A survey of occupied wheelchairs to determine their overall dimensions and weight: 1999 survey

Prepared for Mobility and Inclusion Unit, Department of the Environment, Transport and the Regions

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Executive Summary

Information on the basic dimensions of people in their wheelchairs is needed to ensure accessibility for people with disabilities to transport and buildings. TRL Limited was commissioned by the Department of the Environment, Transport and the Regions (DETR) to carry out a survey of visitors to the 1999 Mobility Roadshow. This survey collected data on the overall dimensions and weight of people in their wheelchairs together with details about the wheelchair used, in order to update previous research carried out by TRL in 1991 (Stait and Savill, 1995). Comparisons were also made with the International Standards Organisation ISO 7193 (1985), which states the maximum overall dimensions of unoccupied wheelchairs, the British Standard for folding or collapsible wheelchairs, BS 5568 (1978), and previous work by Hall and Silcock (1985) and Fenwick (1977). The combined weight of wheelchair and user was compared against the recommended safe working load for lifts given in the British Standard for lifts associated with vehicles, BS 6109: Part 2 (1989), the British Standard for powered lifting platforms for use by disabled persons, BS 6440 (1983) and the Department of Transport code of practice for safety of passengers on buses, VSE 87/1.

Photographs were taken and the weight recorded of 745 people using wheelchairs. This was nearly twice the number of people photographed in the 1991 survey (382 people). The sample included an identical proportion of male and females to the 1991 study, with just over half the people photographed being male (52 per cent). Nearly ten per cent of the sample was judged to be under 16 years old and a quarter over 60 years old. Similar wheelchair types were photographed in each survey, although the distribution of wheelchairs differed between the two surveys. In 1991, nearly half the sample was old style rear wheel drive manual chairs, such as the NHS model 8L (48 per cent) and 17 per cent were new style manual chairs. New style manual chairs were defined as wheelchairs manually driven by the user from the rear wheels, made of modern lightweight construction and often identified by a negative camber on the rear wheels and an adjustable wheelbase. In this survey the distribution was reversed with a fifth of people using old style chairs (19 per cent) and 40 per cent new style chairs. The new style chair was the most popular type of wheelchair in use, followed by electric wheelchairs.

This change in chair distribution was reflected in the percentage of manually operated chairs having brakes. The number without brakes rose from 4 per cent in 1991 to 8 per cent in 1999. Since all the chairs without brakes were new style manual chairs, including those designed for sports use which do not have brakes or handles for an attendant to push, this change was not unexpected. Other features examined (i.e. carrying of walking aids, use of head and leg supports and luggage carried) showed little change over that recorded in 1991.

The overall mean height of wheelchair and user for all types of wheelchair was 1243mm, with a 5th percentile of 1076mm and a 95th percentile of 1374mm. This mean height was 4mm lower than in 1991, but not significantly different. Electric scooters showed the highest average as they tend to have higher seats and there were no children using this type of chair. Attendant propelled chairs had the lowest value as this group included several children using specially designed pushchairs. Hall and Silcock (1985) found a mean height of 1200mm for manual and attendant chairs. However, the lower average found by Hall and Silcock was probably a result of their sample which contained a majority of women (67 per cent), who tend to be shorter than men.

For all types of chair the average length of wheelchair and user was 1078mm and was found to be comparable to the results from the 1991 survey. The 5th percentile was 879mm and the 95th percentile was 1267mm. The study found 32 cases of chairs being over the maximum of 1250mm length given in ISO 7193. These were electric scooters and people using leg supports. When electric scooters, which are not covered by the ISO standard, were excluded from the sample, the 95th percentile for manual and electric wheelchairs was 1253mm.

The survey found an overall mean width of 624mm for all types of wheelchair. The 5th percentile was 549mm and the 95th percentile was 695mm. This represented a significant change from an average mean width of 606mm in 1991 to 624mm in 1999. The increase was partly due to the higher proportion of new style manual chairs and electric wheelchairs in the sample, which both had an average width above the overall average for all chairs. The mean width was also significantly different from that found by Hall and Silcock. ISO 7193 quotes a maximum width of 700mm for electric and manual wheelchairs. This study included 30 cases above this value, although the 95th percentile of 697mm fell within the maximum value quoted in the ISO standard.

The average combined weight of wheelchair and user for the whole sample was 117 kg, with the 5th and 95th percentiles found to be 61kg and 200kg respectively. There were two distinct groupings within the five wheelchair types: attendant propelled chairs and the two manual driven types had mean values between 80 and 100 kg; electric wheelchairs and electric scooters both had a mean value of 166 kg.

The study found that 95 per cent of the sample, with scooters excluded, were within the safe working loads stated in the British Standard for lifts associated with vehicles, BS 6109. It found twenty-eight cases had a combined weight of more than 200kg, the safe working load given in BS 6109 for a lift designed for the use of one wheelchair user without an attendant. Sixteen cases exceeded the safe working load for a lift designed for the use of one wheelchair user and one attendant. The code of practice VSE 87/1 states that a lift must be able to carry at

least 250kg when lifting one wheelchair user and one attendant. With scooters excluded and compensation made for an attendant, there were sixty-one cases above 250kg. The British Standard for general lifting platforms for disabled persons (BS 6440) gives a specification for a platform the same as that given in BS 6109. It also states that the rated load should not be less than 115kg, which is just below the mean value of 117kg from this sample.

These results update those from previous studies and show some potentially important trends in the dimensions of occupied wheelchairs. It is hoped designers of wheelchair accessible transport and architects will be encouraged to consider overall dimensions of occupied wheelchairs and cater for all or almost all wheelchair users in their designs.

1 Introduction

To ensure accessibility for people with disabilities to buildings and transport, architects and designers of transport systems need to take account of the dimensions of occupied wheelchairs. The present survey was commissioned by the Mobility and Inclusion Unit of the Department of the Environment, Transport and the Regions (DETR), to update previous research carried out by TRL Limited, which collected the overall dimensions and characteristics of people in their wheelchairs visiting the 1991 Mobility Roadshow (Stait and Savill, 1995)[1].

In addition, this survey also collected data on the combined weight of the wheelchair and the user. There are currently limited data available on the weight of occupied wheelchairs. Previous work carried out by Fenwick (1977) was aimed at improving wheelchair design and only looked at the dimensions and weight of the wheelchair user and not the chair. Hall and Silcock (1985) took weights and measurements of people in their wheelchairs whilst visiting the 1985 Mobility Roadshow. The study was mainly concerned with manually operated wheelchairs and had very little data on electric wheelchairs and none on scooters

It was also of interest to see how dimensions of people in their wheelchairs compared with those dimensions of unoccupied wheelchairs given in the International Standards Organisation ISO 7193 (1985). This standard gives maximum dimensions of wheelchairs and covers both manual and electric wheelchairs. A comparison was also made with the dimensions given in the British Standard for folding and collapsible wheelchairs, BS 5568 (1978). The weights of occupied wheelchairs were compared against the recommended safe working load for lifts given in the British Standard for lifts associated with vehicles, BS 6109: Part 2 (1989), the British Standard for powered lifting platforms for use by disabled persons, BS 6440 (1983) and the Department of Transport code of practice for safety of passengers on buses, VSE 87/1.

2 Method

The Mobility Roadshow is an outdoor event that provides people with disabilities the opportunity to view mobility products, test drive specially adapted vehicles and meet with organisations and charities. It has been held at TRL every two years since 1983. The 1999 Mobility Roadshow attracted approximately 25,000 visitors over three days (Friday to Sunday). Due to the large number of visitors and their interest in using transport, it was decided to carry out the survey at the Roadshow. The Roadshow is predominately concerned with personal motorised transport, which may have biased the sample to users of this type of transport.

A stand, consisting of a low profile weigh pad and two cameras, was set up in one of the main halls of the Mobility Roadshow. The cameras were mounted above and to the side of the weigh pad. A black and white checkerboard was positioned behind the wheelchair user and black and white checks alongside the weigh pad were used to aid in taking measurements from the photographs (see Figure 1). The camera above the weigh pad was positioned at a height of 333cm and the side camera was 544cm away from the checker board at a height of 75cm. The parallax from the photographs was corrected during the calculating of the dimensions, using scaling from the checker boards and trigonometry.

Visitors using a wheelchair were approached at random as they passed the stand and asked if they were willing to have their photograph and weight taken. The reason for the survey was explained. If they agreed, they were asked to position the front wheels of their wheelchair on a line on the weigh pad and then a photograph was taken simultaneously from each camera.

This method was used in preference to actually taking measurements on the day as it was faster and allows a visual record to be kept that can be used for future reference. The photographs from the 1991 survey, for example, have been used many times since to calculate extra dimensions or look at features on certain types of chair.

The method in 1991 required the wheelchair user to manoeuvre into a right angle formed by two checkerboards and wait while photographs were taken from the side and front. Some people had difficulties manoeuvring into the space, so the procedure was revised to allow a subject to manoeuvre straight onto the weight pad, stop for a few seconds and then manoeuvre straight off again. This method was less time consuming and allowed more people to take part in the survey. The overhead photograph also allowed greater accuracy in the calculation of the width.

2.1 Wheelchair dimensions

From the two photographs of each subject, measurements were taken directly from the prints and the dimensions were calculated by scaling from checkerboards and using trigonometry. The following dimensions were measured:

Height

The distance from the highest point (almost always the users head) to the ground.

Length

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

Width

The maximum width of the wheelchair itself. The width did not include the user, as when having the photograph taken, many users were not in the same position that they would be when travelling, or, for example, negotiating a doorway. Their arms were relaxed, with hands often resting upon the lap.

The same measurements were taken in the 1991 survey and were used for comparison.

[1] *This report is referred to frequently. For ease of reading, it is simply referred to as the 1991 survey.*

Above camera view

Side camera view

Figure 1 Example of photographs

To validate the measurement method, photographs were taken of a person in a wheelchair and then actual measurements were taken in situ. These were found to be within less than one per cent of the calculated dimensions.

Details of the wheelchair types, features and dimensions recorded from the photographs are given below. The estimated age and sex of the occupant were also noted.

2.2 Weight

The combined weight of wheelchair and user was measured on a low profile platform designed and built especially for the survey. This had an accuracy of 0.1 kg and could measure in excess of 1000 kg.

2.3 Wheelchair types

The type of wheelchair was classified into five groups detailed below. An example of each type is shown in Figure 2. It should be noted that, although most of the visitors were in their own wheelchairs, a small number were using hire chairs or demonstration models from various manufactures at the show. Where possible, these were excluded from the analysis.

Attendant propelled wheelchairs

These chairs have small wheels at the rear and are pushed by an attendant. An example is the NHS model 9L.

Electric wheelchairs

An electric wheelchair was defined as any four wheeled chair that was battery powered and controlled by a small joystick or similar device. These included wheelchairs designed both for indoor and outdoor use.

New style manual chairs

These wheelchairs are manually driven by the user from the rear wheels and made of a modern lightweight construction. They are often identified by bright colours, negative camber on the rear wheels and adjustable wheelbase. Some models of this type of chair, such as those designed for sports, do not have brakes or handles for an attendant to push.

Old style manual chairs

These are chairs manually driven by the user from the rear wheels and made to an old design, such as the NHS model 8L.

Electric scooters

Three or four wheeled electric powered wheelchairs steered by means of ‘handlebars’. These vary from large outdoor models that can travel on the public road, to smaller indoor/outdoor models.

In the 1991 survey, there were three additional categories. The reasons for their exclusion are discussed in section 3.1.

2.4 Wheelchair features

From the photographs, certain features present on the wheelchair or being used by the occupant were noted. These were:

Manually operated brakes

It was noted whether there were brakes on the manual or attendant propelled chairs that could be operated by the user. The 1991 survey also noted the presence of brakes on electrically operated wheelchairs. This was sometimes difficult to determine and there would always be some form of braking mechanism in the drive system of the chair. For this reason it was not recorded in this survey.

Leg supports

It was noted whether the user had their leg supported by a device other than the standard footrest.

Head supports

It was noted whether the user had any support on the chair for their head.

Walking aids carried

It was noted whether any walking aid, for example crutches or a walking stick, were carried by the user or attached to the chair.

Luggage carried

It was noted whether the users were carrying any luggage with them or on the chair, and if so, where it was being carried.

Some features were not always visible in the photographs, particularly the presence of brakes. The survey will therefore have underestimated the presence of such features.

3 Results

Over the three days of the show, a total of 943 visitors using a wheelchair were photographed. However, 198 photographs were excluded from analysis due to failure of one of the cameras, a hired wheelchair being used or it being too difficult to obtain accurate measurements. Return visitors and non-standard chairs or ‘specials’ were also excluded. A total of 745 wheelchair users were included in the final sample. This is nearly twice the number of people who were photographed as part of the 1991 survey (382 people).

Where possible the results were compared with previous data using a t-test. Unless stated, this was done at the 5 per cent level ($p<0.05$).

3.1 Wheelchair types and details of occupants

Of the 745 people photographed, 52 per cent were male (see Table 1). Two thirds of the sample (67 per cent) were judged to be in the age band 17 to 60 years and

Attendant propelled chair

Electric wheelchair

New style manual chair

Old style manual chair

Electric scooter

Figure 2 Wheelchair types

nearly one quarter (24 per cent) were judged to be over 60. Nine per cent were judged to be aged 16 or under. The distribution over the sexes was identical to that found in the 1991 survey. New style manual chairs accounted for the highest proportion of the chairs in use (40 per cent), followed by electric wheelchairs (25 per cent) and old style manual chairs (19 per cent). Attendant propelled chairs and electric scooters accounted for 7 and 9 per cent of the sample respectively.

Table 1 Age and sex of user by wheelchair type (frequencies)

	Sex of user		*Age of user*			
Chair type	*Male*	*Female*	*0-16*	*17-60*	*60+*	*Total (%)*
Attendant propelled	20	30	14	21	15	50 (7)
Electric wheelchair	90	93	17	121	45	183 (25)
New style manual chair	186	112	35	219	44	298 (40)
Old style manual chair	67	78	5	94	46	145 (19)
Electric scooter	28	41	0	41	28	69 (9)
Total (%)	391 (52)	354 (48)	71 (9)	496 (67)	178 (24)	745 (100)

The majority (62 per cent) of users of new style manual wheelchairs were male. However, females accounted for the majority of users of attendant propelled chairs and electric scooters (60 per cent and 59 per cent respectively). Fifty-four per cent of the users of old style manual wheelchairs were female. The proportion of males and females using an electric wheelchair was roughly equal (see Table 1).

In the 1991 survey there were three additional categories of wheelchair: car chairs, front wheel drive chairs and manual to electric conversions. In the current survey, there were only two examples of a car chair so it was decided to group these chairs with electric wheelchairs, since they are essentially a special type of electric wheelchair. There was one example of a front wheel drive manual chair in the survey. This chair was grouped with the rear wheel drive old style chairs. Several manual to electric conversions were noted, but since the group was small it was decided to group these with electric wheelchairs. This was chosen in preference to grouping them with manual chairs for two reasons. First, although these chairs are essentially a manual chair and have the same basic dimensions, the added weight of the battery and motor would put a bias on the weight distribution for manual chairs. Secondly, the dimensions of these chairs were not extreme in any way, so they would have little effect on the dimensions of the large electric wheelchair sample.

When the number of car chairs, manual to electric conversions and electric wheelchairs from the 1991 survey are combined, they form 21 per cent of the sample. The 1999 survey found a slightly higher proportion of electric wheelchair users (25 per cent). There was little difference between the 1991 and 1999 surveys in the proportions of attendant propelled wheelchairs or scooters. However, the data show a large difference in the usage of manual wheelchairs. In 1991, 17 per cent of the sample were new style manual chairs and 48 per cent were old style manual chairs. This has almost been reversed for this survey, with 40 per cent new style manual chairs and 19 per cent old style manaul chairs.

3.2 Wheelchair features

3.2.1 Walking aids carried

A total of 115 people (15 per cent) were carrying some form of additional walking aid with them (see Table 2). For most this was a single walking stick. The highest proportion was for the electric scooter group, where 42 per cent within the group were carrying a walking aid. The lowest proportion was for the electric wheelchair group (8 per cent). These figures may be a slight underestimation as some walking aids were being carried by accompanying persons.

Table 2 Features carried or used on wheelchairs (frequencies)

	Walking aid carried		*Leg support used*		*Head support used*		
Chair type	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*	*Total (%)*
Attendant propelled	10	40	0	50	3	47	50 (7)
Electric wheelchair	15	168	3	180	2	181	183 (25)
New style manual chair	27	271	5	293	10	288	298 (40)
Old style manual chair	34	111	4	141	6	139	145 (19)
Electric scooter	29	40	0	69	1	68	69 (9)
Total (%)	115 (15)	630 (85)	12 (2)	733 (98)	22 (3)	723 (97)	745 (100)

The proportion of 15 per cent carrying a walking aid in this survey is similar to the proportion in the 1991 survey (13 per cent). As with the 1999 survey, the highest proportion carrying a walking aid in 1991 were those using electric scooters.

3.2.2 Leg supports and head supports

Leg supports were only used by two per cent of users, and head supports by three per cent (see Table 2). These findings are similar to those found in the 1991 survey where three per cent of people used a leg support and three per cent a head support.

3.2.3 Luggage carried

From the photographs it was noted whether the user was carrying any luggage, and if so where it was being carried. Any small bags, such as handbags, and any papers, such as the Roadshow guide, were not counted. Similarly, a walking aid was not counted as luggage. The totals may be a slight underestimation of those carrying luggage as some bags were passed to accompanying persons before the photographs were taken.

A total of 62 per cent of users were carrying some form of luggage (see Table 3). The majority of those carrying luggage, carried it on the rear of the wheelchair (85 per cent). The results show a rise in those carrying luggage compared with the 1991 survey (55 per cent of users in 1991) though the extra manoeuvring involved in the 1991

photographs may have caused more people in 1991 to hand luggage to an accompanying person. The rise is luggage carried has mainly been by people carrying luggage on the rear of their wheelchair, which increased from 42 per cent in 1991 to 51 per cent in 1999. There was a slight decrease in the proportion of people carrying luggage at the side, from two per cent in 1991 to one per cent of users. The proportion of luggage being carried on the front remained the same (12 per cent).

Table 3 Position of any luggage carried (frequencies)

Chair type	*No luggage carried*	*Position of luggage carried*			
		Front	*Back*	*Side*	*Total[1] (%)*
Attendant propelled	16	0	34	1	34 (68)
Electric wheelchair	53	12	123	5	130 (71)
New style manual chair	136	19	150	0	162 (54)
Old style manual chair	63	8	73	2	82 (57)
Electric scooter	12	52	17	1	57 (83)
Total (%)	280 (38)	91	397	9	465 (62)

[1] The total indicates the number and percentage of users in each wheelchair group who carry some form of luggage. Some wheelchair users carried luggage in more than one location.

3.2.4 Manually operated brakes

The presence of brakes that the user could operate on manual chairs or attendant propelled chairs was noted from the photographs. From these three categories, 92 per cent of chairs did have manually operated brakes. All those without brakes were new style manual chairs.

Comparing these three categories of chair (manual chairs and attendant wheelchair) with the same in 1991, the proportion with brakes has fallen from 96 per cent in 1991 to 92 per cent in 1999.

3.3 Wheelchair dimensions

The dimensions in the following section are for all those wheelchair users surveyed. Additional measurements have been taken and these are listed in Appendices A to D. Appendix A contains the statistics for adults, i.e. excluding those whose age was judged to be 16 or less. Appendix B has the basic dimensions for just electric powered chairs and manual chairs. The dimensions in Appendix C were taken to ensure that dimensions specified in access regulations were representative of occupied electric powered and manual wheelchairs. Appendix D gives the axle spacing of electric powered and manual chairs.

3.3.1 Height

The height of chair and user was taken to be the distance from the highest point of the user or wheelchair (almost always the person's head) to the ground. Table 4 gives basic statistics on the height for each chair type, including the 5th and 95th percentiles. These show that the overall mean height of wheelchair and user for all types of wheelchair was 1243mm, with a 5th percentile of 1076mm and a 95th percentile of 1374mm.

The electric scooter group had the highest mean value

Table 4 Height of wheelchair/user

Chair type	*Survey year*	*Mean (mm)*	*Min (mm)*	*Max (mm)*	*Percentiles (mm)*	
					5th	*95th*
Attendant propelled	1999	1155	924	1374	960	1313
	1991	*1191*	*1059*	*1333*	*1064*	*1324*
Electric wheelchair	1999	1262	1005	1451	1123	1371
	1991	*1265*	*937*	*1407*	*1107*	*1395*
New style manual chair	1999	1237	937	1405	1074	1353
	1991	*1258*	*1059*	*1441*	*1106*	*1371*
Old style manual chair	1999	1217	956	1407	1095	1318
	1991	*1227*	*962*	*1403*	*1068*	*1348*
Electric scooter	1999	1340	1070	1502	1202	1438
	1991	*1372*	*1244*	*1513*	*1253*	*1507*
All chairs	1999	1243	924	1502	1076	1374
	1991	*1247*	*937*	*1513*	*1092*	*1377*

(1340mm) and also contained the highest user measured at 1502mm. The lowest mean and overall value was found in the attendant propelled group. The remaining three groups had a mean value within 45mm of each other and account for the majority (84 per cent) of the wheelchairs in the survey.

Figure 3 gives a histogram of the height of chair and user for all chair types. The histogram is somewhat skewed, showing a gradual rise up, then a concentrated area around the mean, followed by a steeper fall off towards the higher values. Clearly, it would be useful if the population of wheelchair dimensions could be described in terms of normal distribution. A normal curve[2] of the same mean and standard deviation as the measured heights is superimposed on Figure 3, and it can be seen that although it provides a reasonable approximation to the data, there are some differences. In fact, the frequency distribution is statistically significantly different from the normal distribution (Chi-square test at the 5 per cent level ($\chi^2 = 56$, df=20, $p<.05$)).

Given the large sample sizes involved this departure from normality was not sufficient to preclude the use of a t-test to compare means. The mean height for all types of chair was not found to be significantly different from the mean found in the 1991 survey (t= 0.64, df=1125, NS). The mean height fell from 1247mm in 1991 to 1243mm in 1999. None of the individual wheelchair groups was found to be significantly different in height from the 1991 survey (see Table 4).

A comparison with Hall and Silcock (1985) could only be made if electric scooters were removed from the 1999 survey, since Hall and Silcock did not measure any electric scooters. The mean height in the Hall and Silcock survey was 1200mm, which is significantly different (t= -4.33, df=835, $p<.05$) from the mean in this survey with electric

[2] The normal curve is the graph of the probability density function of the normal distribution. The normal distribution is the distribution of many naturally occurring variables, such as heights of adult men in a population.

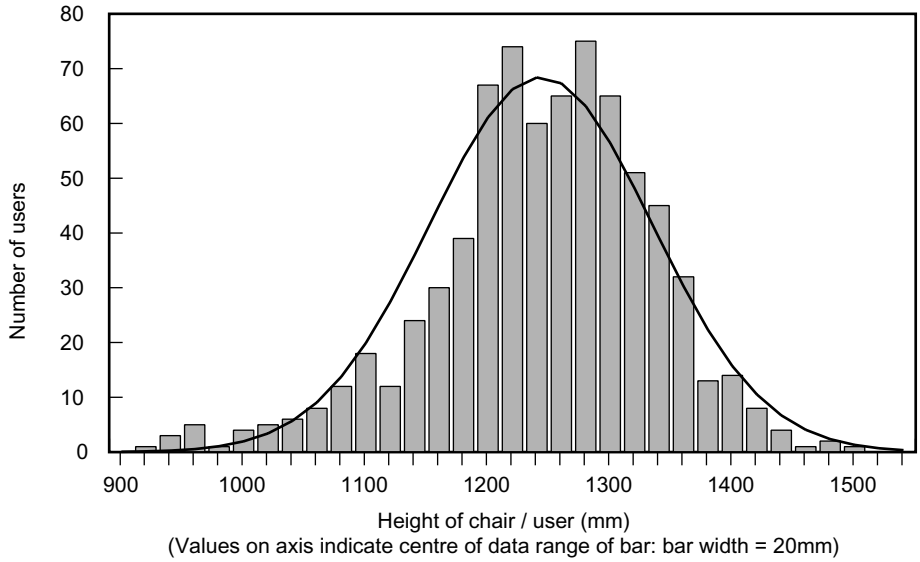

Figure 3 Height distribution

scooters removed (1234mm). The 1991 survey was also found to be significantly different from Hall and Silcock (t= -4.92, df=519, p<.05).

Figure B.1 in Appendix B shows histograms of the height of wheelchair and user for electric powered and manual types of wheelchair. Performing a Chi-square test on the distribution shows the electric wheelchairs are normally distributed (χ^2 = 15.5, df=12, NS) but the manual chairs are not (χ^2 = 45.8, df=16, p<.05).

3.3.2 Length

Table 5 gives statistics on the length of chair and user, taken to be the distance from the furthest point forward of chair or user to the furthest point back. For all types of chair the average length of wheelchair and user was 1078mm. The 5th percentile was 879mm and the 95th percentile was 1267mm.

Table 5 Length of wheelchair/user

Chair type	*Survey year*	*Mean (mm)*	*Min (mm)*	*Max (mm)*	*Percentiles (mm)* 5th	95th
Attendant propelled	1999	1075	742	1318	859	1223
	1991	*1040*	*832*	*1287*	*854*	*1261*
Electric wheelchair	1999	1104	758	1549	949	1318
	1991	*1065*	*825*	*1222*	*951*	*1164*
New style manual chair	1999	1023	707	1256	840	1180
	1991	*1040*	*819*	*1236*	*870*	*1172*
Old style manual chair	1999	1105	862	1357	922	1265
	1991	*1071*	*803*	*1363*	*896*	*1260*
Electric scooter	1999	1187	971	1500	1000	1402
	1991	*1211*	*1032*	*1451*	*1033*	*1447*
All chairs	1999	1078	707	1549	879	1267
	1991	*1070*	*803*	*1451*	*896*	*1243*

The highest average (1187mm) was found in the electric scooter group. Old style manual chairs and electric wheelchairs had very similar average values, followed by attendant propelled chairs and new style manual chairs. The maximum length of chair and user found was in the electric wheelchairs group (1549mm), and the minimum value in the new style manual chair group (707mm).

Figure 4 shows a histogram of the length of wheelchair and user for all types of chair. A Chi-square test showed the data were normally distributed (χ^2 = 36.6, df= 25, NS).

Compared with the 1991 survey, the overall mean length increased by 8mm from 1070mm to 1078mm. This was not significantly different at the 5 per cent level (t=-1.08, df=1125, NS). Electric wheelchairs and old style manual chairs both had mean values significantly higher than in 1991. The mean length of electric wheelchairs increased from 1065mm in 1991 to 1104mm in 1999 (t= -2.57, df= 247, p<.05). For old style manual wheelchairs the mean was 1071mm in 1991 and 1105mm in 1999 (t= -2.92, df= 327, p<.05). The remaining three groups showed no significant changes over the results from 1991.

In the study by Hall and Silcock (1985), only the length of the chair was measured and not the chair and user, so a comparison cannot be made.

The histograms of length of chair and user for electric powered and manual types of wheelchair are shown in Figure B.2 in Appendix B. Performing a chi-square test on the distributions show the electric chairs are not normally distributed (χ^2 = 28.3, df=16, p<.05) but the manual chairs are (χ^2 = 27.2, df=21, NS).

3.3.3 Width

Table 6 shows the statistics for the width in the different wheelchair types. The results found an overall mean width of 624mm for all types of wheelchair. The 5th percentile was 549mm and the 95th percentile was 695mm.

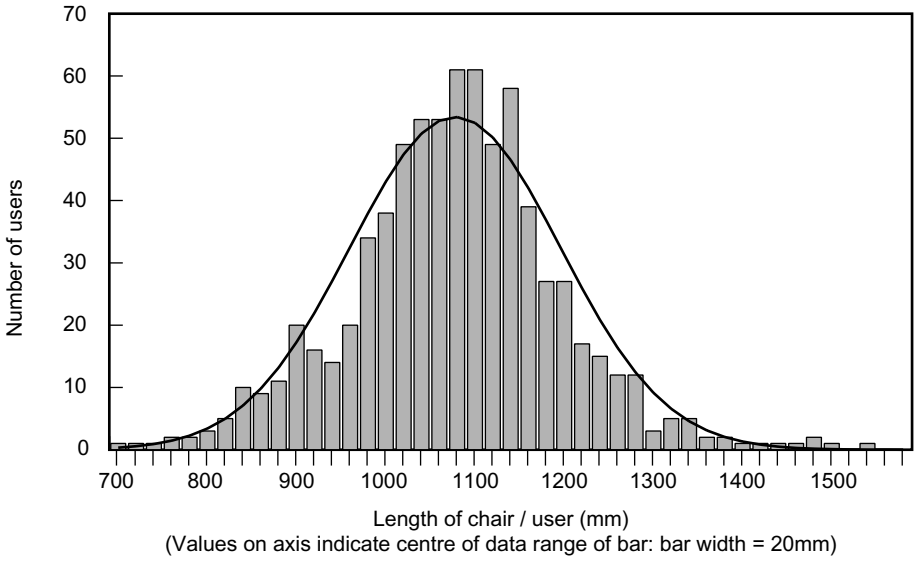

Figure 4 Length distribution

Table 6 Width of wheelchair

Chair type	*Survey year*	*Mean (mm)*	*Min (mm)*	*Max (mm)*	*Percentiles (mm)* 5th	95th
Attendant propelled	1999	586	481	674	515	652
	1991	*590*	*506*	*657*	*507*	*655*
Electric wheelchair	1999	631	484	755	549	704
	1991	*619*	*535*	*735*	*545*	*673*
New style manual chair	1999	633	472	741	561	698
	1991	*622*	*546*	*691*	*555*	*679*
Old style manual chair	1999	615	512	722	559	685
	1991	*598*	*447*	*710*	*543*	*652*
Electric scooter	1999	607	501	695	529	685
	1991	*610*	*549*	*681*	*550*	*676*
All chairs	1999	624	472	755	549	695
	1991	*606*	*447*	*735*	*550*	*664*

New style manual chairs had the highest overall mean of 633mm, which was slightly higher than electric wheelchairs (631mm). The attendant propelled chairs had the lowest overall mean (586mm). The maximum value was recorded in the electric wheelchair group (755mm) and the lowest in the new style manual chair group (472mm).

Figure 5 shows the distribution of the widths with a normal curve. The data was significantly different from that of a normal curve having the same mean and standard deviation as the observed data (χ^2 = 125.3, df=24, p<.05). Overall, the change between 1991 and 1999 is significant (t= -6.48, df= 1125, p<.05), with a rise in means from 606mm to 624mm. From the individual wheelchair groups, only the old style manual chairs showed a significant increase in overall width between the two surveys (t= -4.1, df=327, p<.05). In 1991 old style manual wheelchairs were, on average, 598mm wide and in the current survey 615mm wide.

Comparing the width with the mean of 608mm measured by Hall and Silcock (1985), there is a significant difference

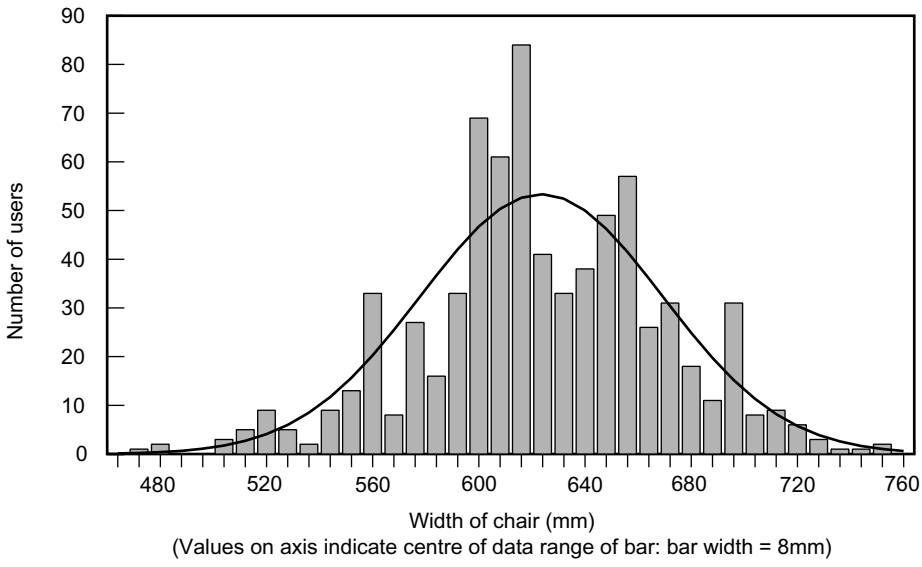

Figure 5 Width distribution

between the two data sets (t= -4.35, df=1036, p<.05). For the comparison, electric scooters were removed from the 1999 data, as Hall and Silcock did not sample this type of chair. A comparison between Hall and Silcock and the 1991 survey showed no significant difference.

Figure B.3 in Appendix B shows histograms of width of chair for electric powered and manual types of wheelchair. A Chi-square test on the distributions show neither electric powered chairs (χ^2 = 28.1, df=15, p<.05) nor manual chairs (χ^2 = 75.6, df=20, p<.05) are normally distributed.

3.3.4 Weight

Table 7 shows the results from the combined weight of chair and user for each wheelchair type. The average for the whole sample was 117 kg, with the 5th and 95th percentiles found to be 61kg and 200kg respectively.

Table 7 Weight of wheelchair and user

				Percentiles (kg)	
Chair type	*Mean (kg)*	*Min (kg)*	*Max (kg)*	*5th*	*95th*
Attendant propelled	81	32	181	42	125
Electric wheelchair	166	94	384	103	248
New style manual chair	90	34	175	54	123
Old style manual chair	100	50	184	68	142
Electric scooter	166	79	314	109	222
All chairs	117	32	384	61	200

There were two distinct groupings within the five wheelchair types. Attendant propelled chairs and the two manual driven types had mean values between 80 and 100 kg. Electric wheelchairs and electric scooters both had a mean value of 166 kg. The highest overall weight of wheelchair and user was in the electric wheelchair group, weighing 384 kg. The lowest was an attendant propelled chair and user, a young child, at 32 kg. No attempt has been made to compensate for luggage carried, which ranged from nothing at all to large bags. However, an attempt was made to compensate for the dogs that accompanied several users on the weighing platform.

Figure 6 illustrates the distribution of weights of wheelchair and user. Although Hall and Silcock (1985) took weights of occupied wheelchairs at the 1985 Mobility Roadshow, the raw data from this survey was not available. From the histograms printed in the report, it is possible to determine that the values obtained are roughly the same as this current study, but statistical comparisons were not possible.

The histograms of weight of chair and user for electric powered and manual types of wheelchair are shown in Figure B.4 in Appendix B.

4 Summary and discussion

A total of 745 wheelchair users who visited the 1999 Mobility Roadshow were photographed and weighed. The revised method used for the calculation of the dimensions proved to be quick, unobtrusive and has provided a permanent record that can be used in the future if required.

The distribution of wheelchairs compared with the 1991 survey was very similar, apart from the two manual driven types of chair. In 1991, 48 per cent of the sample were old style rear wheel drive chairs and 17 per cent were the new style of chair. In this survey there were 19 per cent old style chairs and 40 per cent new style chairs. This result was not unexpected. Many older style chairs would have been replaced with a new style chair during the eight years that have lapsed between the two studies. The change in chair distribution has been reflected in the number of manually operated chairs having brakes. The number without brakes has risen from 4 per cent in 1991 to 8 per cent in 1999. Other features examined (i.e. carrying of walking aids, use of head and leg supports and luggage carried) show little change over that recorded in 1991. The change in procedure may account for the slight increase in the amount of luggage carried at the rear of the wheelchair.

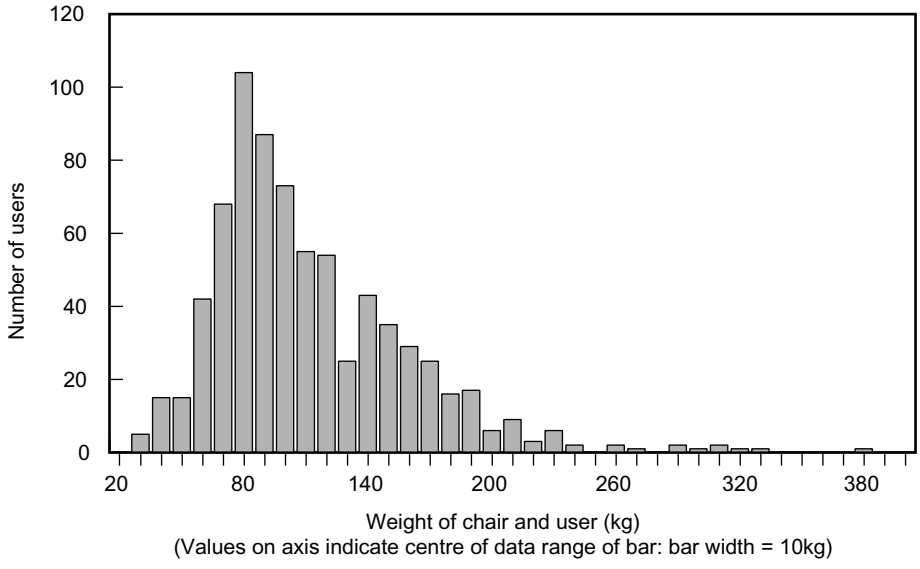

Figure 6 Weight distribution

The user may have removed luggage from the rear of their chair in the 1991 survey to make manoeuvring into the space easier.

The overall height of chair and user in this survey was 4mm lower than in the 1991 survey, a difference that was not statistically significant. Results for each individual group were along the lines of what would be expected. Electric scooters showed the highest average height as they tend to have higher seats and there were no children using this type of chair. Attendant propelled chairs had the lowest value as this group included several children using specially designed pushchairs, which would have the effect of lowering the average. Hall and Silcock (1985) found a mean height of 1200mm for manual and attendant chairs and was significantly different from the mean in this survey with electric scooters removed (1234mm). Hall and Silcock carried out their survey in North Tyneside and the majority of users surveyed were women (67 per cent). There is evidence to suggest that people from the North are generally shorter and women are shorter than men (Knight, 1984). This may go some way to explaining the difference in results.

The length of chair and user were not found to be significantly different from those found in 1991. A comparison was not possible with Hall and Silcock as they only measured the length of the chair itself. ISO 7193 (1985) stated maximum values for dimensions of manual and electric wheelchairs. It gave an overall length of 1200mm but added 50mm for an approximation of the user's feet. Compared with the manual and electric wheelchairs in this study, there were 32 cases of chairs being over 1250mm in length. These extreme values comprised of people using electric scooters and also those using leg supports. The 95th percentile for this group (manual and electric wheelchairs, excluding scooters) was 1253mm, which was similar to the maximum value quoted in the ISO 7193.

Width of the chair, which is perhaps the most important measurement for designers and planners, has shown the largest change over the 1991 study. This could be partly explained by the difference in chair type sampled in this survey, as mentioned earlier. The proportion of new style manual chairs surveyed has more than doubled since 1991 and the proportion of electric wheelchairs has also risen. Both these individual groups had an average width above the overall average for all chairs, so by sampling more chairs from these groups the overall average would be expected to rise. ISO Standard 7193 quotes a maximum value of 700mm for chair width. From the chairs surveyed that are covered by the ISO standard, there were 30 cases above the maximum value stated. The 95th percentile of 697mm is just within the maximum value quoted in the ISO standard. BS 5568 is also only concerned with the wheelchair itself, and gives a figure of 660mm for an adult folding or collapsible wheelchair. This study did not look into whether the wheelchair could be folded so a comparison can not be made here.

To compare the weights of occupied wheelchairs with the British Standard for lifts and ramps associated with vehicles, BS 6109 (1989), and general lifting platforms for disabled persons, BS 6440 (1983), scooters were excluded from sample. It is not recommended that scooters be carried in vehicles. The survey found an average combined weight of wheelchair and user for this group was 112kg and the 95th percentile was 193kg. These weights were both within the safe working loads stated in BS 6109 and BS 6440. BS 6109 states a safe working load of at least 300kg for lifts designed for use with one wheelchair user and an attendant; and 200kg minimum for lifts for use with one wheelchair user alone. A rated load of 200kg is also stated in BS 6440, the standard for general lifting platforms.

The study found 28 cases had a combined weight of wheelchair and user over 200kg. When the weight of an attendant was added to that of the wheelchair and user, the survey found 16 of the 676 cases were over 300kg. The weight of an attendant was taken to be 76.3kg. This is the weight stated in the draft standard ISO/DIS 10542 as the mass of an anthropomorphic test device for testing wheelchair and occupant restraint systems. This standard also quotes a mass of 85kg for a surrogate powered wheelchair. When this is added to the 76.3kg for the test dummy, the figure of 161.3kg compares well with the average of 165.6kg for powered chairs from this survey. The Department of Transport in 1987 issued a code of practice for the safety of passengers in wheelchairs on buses. This stated if adults in powered chairs are to be lifted together with a helper, a rated lift capacity of at least 250kg was needed. In the survey, with scooters excluded, 61 cases were above 250kg.

Dimensions of people in their wheelchairs should be of use to a wide variety of people involved in creating wheelchair accessible transport and general access to buildings. Designers should be encouraged to consider overall dimensions of occupied wheelchairs and cater for all or almost all wheelchair users.

5 Acknowledgements

The authors would like to thank Alistair Smith, Pete Sylvester and Frank Pond from the TRL Visual Media centre for organising the photography on the stand. From the Safety and Environment centre at TRL the authors would like to thank Su Buttress, Judith Cox, Gareth Davies and Pam Lewis for their help on the stand over the three days of the show. The weigh pad used for the survey was designed and built by Neil Johnstone of Interface Force Measurements Ltd. and his help in setting up the stand was gratefully received. Also, technical advice from Yvonne Brown at the Mobility Advice and Vehicle Information Service and Chris Baughan (TRL) was much appreciated.

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Appendix A: Dimensions excluding children

Table A1 Height of wheelchair/user (excluding children)

Chair type	*Survey year*	*Mean (mm)*	*Min (mm)*	*Max (mm)*	*Percentiles (mm)* 5th	95th
Attendant	1999	1190	956	1374	1078	1324
propelled	*1991*	*1211*	*1085*	*1333*	*1117*	*1306*
Electric	1999	1269	1005	1451	1133	1374
wheelchair	*1991*	*1275*	*1135*	*1407*	*1158*	*1382*
New style	1999	1251	1037	1405	1118	1353
manual chair	*1991*	*1273*	*1106*	*1442*	*1150*	*1370*
Old style	1999	1220	956	1407	1119	1320
manual chair	*1991*	*1238*	*1037*	*1403*	*1138*	*1348*
Electric	1999	1340	1071	1502	1202	1438
scooter	*1991*	*1372*	*1244*	*1513*	*1302*	*1474*
All	1999	1255	956	1502	1110	1382
chairs	*1991*	*1258*	*1037*	*1513*	*1136*	*1376*

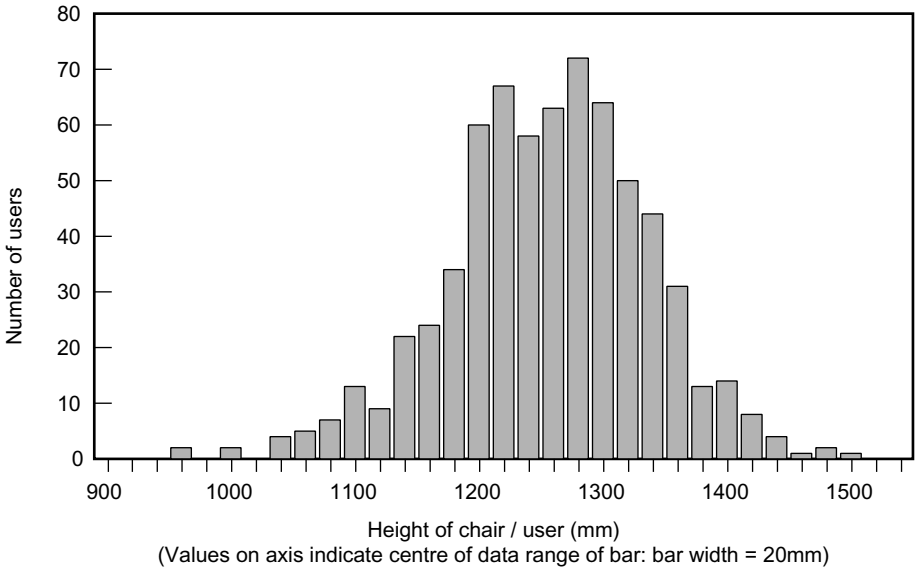

Figure A1 Height distribution (excluding children)

Table A2 Length of wheelchair/user (excluding children)

Chair type	Survey year	Mean (mm)	Min (mm)	Max (mm)	Percentiles (mm) 5th	Percentiles (mm) 95th
Attendant propelled	1999	1080	742	1318	928	1197
	1991	*1061*	*905*	*1288*	*917*	*1203*
Electric wheelchair	1999	1107	758	1549	949	1328
	1991	*1081*	*946*	*1222*	*986*	*1153*
New style manual chair	1999	1033	707	1256	846	1183
	1991	*1046*	*819*	*1236*	*884*	*1157*
Old style manual chair	1999	1108	862	1357	919	1267
	1991	*1077*	*803*	*1363*	*904*	*1258*
Electric scooter	1999	1187	971	1500	1000	1402
	1991	*1211*	*1032*	*1451*	*1043*	*1422*
All chairs	1999	1085	707	1549	894	1273
	1991	*1079*	*803*	*1451*	*906*	*1242*

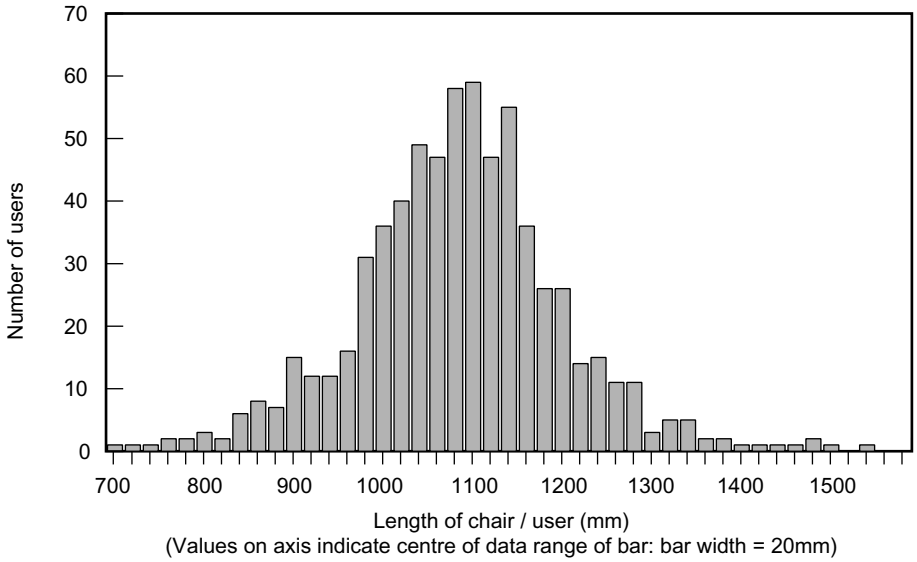

Figure A2 Length distribution (excluding children)

Table A3 Width of wheelchair (excluding children)

Chair type	Survey year	Mean (mm)	Min (mm)	Max (mm)	Percentiles (mm) 5th	Percentiles (mm) 95th
Attendant propelled	1999	596	520	674	528	658
	1991	*597*	*506*	*657*	*508*	*651*
Electric wheelchair	1999	635	521	755	552	706
	1991	*622*	*537*	*735*	*563*	*668*
New style manual chair	1999	638	511	741	579	702
	1991	*625*	*546*	*691*	*557*	*677*
Old style manual chair	1999	616	511	722	560	686
	1991	*603*	*526*	*710*	*558*	*652*
Electric scooter	1999	607	501	695	529	685
	1991	*610*	*549*	*681*	*557*	*651*
All chairs	1999	627	501	755	558	695
	1991	*610*	*506*	*735*	*556*	*664*

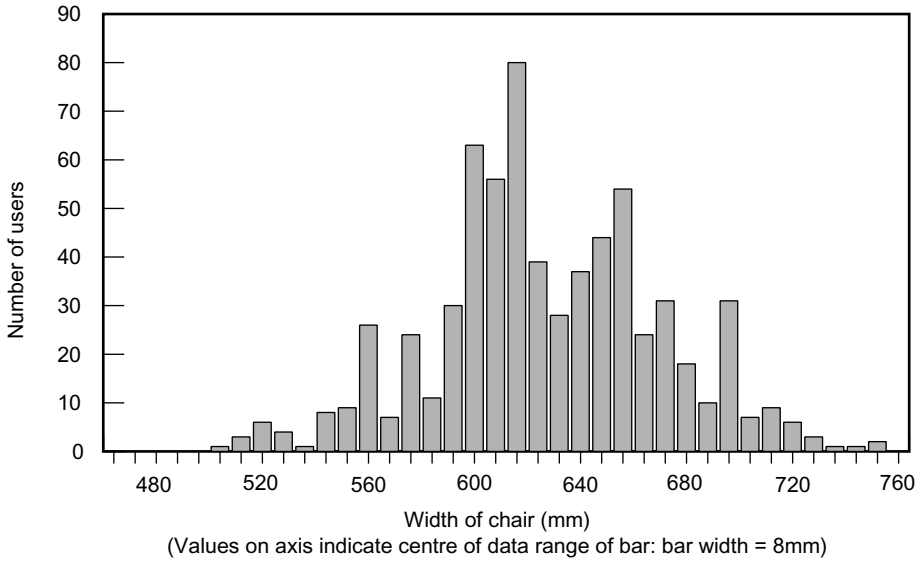

Figure A3 Width distribution (excluding children)

Table A4 Weight of wheelchair and user (excluding children)

Chair type	*Mean (kg)*	*Min (kg)*	*Max (kg)*	*Percentiles (kg)*	
				5th	*95th*
Attendant propelled	89	58	181	68	127
Electric wheelchair	168	94	384	116	258
New style manual chair	93	47	175	66	125
Old style manual chair	101	61	184	69	142
Electric scooter	166	79	314	109	222
All chairs	121	47	384	70	206

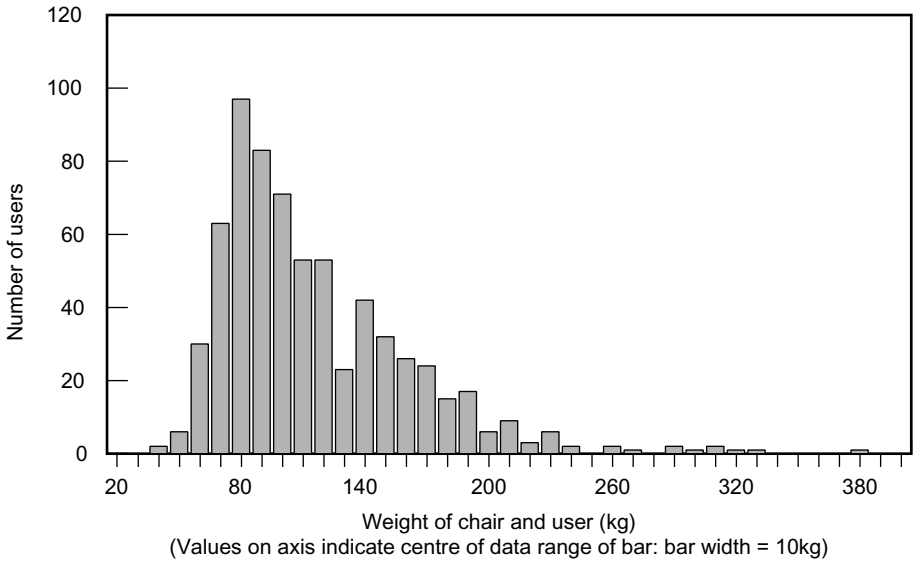

Figure A4 Weight distribution (excluding children)

Appendix B: Dimensions for electric and manual wheelchairs

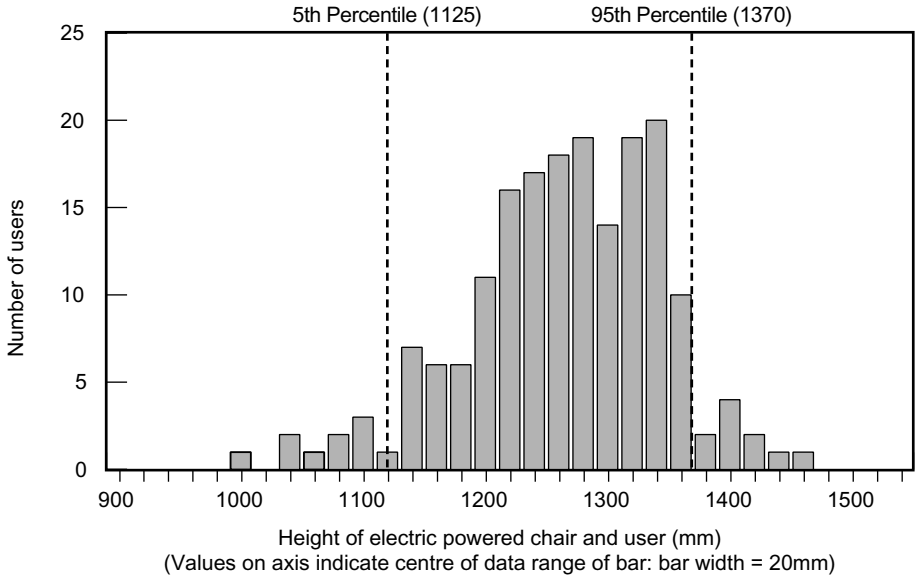

Figure B1 Height of electric powered chair and user

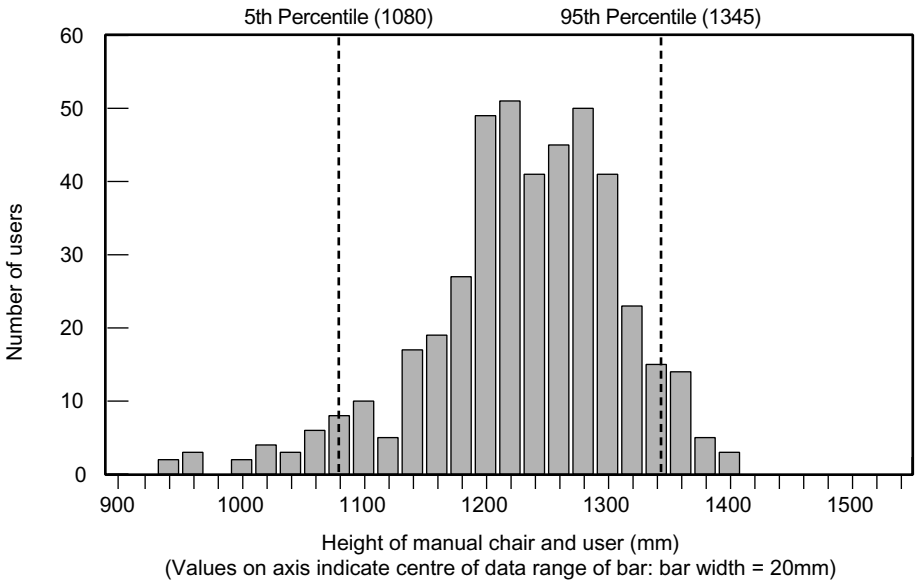

Figure B2 Height of manual chair and user

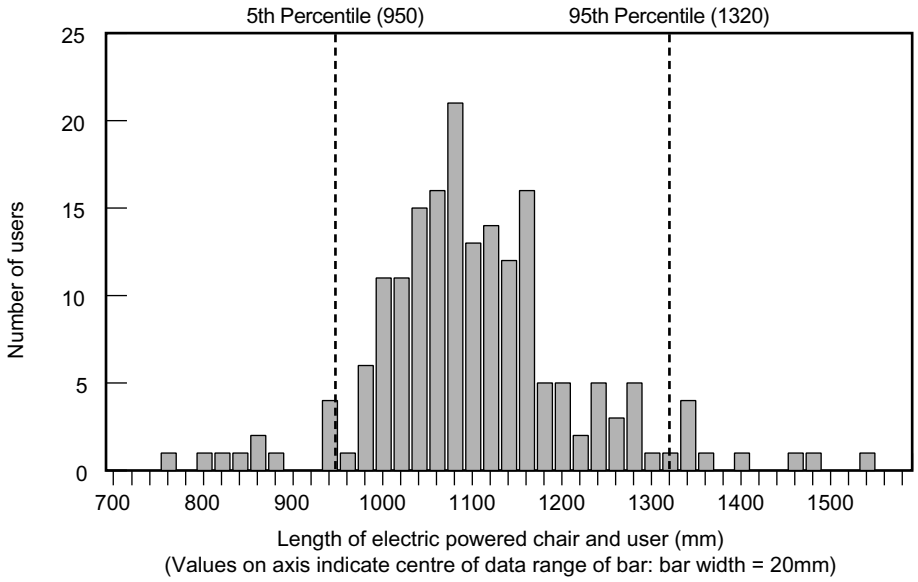

Figure B3 Combined length of electric powered chair and user

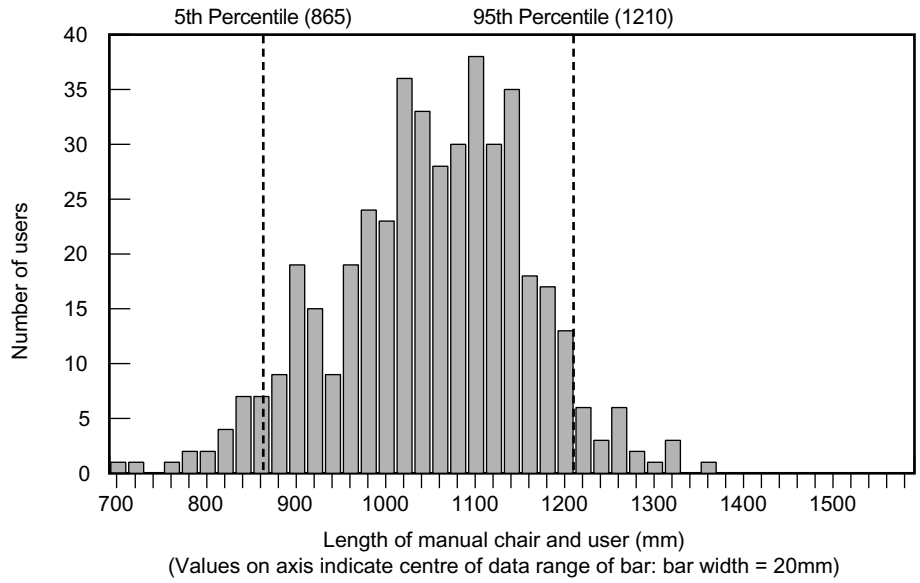

Figure B4 Combined length of manual chair and user

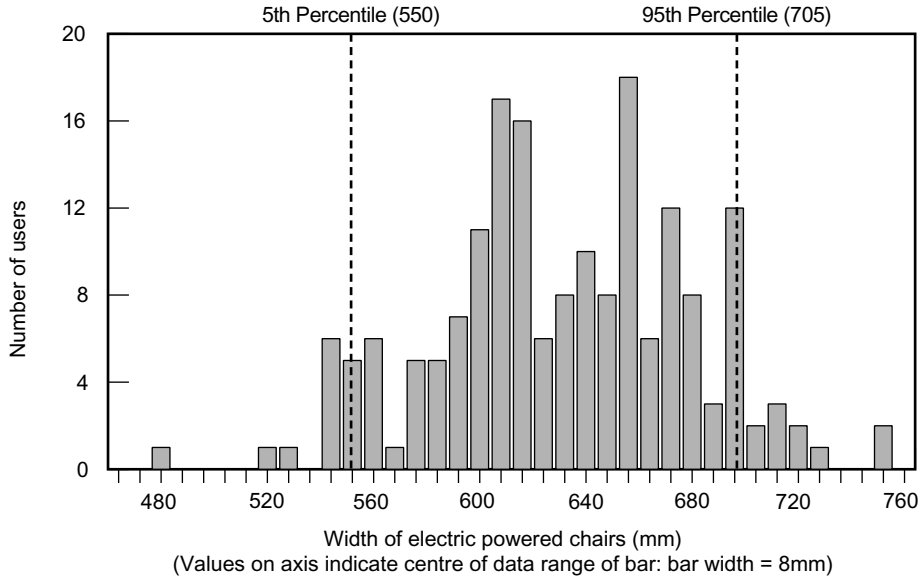

Figure B5 Width of electric powered chairs

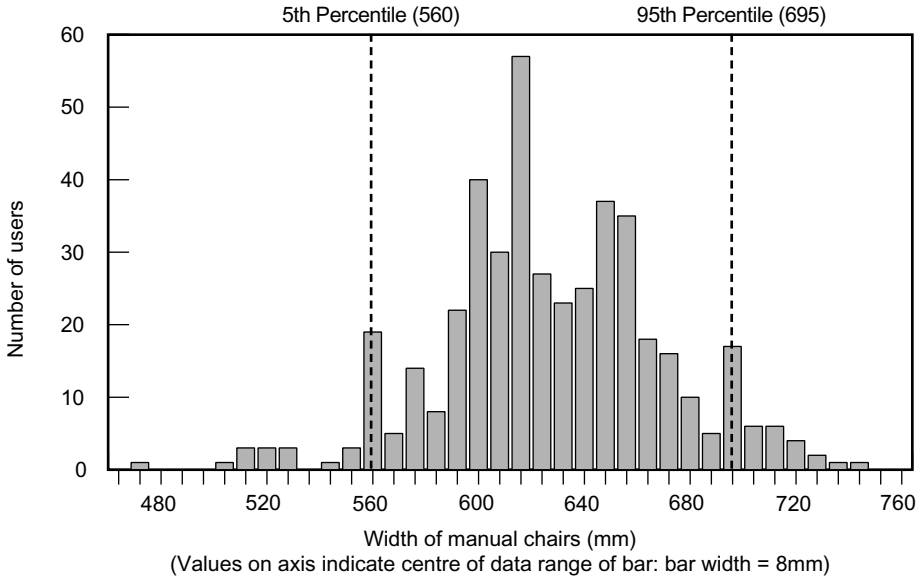

Figure B6 Width of manual chairs

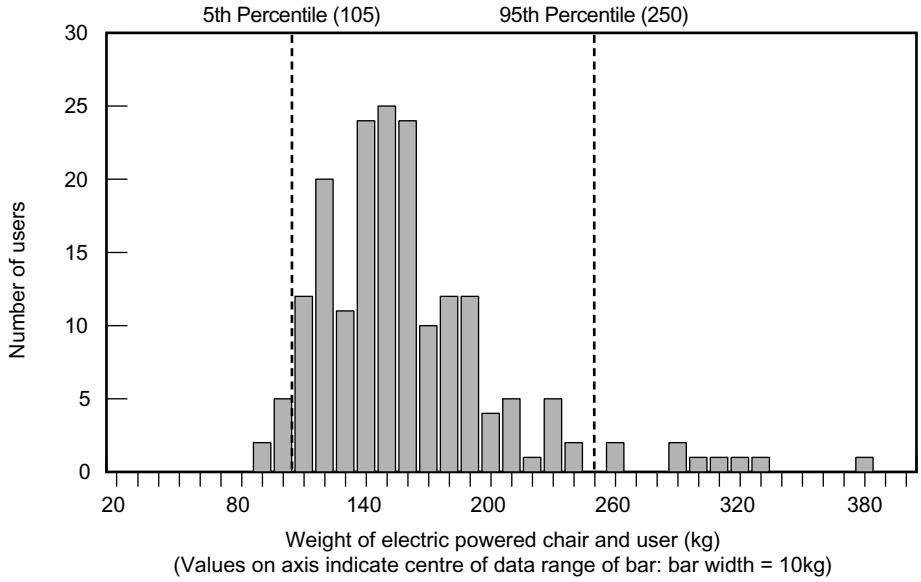

Figure B7 Combined weight of electric powered chair and user

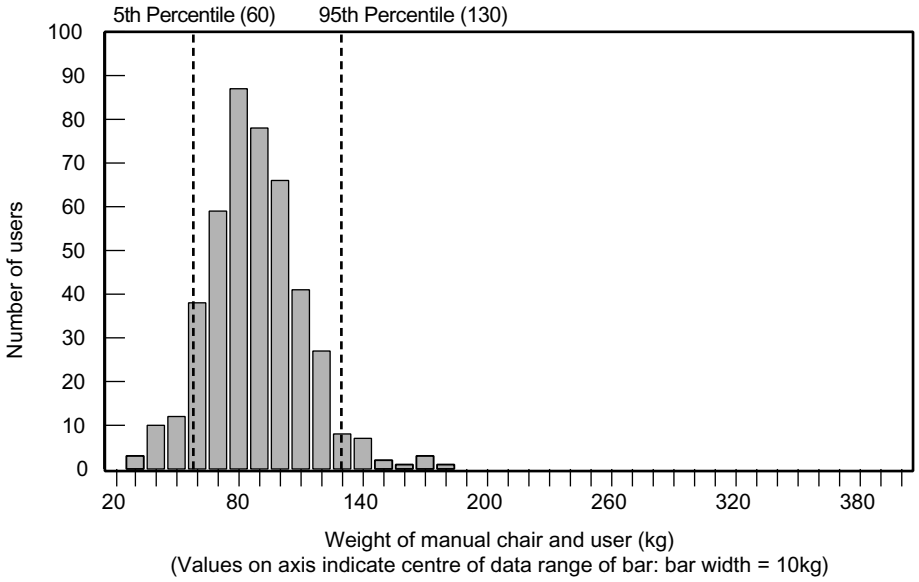

Figure B8 Combined weight of manual chair and user

Appendix C: Additional measurements

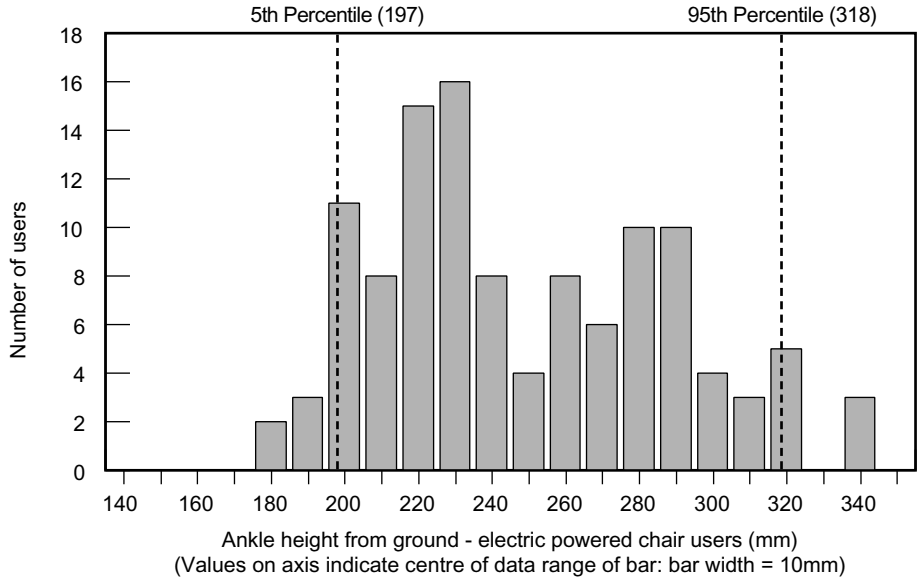

Figure C1 Ankle height of wheelchair user from ground (electric powered chair)

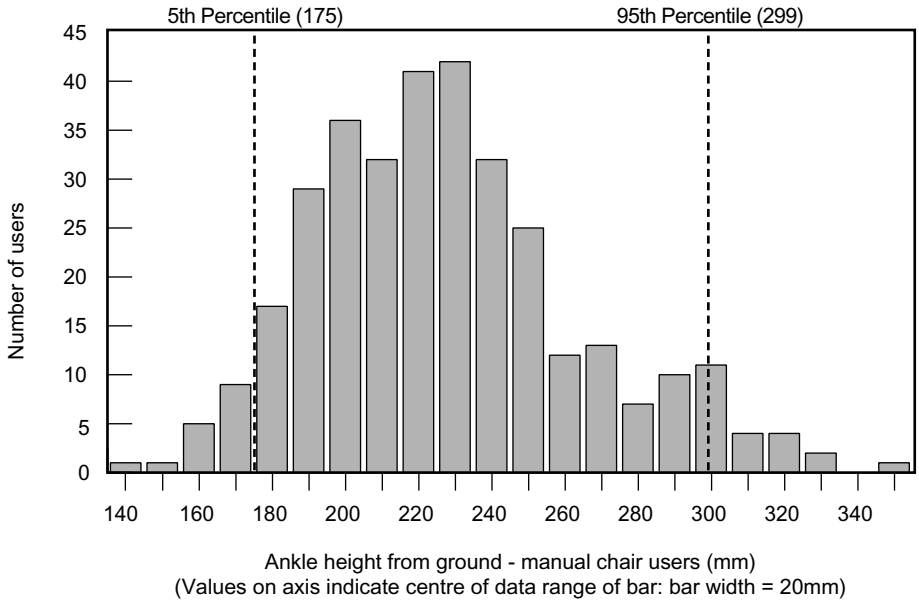

Figure C2 Ankle height of wheelchair user from ground (manual chair)

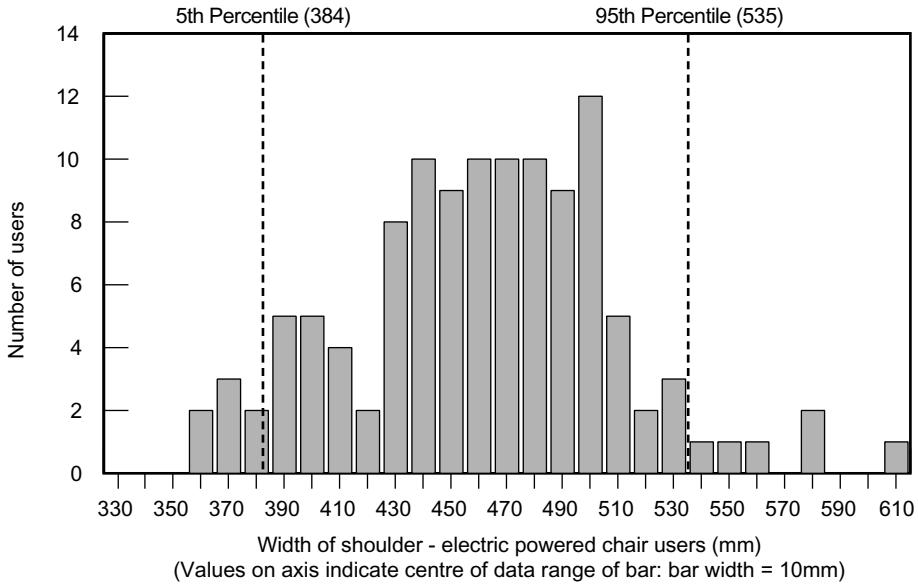

Figure C3 Shoulder width of wheelchair user (electric powered chair)

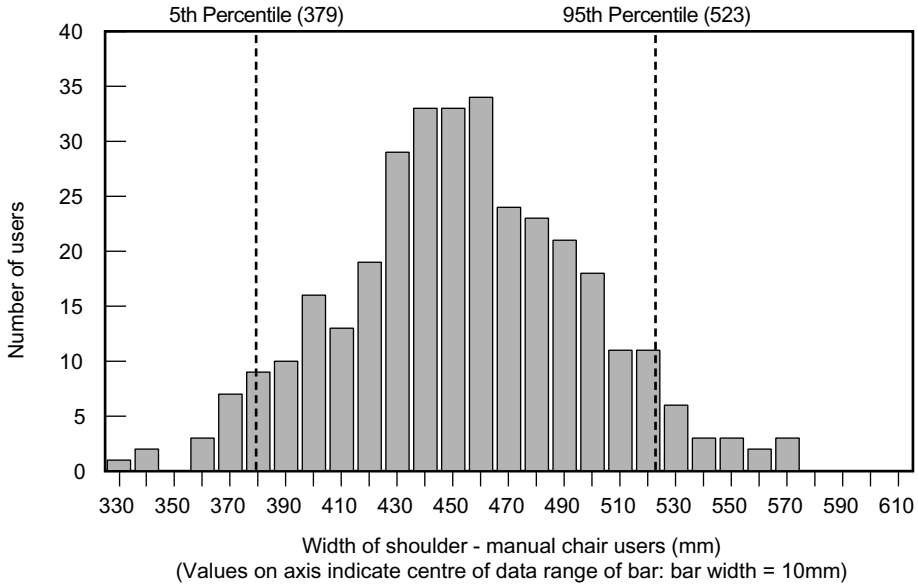

Figure C4 Shoulder width of wheelchair user (manual chair)

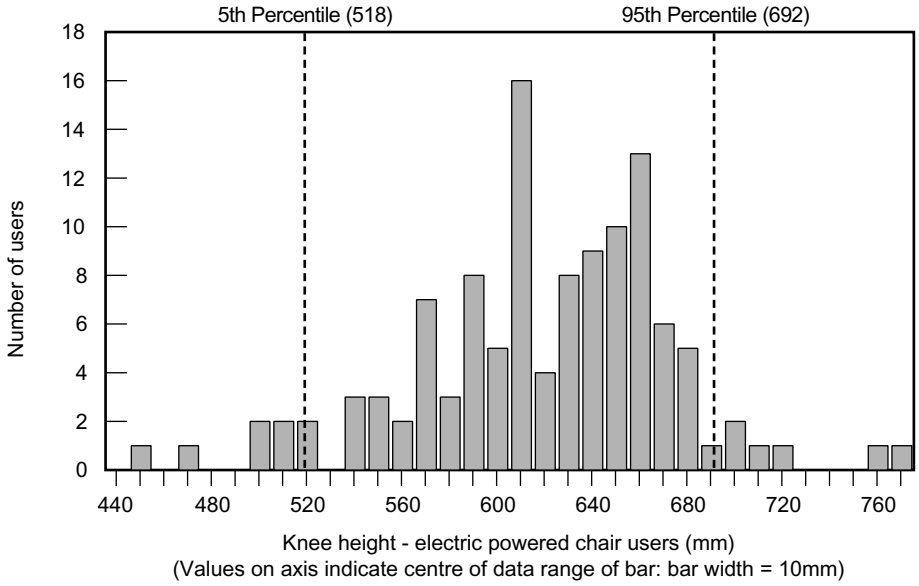

Figure C5 Knee height of wheelchair user from ground (electric powered chair)

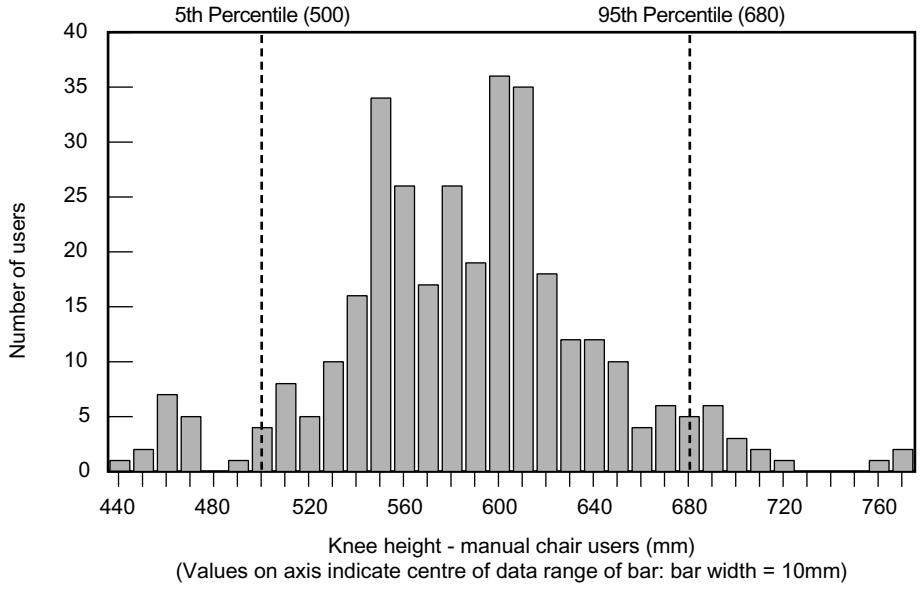

Figure C6 Knee height of wheelchair user from ground (manual chair)

Appendix D: Axle spacing of electric and manual wheelchairs

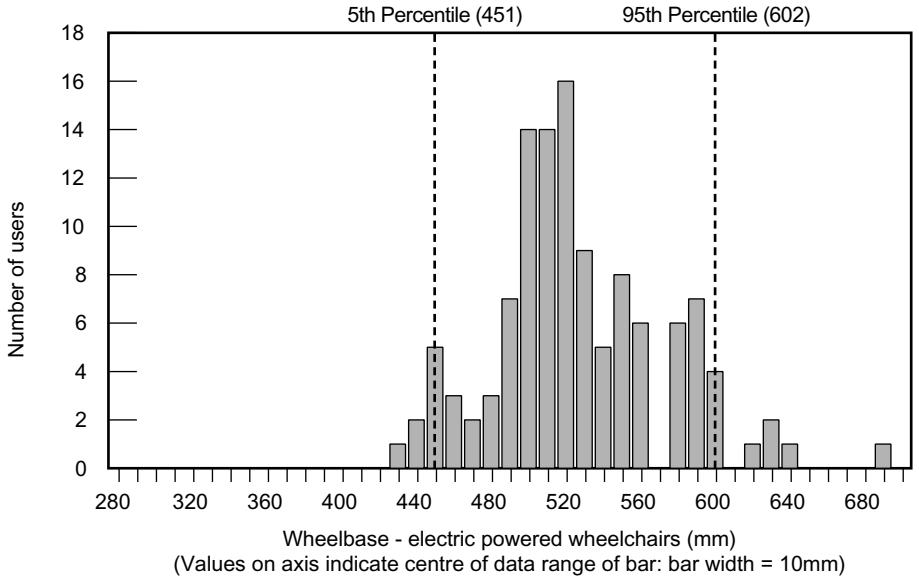

Figure D1 Axle spacing of electric powered chairs

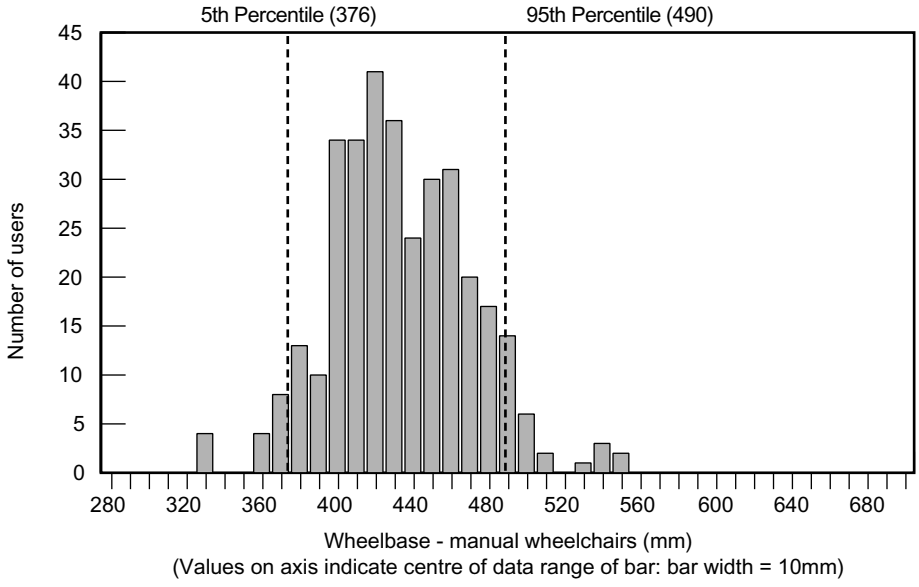

Figure D2 Axle spacing of manual chairs

Abstract

At the 1999 Mobility Roadshow, photographs and the weight of 745 wheelchair users were taken. From the photographs, overall dimensions of people in their wheelchairs were calculated. The wheelchairs being used were classified into five groups and additional features such as whether the person was carrying a walking aid were also noted. The dimensions compare well with previous work, although the distribution of wheelchair types has changed quite considerably. The combined weight of wheelchair and user was found in most cases to be within the safe working load recommended for vehicle lifts. It is hoped the results will aid designers of wheelchair accessible transport and building planners.

Related publications

TRL271 *Evaluation of low-floor bus trials in London and North Tyneside* by I York and R J Balcombe. 1998 (price £35, code H)

TRL150 *A survey of occupied wheelchairs to determine their overall dimensions and characteristics* by R E Stait and T A Savill. 1995 (price £25, code E)

RR85 *Operational trials with a wheelchair-accessible taxi* by M S Hall, D T Silcock and J G James. 1986 (price £20, code B)

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