Working Area of Wheelchairs

Details about Some Dimensions that are specified in ISO 7176-5

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Working group WG1 of Sub Committee SC1 of Technical Committee TC173 of the International Organization for Standardization ISO focuses on

Test Methods for Wheelchairs.

A great number of standards has been developed during the past years. They all are listed in the ISO 7176 series. At present the WG1 is revising the following document:

ISO 7176-5   Wheelchairs - Determination of dimensions and mass.

Even if not yet a ready standard (CD stage) the content and structure are clearly comprised.

The purpose of this International Standard is to provide technical definitions together with appropriate test procedures for measuring important dimensions and masses of manual wheelchairs as well as electrically powered wheelchairs including scooters.

Under the headline Required measurements, the wheelchair features that are most important for the user are listed. Their values will be disclosed in the specification sheets to inform the user before purchase whether the wheelchair will fit to its specific requirements and needs.

Under the headline Architectural considerations, the wheelchair dimensions that are most important for its use in narrow places are listed.

Annexes give typical values and recommended limits for the Required measurements and for the Architectural considerations and specify supplementary dimensions, which are of higher influence to good performance of the wheelchair (driving, steering, tracking etc.) as well as it explains some theoretical details about reversing width, turning diameter, wheelchair longitudinal axis and wheelchair centre-point.

Out from this standard ISO 7176-5 with a total of 36 items, the most relevant ones for the topic of this workshop are explained in deeper detail. These 11 selected items are:

1 Occupied length;

2 Occupied width;

3 Occupied height;

4 Minimum space;

5 Turning diameter;

6 Reversing width (type 1);

7 Reversing width (type 2);

8 Required width of angled corridor;

9 Required doorway entry depth;

10 Required corridor width for side exit; and

11 Ramp angle.

1 Occupied length

Distance between the most forward and most rearward point of the occupied wheelchair including user (see Figure 1).

2 Occupied width

Horizontal distance across the wheelchair including user (see Figure 1).

3 Occupied height

Vertical distance from the test plane to the uppermost point of the head of the user when occupying the wheelchair (see Figure 1).

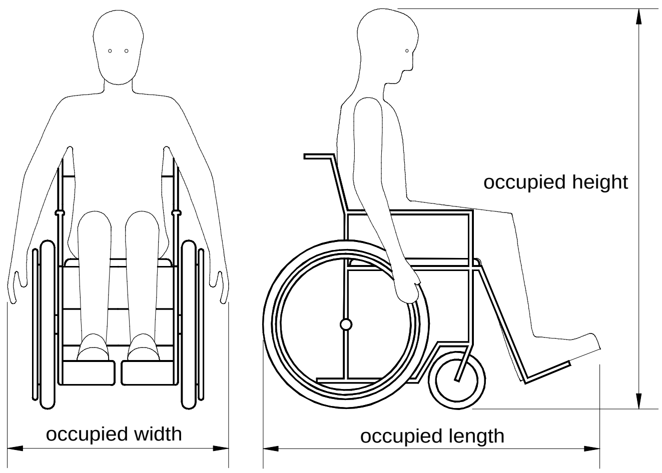


Figure 1 - Dimensions of the wheelchair when occupied

The standard ISO 7176-5 provides the following typical values and recommended limits.

Typical values (in mm)

	Manual wheelchair	Electrically powered wheelchair		
		Class A	Class B	Class C
Occupied length	1200	1240	1300	1300
Occupied width	740	620	680	700
Occupied height	1500	1500	1530	1590

Recommended maximum limits (in mm)

	Manual wheelchair	Electrically powered wheelchair		
		Class A	Class B	Class C
Occupied length	1300	1300	1300	1300
Occupied width	800	700	700	700
Occupied height	1600	1600	1600	1600

4 Minimum space

4.1 Definition

Minimum cylindrical space in which a wheelchair can be used in narrow places without excessive need of repeated reversing movements (see Figure 2).

Required minimum space is expressed as diameter x height in mm.

NOTE This dimension is used to help architects to provide space in toilets, baths, aisles and other narrow places that is minimally acceptable. Rooms need to be large enough to leave the required minimum space free even when the room is fitted with appropriate furniture.

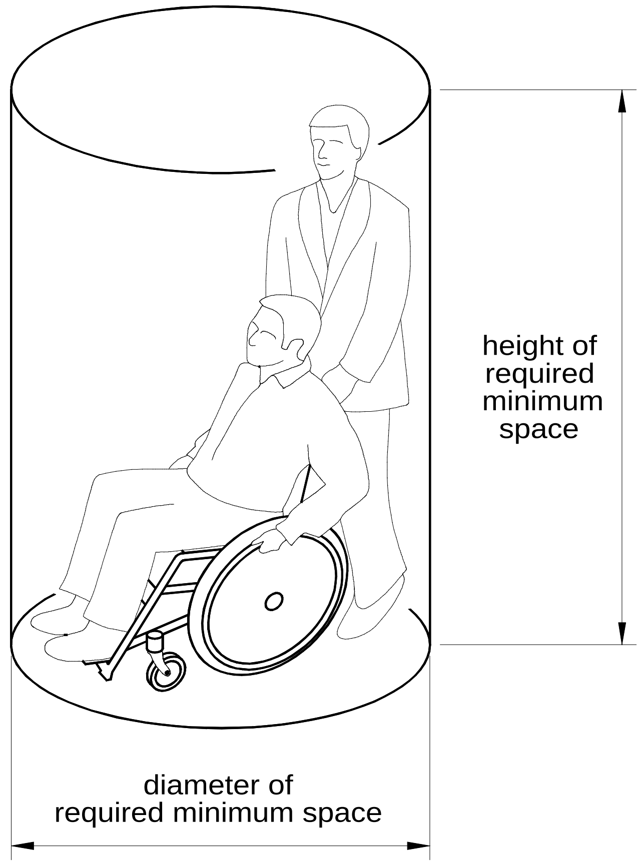


Figure 2 - Required minimum space

4.2 Technical details

Minimum space is not measured but derived from long term experience. But it need to be said, that this dimension is very poor.

When turning a typical wheelchair about a single point (Figure 3 a) not more than 90° are achieved.

When executing a turn with the front part of the wheelchair sliding along the limiting wall (Figure 3 b) the angle can extended to only 145°.

And when executing a 360° turn with several reversing manoeuvres (Figure 3 c) almost 7 backing operations are necessary.

Since the minimum space only specifies the circle around which the walls are arranged and sanitary equipment and furniture are located, some extra space might be available in real life. But since one cannot guarantee this extra space, you should be aware of this effect.

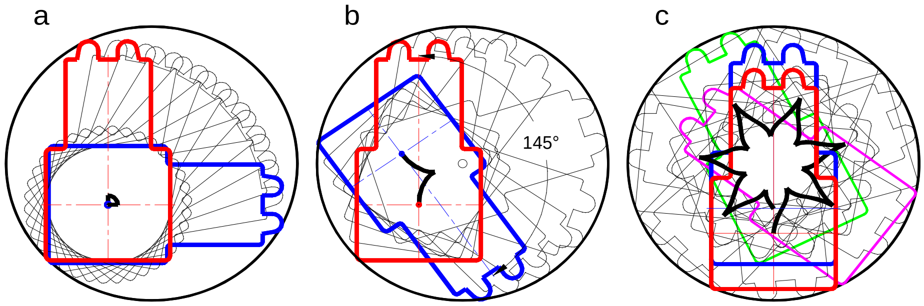


Figure 3 – Wheelchair manoeuvres in a circle of 1500 mm (minimum space)

The standard ISO 7176-5 provides the following recommended limits.

Recommended limits of required minimum space (in mm)

Manual wheelchair	Electrically powered wheelchair		
	Class A	Class B	Class C
1500∅ x 2000	1500 ∅ x 2000	1500 ∅ x 2000	1800 ∅ x 2000

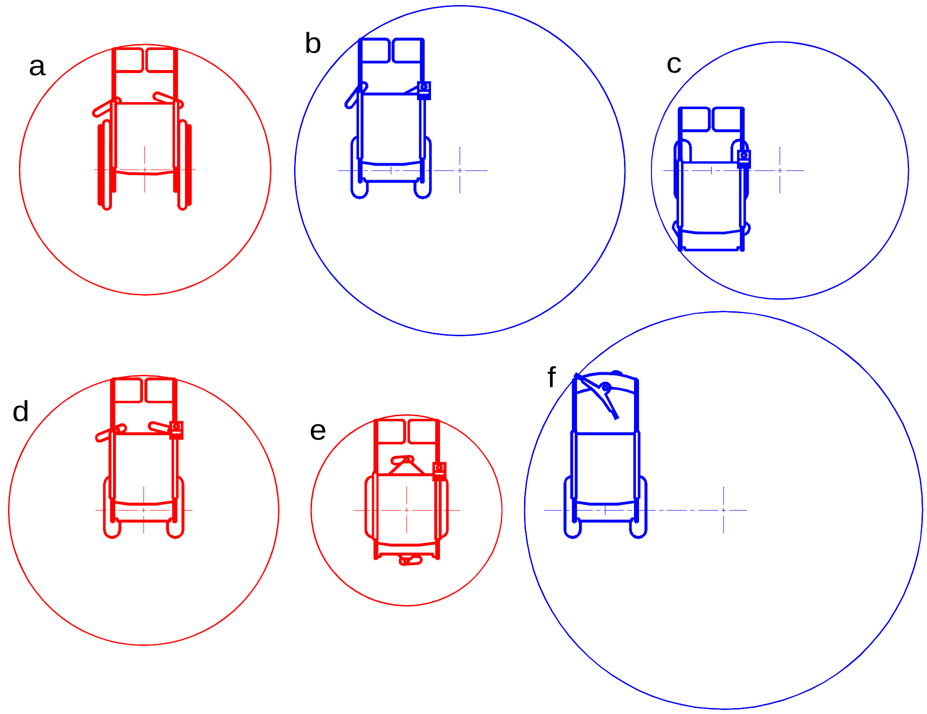
5 Turning diameter

5.1 Definition

The diameter of the smallest cylindrical envelope in which the unloaded wheelchair can drive in a circle through 360° (see Figure 4).

NOTE 1 The midpoint of turning will always lie on the axis of the fixed wheels. It will be more or less close to the wheelchair centre-point. Some wheelchairs can turn about a very near midpoint of turning while others only can turn about a more remote point. Wheelchairs with full differential steering can turn with the midpoint of turning lying at the wheelchair centre-point. Wheelchairs with direct steering have their midpoint of turning at the point of intersection between axis of fixed wheels and axis of steering wheels when the steering wheels are in their most extreme steering position.

NOTE 2 The turning diameter is intended as a theoretical dimension when comparing manoeuvrability of different wheelchairs.



Key:
a manual wheelchair
b electrically powered wheelchair with rear wheel drive and direct steering
c electrically powered wheelchair with front wheel drive and direct steering
d electrically powered wheelchair with rear wheel drive and full differential steering
e electrically powered wheelchair with mid wheel drive and full differential steering
f electrically powered wheelchair with scooter design and direct steering

Figure 4 - Turning diameter (examples for various wheelchair types)

5.2 Technical details

5.2.1 Wheelchair with direct steering

When a wheelchair has:

- direct steering;
- symmetrical construction without any wheel misalignment; and
- pivot wheels or pivot drive wheels which are vertical and pivot about vertical axes

and when all dimensions are projected to the test plane, the minimum turning diameter (TD_{DIR}) is calculated from:

$$TD_{DIR} = 2 \times \sqrt{\left(y + h + \frac{g}{\tan a}\right)^2 + x^2}$$

where

TD_{DIR} is the turning diameter for wheelchairs with direct steering, equal to the double distance between M and W, see Figure 5);

M is the midpoint of the turn;

W is that point of the wheelchair which is most remote from M;

y is the distance between W and wheelchair longitudinal axis;

h is the distance between G and wheelchair longitudinal axis ;

G is the ground contact point of the inner pivot wheel when the steering angle is at its maximum with the front in the lateral direction;

g is the distance between G and the axis of the fixed wheels;

a is the maximum steering angle of the inner pivot wheel (in degrees) with the front in the lateral direction; and

x is the distance between W and the axis of the fixed wheels.

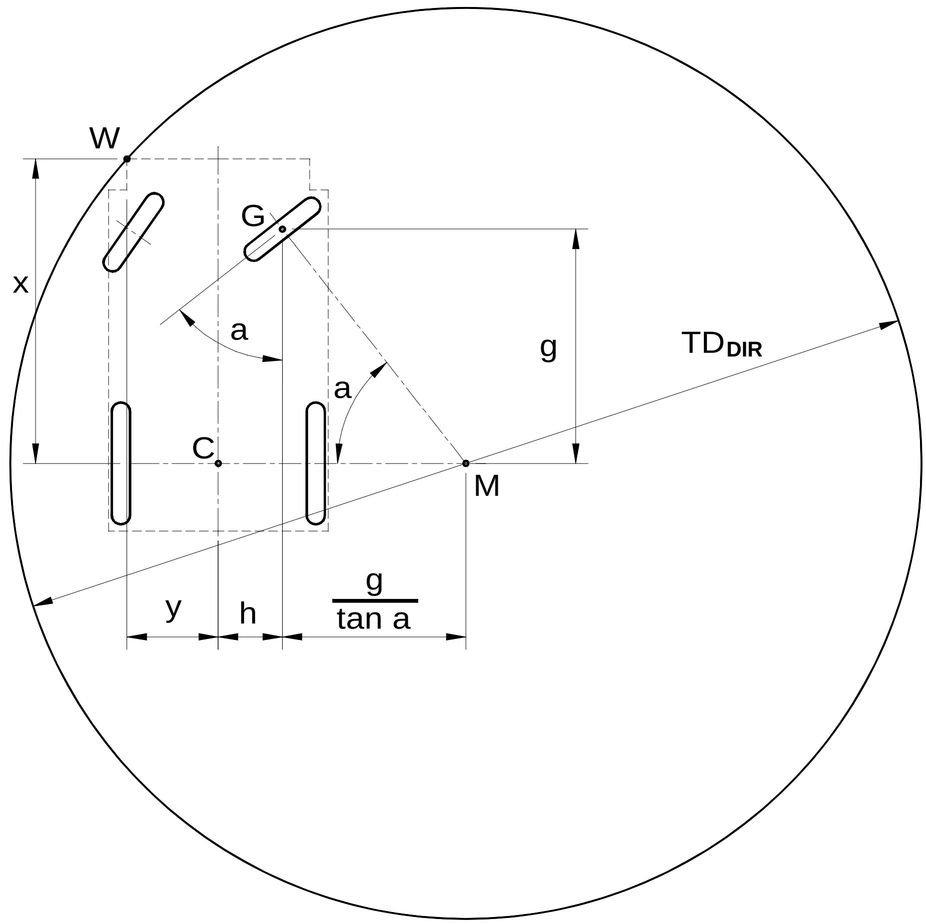


Figure 5 - Turning diameter, wheelchair with direct steering (TD_{DIR})

5.2.2 Wheelchair with differential steering

When a wheelchair has:

- limited differential steering;
- symmetrical construction without any wheel misalignment;
- castor wheels which are vertical and pivot about vertical castor axes

and when all dimensions are projected to the test plane, the minimum turning diameter (TD_{DIF}) is calculated from:

$$TD_{DIF} = 2 \times \sqrt{\left(\frac{t(v_o + v_i)}{2(v_o - v_i)} + y \right)^2 + x^2}$$

where

TD_{DIF} is the minimum turning diameter for a wheelchair with limited differential steering, equal to the double distance between M and W, see Figure 6);

M is the midpoint of the turning circle;

W is the point of the wheelchair that is most remote from M;

t is the wheel track of the manoeuvring wheels;

v is the speed of each manoeuvring wheel (indices: o...outer wheel, i...inner wheel);

y is the distance between W and wheelchair longitudinal axis; and

x is the distance between W and axis of manoeuvring wheels.

For a wheelchair with full differential steering the situation is much simpler. In this case the forward speed of one manoeuvring wheel equals the rearward speed of the other manoeuvring wheel ($+ v_o = - v_i$). Hence, the formula given above simplifies to

$$TD_{DIF-FULL} = 2 \times \sqrt{y^2 + x^2}$$

because the midpoint M of the smallest turning circle coincides with the wheelchair centre point.

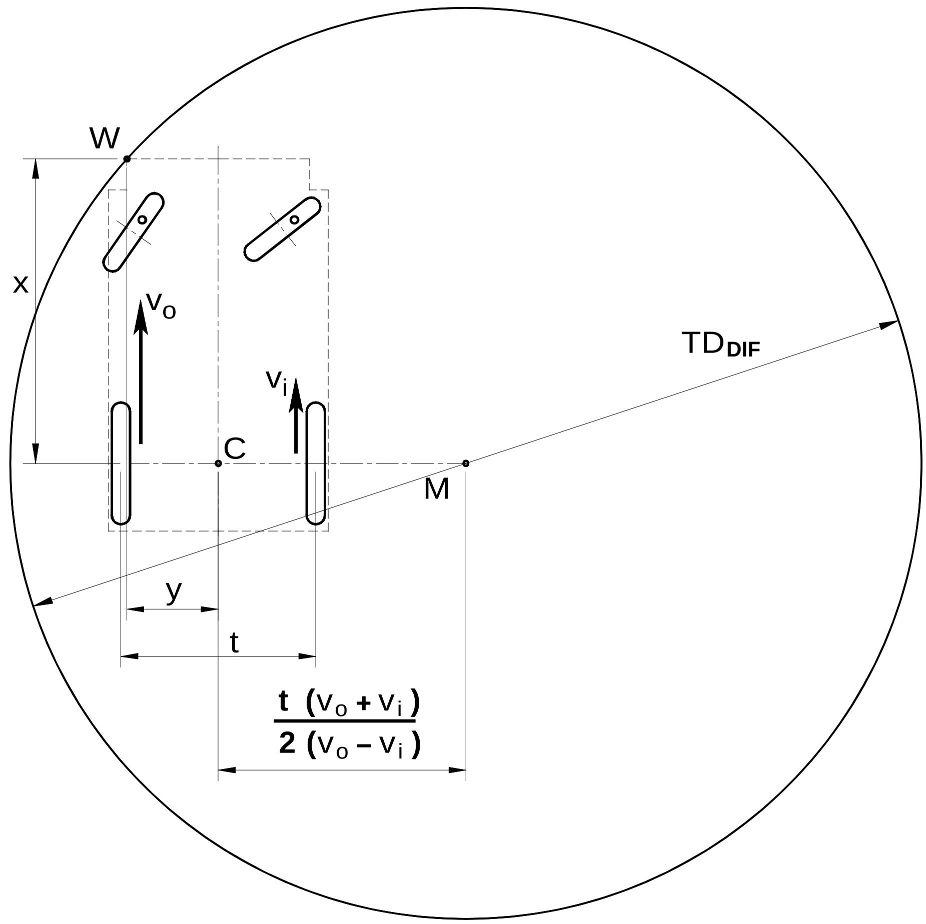


Figure 6 - Turning diameter, wheelchair with differential steering (TD_{DIF})

The standard ISO 7176-5 provides the following typical values and recommended limits.

NOTE No matter of steering type.

Typical turning diameter (in mm)

Manual wheelchair	Electrically powered wheelchair		
	Class A	Class B	Class C
1650	1780	1795	2700

Recommended maximum limits of turning diameter (in mm)

Manual wheelchair	Electrically powered wheelchair		
	Class A	Class B	Class C
2000	2000	2300	2800

6 Reversing width (type 1)

6.1 Definition

Minimum distance between two vertical and parallel walls between which an occupied wheelchair with full differential steering can turn around for 180° with one single and smooth turning manoeuvre (see Figure 7).

NOTE The reversing width (type 1) is intended as a clinical dimension to estimate the space needed in real live situations.

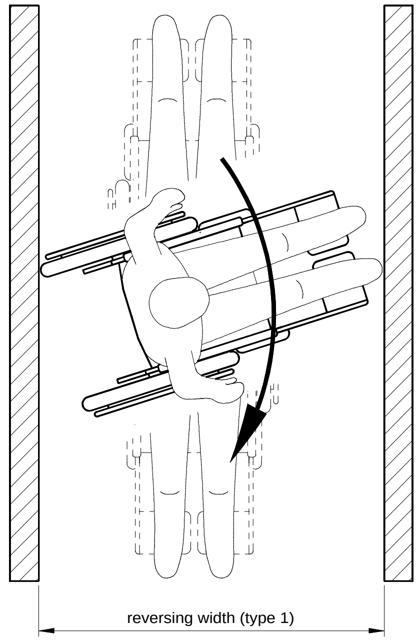


Figure 7 - Reversing width (type 1)

6.2 Technical details

Reversing width (type 1) is applicable for wheelchairs with full differential steering only.

The shape of the footprint (all dimensions are projected to the test plane) of a typical wheelchair is known from field experience. The footprint of a typical manual wheelchair with typical dimensions is shown in the left sketch of Figure 8 as an example. It is symmetrical and the greatest width of the wheelchair is at the drive wheels, while at the footrests the wheelchair is narrower. Its typical overall length and overall width are known from A.1 and A.3. The feet of the user are represented by the two bows at the front end, 200 mm apart and adding 100 mm to the length. The sketch also shows three distances of importance:

Distance R reaches from the wheelchair centre point C to that point of the footprint, which is to the rear and to the right of C and most remote from it. Its length is 432 mm and it will be perpendicular to the walls after the wheelchair has turned for 44°. This distance is shown in bold lines intermitted by small squares;

Distance D is located between the two points of the footprint that are furthest apart from each other. Its length is 1267 mm and it will be perpendicular to the walls after the wheelchair has turned for 71°. This distance is shown in bold lines intermitted by circles.

Distance F reaches from C to that point of the footprint, which is in front and to the left of C and most remote from it. Its length is 901 mm and it will be perpendicular to the walls after the wheelchair has turned for 83°. This distance is shown in bold lines intermitted by asterisks; and

NOTE 1 The end points of distances R and F usually are very close to but not identical with those of distance D

When an experienced user executes a turning manoeuvre between limiting walls, the front part of the wheelchair will swing around without any visible deviation from a smooth and unidirectional move. Meanwhile, without spending so much attention to this fact, the user will correct the position of the wheelchair intuitively by using micro steering manoeuvres. This is needed in order to adapt the position of the wheelchair between the walls.

The turning manoeuvre is performed as follows:

NOTE 2 It is assumed the distance between the adjustable walls is already reduced to the reversing width (type 1).

The wheelchair is placed between and parallel to the walls.

The turning manoeuvre can be started at any point, but it will need some drive to reach the best starting position from which it can be executed with a minimum of travel.

The right sketch of Figure 8 illustrates the path of the wheelchair when starting from the best starting position.

The best starting position is with C the distance R away from the right wall to allow as much as possible free space for the turn (C is at location 1 which is shown in the middle of the right sketch and in magnified view below). This position is shown in bold line near the word “start”.

The wheelchair turns about C (with C still on location 1) allowing its right rear end to pass by very closely at the right wall after a turn of 44° (distance R is perpendicular to the wall). This position and distance R are shown in bold lines intermitted by squares.

The wheelchair continues to turn about point C (with C still on location 1) until the left front end hits the left wall. This position is shown in bold lines intermitted by plus signs.

During the following turning manoeuvre, C needs to drive along the V-shaped line (which is shown in the middle of the sketch and in magnified view below) while the front part of the wheelchair slides along the left wall.

This turning manoeuvre is continued until C reaches location 2 and after the wheelchair has turned for 71°. The end points of distance D of the wheelchair will touch both walls at one time. This position and distance D are shown in bold lines intermitted by circles.

NOTE 3 If the walls are further apart so that the wheelchair cannot touch both walls at one time, the reversing width (type 1) is not yet achieved.

Hence, the reversing width (type 1) is equal to the distance D.

The turning manoeuvre continues with C driving along the V-shaped line and with the front end of the wheelchair sliding along the left wall until C reaches location 3 after a turn of 83°. The wheelchair will be the distance F away from the left wall. The front part of the wheelchair is no longer restricted from turning freely by the wall. This position and distance F are shown in bold lines intermitted by asterisks.

A further turn of the wheelchair about C (with C still on location 3) will bring it to a position that is perpendicular to the walls. This position is shown in bold lines intermitted by triangles. The first half of the turning manoeuvre (90°) is completed.

Since a symmetrical pattern of the turning manoeuvre is used, its first half only needs to be mirrored to receive the respective positions of the wheelchair during its second half. These positions and distances are shown in thin lines intermitted by their respective mirrored symbols.

During the second half of the turning manoeuvre C drives from location 3 via 4 to 5.

Since the sum of distance R plus distance F is 66 mm greater than distance D, the distance between location 1 and location 3 is 66 mm when measured perpendicular to the walls.

At the end of the turning manoeuvre the wheelchair again is parallel to the walls but turned around for 180°.

To demonstrate the whole drive pattern of the wheelchair when executing reversing width (type 1) in a way that is easier to imagine, also the total paths of two prominent wheelchair points is shown:

The wheelchair centre point C moving along the V-shaped line from location 1 via 2, 3 and 4 to 5; and

the middle of the foot support moving along the bowed line between “start” and “end”. This path is shown with a bold dash-dot line.

NOTE 4 The flat section in the middle of this bowed line indicates one important difference between the reversing width (type 1) and part of the turning diameter of a wheelchair with full differential steering (which is twice the distance F).

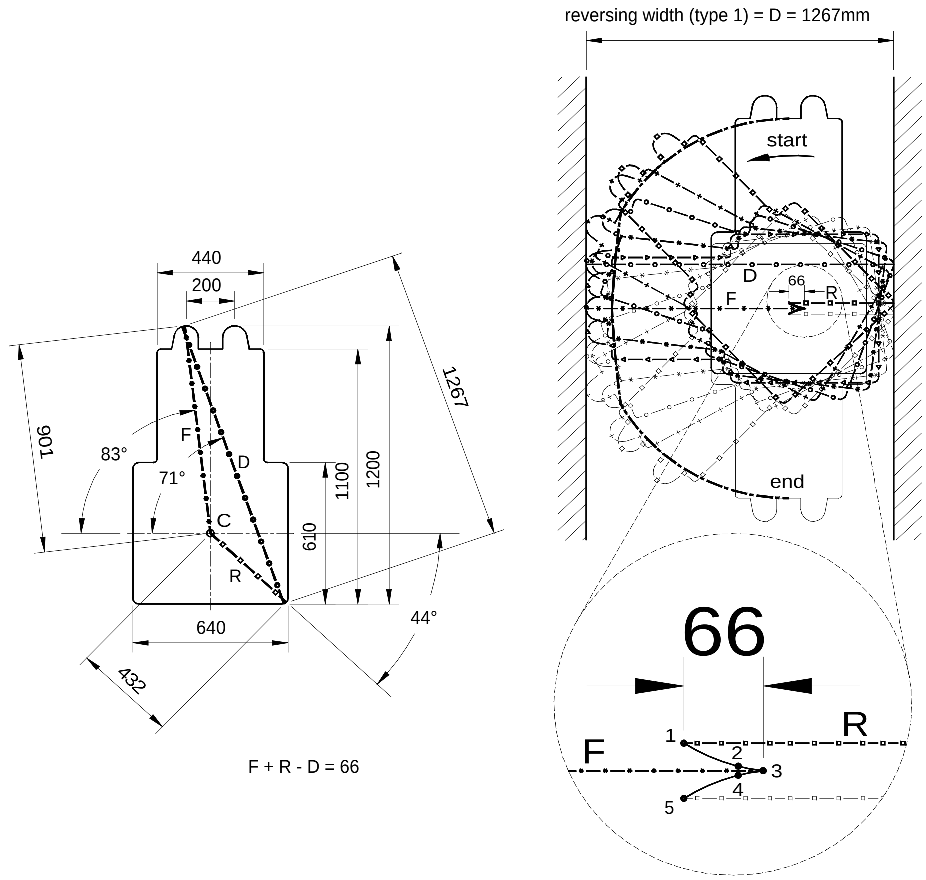


Figure 8 - Reversing width (type 1) (example)

The standard ISO 7176-5 provides the following typical values and recommended limits.

NOTE Class C wheelchairs and scooters usually do not have differential steering.

Typical reversing width (type 1) (in mm)

Manual wheelchair	Electrically powered wheelchair		
	Class A	Class B	Class C
1270	1250	1310	---

Recommended maximum limits of the reversing width (type 1) (in mm)

Manual wheelchair	Electrically powered wheelchair		
	Class A	Class B	Class C
1400	1400	1400	---

7 Reversing width (type 2)

7.1 Definition

Minimum distance between two vertical and parallel walls between which an occupied wheelchair with direct steering or limited differential steering can turn around for 180° with one initial forward drive, one single rearward drive and one final forward drive (see Figure 9).

NOTE The reversing width (type 2) is intended as a clinical dimension to estimate the space needed in real live situations.

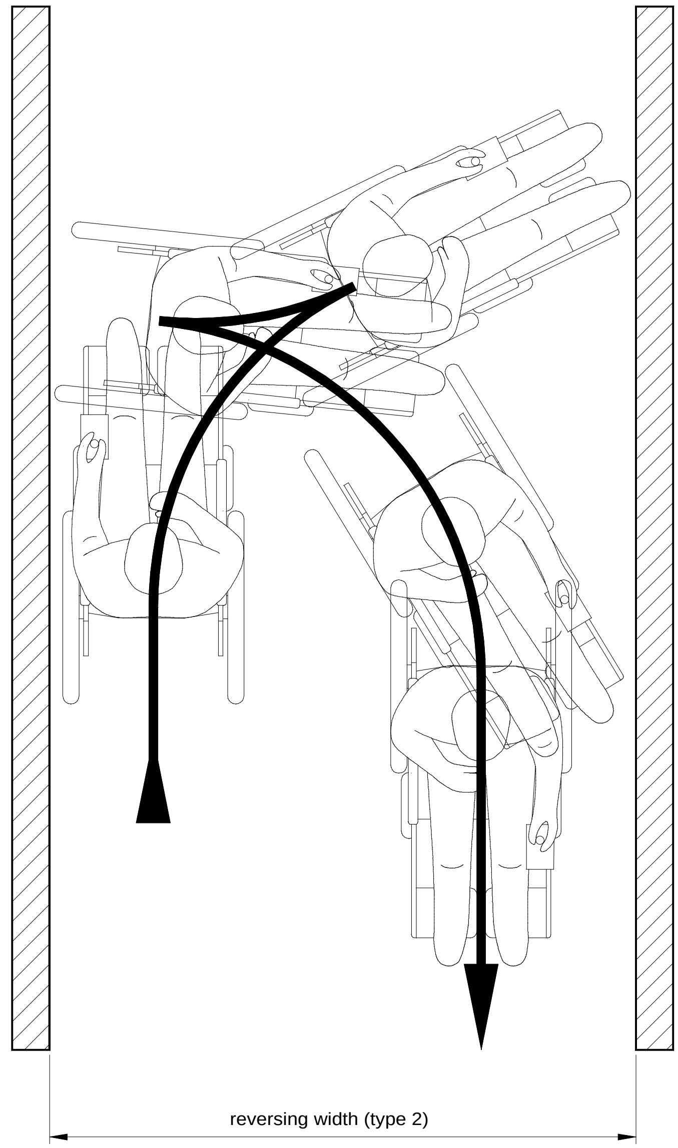


Figure 9 - Reversing width (type 2)

7.2 Technical details

Reversing width (type 2) is applicable for wheelchairs with direct steering or limited differential steering only.

The shape of the footprint (all dimensions are projected to the test plane) of a typical wheelchair is known from field experience. The overall length and overall width are known from A.1 and A.3. The footprint of a typical wheelchair with the typical dimensions of a wheelchair with direct steering is shown in the left sketch of Figure 10.

The minimum radius R_{DIR} of the trace of the wheelchair centre-point C of the wheelchair (distance measured between C and closest midpoint M of turning) is derived as follows:

For a wheelchair with direct steering, when the inner pivot wheel or pivot drive wheel is at maximum steering angle {a typical example is given in curved brackets}:

$$R_{DIR} = \frac{g}{\tan a} + h\ldots\ldots\ldots\ldots\ldots\ldots\left\{R_{DIR} = \frac{848}{\tan 61°} + 230 = 700mm\right\}$$

where

R_{DIR} is the radius of the path of C when tuning about M;

g is the distance between G and the axis of the fixed wheels;

G is the ground contact point of the inner pivot wheel when its steering angle is at its maximum;

a is the maximum steering angle of the inner pivot wheel (in degrees) with the front in the lateral direction; and

h is the distance between G and the wheelchair longitudinal axis.

A minimum radius R_{DIR} = 700 mm is achieved for the example in Figure 10.

For a wheelchair with limited differential steering, when the difference between speed of inner and outer manoeuvring wheel is at its maximum:

$$R_{DIF-LIM} = \frac{t(v_o + v_i)}{2(v_o - v_i)}$$

where

$R_{DIF-LIM}$ is the radius of the path of C when turning about M with a wheelchair with limited differential steering;

t is the track of manoeuvring wheels; and

v is the speed of each manoeuvring wheel (indices: o...outer wheel, i...inner wheel).

When executing the test for reversing width (type 2) the wheelchair will travel along a pattern as shown in the right ketch of Figure 10 as an example.

The wheelchair is positioned between and parallel to the walls.

The best starting position is with the wheelchair's right closest midpoint M1 for the initial forward drive at a distance from the left wall that is equal to the distance between M1 and that point J of the footprint, which is to the left and to the rear of C and most remote from M1.

The wheelchair performs the initial forward drive about M1 until it touches the right wall with a front point L.

It follows the single rearward drive about the left closest midpoint M2 until the wheelchair touches the left wall with a rear point N.

Then the wheelchair performs its final forward drive about its right closest midpoint M3.

The location of M3 should already be at a distance from the right wall that is equal to the distance between M3 and that point K of the footprint, which is to the left and in front of C and most remote from M3.

This enables the wheelchair to complete the 180° turning manoeuvre without wasting space and without hitting the walls.

The reversing width (type 2) expressed in mathematical notation is

$$RW2 = MJ + MF - 2R \cdot \cos\left(180° - g - \arccos\frac{RW2 - MJ}{MG}\right) - 2R \cdot \cos\left(180° - k - \arccos\frac{RW2 - MF}{MK}\right)$$

where

RW2 is the reversing width (type 2);

MJ is the distance M-J;

MF is the distance M-F;

R is the radius of the path of C when tuning about M;

g is the angle C-M-G;

MG is the distance M-G;

k is the angle C-M-K;

MK is the distance M-K; and

F, G, J and K are the four points of the occupied wheelchair that come in contact with the walls.

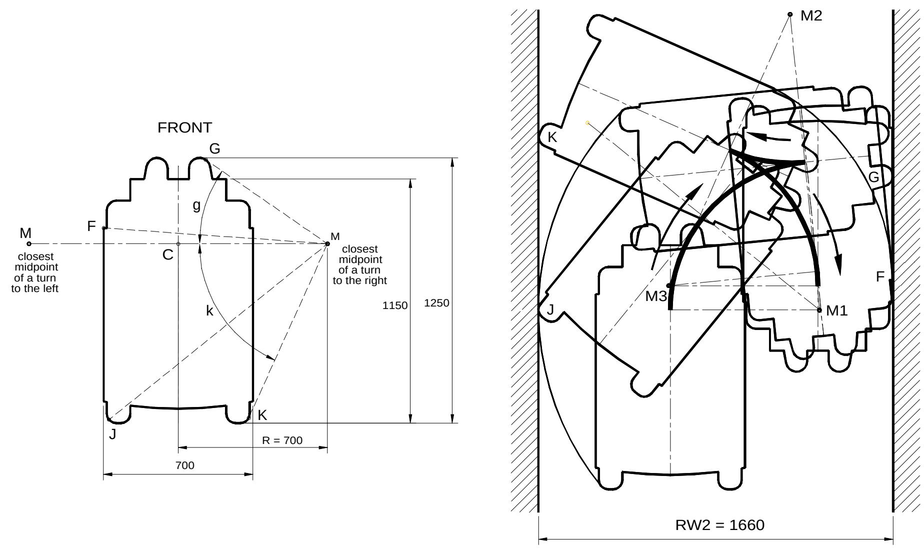


Figure 10 - Reversing width (type 2) (example)

The standard ISO 7176-5 provides the following typical values and recommended limits.

NOTE Manual wheelchairs and Class A and B wheelchairs usually do not have direct steering.

Typical reversing width (type 2) (in mm)

Manual wheelchair	Electrically powered wheelchair		
	Class A	Class B	Class C
---	---	---	1660

Recommended maximum limits of the reversing width (type 2) (in mm)

Manual wheelchair	Electrically powered wheelchair		
	Class A	Class B	Class C
---	---	---	1740

8 Required width of angled corridor

8.1 Definition

Minimum width of a corridor with a right angles turn in which an occupied wheelchair can be driven in forward and rearward direction (see Figure 11).

NOTE This is a clinical dimension that is intended to estimate the space needed in real life situations.

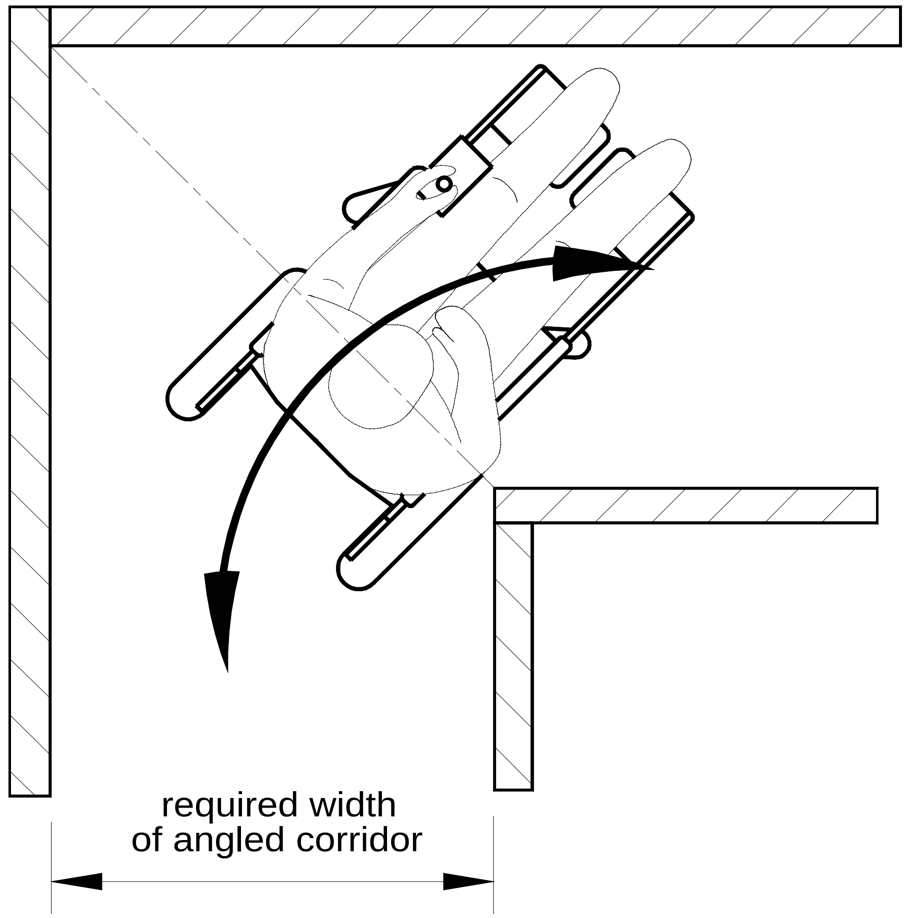


Figure 11 - Required width of angled corridor

8.2 Technical details

The most space saving way of driving along the angled corridor is with the front part of the wheelchair sliding along the wall. The pattern of movement shows a mild bend of the path of the wheelchair centre point and a long stretch of the path of the point in the middle of the footrests. The hook at the end of the footrest's path shows the final turn to have the wheelchair parallel to the walls (see Figure 12).

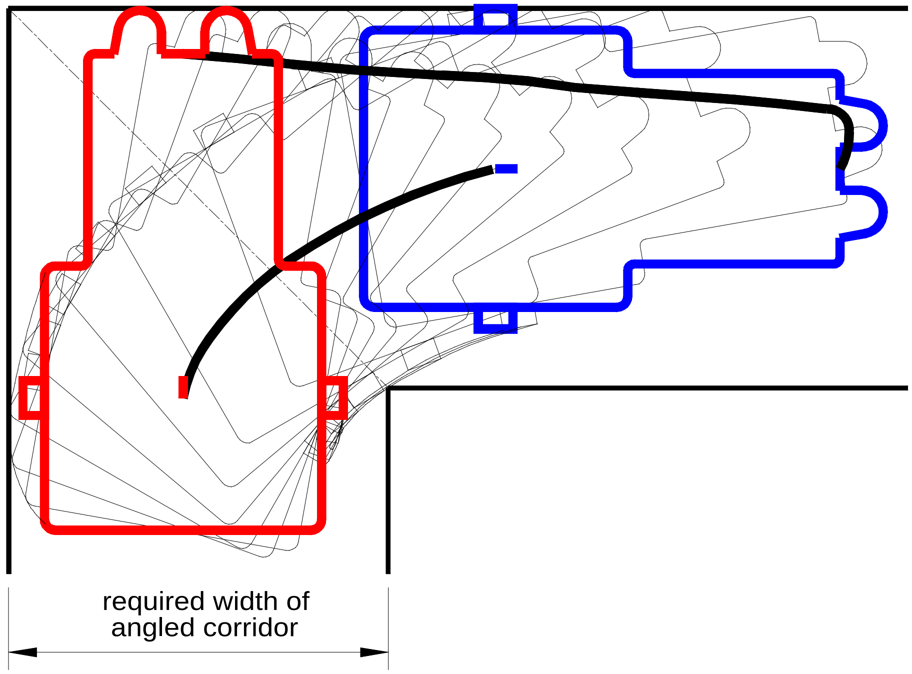


Figure 12 - Required width of angled corridor

The standard ISO 7176-5 provides the following typical values and recommended limits.

Typical required width of angled corridor (in mm)

Manual wheelchair	Electrically powered wheelchair		
	Class A	Class B	Class C
880	840	870	960

Recommended maximum limits of required width of angled corridor (in mm)

Manual wheelchair	Electrically powered wheelchair		
	Class A	Class B	Class C
1010	1000	1000	1030

9 Required doorway entry depth

9.1 Definition

The minimum distance between the wall and the most remote point of the occupied wheelchair when opening a door that is located near a wall's corner (see Figure 13).

NOTE 1 The required doorway entry depth is intended as a clinical dimension to estimate the space needed in real live situations.

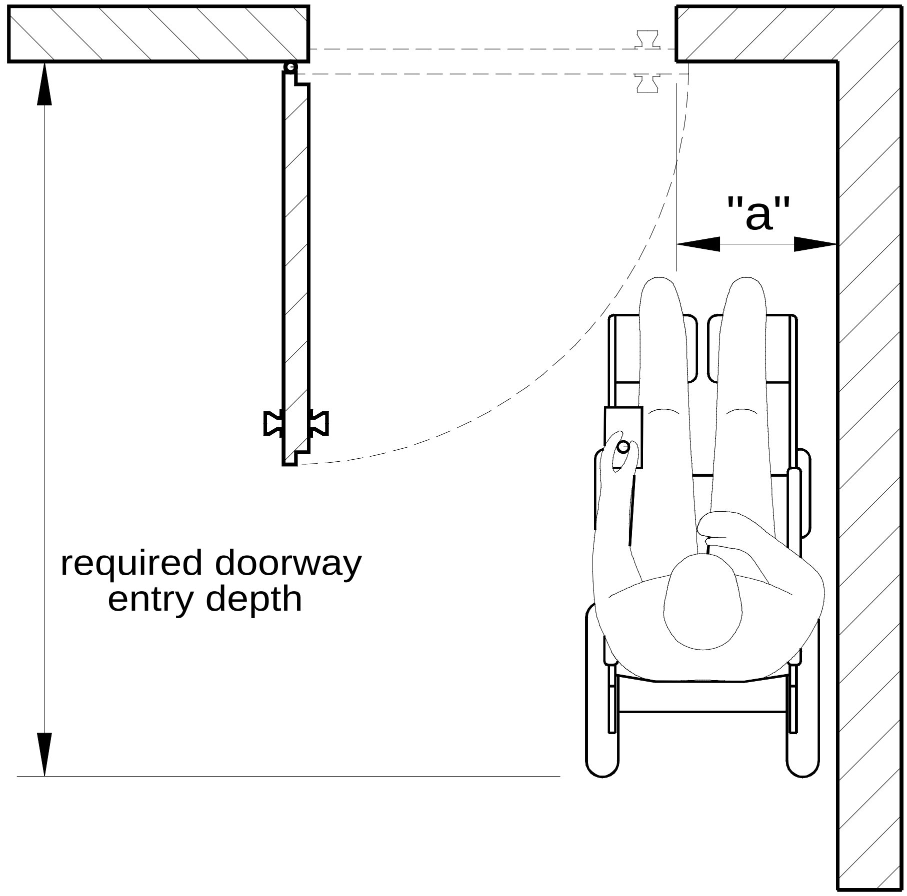


Figure 13 - Required doorway entry depth

9.2 Technical details

When providing place for the swinging door, the wheelchair will need to drive back. Determined by distance "a" the space for the required doorway entry depth will vary. Two examples are show. A typical occupied manual wheelchair with extra space for feet and hands of the user at front and sides, and a wheelchair with maximum recommended dimensions. It is represented by a rectangle with maximum recommended length and width. Again, the same extra space for the occupant is added. When measuring required doorway entry depth, dimension "a" is varied between 800 mm and 0 in 100 mm increments for several situations.

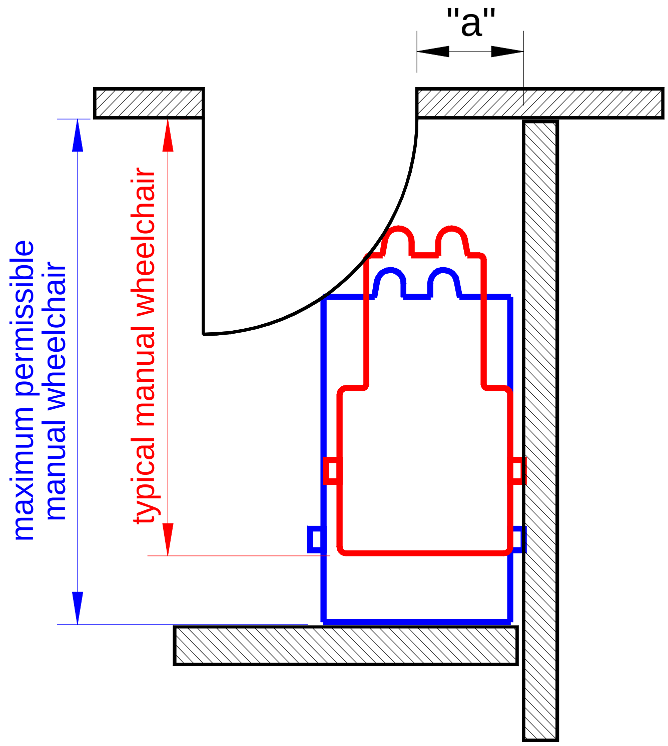


Figure 14 – Required doorway entry depth

The standard ISO 7176-5 provides the following typical values and recommended limits.

Typical required doorway entry depth (in mm)

Distance “a”	Manual wheelchair	Electrically powered wheelchair		
		Class A	Class B	Class C
800	1200	1210	1265	1249
700	1200	1210	1265	1249
600	1200	1210	1265	1385
500	1460	1311	1448	1541
400	1610	1526	1631	1661
300	1720	1656	1746	1760
200	1820	1767	1846	1847
100	1890	1851	1923	1919
0	1940	1913	1980	1973

NOTE For practical reasons, a gross but sovereign method is introduced. To determine the typical required doorway entry depth (RDED) for any wheelchair under any test set-up, one could use the formula:

RDED = 2100 – a

to receive an amount that is on the safe side under all circumstances. On the other hand, the result will be not more than 250 mm above the value measured.

Recommended maximum limits of the required doorway entry depth (in mm)

Distance “a”	Manual wheelchair	Electrically powered wheelchair		
		Class A	Class B	Class C
800	1300	1300	1300	1300
700	1480	1300	1300	1300
600	1670	1590	1590	1590
500	1780	1730	1730	1730
400	1870	1830	1830	1830
300	1930	1900	1900	1900
200	1960	1950	1950	1950
100	2000	1980	1980	1980
0	2040	2030	2030	2030

NOTE For practical reasons, a gross but sovereign method is introduced. To determine the maximum limit of required doorway entry depth (RDED) for any wheelchair under any test set-up, one could use the formula:

RDED = 2300 – a

to receive an amount that is on the safe side under all circumstances. On the other hand, the result will be not more than 300 mm above the value measured.

10 Required corridor width for side exit

10.1 Definition

Minimum width of a corridor when entering and leaving through a side exit with an occupied wheelchair in forward and rearward direction (see Figure 15).

NOTE 1 The required corridor width for side exit is intended as a clinical dimension to estimate the space needed in real live situations.

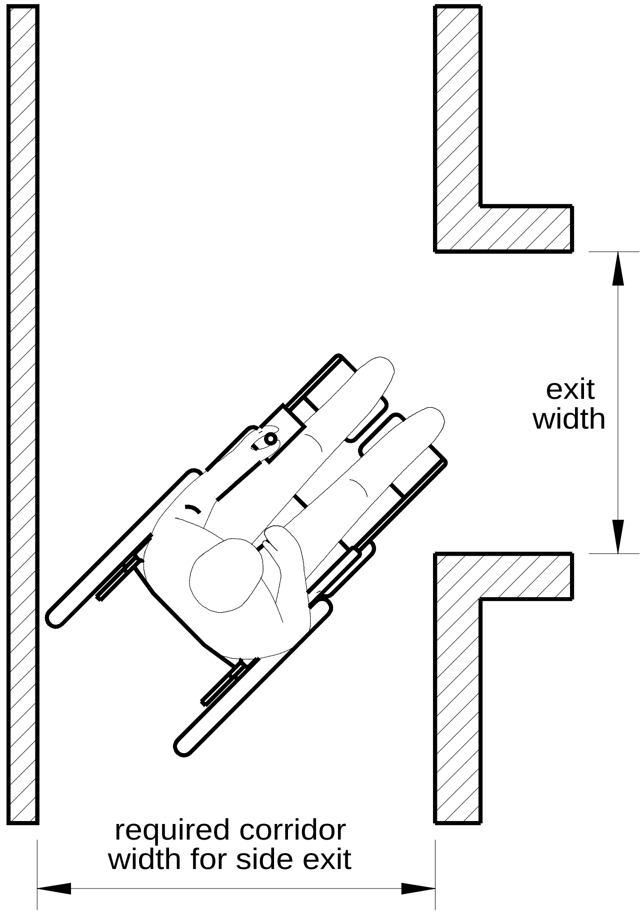


Figure 15 - Required corridor width for side exit

10.2 Technical details

The best space saving way of leaving (and entering) a corridor through an side exit is with the front part of the wheelchair consuming as much space of the corridor for swinging around before entering the exit. The pattern of movement shows a mild bend of the path of the wheelchair centre point and a S-curve of the path of the point in the middle of the footrests (see Figure 16).

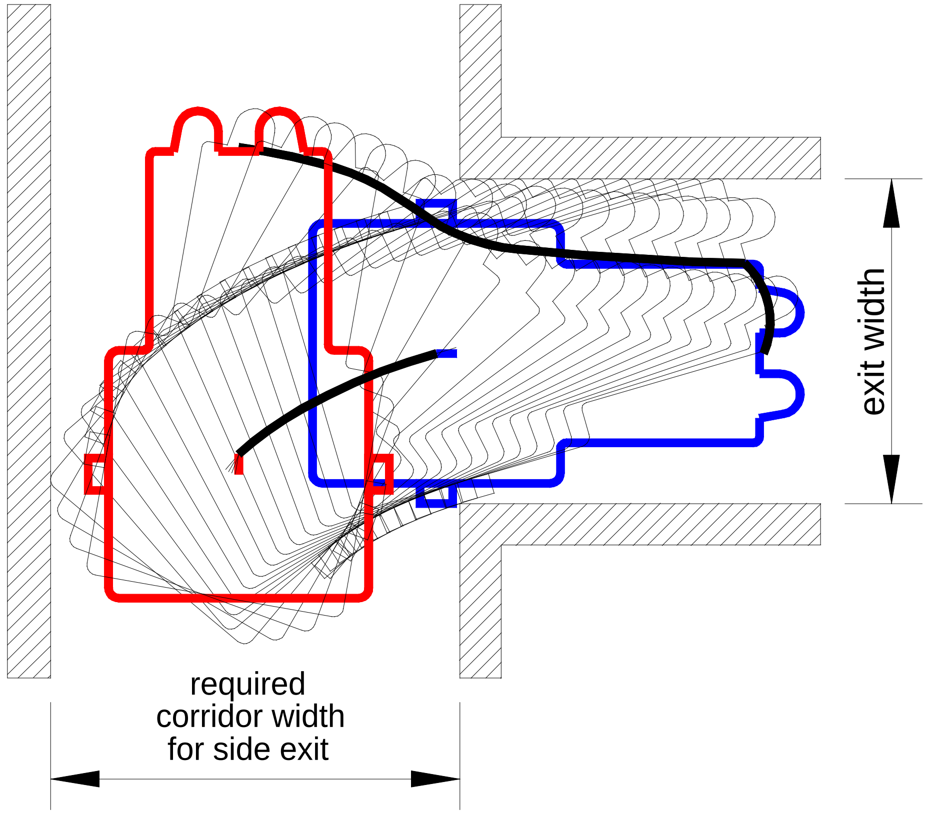


Figure 16 – Required corridor width for side exit

The standard ISO 7176-5 provides the following typical values and recommended limits.

Typical required corridor width for side exit (in mm)

Door width	Manual wheelchair	Electrically powered wheelchair		
		Class A	Class B	Class C
1000	810	760	800	930
900	870	800	850	1060
800	1020	900	1000	1360
700	---	---	---	---

Recommended maximum limits of the required corridor width for side exit (in mm)

Door width	Manual wheelchair	Electrically powered wheelchair		
		Class A	Class B	Class C
1000	1020	990	990	1080
900	1290	1260	1260	1400
800	1830	1810	1810	2050

11 Ramp angle

Angle of the steepest ramp the transitions of which to level ground can be negotiated by a wheelchair without contacting the ramp or the ground with any other part than the wheels.

It is the smallest angle achieved when climbing a ramp (see Figure 17) :

with front parts at the lower landing;

with rear parts at the lower landing; and

with parts that are located between the wheels at the upper landing.

The ramp angle is expressed in degrees.

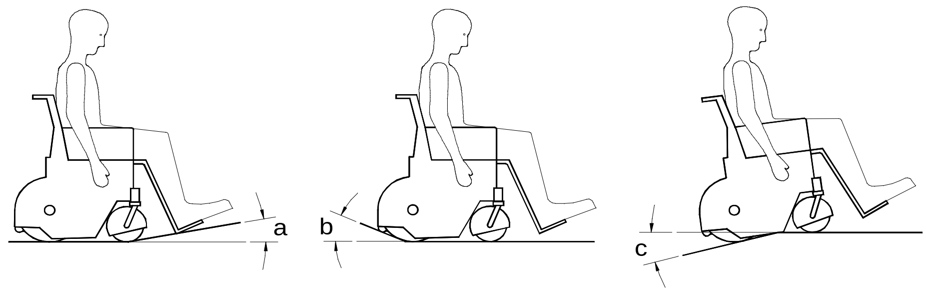


Figure 17 - Ramp angle

The standard ISO 7176-5 provides the following typical values and recommended limits.

Typical ramp angle (in degrees)

Manual wheelchair	Electrically powered wheelchair		
	Class A	Class B	Class C
12	12	15	20

Recommended minimum limits of ramp angle (in degrees)

Manual wheelchair	Electrically powered wheelchair		
	Class A	Class B	Class C
10	10	10	15

NOTE The recommended minimum limits of ramp angle should correspond to the steepest slope for which the wheelchair is recommended by the manufacturer.