Reference wheelchairs

The reference wheelchair for public transport vehicles
Report

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Title photo:
1:1 scale model of the reference wheelchair for public transport
Left: PRM TSI version
Right: FOT version

Imprint:

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Contents

1. Assignment

This report is intended to serve as an aid to interpretation of the European Standards mentioned below for their application in Switzerland.

- PRM TSI, 2014 edition, Appendix M
  Commission Regulation (EU) No 1300/2014 on the technical specifications for interoperability relating to accessibility of the Union's rail system for persons with disabilities and persons with reduced mobility
- EN 16585-1:2017, Annex B
  Railway Applications – Design for PRM Use – Equipment and Components On Board Rolling Stock – Part 1: Toilets

Both show the necessity of a toolbox for the different project phases when commissioning a rail vehicle (from the first layout plan up to approval), which can be applied to examining the wheelchair conformity of any project phase.

A distinction should be made according to:

- a toolbox for rail vehicles that travel on the Swiss interoperable network, as defined by the FOT.
- a toolbox for rail vehicles, including trams, that travel on rail networks outside the interoperable network.

2. At a glance

1. As a reference wheelchair for public transport we are using a 1:1 scale volume model that we have ourselves developed, using the maximum permissible measurements of a wheelchair according to the PRM TSI. It enables wheelchair spaces in vehicles to be accessed and in theory public transport facilities as well.
   The study was limited to railway and tram vehicles.

2. This accessing of wheelchair spaces by the reference wheelchair for public transport, and thus the performance of the necessary manoeuvres to fulfil this function, should be viewed as the most reliable and unambiguous verification procedure for the conformity of wheelchair spaces (manoeuvring and parking spaces) in accordance with PRM TSI.

3. For the planning phase in the development of railway and tram vehicles for public transport, 1:10 and 1:20 scale floor plan models were created with the measurements, driving and manoeuvring characteristics of the reference wheelchair for public transport.

4. The accessing of wheelchair spaces by randomly selected wheelchair users cannot verify the conformity of wheelchair spaces in accordance with PRM TSI. This is because any deviations from the PRM TSI wheelchair in terms of measurements or steering behaviour of randomly selected wheelchairs cannot be known.

3. Summary

The PRM TSI and its implementing European Standard “EN 16585-1:2017: Toilets” define a detailed public transport wheelchair volume model and its steering characteristics.

The PRM TSI and its implementing European Standards give area requirements (length / width / height) as planning data for the wheelchair space:

- Wheelchair space measurements
- Manoeuvring areas (e.g. turning circle)
- Passage widths for 90° changes in direction where no wheelchair turning circle is described
- Passage widths in combination with handrails.

The clearest and most reliable procedure to verify the conformity of wheelchair spaces to the PRM TSI is to drive through the wheelchair spaces, completing the necessary manoeuvres for verification using the reference wheelchair for public transport.

This form of evidencing an aspect of wheelchair conformity is not provided for in the current PRM TSI and its implementing European Standards.

Therefore we cannot currently deduce how to proceed if there are contradictions between areas defined by the PRM TSI and its implementing European Standards, and the space required for driving and manoeuvring using the reference wheelchair for public transport.

The **1:1 scale wheelchair volume model** (Fig. 1) can be converted between the two basic versions with identical plan measurements

- PRM TSI, for the interoperable normal gauge network
- FOT (Implementing Provisions of 15 December 1983 to the Railways Ordinance**,** IP-RailO) for the rail network outside the interoperable network (metre-gauge railways and trams).

The height of the reference wheelchair for public transport was limited to 950 mm, in order to maintain an overview when driving.

Fig. 1 on page 7 gives the detailed dimension sheet (plan and side views) of the reference wheelchair for public transport, supplemented with the isometric diagram of the PRM TSI version and the FOT version.

To be able to prove wheelchair conformity at an early planning stage (layout plan and sections), there are **two drivable floor plan models at scales of 1:10 and 1:20** (Fig. 2). These models each have a pair of wheels, so that the steering and driving characteristics can be taken into account in the manoeuvres.

A **graphical iterative procedure** was also developed, to determine the tractrix or envelope curves of the reference wheelchair for public transport. Application of this procedure at the layout plan stage can simulate the accessibility of wheelchair spaces.

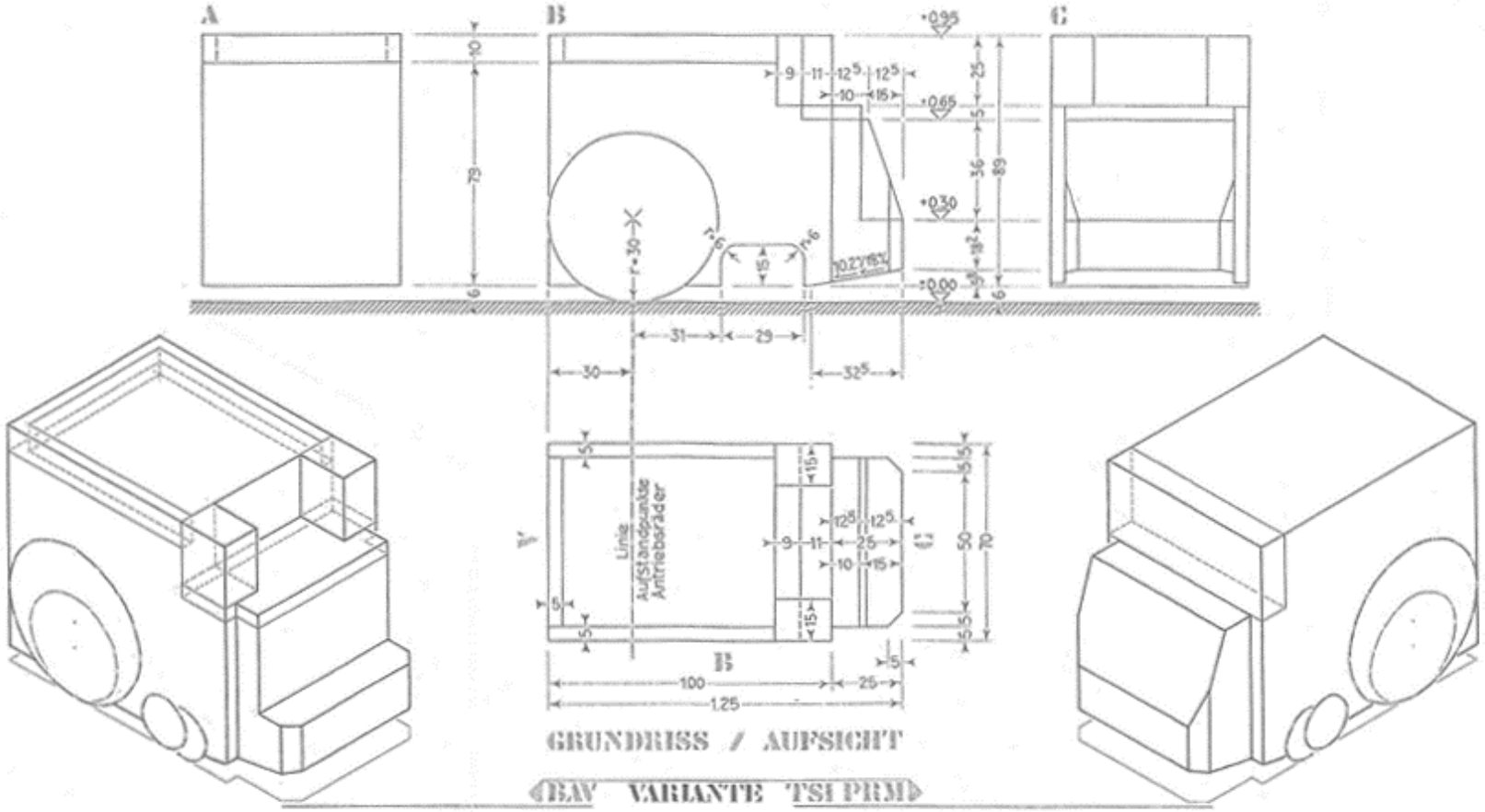

Fig. 1
Dimension sheet of the reference wheelchair for public transport according to PRM TSI and EN 16585-1:2017, supplemented with two isometric diagrams
Left: FOT module Right: PRM TSI module

A Glossary of German terms contained in the Figures is given on the final page of this document.

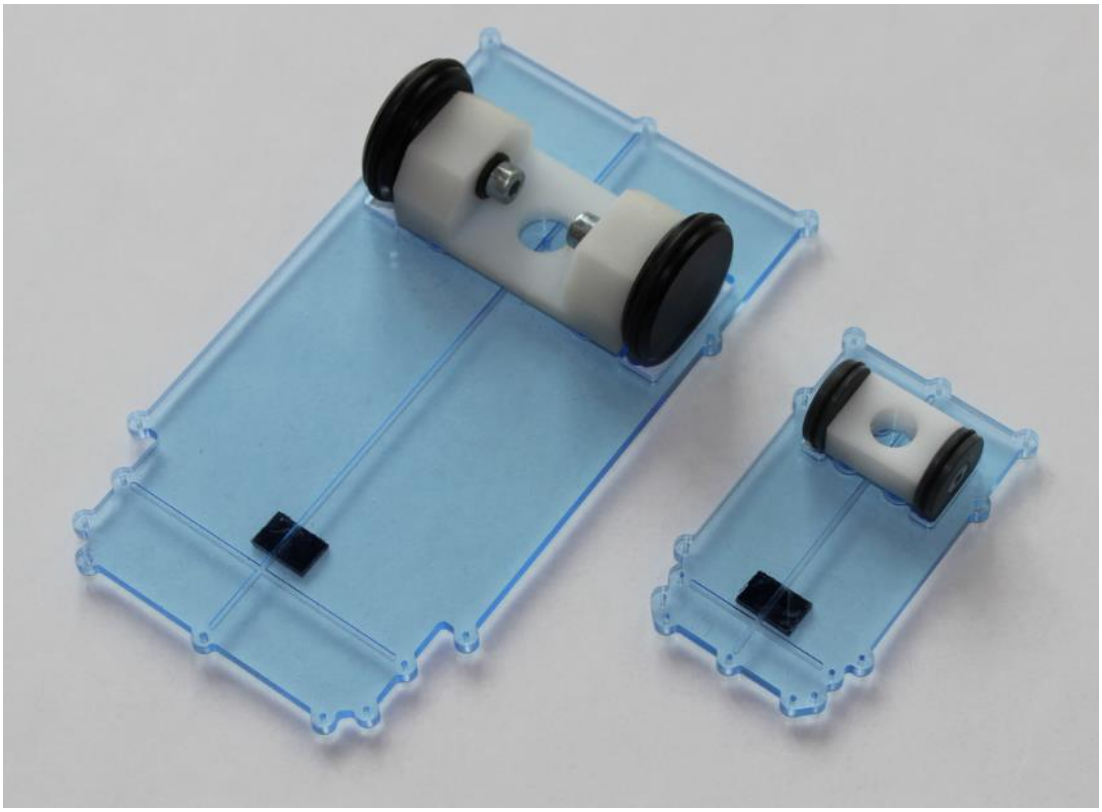

Fig. 2
Drivable floor plan models; left scale 1:10, right 1:20

4. Vehicle approvals procedure

We distinguish between vehicles assigned to interoperable rail transport and those that do not travel on interoperable networks. For vehicles that travel on the Swiss interoperable routes (= practically all linked normal gauge networks in Switzerland), the inspection organisation is a Notified Body (NoBo), which issues an inspection certificate, on the basis of which approval is granted.

For vehicles that do not travel on interoperable routes, wheelchair accessibility must be declared by the applicant, as previously. Accessibility is checked by the FOT using random inspections, and now usually tested using the FOT wheelchair volume model. An inspection certificate is not required.

Legislative level

There is a substantial difference between Swiss legislation and the European rules in the fundamental principle of usability by persons in wheelchairs:

EU

The **accessibility** of interoperable public rail transport to wheelchair users is regulated in the PRM TSI and the associated implementing provisions, and basically **permits** design that makes **aid provided by third parties** necessary to access a vehicle, e.g. lifts, ramps with a slope of 18%.

CH

The Swiss legislation and case law gives particular importance to autonomy overall, and the autonomous use of public transport in particular.
The **independent use** of public transport by wheelchair users is regulated by the Public Transport Adaptation Ordinance (PTAO).
The implementing provisions to PRM TSI and the relevant implementing European Standards (EN) are incorporated into Swiss Federal law through the revision of the PTAO and the IP-RailO as of 1.7. 2016.

The previously applied criterion of **independent autonomous use is maintained** and not replaced by the term “accessibility” within the meaning of European law. The FOT has notified the European Commission of a Notified National Technical Rule (NNTR) to the PRM TSI.

“Independent use” presupposes that wheelchair users who are able to move about public space independently are able to use public transport vehicles via step-free access, fundamentally without help from third parties (public transport staff or private individuals). This requires “step-free access” in accordance with PRM TSI Section 2.3 (“Other definitions”) to be the norm.

Derogations from this are possible only within the principle of proportionality, and would require interests to be weighed up and approved by the FOT.

Differences between PRM TSI and general building standards in terms of wheelchair accessibility:

PRM TSI standard for public transport rail vehicles European Standard and country-specific standards	Standards in the construction sector Country-specific standards
Areas are specified in terms of shape, size and passage width, as well as the volumes of a reference wheelchair and, indirectly, its steering characteristics.	The area required for particular activities is specified. Wheelchair measurements (length and width) are given for information. (e.g. BS 8300:2009+A1:2010; ISO 21542:2011; SIA 500

5. Why have a reference wheelchair for public transport?

Rail vehicles are limited by their external and internal volumes, and so the more generous dimensions of areas specified by the construction sector cannot be realised inside them.

In Switzerland, wheelchair accessibility has up to now been tested in collaboration with disability organisations, which have delegated wheelchair users to test the passability of spaces.

This process is quite random. There is great diversity in the wheelchairs available. The REHADAT directory includes more than 550 types of wheelchair for Germany, and these will show varied measurements for a single type, according to the adjustments made to suit the individuals using them.

Space calculations using a reference wheelchair for public transport mean that wheelchair users can use the particular functions if they are moving within these spaces.

This means that the **floor plan dimensions** (footprint) and the **manoeuvrability**, primarily determined by the position of the drive wheels, form a mutually interacting **wheelchair unit**.

This **wheelchair unit, together with the occupant, forms the system unit "person in wheelchair"**. This system unit must be able to move within the floor space requirements using the reference wheelchair for public transport, without individual subelements or criteria being checked for their adherence to the PRM TSI measurements.

6. Derivation / development of a volume model for the reference wheelchair for public transport

PRM TSI, Appendix M

Only those details from Appendix M that are relevant to the volume model are listed below. For the full text with more detailed specifications from EN 16585-1:2017, see the Appendix.

M.2 CHARACTERISTICS

The minimum technical requirements are:

Basic dimensions

– Width* of 700 mm ① plus 50 mm min each side for hands when moving

– Length* of 1 200 mm ② plus 50 mm for feet

*Should not length and width, analogously to height also have the word “max” followed by the dimension, instead of the word "of" followed by the dimension: «Width 700 mm max», «Length 1 200 mm max»?

Height

– 1 375 mm max ③ including a 95th percentile male occupant

Obstacle height that can be overcome and ground clearance

– Obstacle height that can be overcome 50 mm (max)

– The sentence «Ground clearance 60 mm (min) ④ with a [sic] upward slope angle of 10° ⑤** on top for going forward (under the foot rest)» should be replaced by «The footrest must have an upward slope angle of 10° for going forward (moving up or down the ramp) in order to manage a change of gradient of 170° (180° minus 10°).»

**⑤ The 330 mm dimension in Fig. 2 corresponds to the foot length in a shoe of a 95th percentile man.

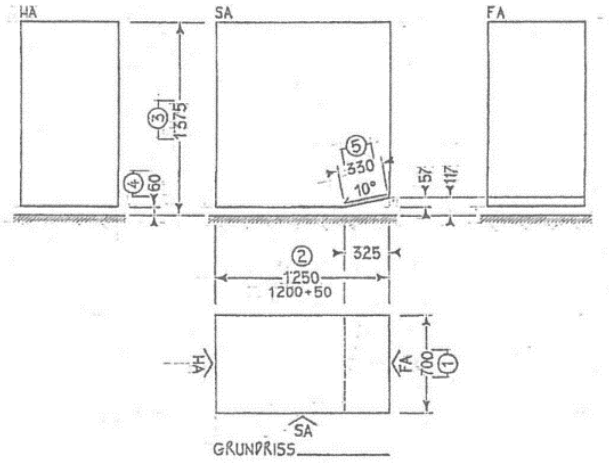

Fig. 3
Basic dimensions of a wheelchair including 95th percentile male occupant according to PRM TSI, Appendix M

A Glossary of German terms contained in the Figures is given on the final page of this document.

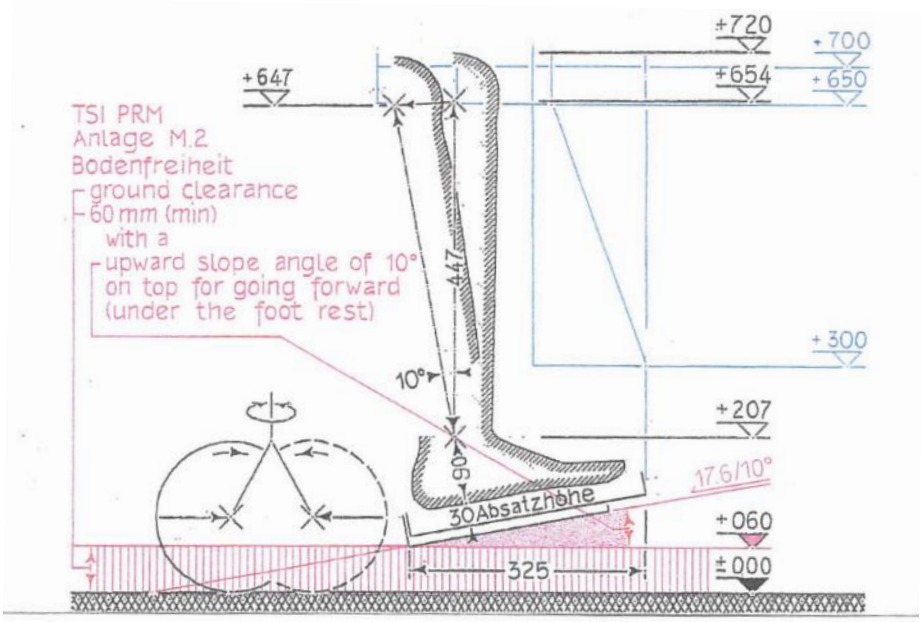

Fig. 4
Ground clearance 60 mm ④ and footrest at 10° angle ⑤

A Glossary of German terms contained in the Figures is given on the final page of this document.

EN 16585-1:2017: Toilets, Annex B, B.1

This Appendix develops the basic dimensions for a person in a wheelchair according to PRM TSI, Appendix M into a differentiated model.

It contains modifications in the foot and knee area, and as a basis for determining manoeuvrability it defines the position of the drive wheels and thus the points of contact of the wheels.

Details on ground clearance are not given, but drawings show a transitional space in the area at the front and rear between the floor and the wheelchair volume, in the form of a right-angled triangle with legs of 50 mm.

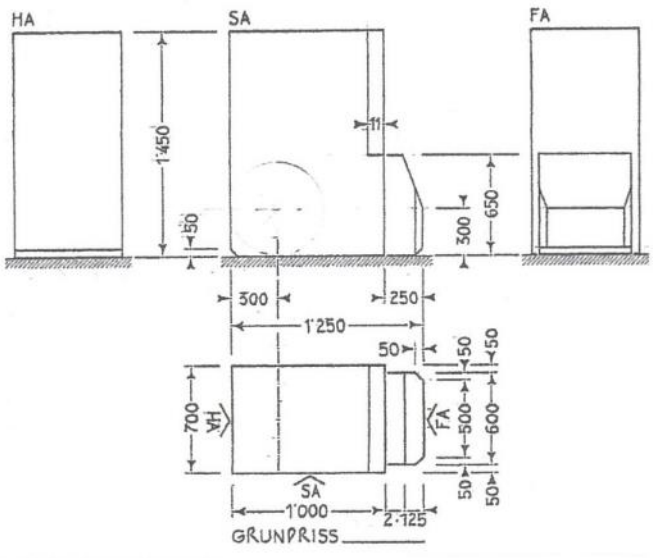

Fig. 5
Volume specification for person in wheelchair in accordance with EN 16585-1:2017: Toilets, Appendix B, Section B.1.
This diagram of a transitional triangle can be interpreted to mean that in a universal toilet, the transition from floor to wall does not have to be a right angle, but could diagonal or curved.

A Glossary of German terms contained in the Figures is given on the final page of this document.

Reference wheelchair for public transport

Fig. 6 shows a plan and other views of a synthesis between the provisions in the PRM TSI and EN 16585-1:2017.

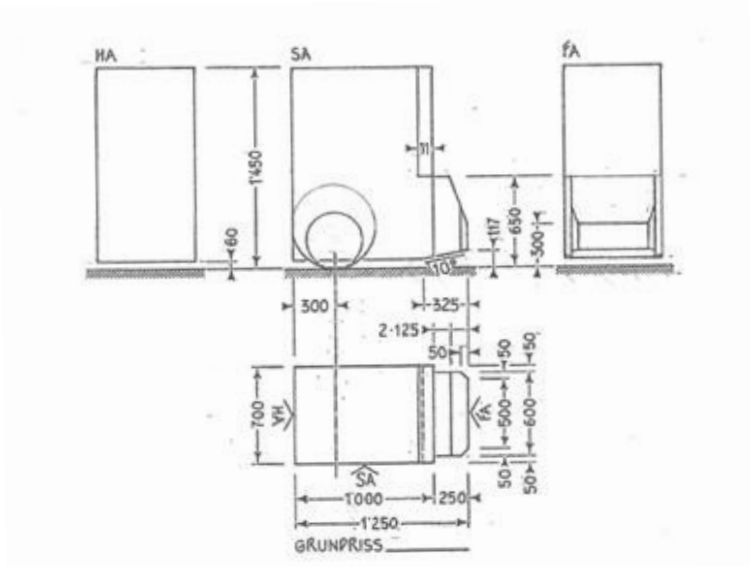

Fig. 6
Reference wheelchair for public transport in accordance with PRM TSI and EN 16585-1:2017

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We used this as a basis for further development into a real volume model at a scale of 1:1, with which built 1:1 spatial situations (maquettes, vehicles) could be tested for conformity in terms of wheelchair spaces. The wheelchair conformity of ramp slopes was tested separately.

In this further development, height was reduced from 1 450 mm to 950 mm, since above this height the sitting person does not require a width of 700 mm (unclothed shoulder width of a 95th percentile man = 506 mm), and no fixed elements on the wheelchair (e.g. backrest) are to be expected. Neither do we expect fixtures and fittings to intrude above this height without also already intruding below 950 mm.
There is also a practical reason for the height of 950 mm: an overview of the volume of the reference wheelchair can be maintained when it is manoeuvred about.

The 1:1 model of the reference wheelchair for public transport can be configured into a “PRM TSI” module and a “FOT” module.

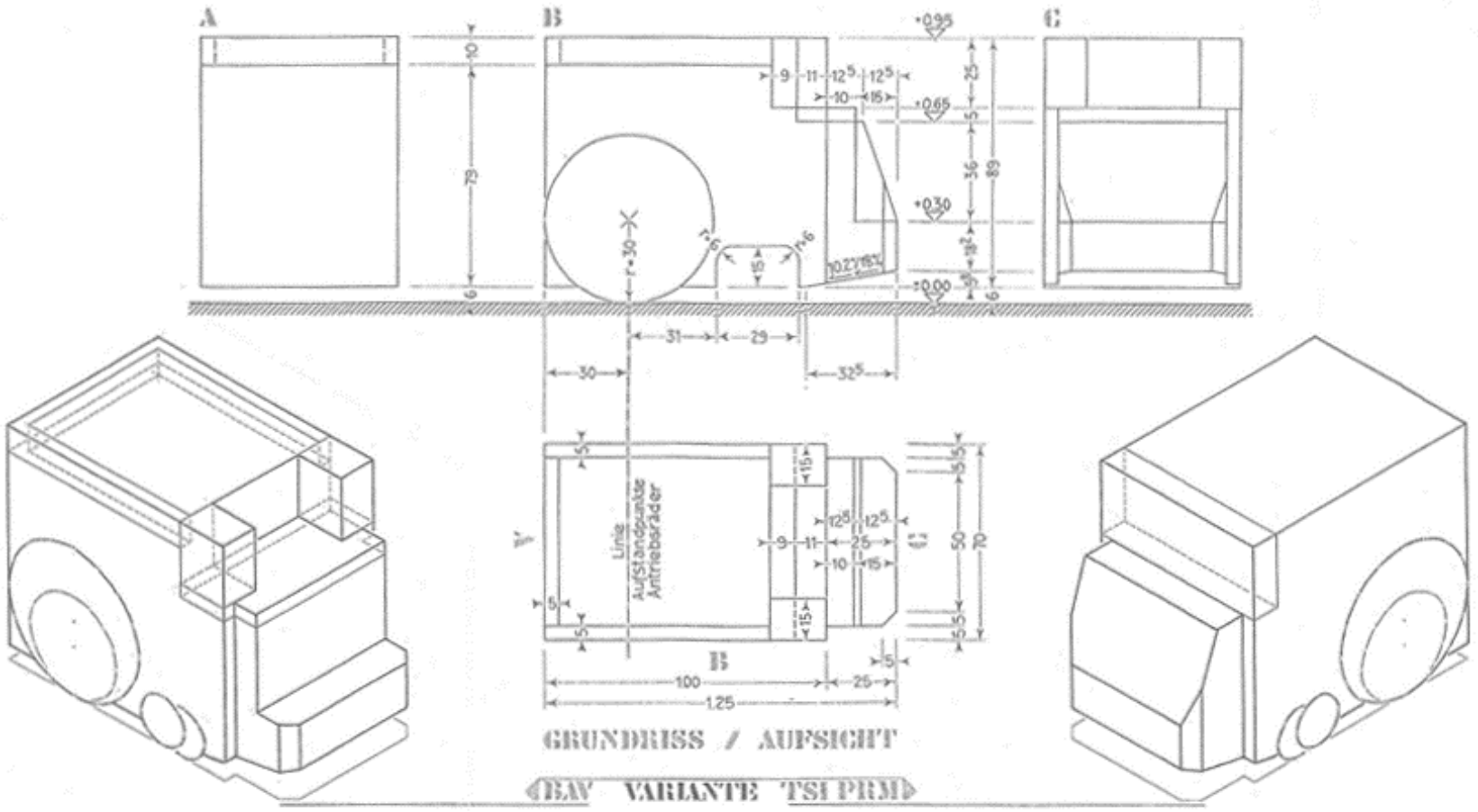

Fig. 7
Dimension sheet of the reference wheelchair for public transport according to PRM TSI and EN 16585-1:2017, supplemented with two isometric diagrams
Left: FOT module Right: PRM TSI module

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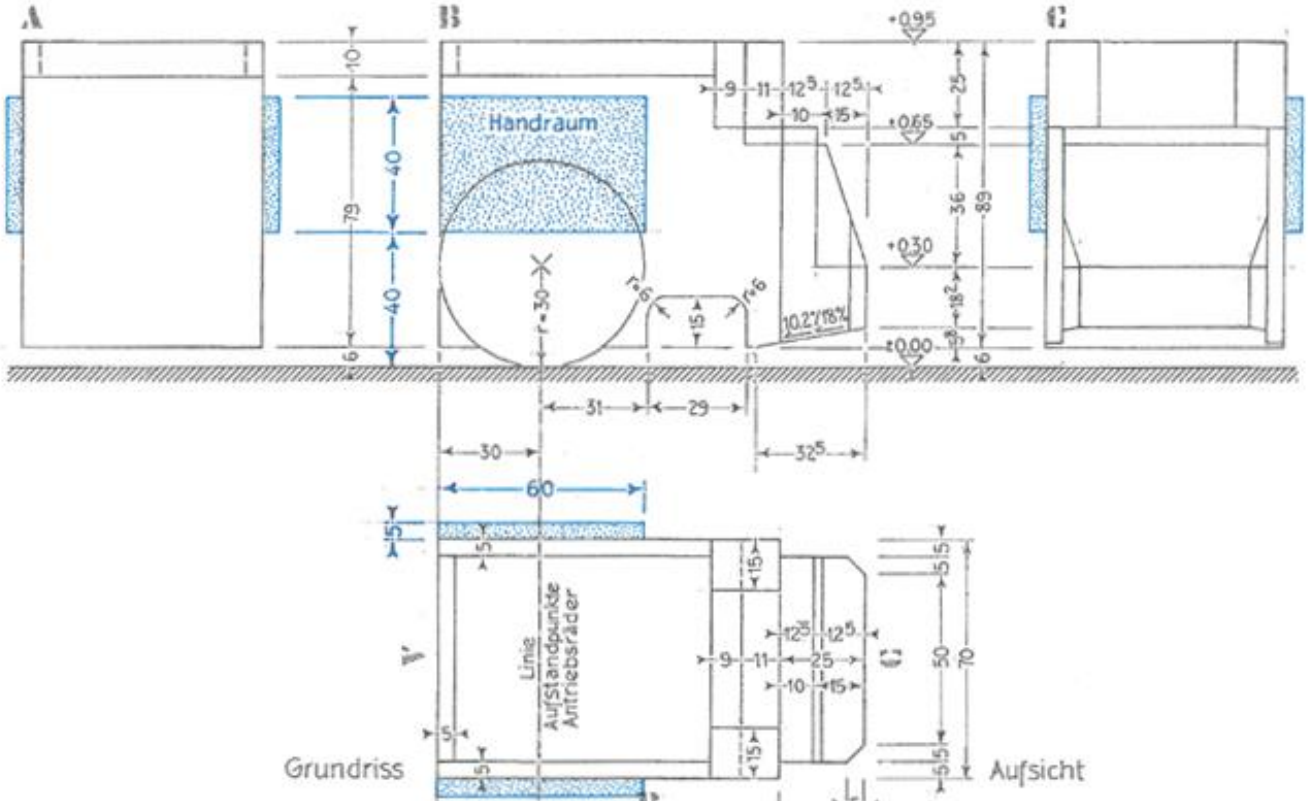

Fig. 8
Dimension sheet of the reference wheelchair for public transport according to PRM TSI and EN 16585-1:2017, supplemented with space for the hands on both sides (blue), for the occupant of a manual wheelchair to move it independently

A Glossary of German terms contained in the Figures is given on the final page of this document.

7. FOT reference wheelchair

The FOT version of the reference wheelchair differs from the reference wheelchair for public transport in the following points:

		PRM TSI	FOT
Toe clearance	Depth	None	150 mm (1)
	Height		300 mm (1)
Knee clearance	Height	650 mm	700 mm (1)
	From toe		250 mm (1)
Extra clearance for knees at table space	Depth	110 mm	200 mm
Clearance of handrails at wheelchair spaces in multifunctional areas	From height	None	850 mm
	Depth		50 mm

(1) Clearance with these elements may also be applied to movement areas

The reasons for these differences, which decrease the measurements for wheelchair spaces, lie primarily in the smaller dimensions of narrow-gauge rolling stock.

Clear space in the foot area allows the feet to pass under seat areas without direct floor support.

Clear space in the knee area allows the knees to pass under intrusions such as handrails and counters.

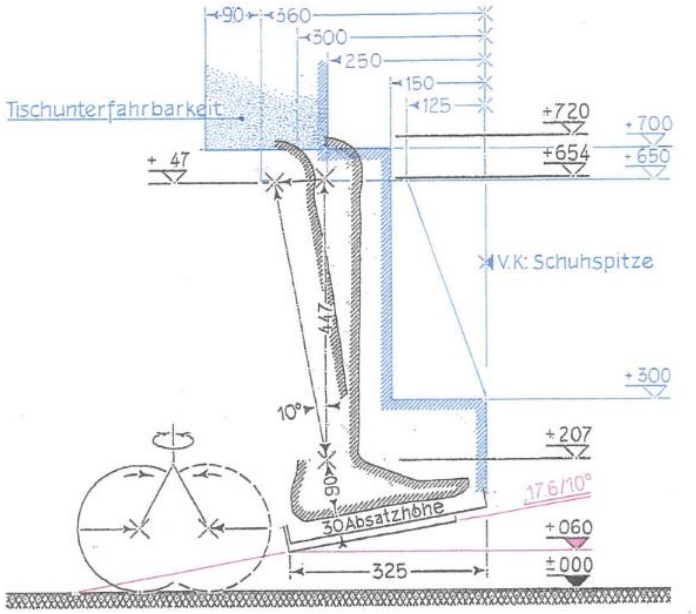

Fig. 9
Toe and knee clearance for the FOT reference wheelchair

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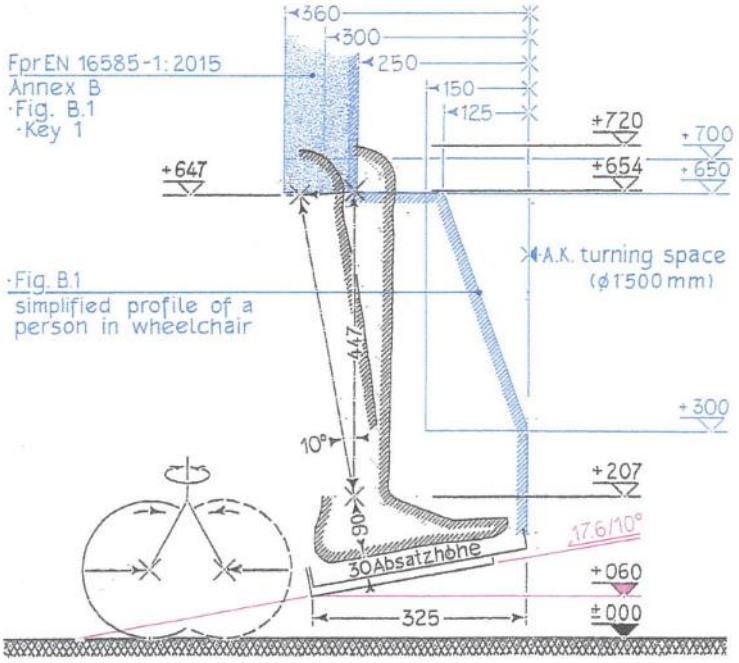

Fig. 10
Knee clearance in accordance with PRM TSI and EN 16585-1:2017

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8. The steering characteristics of wheelchairs

At a glance

1. The PRM TSI standard for the space needed for wheelchair spaces is based on an indirectly steered wheelchair with passively swivelling steering wheels (360°).
2. The (indirectly steered) wheelchair's centre of rotation always lies on a straight line defined by the two points of contact, which are identical to the centre of the drive wheels.
   - If the **centre of rotation lies between the two wheels**, i.e. the drive wheels are rotating in the opposite direction, we speak of **turning on the spot**.
   - If the **centre of rotation lies outside the two wheels** but on the line extending through the points of contact, and if the wheels are rotating at different speeds, the wheelchair is **driving in a curve**.

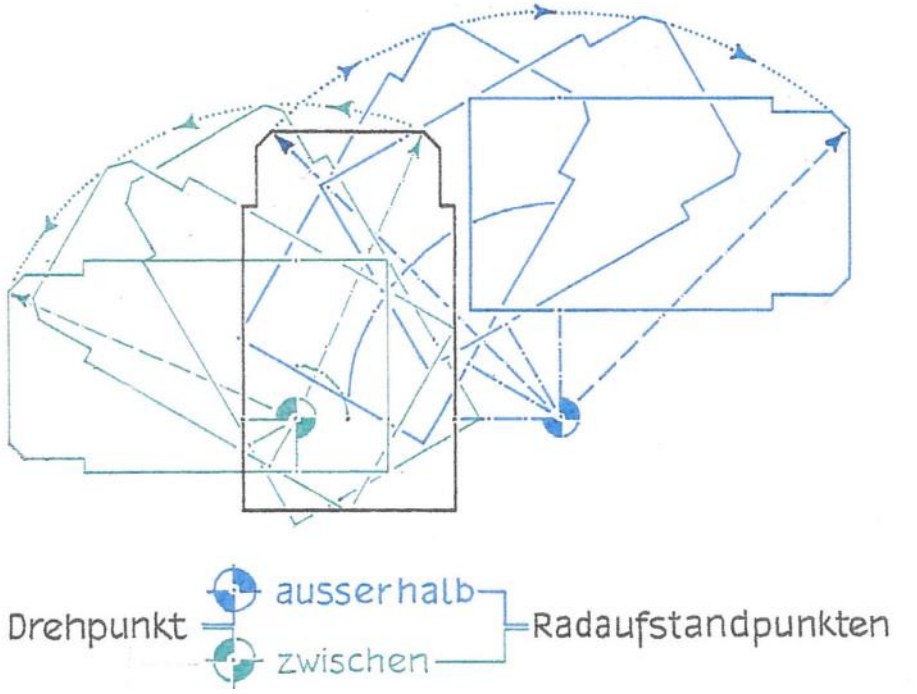

Fig. 11
Two 90° turns, each with a centre of rotation on the straight line defined through the points of contact of the drive wheels. One centre of rotation between the drive wheels (green) and one outside the drive wheels (blue)

A Glossary of German terms contained in the Figures is given on the final page of this document.

There is a fundamental distinction between three types of wheelchair according to steering characteristics:

- Indirectly steered wheelchairs
- Directly steered wheelchairs
- Indirectly steered wheelchairs with restricted lock on the steering wheels

- Indirectly steered wheelchairs:
  The drive wheels control the steering, and can be driven at different speeds, up to the point of rotating in opposite directions.
  The “steering wheels” are passive, and can swivel up to 360°. Their only function is as stabilisers, i.e. they are not active.
  The drive wheels can be at the back, middle or front of the wheelchair.

- Directly steered wheelchairs (e.g. scooter):
  Steering is generally controlled by the driver via steering linkage to the front wheels, or by a drive motor that controls the direction of the steering wheels. The steering angle or lock is restricted in both cases, with the consequence that the wheelchair requires more manoeuvring space than an indirectly steered wheelchair.
- Indirectly steered wheelchairs with restricted lock on the steering wheels:
  This category must be assigned to the directly steered wheelchairs because of the amount of manoeuvring space required.

The position of the drive wheels in the longitudinal direction of the wheelchair directly affects the manoeuvring space needed, if the floor plan measurements are identical.

Figure 12 below shows the example of a 360° wheelchair rotation for three theoretical drive wheel positions.

The drawing shows a wheelchair turning on the spot, i.e. the centre of rotation lies within the wheelchair plan, midway between the two drive wheels, which thus gives the minimum radius for a 360° rotation “in one go”.

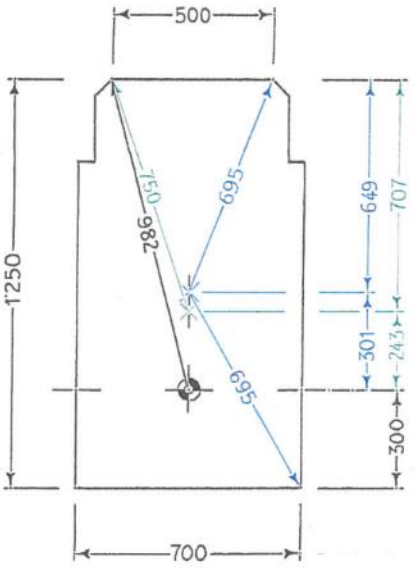

Fig. 12
360° turning circle radius as function of the position of the drive wheels
Black: r = 982 mm
PRM TSI reference wheelchair
Green: r = 750 mm
Position of drive wheels needed for rotation in “PRM TSI turning circle”
Blue: r = 695 mm
Position of drive wheels needed for smallest turning circle dimensions

9. Graphical iterative procedure to determine tractrix or envelope curves

Precision and reproducibility of the procedure:

1. The procedure creates any number of defined points in a wheelchair plan, which can be linked to form a curve.

2. The shorter the iterative steps, the more precise is the result. We recommend a step length of ¼ to ⅓ of the relevant basic length of the reference wheelchair, shown as $lP_0\ A_0l$ in Figure 13 (cf. explanation "Starting position" below).

Starting position, Figure 13

- Wheelchair plan with points P_0 and A_0
  - P = guidance point for the movement
  - A = point on the axis of the points of contact of the drive wheels
  - both points in the example on the longitudinal axis of the wheelchair *
  - the stretch between P_0 and A_0 is designated $lP_0\ A_0l$

1st step

Shift P_0 to P_1

- Assumption: Moving in a curve (continuous changes in direction; there is a tangent at each point, but with a different tangential gradient), not in a straight line.

2nd step

- Draw a straight line through points P_1 and A_0

3rd step

- On the straight line, display $P_1\ A_0$ in P1 $lP_0\ A_0l = A_{X1}$

4th step

- On the straight line $lA_{X1}\ A_0l$ construct a perpendicular bisector and cut it with $lP_0\ A_0l$ = point S_{MS1}

5th step

- Draw a straight line through points P_1 and S_{MS1}

6th step

- On the straight line, display $P_1\ S_{MS1}$ in $P_1lP_0\ A_0l = A_1$

7th step

- $lP_1\ A_1l$ = new starting position

8th step

- As for step 1: P_1 to P_2
- and so on; see Fig. 14

* The longitudinal wheelchair axis does not have to be the assumption; the position of point A on the drive wheel axis is however compelling.

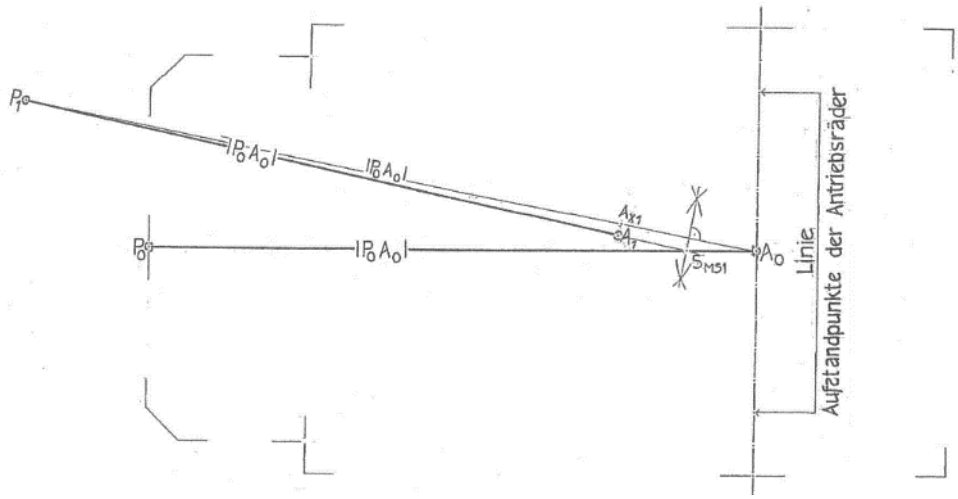

Fig. 13
Principle of the graphical iterative procedure to determine the tractrix curves in steps 1 to 7

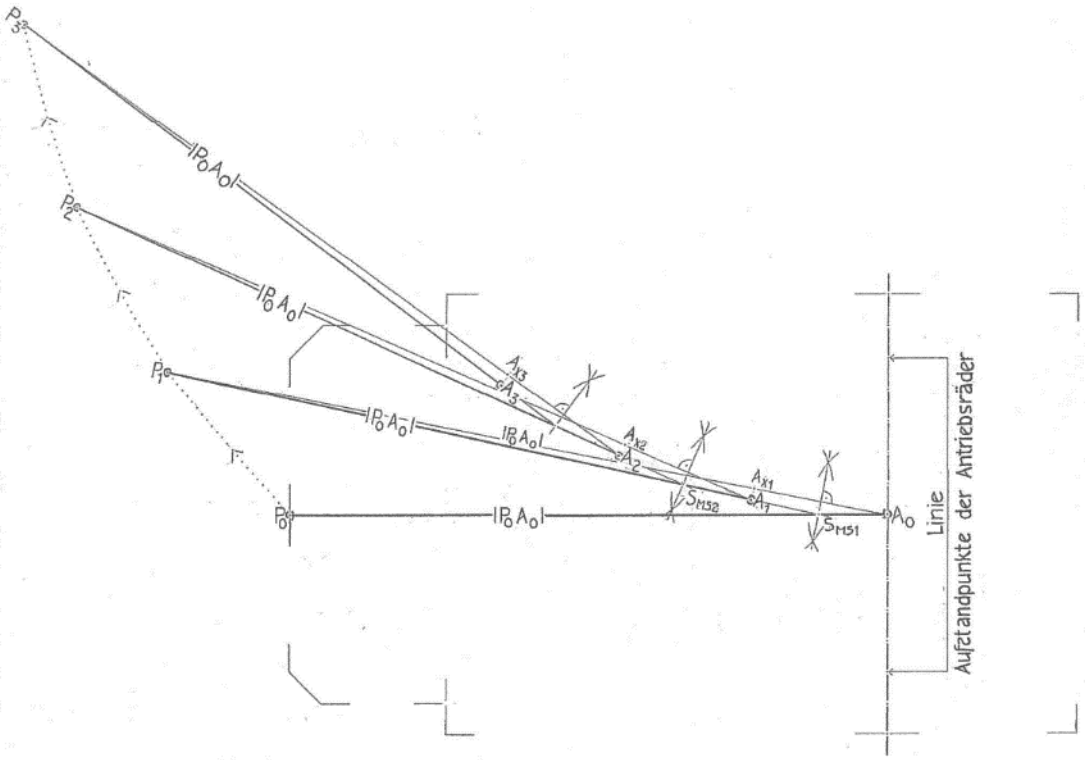

Fig. 14
Principle of the graphical iterative procedure to determine the tractrix curves with further repetition of steps 1 to 7

A Glossary of German terms contained in the Figures is given on the final page of this document.

10. PRM TSI, Appendix M – Comparison of German and English versions

German	*English*
TSI PRM, Anlage M **Im Zug transportable Rollstühle**	**PRM TSI, Appendix M** **Wheelchair transportable by train**
M. 1 Inhalt	M.1 SCOPE
Diese Anlage enthält Grenzwerte für die technische Ausführung transportabler Rollstühle	This appendix identifies the maximum engineering limits for a wheelchair transportable by train
M. 2 Merkmale Technische Mindestanforderungen (*sollte richtigerweise heissen: «maximal zulässige Werte und Mindestanforderungen»*):	M. 2 CHARACTERISTICS The minimum technical requirements are (*correctly: «maximum values / minimum requirements»*)
Grundlegende Abmessungen - Breite (*max.)* 700 mm zuzüglich 50 mm an jeder Seite für die Hände bei Fortbewegung - Länge (*max.)* 1 200 mm zuzüglich 50 mm für die Füsse	Basic Dimensions - Width of 700 mm *(max)* plus 50 mm each side for hands when moving - Length of 1 200 mm *(max)* plus 50 mm for feet
Räder - Das kleinste Rad muss einen Spalt mit 75 mm horizontaler und 50 mm vertikaler Abmessung überwinden können	Wheels - The smallest wheel shall accommodate a gap of dimensions 75 mm horizontal and 50 mm vertical
Höhe - Höchstens 1 375 mm einschliesslich eines männlichen Rollstuhlfahrers (95. Perzentil)	Height - 1 375 mm max including a 95th percentile male occupant
Wendekreis - *(Höchstens)* 1 500 mm	Turning circle - 1 500 mm *(max)*
Gewicht	Weight

- Elektro-Rollstühle, die ohne Schiebehilfe eine Einstiegshilfe Überqueren können: Höchstgewicht 300 kg für Rollstuhl mit Rollstuhlfahrer (einschliesslich Gepäck)
- Handrollstühle: Höchstgewicht 200 kg für Rollstuhl mit Rollstuhlfahrer (einschliesslich Gepäck)

Überwindbare Hindernishöhe und Bodenfreiheit
- Maximale Höhe eines überwindbaren Hindernisses: 50 mm
- Bei einem Steigungswinkel von 10° muss die Bodenfreiheit für die Vorwärtsfahrt am Ende der Steigung mindestens 60 mm (unter der Fussstütze) betragen

Maximale Neigungswinkel, bei dem der Rollstuhl stabil bleibt
- Dynamische Stabilität in allen Richtungen bei einem Winkel von 6 Grad
- Statische Stabilität in allen Richtungen (auch bei angezogener Bremse) bei einem Winkel von 9 Grad

- Fully laden weight of 300 kg for wheelchair and occupant (including any baggage) in the case of an electrical wheelchair for which no assistance is required for crossing a boarding aid.
- Fully laden weight of 200 kg for wheelchair and occupant (including any baggage) in the case of a manual wheelchair.

Obstacle height that can be overcome and ground clearance
- Obstacle height that can be overcome 50 mm (max)
- Ground clearance 60 mm (min) with a [sic] upward slope angle of 10° on top for going forward (under the foot rest)

Maximum safe slope on which the wheelchair will remain stable:
- Shall have dynamic stability in all directions at an angle of 6 degrees
- Shall have static stability in all directions (including with brake applied) at an angle of up to 9 degrees

(1) EN 16585-1:2017 inserts the following relativisation:
“The turning space shall be as a minimum a 1 500 mm diameter circle but this would require several manoeuvres to achieve a 180° turn. A simple pivot would create a swept envelope of approximately 1 925 mm longitudinally and 1 450 mm vertically (see Figure A.2 and Figure B.1).”

Glossary of German terms contained in the Figures

Deutsch	English
Fig. 1	
Grundriss	Plan
Aufsicht	Overview
Variante	Version
Linie Aufstandpunkte Antriebsräder	Drive wheels' point of contact
Fig. 3	
Grundriss	Plan
Fig. 4	
Ground clearance	Ground clearance
Absatz height	Heel height
Fig. 5	
Grundriss	Plan
Fig. 6	
Grundriss	Plan
Vorderkante Schuhspitze	Toe of shoe
Fig. 7	
Grundriss	Plan
Aufsicht	Overview
Variante	Version
Linie Aufstandpunkte Antriebsräder	Drive wheels' point of contact
Fig. 8	
Handraum	Space for hands
Grundriss	Plan
Aufsicht	Overview
Linie Aufstandpunkte Antriebsräder	Drive wheels' point of contact
Fig. 9	
Tischunterfahrbarkeit	Clear knee space under table
V.K. (Vorderkante) Schuhspitze	Toe of shoe
Absatz height	Heel height
Fig. 11	
Drehpunkt	Centre of rotation
ausserhalb	Outside
zwischen	Between
Radaufstandpunkte	Wheels' points of contact

Fig. 13 / 14	
Linie Aufstandpunkte der Antriebsräder	Drive wheels’ point of contact