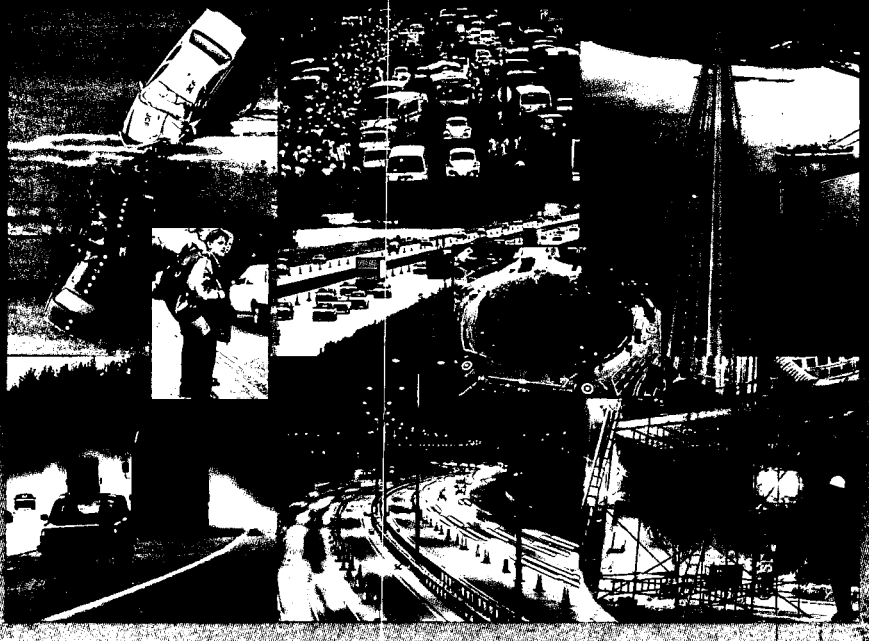

A survey of occupied wheelchairs to determine their overall dimensions and characteristics

by R E Stait and T A Savill

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TRL Report 150

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TRL REPORT 150

A SURVEY OF OCCUPIED WHEELCHAIRS TO DETERMINE THEIR OVERALL DIMENSIONS AND CHARACTERISTICS

by R E Stait and T A Savill

Prepared for: Project Record: PRS304J Wheelchairs in Motor Vehicles
Customer: Mobility Unit, DOT (Mr E Stait)

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EXECUTIVE SUMMARY

There is a lack of data on the basic dimensions of people in their wheelchairs. This information is needed to assist in the design of wheelchair accessible transport vehicles and the associated infrastructure. The aim of this report was to gather this information and to determine the types of wheelchair in use.

At the 1991 Mobility Roadshow, photographs were taken of 382 people in their wheelchairs. The people were photographed from the front and side, with black/white checkerboards immediately behind the wheelchair. From these photographs, a variety of data was gathered, including the type of wheelchair used, features on the chair such as rests and supports, and basic dimensions.

A wide range of wheelchairs were photographed, with the most popular type being the rear wheel drive traditional chair (48 per cent), followed by the modern version of this chair (17 per cent) and electrically driven chairs (17 per cent). Seven per cent of the chairs were designed to be pushed by an attendant and six per cent were scooters. Just over half the people photographed were male and the sample included 11 per cent estimated to be below the age of 18 years and 17 per cent over the age of sixty.

Eighty two per cent of the chairs were fitted with manually operated brakes, and most of those not fitted with brakes were modern rear wheel drive wheelchairs. Where it could be determined, 78 per cent of wheelchairs could be folded. Electrically driven chairs and scooters accounted for over three quarters of those that could not be folded.

Nearly all the wheelchairs were fitted with armrests (81 per cent) and footrests (92 per cent), but less than five per cent had head or leg supports. Half the occupants were sitting on a cushion and 13 per cent were carrying an additional walking aid. Of those carrying luggage, three quarters carried it on the rear of their chair.

The maximum, minimum, mean and 5th and 95th percentiles were computed for the height and length of the occupant plus wheelchair, and for the width of the wheelchair itself. The mean for these respectively were 1247mm, 1070mm and 606mm. These data are listed by wheelchair type where there are large differences between each class. Overall these results showed close agreement with previous work by Hall and Silcock (1985).

It is concluded that the information contained in the report should help people designing wheelchair accessible transport systems.

A SURVEY OF OCCUPIED WHEELCHAIRS TO DETERMINE THEIR OVERALL DIMENSIONS AND CHARACTERISTICS

ABSTRACT

In order to provide basic information on the dimensions of people in their wheelchairs, photographs were taken of 382 visitors at the 1991 Mobility Roadshow. From these, the height, width and length of people in their wheelchairs were computed. The wheelchairs were classified into one of eight groups and features such as whether the chair could be folded were also noted. It was found that a wide variety of wheelchairs were in use, and it is hoped that the information will aid designers of wheelchair accessible transport systems.

1. INTRODUCTION

In order for transport systems to be accessible to people in wheelchairs, it is important to know what the access requirements are. The designers of wheelchair accessible buses would, for example, need to know the width of occupied wheelchairs when specifying a door width. Information on the basic overall dimensions of people in their wheelchairs has a potentially wide area of application. It is surprising, therefore, that little research has been carried out in this area. Previous work has been carried out by Fenwick (1978) and Hall and Silcock (1985). Fenwick (1978) looked at NHS wheelchairs and mainly considered the dimensions of the user with the aim of helping with the design of future wheelchairs. Hall and Silcock (1985) studied wheelchairs in use in North Tyneside. The report had only a small section on dimensions, but it still contained very useful information, such as maximum, minimum and percentile values for the height and width of people in their wheelchairs.

The aim of the present study was to gather information on the basic dimensions of people in their wheelchairs and to determine whether these have changed since the Hall and Silcock (1985) study. Additional information, such as whether people were using headrests or leg supports was also required. It was also of interest to see how dimensions of people in their wheelchairs compare with access dimensions of unoccupied wheelchairs given in ISO 7193 (1985). This standard covers both manual and electric chairs. BS 5568 (1978) also gives recommended wheelchair dimensions, but is only concerned with folding chairs.

Every two years since 1983 the Department of Transport has held a major event at TRL where disabled motorists can view car adaptation products and test drive standard production cars adapted for use by disabled people. This event is called the Mobility Roadshow and is attended by approximately 40,000 people over three days (Friday to Sunday). It was decided to carry out the study at the Roadshow because of the large number of visitors and their interest in using transport. The sample may, however, be biased towards those who use personal transport as the Roadshow is predominantly concerned with this. It should be noted that, although most of the visitors were in their own wheelchairs, a small number were using trial or demonstration models from various manufactures at the show.

2. METHOD

In the reception area at the 1991 Mobility Roadshow a stage was set up consisting of two vertical black/white checkerboards perpendicular to each other. These were used to provide a standard background and to aid with the measuring. Two cameras were positioned, one viewing each board. As the wheelchair users came through the reception area, they passed the stand and were asked if they were willing to have their photograph taken, the purpose of the study being briefly explained. The wheelchair user was then asked to position him or herself as close as possible to the corner where the two boards met (Figure 1). One photograph was taken of the right hand side view and one of the front view. Photographs were taken on all three days of the Roadshow.

From each photograph, the type of wheelchair, its features and the age and sex of the occupant were noted. In addition, three dimensions were measured. Details of the type and features of the wheelchairs and the dimensions taken are given below.

2.1 WHEELCHAIR TYPES

The type of wheelchair in which each person was photographed was recorded into one of eight classifications:

Rear wheel drive (Rwd) traditional chairs
These are chairs such as the NHS model 8L which are manually driven from the rear wheels.

Rear wheel drive (Rwd) modern chairs
These are chairs manually driven from the rear wheels but are of a modern lightweight construction. They are often recognisable by their bright colours, negative camber on the rear wheels and adjustable wheelbase.

Electrically driven chairs
An electrically driven chair was taken to be any four wheeled chair that was battery powered and controlled by the use of a small joystick or other similar device.

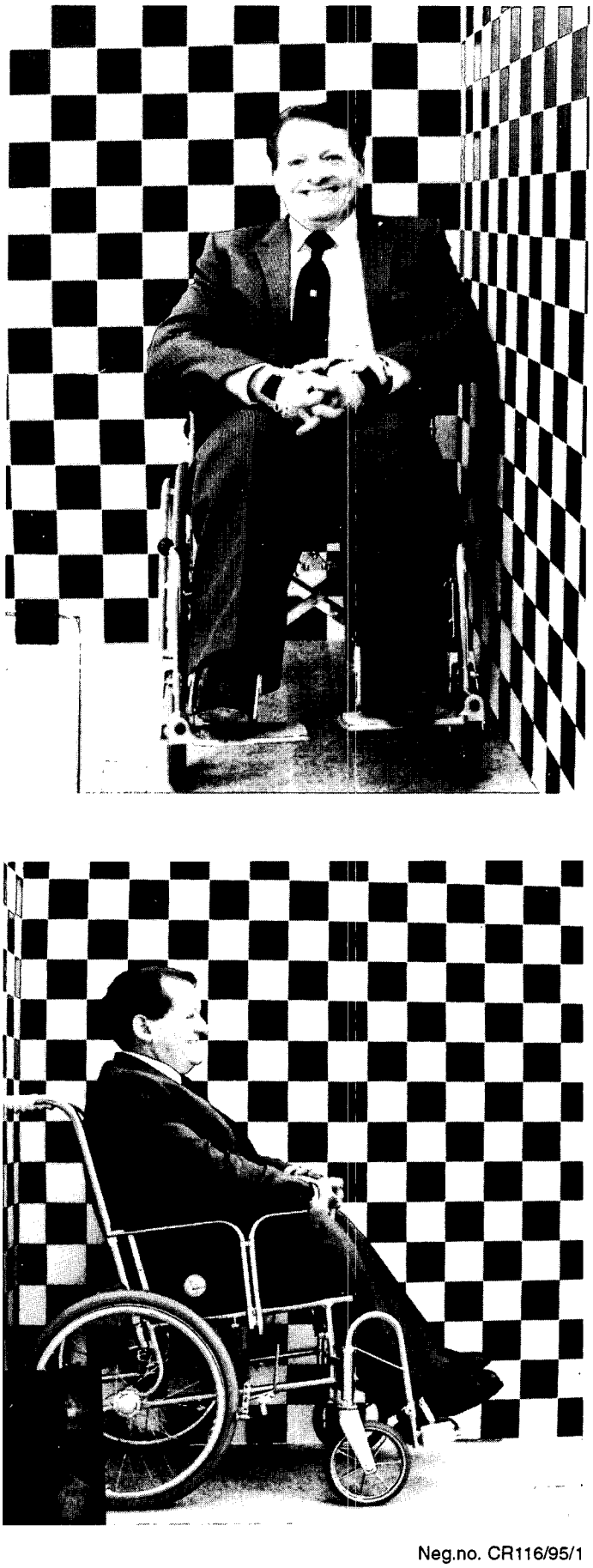

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Fig. 1

Attendant propelled chairs

A chair which is pushed by an attendant[1]. These have small wheels at the rear, such as the NHS model 9L.

Electric scooters

Three or four-wheeled electric-powered wheelchairs steered from the front by 'handlebars'.

Car chair

These are a special type of electrically driven chair which fit into an adapted car to replace the driver or passenger seat.

Front wheel drive (Fwd) traditional chairs

These are traditional style chairs manually driven from the front wheels.

Manual to electric conversions

These are manual chairs which have been converted so that the rear wheels can be electrically powered.

2.2 WHEELCHAIR FEATURES

The presence of a number of features on the wheelchairs was noted from the photographs. These are listed below.

- Manually operated brakes
- Whether the chair could be folded
- Armrests
- Footrests
- Leg supports
- Head supports
- Additional walking aids carried by the occupant
- Use of a cushion[2]
- Whether the user was carrying any luggage with them or on the chair, and if so where it was being carried.

It is possible that some chairs had features that were not visible in the photographs. The presence or otherwise of manually operated brakes, cushions, and provision for folding were particularly difficult to detect on some photographs.

2.3 WHEELCHAIR DIMENSIONS

The dimensions were calculated by scaling from the checkerboards and using trigonometry. Figure 2 shows this method when calculating the length. Dimensions 'a' and 'b' were measured from the photographs and then used to calculate 'x'.

Height

The distance from the highest point (almost always the occupant's head) to the ground.

Length

The furthest point back (either user or wheelchair), to the furthest point forward (either user or wheelchair).

Width

The maximum width of the wheelchair itself.

These measurements are illustrated in Figure 3.

3. RESULTS

3.1 WHEELCHAIR TYPES AND DETAILS OF OCCUPANTS

A total of 382 people were photographed at the Roadshow over the three days. Eleven per cent were judged to be under the age of 18 years and 17 per cent were over sixty. Fifty two per cent of the sample were male (see Table 1). There were more males than females photographed using rear wheel drive modern chairs and car chairs, with males accounting for 67 and 75 per cent of use respectively. Females accounted for 72 per cent of those using attendant propelled chairs. Within most of the remaining classes of wheelchair type there was an even split of male and female users.

Nearly half of all wheelchairs used were traditional rear wheel drive manual chairs. Electrically driven chairs and rear wheel drive modern chairs were the next most widely used, each accounting for 17 per cent (see Table 1).

3.2 WHEELCHAIR FEATURES

Manually operated brakes

It was noted whether the wheelchair had a brake operated by a lever. Although only visible brakes were noted, many scooters, electrically driven chairs and car chairs would have some braking mechanism in the drive system of the chair. If these three types are excluded, then only 4.2 per cent of all wheelchairs had no visible brake, and the majority of these were rear wheel drive modern chairs (Table 2). Since the photographs were used to discern whether the wheelchairs had manually operated brakes, it is possible that although some did, these were not visible from the photographs.

Folding chairs

Table 2 shows that, where it could be determined, 78 per cent of wheelchairs could be folded. The majority of those not folding were scooters or electrically driven chairs (79 per cent).

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1 Some rear wheel drive traditional chairs were being used as attendant propelled chairs, with a helper always pushing the chair. These were still treated as rear wheel drive chairs.

2 A separate cushion, not including any padded upholstery.

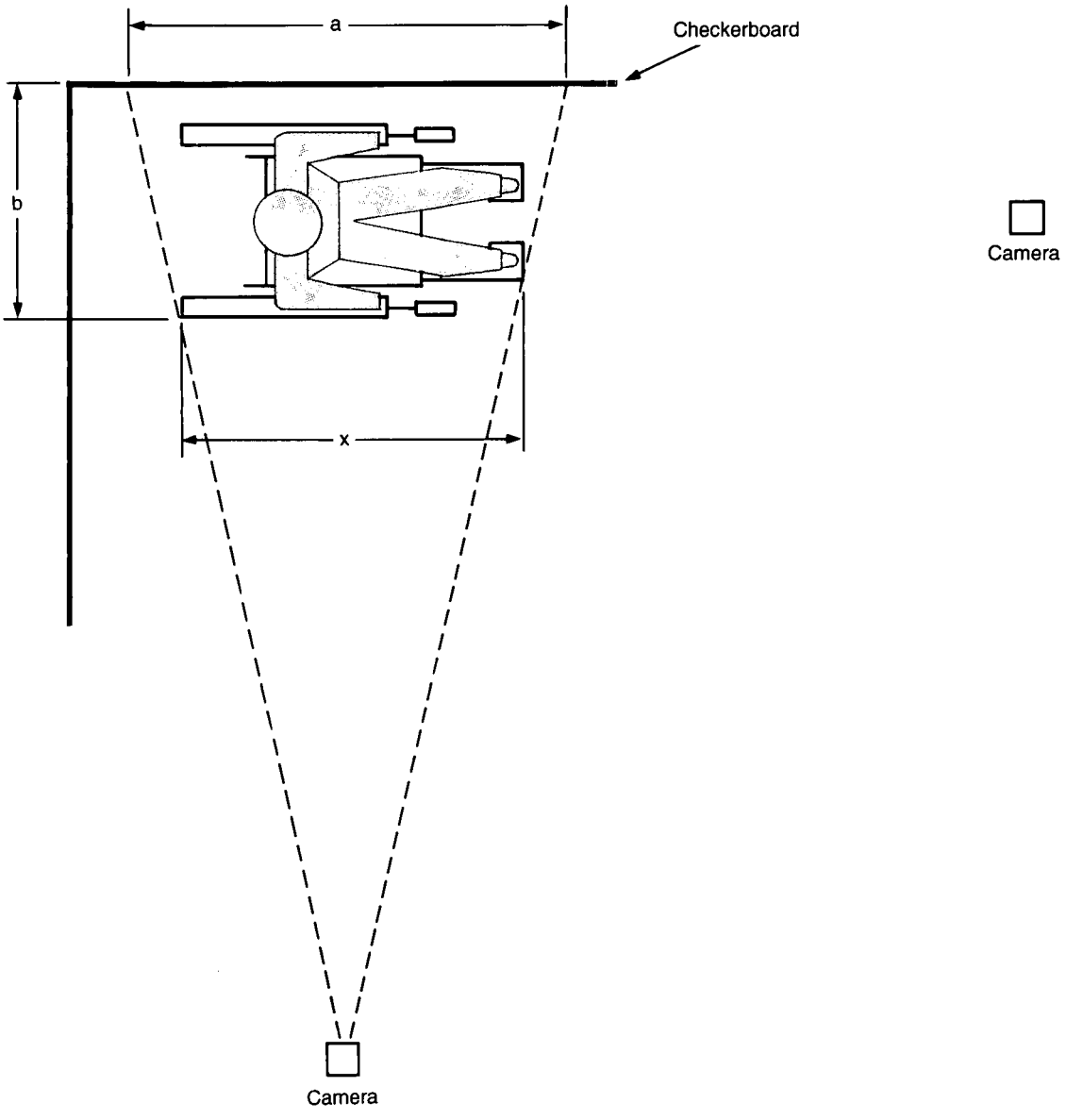
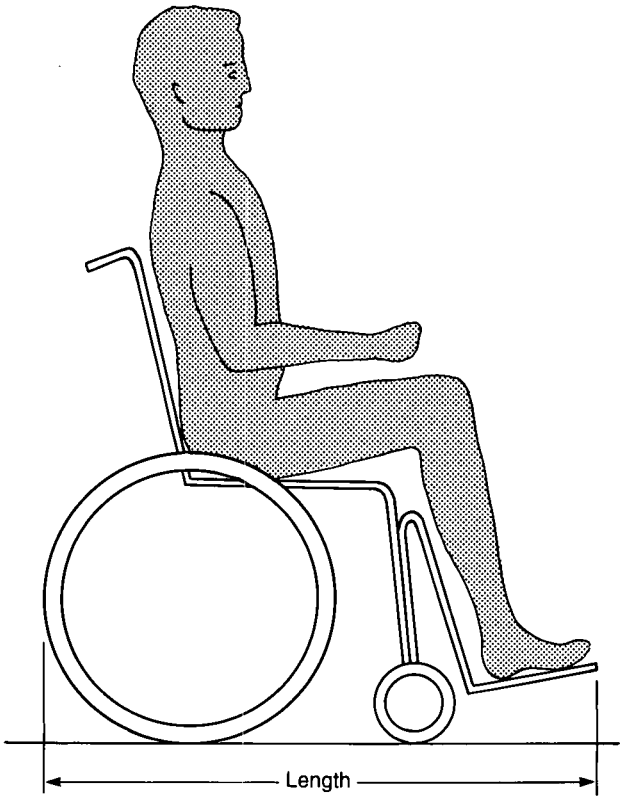


Fig. 2



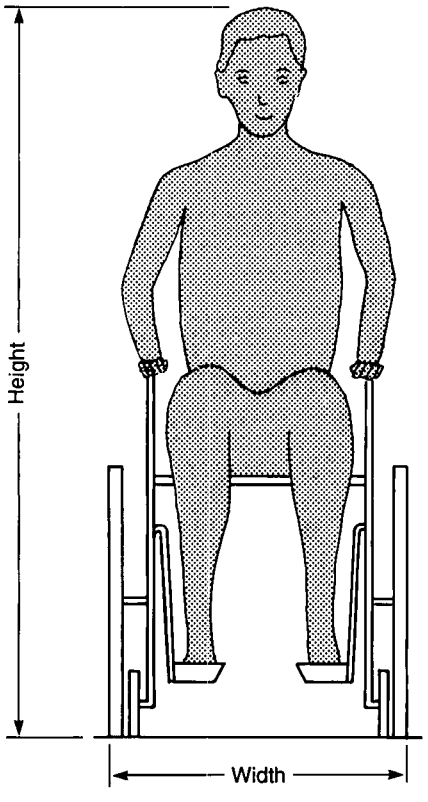


Fig. 3

TABLE 1

Type of wheelchair used tabulated by age and sex of occupant.

	Age				Sex		
	0 - 10	11 - 17	18 - 60	61+	Male	Female	Total (%)
Rwd manual traditional	4	12	131	37	93	91	184 (48)
Rwd manual modern	1	7	58		44	22	66 (17)
Electrically driven chair	3	10	45	8	32	34	66 (17)
Attendant propelled	4	1	12	8	7	18	25 (7)
Electric scooter			14	8	10	12	22 (6)
Car chair		1	6	1	6	2	8 (2)
Fwd manual			5	1	3	3	6 (2)
Manual to electric			4	1	3	2	5 (1)
Total (%)	12 (3)	31 (8)	275 (72)	64 (17)	198 (52)	184 (48)	382 (100)

TABLE 2

Whether the chair could be folded or had brakes.

	Brakes		Folding chair			
	Yes	No	Yes	No	D/K*	Total (%)
Rwd manual traditional	184		175	2	7	184 (48)
Rwd manual modern	56	10	37	4	25	66 (17)
Electrically driven chair	32	34	13	34	19	66 (17)
Attendant propelled	24	1	20		5	25 (7)
Electric scooter	1	21		22		22 (6)
Car chair	7	1		8		8 (2)
Fwd manual	5	1	5		1	6 (2)
Manual to electric	5		1	1	3	5 (1)
Total (%)	314 (82)	68 (18)	251 (66)	71 (18)	60 (16)	382 (100)

* = Don't know / Not known

Armrests

Most of the wheelchairs (81 per cent) were fitted with armrests (Table 3). Rear wheel drive modern chairs accounted for two thirds per cent of those with no arm rest. In this group of chairs there were more without armrests (71 per cent) than with armrests (29 per cent).

Footrests

Footrests were fitted on 92 per cent of wheelchairs (Table 3). There were no major variations in the type of chair not having a footrest.

Leg supports and head supports

Leg supports and head supports were not widely used, with just 3 per cent of wheelchairs having a leg support and 3 per cent using a head support (Table 3).

Use of cushions

In 48 per cent of cases, it was possible to tell that the occupant was using a cushion of some kind (Table 4). It is possible that more people were using a cushion but that this could not be seen from the photograph.

Additional walking aids

Thirteen per cent of all people photographed were carrying some form of walking aid, ranging from a single walking stick to a pair a crutches (Table 4). Although most of those carrying a walking aid were using rear wheel drive traditional chairs, they only accounted for 15 per cent of this group. In contrast, 41 per cent of those using an electric scooter and 24 per cent of those using an attendant propelled chair were carrying some form of walking aid. These figures might be a slight underestimation of those carrying walking aids, as some could have been handed to friends or helpers before the photographs were taken.

Luggage carried

When noting whether the person was carrying luggage, any small bags, such as handbags were ignored, as were any papers. The luggage was classified into whether it was carried on the front, side or rear of the wheelchair or on the person's lap. Just over half the sample were carrying some form of luggage with them (Table 5). This might be a slight underestimation of those carrying luggage as some bags could have been handed to friends or helpers before the photographs were taken. Three quarters of those carrying luggage were carrying it on the rear of their chair.

3.3 WHEELCHAIR DIMENSIONS

The dimensions were calculated by scaling from the checkerboards and using trigonometry. Validation checks were carried out on the measurement method by photographing and then physically measuring a person in a wheelchair. The actual dimensions of the wheelchairs were verified using manufacturer's data where possible. The two sets of measurements were then compared, giving an average error of 1.9 per cent, with the highest found being 4 per cent.

TABLE 3

Details of equipment fitted to the chairs.

	Arm rest		Foot rest		Leg support		Head support		
	Yes	No	Yes	No	Yes	No	Yes	No	Total (%)
Rwd manual traditional	164	20	164	20	9	175		184	184 (48)
Rwd manual modern	19	47	65	1		66		66	66 (17)
Electrically driven chair	65	1	58	8	3	63	6	60	66 (17)
Attendant propelled	24	1	23	2		25	3	22	25 (7)
Electric scooter	21	1	22		1	21	1	21	22 (6)
Car chair	8		7	1		8		8	8 (2)
Fwd manual	5	1	6			6		6	6 (2)
Manual to electric	5		5			5		5	5 (1)
Total	311	71	350	32	13	369	10	372	382
(%)	(81)	(19)	(92)	(8)	(3)	(97)	(3)	(97)	(100)

TABLE 4

Use of additional walking aids and cushions.

	Cushion			Walking aid		
	Yes	No	D/K	Yes	No	Total (%)
Rwd manual traditional	100	55	29	28	156	184 (48)
Rwd manual modern	37	21	8	1	65	66 (17)
Electrically driven chair	28	15	23	5	61	66 (17)
Attendant propelled	10	12	3	6	19	25 (7)
Electric scooter	1	19	2	9	13	22 (6)
Car chair	3	4	1		8	8 (2)
Fwd manual	3	1	2		6	6 (2)
Manual to electric	2	3			5	5 (1)
Total (%)	184 (48)	130 (34)	68 (18)	49 (13)	333 (87)	382 (100)

TABLE 5

Position of luggage.

	None	Front	Side	Rear	Side and Rear	Total (%)
Rwd manual traditional	92	27		65		184 (48)
Rwd manual modern	36	4		26		66 (17)
Electrically driven chair	17	1	1	44	3	66 (17)
Attendant propelled	11	1		12	1	25 (7)
Electric scooter	9	11	1	1		22 (6)
Car chair	3	1	1	3		8 (2)
Fwd manual	2			4		6 (2)
Manual to electric	4			1		5 (1)
Total (%)	174 (45)	45 (12)	3 (1)	156 (41)	4 (1)	382 (100)

Height

The height was measured, using the photographs, as the maximum distance from the highest point (almost always the person's head) to the ground (see Figure 3). Due to the weather at the Roadshow in 1991, some of the participants were wearing hats or hoods. When this was the case, the top of the person's hat or hood was taken as the highest point. Table 6 gives a summary of the height measurements for each type of wheelchair, and includes the maximum and minimum for each type of chair, the mean, and 5th and 95th percentiles[3]. In some cases in the table the percentiles and max / min values are the same. This is because of the small sample sizes involved.

Figure 4 gives a histogram showing the heights with a normal curve[4] of the same mean and standard deviation superimposed over the data. A significance test at the 5% level shows there is no significant difference between the observed values and those of the theoretical normal distribution with the same mean and variance.

TABLE 6

Height of chair / user (mm).

	Max	Min	Mean	Percentiles 5	95
Rwd manual traditional	1403	962	1227	1068	1348
Rwd manual modern	1441	1059	1258	1106	1371
Electrically driven chair	1407	937	1265	1107	1395
Attendant propelled	1333	1059	1191	1064	1324
Electric scooter	1513	1244	1372	1253	1507
Car chair	1369	1113	1261	1113	1369
Fwd manual	1320	1056	1215	1056	1320
Manual to electric	1429	1239	1311	1239	1429
All chairs	1513	937	1247	1092	1377

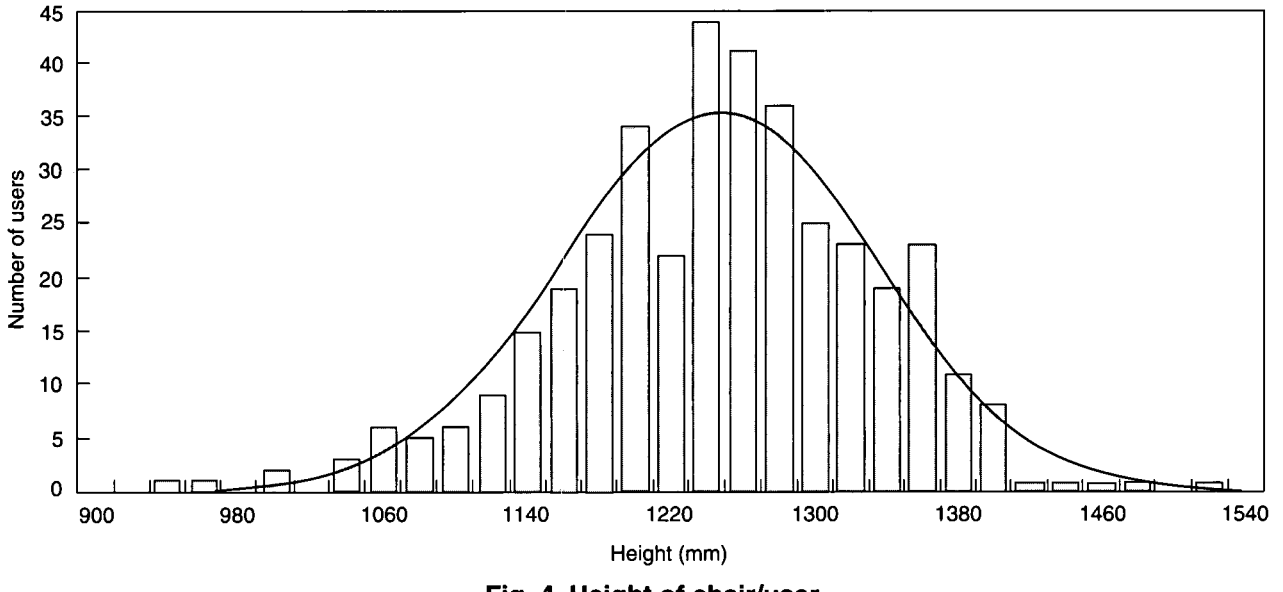


Fig. 4 Height of chair/user

3 Nearly all (95 per cent) of the sample have values greater than the 5th percentile. Nearly all (95 per cent) of the sample have values less than the 95th percentile. For example with electrically driven chairs, 95 per cent of wheelchair users are below 1395mm in height.

4 The normal curve is the graph of the probability density function of the normal distribution.

Length

The length was measured from the furthest point back (either user or wheelchair), to the furthest point forward (either user or wheelchair) (see Figure 3). Normally this measurement was from any handles used for pushing the chair to the users feet or the footrest of the chair, measured horizontally along the ground. Table 7 gives summary measurements for each type of chair. The numbers in brackets give the values when those using leg supports are excluded.

Figure 5 shows a histogram of the lengths with a normal curve of the same mean and standard deviation superimposed over the data. As with the height, a significance test at the 5% level shows no significant difference between the observed values and those of the theoretical normal distribution with the same mean and variance.

TABLE 7

Length of chair / user (mm).

	Max	Min	Mean	Percentiles 5	Percentiles 95
Rwd manual traditional	1363 (1315)	803 (803)	1071 (1060)	896 (893)	1260 (1218)
Rwd manual modern	1236	819	1040	870	1172
Electrically driven chair	1222 (1222)	825 (825)	1065 (1063)	951 (949)	1164 (1164)
Attendant propelled	1287	832	1040	854	1261
Electric scooter	1451 (1451)	1032 (1032)	1211 (1206)	1033 (1033)	1447 (1449)
Car chair	1245	856	1048	856	1245
Fwd manual	1165	891	998	891	1165
Manual to electric	1251	1019	1160	1019	1251
All chairs	1451 (1451)	803 (803)	1070 (1064)	896 (893)	1243 (1225)

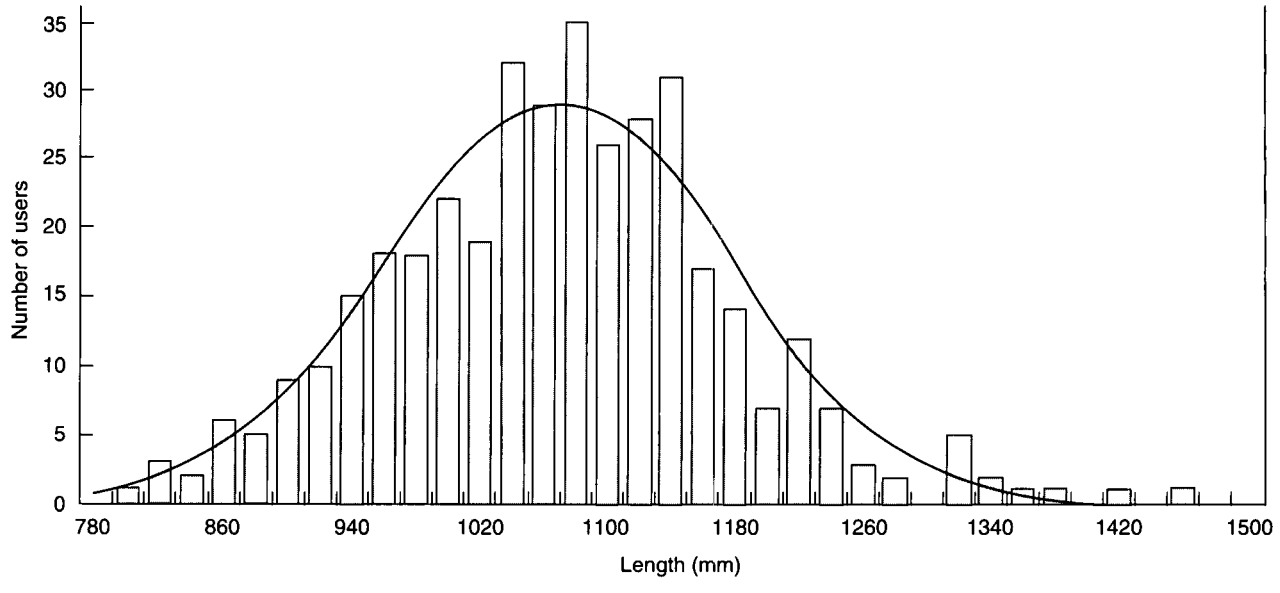


Fig. 5 Length of chair/user

Width

The width was taken to be the measurement of the maximum width of the wheelchair itself (see Figure 3). Anything protruding from the side of the wheelchair, for example the users elbows, were not included. Table 8 gives summary measurements for each type of chair.

Figure 6 shows a histogram of the widths with a normal curve of the same mean and standard deviation superimposed over the data. Unlike height and length, the width does not involve the wheelchair user, and does not fit well to a normal curve as each type of chair has a standard width. As a result, the histogram shows two large peaks, around 584mm and 624mm. These can be tied in with the mean values for certain types of chair. The peak at 584mm is near to the mean values of four types of chair - rear wheel drive traditional, attendant propelled, car chairs and manual to electric conversions. The peak at 624mm is nearer to the remaining four types of chair. Extreme values are accounted for by special adaptations. Again a significance test at the 5% level shows the observed values follow a normal distribution.

TABLE 8

Width of wheelchair (mm).

				Percentiles	
	Max	Min	Mean	5	95
Rwd manual traditional	710	447	598	543	652
Rwd manual modern	691	546	622	555	679
Electrically driven chair	735	535	619	545	673
Attendant propelled	657	506	590	507	655
Electric scooter	681	549	610	550	676
Car chair	636	555	583	555	636
Fwd manual	643	584	607	584	643
Manual to electric	622	572	596	572	622
All chairs	735	447	606	550	664

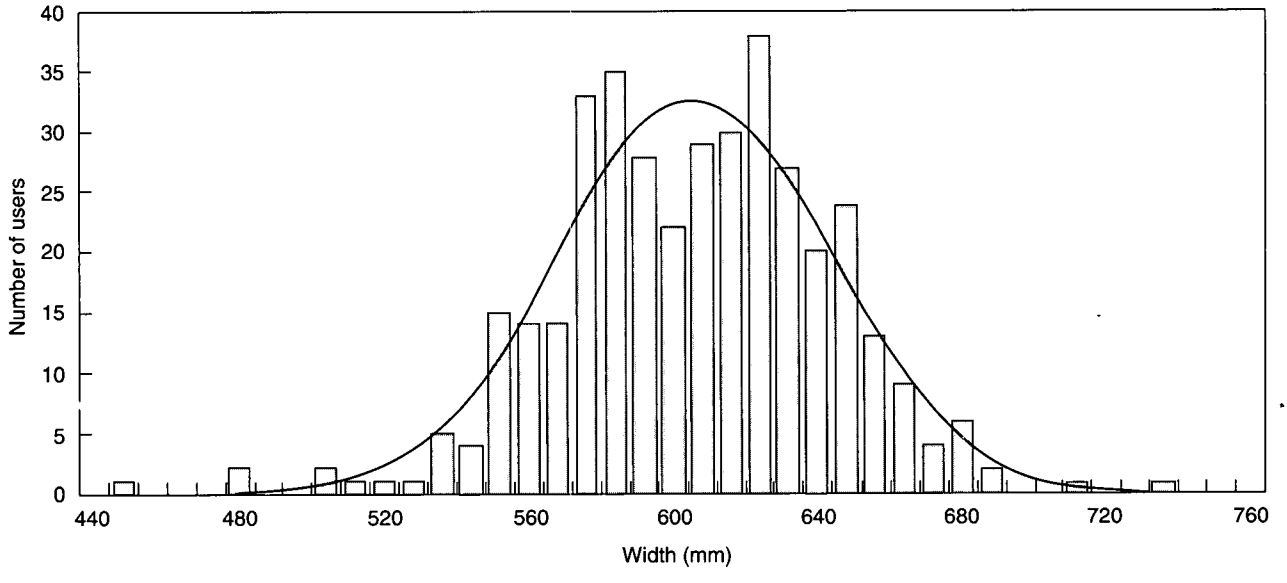


Fig. 6 Width of chair

Comparison of data with Hall and Silcock (1985)

A comparison with the results from Hall and Silcock (1985) is given in Table 9. Only width and height can be compared since Hall and Silcock measured the length of the chairs, and not the chair and user. In their study the respondents and wheelchairs were physically measured, with 159 measured for height and 364 for width. The maximum and minimum values for height differ quite a lot, although the Hall and Silcock study did not include any outdoor scooters, which tend to have higher seats than other types of wheelchairs. If these are excluded, then the mean falls to 1239mm (3.2 per cent difference) and the maximum to 1441mm (6 per cent difference). This difference is significant at the 5% level. Differences in height can also be accounted for by the greater proportion females in the Hall and Silcock study (68 per cent compared to 48 per cent in the present study). In addition, Hall and Silcock carried out their survey in North Tyneside, and refer to work showing that people from the north of the country are marginally shorter those in the rest of England and Wales. Comparing the widths gives a much closer result between the two studies, with the overall mean being just 0.3 per cent different between the two studies. A significance test at the 5% level suggests this difference is not significant.

4. DISCUSSION

Photographs were taken of 382 people in their wheelchairs at the 1991 Mobility Roadshow. This method proved to be a quick and unobtrusive means of obtaining a large amount of information of people and their wheelchairs.

It was found that people were using a wide variety of wheelchairs, although nearly half of those photographed were traditional rear wheel drive chairs. Seventeen per cent of chairs were the modern version of this chair and most of the people using these were male.

Within the eight wheelchair classifications, there were variations such as whether the chair had manually operated brakes or whether it could be folded. Overall, it was estimated that 82 per cent of the chairs had brakes and 66 per cent could be folded. However, these may be underestimations as these features were not always discernable from the photographs. Features such as arm and footrests and leg and head supports will affect the overall dimensions of the chair. Nearly all those photographed were using armrests (81 per cent) or footrests (92 per cent). However, very few people were using leg or head supports.

Thirteen per cent of those photographed were carrying an additional form of walking aid, such as crutches or a walking stick. In addition, around half the sample were carrying luggage on their lap or on the chair.

It was found that the height and length of the people in their chair were normally distributed with an overall mean of 1247 and 1070mm respectively. The mean width of the wheelchair itself was found to be 606mm, and this compared well to the work by Hall and Silcock (1985) who found a mean of 608mm.

ISO 7193 (1985) gives maximum values for the length, width and height of wheelchairs. The maximum width quoted in ISO 7193 of 700 mm compares well with that found in the present study, where only two of the 322 cases of manual and electric chairs were over this value. ISO 7193 also gives an overall length of 1,200 mm but adds that the user's feet add approximately 50 mm to this. This is slightly below the maximum length of 1363 mm found in the present study.

As with the international standard, BS 5568 (1978) is also only concerned with the wheelchair itself. Here a value of 660mm is given as a maximum for adult folding or collapsible wheelchairs. Ninety four per cent of the 251 folding chairs in the present study were found to be below 660mm.

The dimensions of people in their wheelchairs should be of interest to a wide variety of people, but is especially aimed at those specifying designs for wheelchair accessible forms of transport such as taxis, trains and public service vehicles. Rather than using ISO 7193 (1985) or BS 5568 (1978) as a guide to access requirements, designers should be encouraged to consider the overall dimensions of *occupied* wheelchairs. Designers should also be encouraged to cater for all or almost all wheelchair users - and the 5th and 95th percentile dimensions presented in this report should assist them to do this.

TABLE 9

Comparison of dimensions with previous work.

	Height			Width		
	Max	Min	Mean	Max	Min	Mean
Present study	1513	937	1247	735	447	606
Hall and Silcock	1360	870	1200	730	470	608
% difference	11.3	7.7	3.9	0.7	5.1	0.3

It should be noted that there were some problems with the measurement technique. The wheelchair users were asked to manoeuvre into a corner where the checkerboards met, which sometimes caused problems with less manoeuvrable chairs. This made the measuring stage difficult since the chairs were not always central or in the whole picture. Future work in this area should consider means of simplifying the procedure further.

5. CONCLUSIONS

Three hundred and eighty two people were photographed in their wheelchairs. A wide variety of wheelchairs were included in the study, and the dimensions in particular should be of use to people involved in creating wheelchair accessible forms of transport.

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