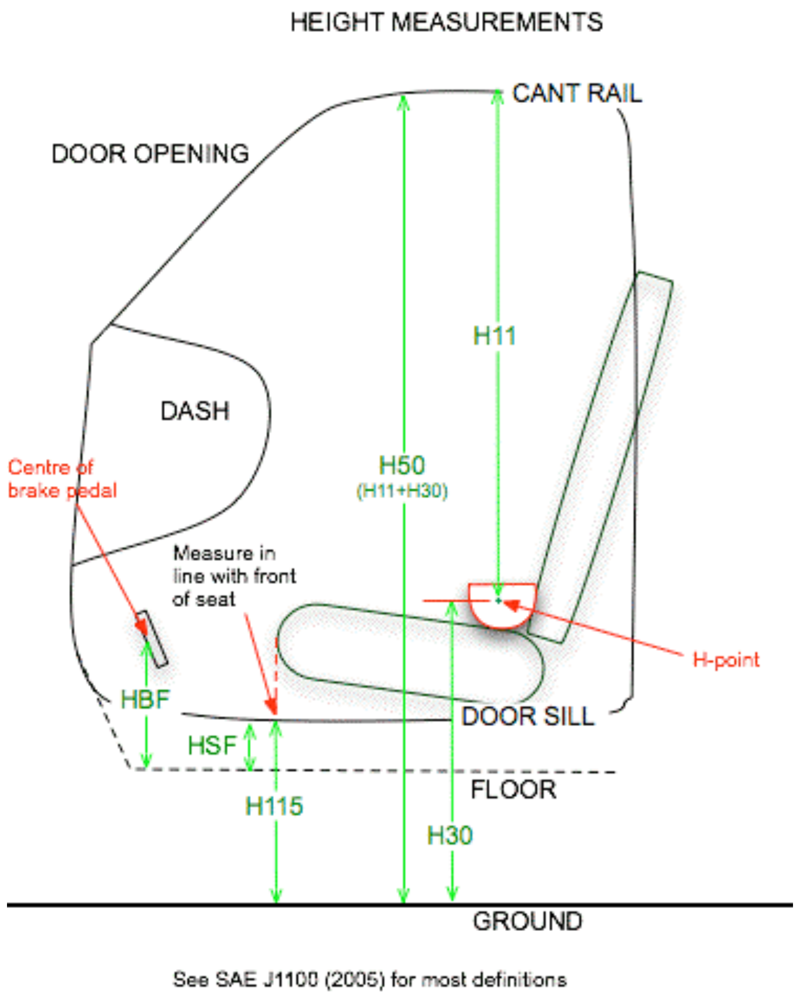

Figure 3. Proposed vertical measurements

Table 1. Vertical Measurements

Code	Description	Good Range	Marginal Ranges	Comments
H30	H-point to ground (mm)	580-700	530-575 705-750	Petzall (1988), and Bodenmiller (2002)
H11	H-point to cant rail (top of door opening) (mm)	700-800	650-699 805-900	Petzall (1988) and Woodson (1970). Upper limit desirable for reaching roof handholds
H115	Door sill to ground (mm)	330-450	0-325 455-500	Petzall (1988) and Bodenmiller (2002)
HSF	Door sill to floor (mm)	0-90	95-110	Petzall (1988), Nakahama (2000) up to 50mm
HHF	H-point to floor (mm)	350-400	300-345 405-450	Woodson (1970)
HBF	Brake pedal to floor (mm)	120-190	100-115 195-220	Parenteau (2000)

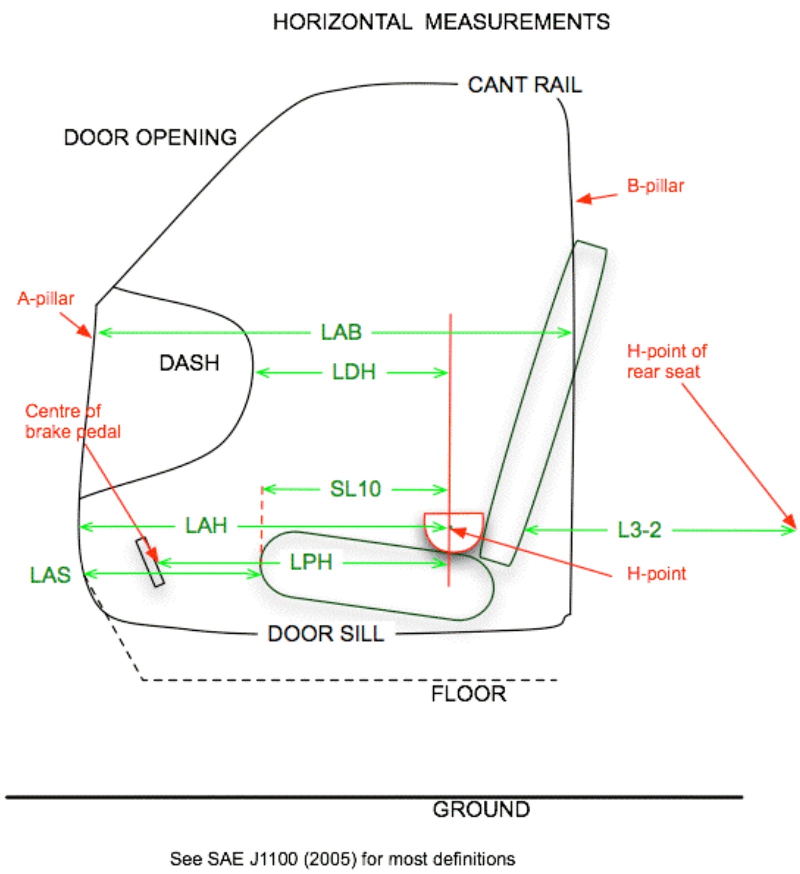

Figure 4. Proposed horizontal (longitudinal) measurements

Table 2 - Longitudinal Measurements

Code	Description	Good Range	Marginal Ranges	Comments
LAB	A-pillar to B-pillar at window level (mm)	600-900	550-595 >900	Petzall (1988) & Woodson (1970)
LDH	H-point to rearmost point of dash (mm)	500-600	450-495 >600	For access & support (driver controls should be less)
SL10	H-point to front of seat (mm)	350-450	300-345 455-500	Woodson (1970)
LAH	H-point to A-pillar at hip height (mm)	700-900	600-695 >900	Petzall (1988).
LAS	Seat front to A-pillar (mm)	350 or more	300-345	Petzall
LPH	H-point to brake pedal (mm)	800-900	750-795 905-950	Parenteau (2000)
L3-2	Rear seat H-point to back of front seat (mm).	600 or more	550-595	Woodson (1970) & bus regulations

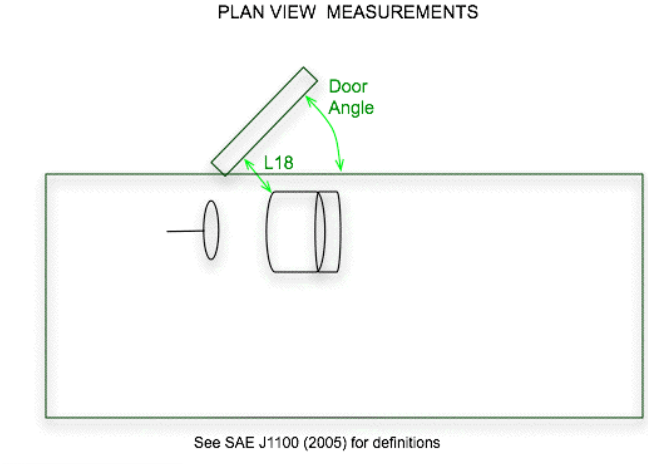

Figure 5. Door clearances

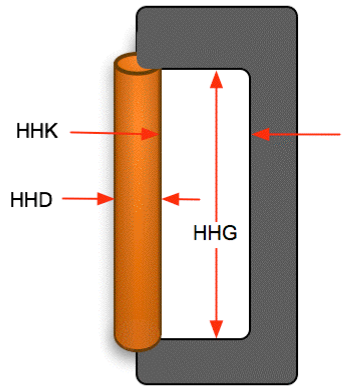

Figure 6. Handholds

Table 3 - Other measurements

Code	Description	Good Range	Marginal Ranges	Comments
L18	Minimum horizontal distance between front corner of seat and fully open door (mm)	350-500	300-345 500-600	Access & reach to door handle
Door angle	Door angle when fully open (degrees)	60-80 degrees	50-59 >80	Access & reach to door handle. Wheelchair access may require larger angle
HHD	Handhold diameter (to nearest mm). If not circular, use the smallest distance through a cross-section. Use minimum/maximum over "grip length".	25-40	15-24 41-60	US Uniform Federal Accessibility Stds. SAE J185 recommends min 16mm for agricultural machinery. Diffrient et al (1981) recommends 25 – 38 mm as “optimum” for cylinder handles.
HHK	Handhold knuckle clearance (to nearest mm) - minimum over "grip length".	38 or more	30-37	US Uniform Federal Accessibility Stds. SAE J185 recommends min 75mm for agricultural machinery Diffrient et al (1981) recommends minimum of 51 mm for the average man/large woman
HHG	Handhold grip length (to nearest mm)	110 or more	95-109	SAE J185 recommends min 150mm for agricultural machinery. 250mm preferred. Diffrient et al (1981) recommends minimum of 108 mm for the average man/large woman to accommodate 4 fingers

Handholds

Table 3 includes dimensional limits for handholds. There should be at least one handhold on the ceiling or pillar, close to the top of the door opening. There should be another handhold on the interior of the door. Handholds must be strong enough to easily support the full weight of a person (worse case scenario).

The handhold should allow all fingers of one hand to wrap around it. Recesses in trim are not regarded as handholds because frail people are unable to grip them firmly enough to maintain stability. If any radius of the graspable part of the device is less than 3mm or is a sharp edge then it should not be treated as a handhold.

Nakahama and others (2000) suggest a handhold on the b-pillar would be useful. However, it is not clear how this might be achieved with modern vehicle designs. A handhold on the end of the dash, that is concealed by the door trim when the door is closed, might be a practical alternative to a b-pillar handhold.

Sample measurements

The appendix contains a range of measurements from sample vehicles. These are based on provisional measurements of three vehicles (2003 Renault Clio hatch, 2004 Subaru Outback wagon and 2000 Honda Odyssey minivan) and the data reported by Bodenmiller & others (2002) for a 2001 Pontiac Bonneville sedan, 2001 Oldsmobile Silhouette minivan and a 2000 Chevrolet Silverado.

The proposed rating agree with Bodenmiller's conclusion that the minivan provided the optimal design for ingress and egress for the majority of test subjects in their field study.

Discussion and Recommendations

The authors have had personal experience, over several years, with transporting partially disabled adults in the three vehicles that were provisionally assessed. Both adults needed to use a walking frame when standing or walking. Their balance and leg strength was poor. The best vehicle of the three was the Honda Odyssey. Next was the Subaru Outback, which they found more difficult to get out of. For a small car, the Clio was reasonable but was noticeably more difficult to use than the other two vehicles. These findings are in agreement with Bodenmiller and others (2002).

One author has had significant experience transporting large numbers of individuals with various disabilities as passengers as well as advising regarding driver cabin design for drivers with disabilities. It is not possible to define parameters that are optimal for all occupants under all circumstances as individual factors need to be considered such as body shape and weight as well as joint or mobility restrictions. Several of the reviewed papers and brochures pointed out the need to try out the vehicles wherever possible This is particularly the case where the users are much taller or much shorter than "average".

Other factors such as design and location of handholds are also important for ingress and egress. Also some parameters that are best for ingress/egress may make other tasks more difficult, such as operation of driver controls (Ellis and Talbot, 2006)..

Subject to these precautions, it is recommended that ranges shown in Tables 1,2, and 3 be used for a provisional rating of the accessibility of vehicles.

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Appendix - Provisional vehicle assessments

The following table sets out the results of approximate measurements of key vehicle dimensions. Proposed ratings are indicated by colours: green=good, yellow=marginal, red=poor.

Provisional Measurements (mm)

Measurement	Renault Clio 01 Hatch	Subaru Outback 04 Wagon	Honda Odyssey 97 Minvan	Pontiac Bonneville 01 Sedan	Oldsmobile Silhouette 01 Minivan	Chevrolet Silverado 00 Pickup
H11 Hpt-cant rail	750	765	810			
H30 Hpt-ground	530	560	670	520	680	890
H50 (H11+H30) Cant rail-ground	1310	1325	1510			
H115 Sill-ground	360	420	410	380	420	530
HSF Sill-floor	110	90	80			
L12 Door clearance	400	365	450			
LDA A-B pillar	850	845	760			
LAH Hpt-Apillar	780	685	750			
LAS Seat-Apillar	420	370	460			
SL10 Hpt-seat front	380	300	380			
LDH Hpt-dash	600	470	590			
L3-2 Rear seat knee	520	660	690			
LPH Hpt-pedal	830	800	810			
HHD - roof Handhold dia	17x28	17x25	12x20			
HHK - roof Knuckle	40	40	33			
HHG - roof Grip length	130	100	95			
HHD - door Handhold dia	Recess	25x40	Recess			
HHK - door Knuckle	Recess	40	Recess			
HHG - door Grip length	Recess	140	Recess			