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Public Transportation - Accessibility for All

Deliverable 3.1

Recommendations for Improving Boarding Assistance Systems

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1 Executive Summary & Introduction

This Deliverable is the result of the task 3.1 – Develop Best Practices BAS Recommendations - and partially of the task 3.2 – Prepare Design Recommendations for Improved BAS. These tasks are elaborated in WP3 – Develop BAS Improvement Strategies. The structure of this deliverable follows the same way: chapter 2 elaborates the best practice recommendations for existing BAS, and chapter 3 give the design recommendations for improved BAS.

The task 3.1 is mainly based on the evaluation of existing BAS completed in WP 2 [1,2]. Evaluations made in deliverable 4.1 [3] are also taken into account. Some additional information regarding operating practices which were collected after the competition of deliverables 2.1 and 2.2 are also included. A further approach was to combine the results from PubTrans4All research and relevant European projects [4,5,6,7,8], international [9, 10], European [11, 12, 13, 14, 15, 16, 17] or national [18] regulations etc. in order to make the list of recommendations for existing BAS as complete as possible.

The approach was to elaborate relevant issues in logical order one by one and then stipulate corresponding recommendations. Especially for new BAS that should be developed in PubTrans4All project, the recommendations are given in chapter 3.2.

The task 3.2 was based on the evaluation of existing BAS solutions and practice. However, the analysis of the BAS in Deliverable 2.2 shows that there are no existing BAS solutions on passenger coaches with doors of 800mm width, positioned in the front area, directly behind the buffers. This is a very common situation with existing UIC type coaches.

A comprehensive analysis of the general technical conditions shows that there are some demanding boundary conditions and constraints that prevent many of the common BAS solutions to be applied on this type of vehicles. The analysis presented in chapter 3 leads to minimum recommendations and requirements for new BAS for existing UIC type vehicles. This recommendation includes some restrictions in comparison to new vehicles with wider doors, vehicles without buffers, or vehicles with doors located further away form the buffer area.

Deliverable 3.1 with draft recommendations was prepared by the University Belgrade (UB) and Vienna University of Technology (TUV). Railway operators, manufacturers, as well as members of the consortium have also contributed to this report. The inputs of meetings of the Prototype Development Group, which includes both universities, manufacturers participating in the consortium and representatives of Bulgarian Railways (BDŽ), after being discussed at the 3rd Consortium Meeting, were included in the final version of the deliverable.

2 Best Practices BAS Recommendations

This part of Deliverable 3.1 deals with the recommendations that should provide ideas for improving access to rail vehicles that use the existing Boarding Assistance Systems (BAS). The recommendations are mainly based on the evaluation of existing BAS completed in WP 2. Good ideas from other similar projects and recommendations from various regulations dealing with accessibility are also included.

The first subchapter develops the recommendations that can be applied to all types of BAS and includes mainly the organisational measures that can improve the usage of the existing BAS.

The second subchapter addresses specifics of typical boarding/alighting situations. These are divided into four typical boarding/alighting situations:

- Level boarding/alighting
- One or two steps upwards boarding and downwards alighting
- Step down boarding and upwards alighting
- Boarding/alighting in case of a height difference of more than approximately 400 mm

For each of this situation specific recommendations are stipulated.

2.1 Common recommendations for all types of BAS application practice

There are various considerations of the BAS usage that are independent from the BAS type, such as organisational and other measures that should facilitate BAS implementation. This interrogation is covered within the following sub-chapters.

2.1.1 Vehicle based versus platform based solutions – an overview

Both vehicle-based and platform-based systems are used by operators as Boarding Assistance Systems, depending on the operational environment and task. Each option has several advantages as well as disadvantages at the same time.

2.1.1.1 Platform based systems

Platform based systems are positioned and located on the platform and should be usable in combination with all vehicle-types being in use at train-stations. The BAS is usually operated by the station personnel and is not intended for use without staff assistance. The BAS can be applied independently from the technical characteristics of the rail vehicle.

Platform based ramps

The Ramp is stowed at the station usually on the platform in a folded position, and is carried to the applicable coach when needed. Its operation is performed by the train personnel. The BAS is usable by all passenger groups. Its application is limited due to the gradient of the ramp and usable station platform width.

Figure 2.1: Platform based ramp, New Zeeland

Platform based lifts

The hydraulic or mechanical, manually operated lift is stowed on the platform and positioned at the accessible train entrance when needed. This type of lift serves all vehicle types. During its operation the entrance is occupied for the use of other passengers. Most operators only allow wheelchair occupants to use this type of BAS.

Figure 2.2: Platform based lift - DB

2.1.1.2 Vehicle based systems

Vehicle based systems are either fixed mounted on the vehicle (e.g. lifts), or otherwise stored on the train (e.g. mobile manual ramps for bridging gaps)

These systems are operated either by assisting train personnel, automatically, or independently by the passenger. The BAS is usable independently from the provided train-station infrastructure, and safe from vandalism at the train station.

The following examples describe possible technical versions of vehicle based BAS for high floor vehicles.

Vehicle based ramps

The ramp is stored in the vehicle and unfolded from the vehicle when in use. The ramp is usable for all passengers, and is manually applied by the train personnel. A disadvantage is its limited application due to the maximum gradient of the ramp and usable station platform width.

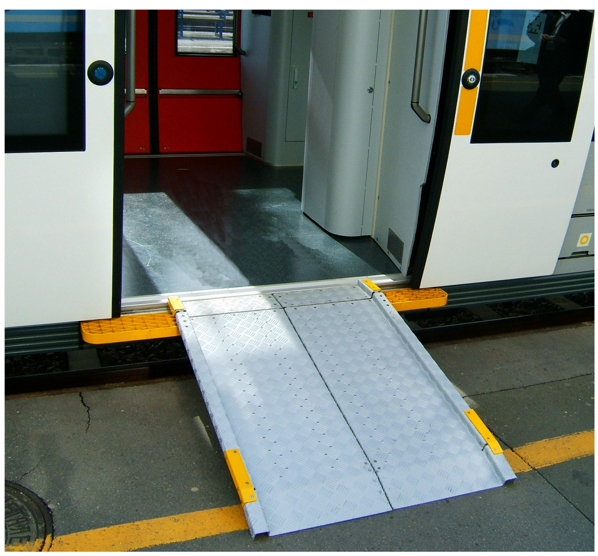


Figure 2.3: Vehicle based ramp

Vehicle based lifts

The lift is installed into the vehicle and unfolded out of the vehicle for its operation. A great advantage of the lift is its nearly unlimited application for all platform heights, and also the possibility of an emergency evacuation in-between station. Amongst all operators, its use is only allowed for wheelchair users. The vehicle entrance is not available for other passenger groups during the lift operation. The boarding and alighting process is performed only while the train is not in motion and the lift is operated by train personnel.

A further possibility of vehicle based lift is a lift installed into the vehicle that can be used independently by the user itself. The lift is available to all passengers, and only partly blocks the vehicle entrance.

Figure 2.4: Vehicle based lift

Vehicle based internal lifts

Internal lift systems that can be operated during the ride prior to the stop at the station (e.g. SJ – Regina lift) are able to save time for the operational cycle of the lift and dwell times An disadvantage of such solution is that the gap between platform and vehicle should be additionally bridged e.g. by vehicle based or platform based ramp.

Figure 2.5: Internal lift SJ – Regina

Table 2.1 Vehicle based versus platform based solutions- abstract

	Advantage	Disadvantage	Comments
Platform based ramps	Relatively low purchase costs, applicable for all vehicle entrances and usable for all customers.	Limited application due to its maximum gradient and maximum platform width, personnel required on the platform. Should be available on each station, preferably on each platform.	Low purchase cost, but cannot be applied to all vehicles. Significant funds are needed to equip majority of stations/platforms.
Platform based lifts	Limitations depending on coach, also usable on narrow platform.	Personnel required, vehicle-entrance blocked for duration of BAS operation, higher purchase costs, not usable for all PRM. Should be available on each station, preferably on each platform.	Significant funds are needed to equip majority of stations/platforms.
Vehicle based ramps	BAS can be used independently from the train station's infrastructure, relatively low purchase costs, usable for all types of vehicle entrances and by all passenger groups.	Limited application options due to the ramp gradient and station platform width limit.	Not usable for all vehicle types, difficulties with ramp-length.
Vehicle based lifts	BAS usable independent of the train-station's infrastructure (i.e. on all stations) BAS has no limitations regardless the type of coach, also usable at narrow platforms.	Vehicle entrance blocked while BAS is in use, not usable for all passenger groups. The costs for purchasing and installing are significant.	No limitations in reference to height difference. Implementation on existing vehicles can require internal adaptations.
Vehicle based internal lifts	Independent operation performed by user, a part of the operation can start during the train ride before the stop at the station, therefore reduces dwell time.	Difficult to retrofit onto existing vehicles, still existing gap between the vehicle and platform, problems of unintended use and vandalism.	Ideal solution on train systems using the same platform height throughout.

Recommendation:

- Platform based systems are recommended to cover the operation in combination with various train types not fitted with their own BAS.
- Vehicle based systems are recommended as providing a usable BAS at all times, regardless of the train station infrastructure. They are also better protected from vandalism and other influences (e.g. weather conditions), can be used in case of an emergency stop between two stations for the evacuation of persons with reduced mobility and are operated by the existing train staff.
- The application of lifts is recommended in cases were variety regarding different height-differences between the vehicle and platform exists.

2.1.2 Signage of the expected position of the BAS on the platform

Highlighting and marking of the position of the BAS on the platform leads to a shorter dwell time, as the PRM passenger can wait in the correct platform area. If one follows the correct information, the platform-bound BAS can be positioned accordingly by train station personnel. The improvement of the customer satisfaction due to the reduction of unnecessary walkways, as well as the improvement of the personnel efficiency due to customised aid, are very important.

With the aid of modern passenger information systems on the platform it is possible to consider different train lengths and PRM accessible coach position. The area where the accessible coach is supposed to stop can be distinguished accordingly.

Signage on the platform: Highlighting the exact position of the BAS on the train which can be performed applying various methods.

Signage using contrast colours on the platform

Such signage methods are mainly used in closed train systems using one vehicle type only. Such coloured markings are using a contrast colour and/or a textured surface in order to be recognisable for passengers with visual impairments.

	
Figure 2.6: Signage on the platform of the tramway system in Melbourne	Figure 2.7: Signage on underground platforms

Permanent fixed Visual Information Systems

Visual Information Systems using conventional fixed signs enable a simple and direct information flow. A disadvantage is the lack of flexibility in the event of changes in a short time.

Digital Information Systems

These systems provide information also in the situation of a variation of the train vehicle composition, and are therefore usable for international cross-border train traffic. The information flow can be provided through electronic coach position signage.

Figure 2.8.Digital information on platforms

Audible information systems

Audible information about the positioning of the BAS for incoming trains is the next possible solution. Audible information is important, especially to override any unexpected changes in services and in emergencies.

A disadvantage though is the lacking recognisability of the information for elderly people and people with hearing impairments. Especially the noise from other sources, e.g. track noise, train brakes, acceleration noise, interior passenger noise level etc. can overlap with the audible information.

Signage on the vehicle:

The signage for the accessible entrance at the vehicle door is an additional important factor in order to speed up the boarding and alighting process and to reduce the dwell time to a minimum. An example is given in figure 2.9.

Figure 2.9: Vehicle entrance in contrast colours and signature of wheelchair access in practice (SBB –Swiss)

Coloured signage of the accessible vehicle-entrance

The TSI PRM [11] specifies the coloured area for the accessible vehicle entrance. A highly visual contrast colour in comparison to the vehicle is being used in order to mark the accessible area of the vehicle, which enables a quick orientation of the customer. Additionally a visual symbol is used for the accessible entrance area. Signage of the accessible entrance on the train itself doesn't exclude the requirement to provide information for the corresponding position on the platform.

Good examples of an entrance with big and smaller windows on door leaves are shown in figure 2.10. Regardless of doors being open or closed, the contrast to the car body colouring is recognizable.

Figure 2.10 Examples of contrast colours of entrance doors

Table 2.2 Information about BAS positioning - abstract

	Advantages	Disadvantages	Comments
Colour/ texture signage on the platform	Also usable for blind and visually impaired passengers.	Only applicable for closed train systems using the same vehicles only, low visibility at train stations without roof in the winter-season.	Fixed signage integrated in the platform floor is only usable within closed train systems.
Visual Information Systems	Easy installation.	Low flexibility in case of short time changes. Not helpful for visually impaired people.	Fixed installation of signage only makes sense within train systems using constantly the same vehicles and train components.
Digital Information Systems	Accurate and flexible information about the position of an accessible entrance.	Vast infrastructure around the platform area required. Significant investments are needed.	Digital information systems on the platform provide an accurate information source, but are dependable on the platform infrastructure.
Audible information systems	Audible systems are usually already installed.	Information not recognisable for some categories of passengers. Language related problems possible in international services.	Audible information shall always be in combination with visual information.
Coloured accessible entrance	Quick orientation for the passenger.	No information about the BAS position prior to train-arrival.	Positive addition to information systems on the platform.

Recommendations:

- It is very important to provide correct and timely information for the disabled passengers in regard to the exact location of the BAS, in order to reduce the dwell time of the train.
- It is recommended to provide a combination of visual and audible information, information on the platform and on the vehicle, to improve the client satisfaction and efficiency of the personnel.

2.1.3 Required dwell times and organisational measures

In order to reduce the needed dwell time to a minimum, an efficient and effective organisation is required. The necessary dwell time is based on the boarding and alighting processes, which depend on the technical and infrastructural environment and systems being applied.

The reduction of the required dwell time is possible by applying organisational measures before and after the operation of the BAS.

Boarding Assistance System and personnel

The application of technically advanced systems speeds up the boarding process and shortens dwell times. Preparation times and after-care times (e.g. storage) also need consideration. The necessary dwell times can only be achieved through efficient systems and trained personnel.

Marking the position of the BAS

As described in the section BAS positioning, efficient signage on the train and on the platform enable people with reduced mobility, e.g. a wheelchair passenger to wait in the correct area on the platform before train arrival, and platform bound BAS can be positioned accordingly by train station personnel.

Services at the station

As described in more detail in the subchapter 2.1.6, many operators offer people with reduced mobility, especially wheelchair passengers, to bring them in their own wheelchairs from the station entrance to the accessible train entrance. Occasionally a baggage service is also provided, which usually requires pre-booking and is seldom free of charge.

Table 2.3 Dwell times and organisational measures - abstract

	Advantages	Disadvantages	Comments
Boarding Assistance System and personnel	A high degree of automation enables quick BAS operations as well as well trained personnel provide the required short dwell times.	A high degree of automation bares a higher risk of malfunction and reduces the availability of the BAS at all times.	The dwell time can be reduced to a minimum by using trained personnel and technical aids (BAS).
Marking the position of the BAS	The passenger and the service personnel can position themselves in the accessible platform area.	The information systems need to be flexible and fool-proof, otherwise only a part of the vehicles can be used.	Systems providing information about the BAS reduce the required dwell times for the passengers.

Table 2.3 Dwell times and organisational measures – abstract (continuation)

Services at the station	Customer service for the passenger.	Inflexible system due to pre-registration.	Services provided for the customers do only make sense when flexible pre-registration systems are applied.

Recommendations:

- It is recommended to use BAS in conjunction with well trained personnel to reduce dwell time of the trains.
- Effective signage and information concerning the BAS position reduce dwell times accordingly.
- Additional services at the station e.g. assistance for luggage are recommended not only for people with disabilities but for all passengers.
- The use of customer assistance services and the BAS shall be organised to be flexible enough, and accordingly pre-registration notice times need to be as short as possible, to be attractive and helpful to all users.

2.1.4 Trouble-shooting and Emergency Stop

Besides a user-friendly operation of the BAS and availability at all times, safety feature such as emergency stops and a clear trouble-shooting process are essential.

Trouble-shooting

A clear trouble-shooting process enables the personnel to identify the source of the malfunction and a rapid repair, also to decide upon the use of the manual backup system. The malfunction could be shown as a code as well as on a visual display. In case of malfunction during the usage, it is necessary to also give some audible information to people with hearing impairments.

Operation performed by trained personnel

The simplest way to trouble-shoot and solve a malfunction is extensive staff training and the regular operation of the BAS by the personnel. In the opposite case, when the automatic BAS is controlled by the passengers, the train personnel are usually not available immediately when automatic boarding devices fail. Following delays are inevitable in such situations. It should be noted that TSI PRM [11] for vehicle based automatic BAS requires deploying the BAS unexceptionally by staff.

One recommendation regarding the automated vehicle based BAS shall be that they should be installed at the doorway nearest to the driver cabin or staff cabin, so that he may observe the process of boarding and alighting of the passenger and react if a problem occurs.

Safety devices

During the operation of the BAS several safety features are necessary in order to prevent the passenger and the train personnel from injuries.

Warning signals during operation

Audible and visual warnings are quite common during the operation of the BAS. Audible warnings help visually impaired people to identify obstacles on the platform. Flashlights and edges and corners clearly marked with the help of contrast-colours improve awareness.

Emergency-stop

An emergency stop, such as the commonly used red and round emergency button, is essential in order to prevent from potential hazards and injuries. The design of the emergency stop shall enable easy access and easy use in order to be operated quickly and safely when needed.

Table 2.4 Trouble-shooting and Emergency Stop - abstract

	Advantage	Disadvantage	Comment
Trouble-shooting	Clearly identifiable display of faults enables trouble-shooting.	The more complex the system, the more difficult is the trouble-shooting process.	An automatic display of the fault source only makes sense in those cases in which the personnel can fix the problem.
Operation performed by trained personnel	Trained staff is aware of the system and of potential mal-functions.	The system cannot be operated by the passenger himself.	The personnel not only operate the BAS, but are also available for all other passengers. Obligatory according to TSI PRM.
Warning signals during operation	Passengers and staff are warned about a BAS being operated.	Warning signals shall not limit the operation of the BAS at any time.	Warnings do make sense, the operation of the BAS shall not be influenced though.
Emergency-stop	Prevention of injuries.	Unwanted operation of the emergency stop.	The operational functions of the BAS shall not be influenced by the emergency-stop.

Recommendations:

- It is recommended to display a clearly identified malfunction in order to save time and reduce the train delay.
- BAS shall be operated by well trained staff only.
- Automated vehicle based BAS used by the passengers shall be installed at the doorway nearest to the driver, so that he may observe the process of boarding and alighting and react if a problem occurs.
- A high safety-standard of the BAS prevents from injuries and provides a BAS usable at all times.
- Warning signals shall not distract operators/users attention from the BAS operation.

2.1.5 Wheelchair accessible coach interior

A wheelchair accessible coach interior facilitates and enables the wheelchair passengers to make use of the train infrastructure.

Vehicle-bound wheelchairs

The clear door width in-between classic coaches and passageways inside the vehicle are usually too narrow to be used with wheelchairs. In order to make use of the provided train infrastructure without limitations, some operators provide vehicle-bound wheelchairs that are narrower than standard chairs. The wheelchair occupant uses his or her own wheelchair for the journey, positions the chair and her/himself in the dedicated wheelchair area of the coach for the ride. Therefore the wheelchair position serves as the seating position for the wheelchair occupant during day time.

Figure 2.11: Special narrow wheelchair used in Canada

If the wheelchair occupant wishes to visit the restaurant for example, the vehicle-bound special narrow wheelchair is provided so that the train infrastructure can be used without limitations, supposing the wheelchair provided is suitable for the wheelchair passenger. Figure 2.11 [6] shows a special narrow wheelchair used in Canada.

Alternatively or for the wheelchair user not wiling or not able to change the wheelchair, the operator can offer special meal/drink service at the place for PRM. For this purpose a service button with communication possibility to responsible personnel should be available.

Power supply for electric wheelchairs (2)

For the daily use of electric wheelchairs power supply is essential which can be provided through an electric power socket in the dedicated wheelchair area in the coach.

Table 2.5 Wheelchair accessible coach interior - abstract

	Advantages	Disadvantages	Comments
Vehicle-bound wheelchairs	Train passengers may use it through complete train infrastructure.	Vehicle bound wheelchairs require storage facilities on the train.	The solution is limited when in conventional use, and makes no sense on trains without restaurants. Not all wheelchair users are able to change their own wheelchair.
Power supply for electric wheelchairs	Add-on service for the train passenger.	A space requirement for electric wheelchairs is limited.	An electric power socket for electric wheelchairs does make sense, but is questionable at the same time due to the limitations when transporting power wheelchairs.

Recommendations:

In case of long distance trains, if the restaurant car or other facilities are adapted for the wheelchair user, the operator can provide a special narrow wheelchair that allows wheelchair user circulation along narrow corridors to the wagon restaurant or buffet. Alternatively, special on place service for PRM accessible by service button and communication device can be offered.

- An electric power socket for charging of electric wheelchairs in the dedicated wheelchair area is a good practice, especially when one takes into account the increasing share of electrically powered wheelchairs.

2.1.6 Additional services provided by operators

Railways and public transportation authorities should cooperate with associations and organisations that gather people with reduced mobility, and inform them upon the available accessibility services amongst public transport systems, especially about accessible railway-systems. One of the main activities should be the communication concerning the achievements made and several options for a comfortable transport for all passenger groups. The best way for encouraging people and convincing them that trains and public transportation vehicles are accessible is to invite them to a promotional train ride or to organize presentations such as "accessibility-info days" in the railway stations.

Different additional services for people with reduced mobility and for other passengers exist in many countries. Specialised services provided in France and Spain, as well as in Bulgaria, available for people who need assistance during the train journey, will be presented as examples.

Service Accès Plus of SNCF

Accès Plus Center is a contact point for everybody facing a handicap. It is a specialised service dealing with handicapped persons and persons with reduced mobility, and accompanying them on the train. This personalised service shall facilitate the journey of a passenger with a handicap by providing assistance for ticket reservation, includes the reception of the passenger at the station, accompanying PRM passengers to and onto the train, also during the journey if required and requested. A dedicated place on the train is being pre-reserved in advance, a tailor-made location which fulfils the specific requirements of the PRM, in order to simplify and facilitate the journey for the passenger. The station of destination is already prepared to meet the PRM passenger and deal with his specific needs.

SNCF is also offering a door-to-door luggage service in cooperation with GEOIS, a logistic company, including wheelchairs and bicycles.

In France, over 460,000 disabled passengers are travelling by train each year. For people with reduced mobility, SNCF has adapted its stations and reinvented its customer services. Since the first quarter of 2008, Accès Plus centres are available in over 350 stations

User related activities & services: disabled passengers now have access to a dedicated Service Centre. They can simply contact the Accès Plus Centre (by phone, fax or e-mail) up to two days before the date of departure. This is a free service for holders of disability cards (80% disability or more), military service discharge/war pensioner cards and all wheelchair users. The Accès Plus centre is available 7 days a week from 7am to 10pm.

Figure 2.12: Signage on the doors where BAS is available on SNCF

An advisor is available seven days a week (7am to 10pm) to deal with requests and arranges the journey from departure to arrival. The advisor informs the traveller of the level of accessibility of stations and trains throughout his journey, ensures that his specific needs are met and reserves his ticket. The passenger can also reserve the "Plus" service that is needed: a greeter at the station and/or assistant guides the PRM to the dedicated seat on the train. The on-board supervisor is informed in advance of the presence of the person with reduced mobility by the advance reservation.

In the event of unforeseen difficulties or an incident during the journey, a special Emergency Access Line enables the emergency services to locate the person with reduced mobility and provide treatment in a station, or even on the train. Customers can call a dedicated service hotline. Hearing impaired passengers can send a text message without any surcharge.

Figure 2.13: SNCF information point for people needed assistance

Service Atendo ("I am awaiting you") – Service of RENFE (Spanish railways)

RENFE developed the so called "Accessibility Plan 2007-2014" consisting of two main activities:

- Atendo – special service for all travellers who need assistance
- Rolling stock
    - Adapting old trains
    - New accessible trains

The aim of Atendo is to offer special service to all passengers who need assistance or wish to get any help they need. One of the key factors of Atendo is to make use of professional service assistants. The uniforms of the staff are standardized as well as the different facilities, service points etc. Orange is the typical colour for Atendo. So passengers who need any help can orientate very easily. All bigger stations have special service desks close to the entrance. Passengers needing help can contact the help desk and make use of the service without any registration or announcement. To be sure that an assistant will be available one should come about 30min before the train departure or call 12h before needing the assistance. It is important to call in time if one needs help when arriving at a station so that an assistant can be in time at the right place.

Figure 2.14: Service desk in Madrid Atocha Station

Passengers needing help will be attended from the service desk to the train. The assistants will help on the way to the train, while boarding the train and also for getting to the seat. Usually elderly, walking disabled or wheel chair occupants make use of this service, also passengers who have troubles with large luggage or baby prams.

One typical job of the assistance is to operate Boarding Assistance Systems like platform based lifts. But in bigger stations assistants can also be found walking around in the stations looking who might need help or also for giving required information.

At the moment (2010) 350 mobility assistants work in 120 stations on the Spanish network. In sum about 83% of all high-speed, long and medium distance travellers pass through these 120 stations. The service started in 2008. In the first year about 100.000 passengers made use of this service, in 2009 already about 235.000 passengers used this service and for 2010 about 300.000 passengers using this service are expected.

Figure 2.15: Operation of a wheelchair lift by Atendo personnel

Figure 2.16: Everybody can get help

Bulgarian service for people with reduced mobility

Regarding the new European countries, the example from Bulgaria can be mentioned. Since the year 2002 Bulgarian railways (BDŽ) has had the the so-called door to door" experience for servicing people with reduced mobility. Under preliminary request the wheel chair users are picked from their homes by specialized automobile transport that transfers them to the stations where the station staff accompanies them until their accommodation in the coach. The transfer costs are covered from the municipalities of the specific settlement, or the cost is equal to the cost for transfer by public transport.

Recommendation:

- It is very important to give the exact information about the possibilities and achievements for accessible and assisted transport.

- If it is impossible to design a technical Boarding Assistance System for all passengers, it seems to be a very good compromise to offer a technical solution only for wheelchair occupants, and if possible also for the group of severely walking impaired persons, and to have additional personal service available for all other passengers needing help.

- It is a good practice to have on-board staff of the train especially trained to wait in advance at dedicated and signed accessible doors of the vehicle, who will offer help to all persons needing and wishing assistance.

- It seems to be an easy and cost efficient way to offer service and assistance to all passengers. The experience of some operators shows that an assistant service for all passengers is possible and also well accepted by passengers.

2.2 Specific recommendations for typical boarding situations

2.2.1 Level boarding

Level boarding includes boarding/alighting situations where the levels of the platform and the vehicle floor are in the same plane, or with a height difference of up to ± 50 mm, combined with the horizontal gap. This scenario allows solving the boarding/alighting for people with reduced mobility without any BAS in case that the horizontal gap is small enough, or by using gap bridging devices in case of larger horizontal gaps.

It is very difficult to maintain horizontal gaps within tight limits and provide a safe train service, especially at platforms along curved tracks. The problems arose because of limitations imposed by undisturbed train curve negotiation followed by track widening and cant. In such situations the horizontal gaps between floor and platform should be kept wider in order to avoid the contact between the train and the fixed installations. Caused by a variety of vehicle geometrical parameters small gaps between the vehicle and station platforms are not possible in regular railway systems. They can be designed only within closed systems like tram or metro systems with typecasted vehicles.

For the boarding situation that could be categorized as level boarding (i.e. with a vertical gap up to 50mm), with a horizontal gap that cannot be overcome without special devices, three solutions can ensure accessibility for passengers in wheelchairs and for those with severe mobility impairments:

- Gap reducing plate (gap filler), see subchapter 2.2.1.2
- Folding access ramp, see subchapter 2.2.1.3
- Bridging plate, see subchapter 2.2.1.3

2.2.1.1 Maximum horizontal gap not requiring a gap bridging system

If assumed that height differences between the vehicle floor and the platform is within the range ± 50 mm, the necessity of using any type of device is defined by the limit value for the horizontal gap.

The criterion for the gap limit value that does not require special devices is set regarding the existing wheelchairs dimensions, general comfort of the passengers and safety against wheel entrapment into the gap

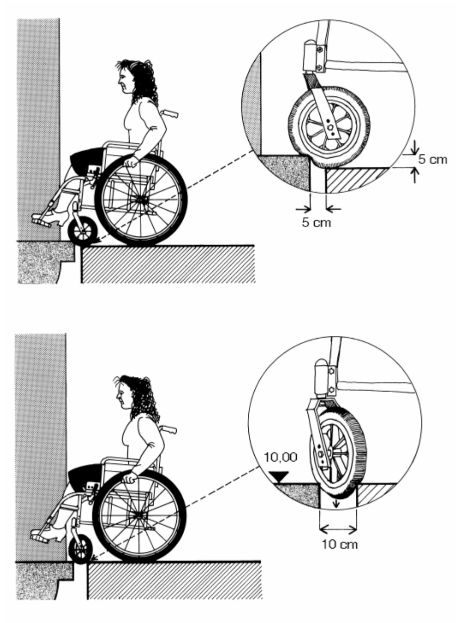


Figure 2.17: Horizontal gap [4]

According to [4] for wheelchair users horizontal gaps (figure 2.17) must not be greater than 100 mm (50 mm is preferred), and not greater than 75 mm according to TSI PRM [11].

Regarding people with reduced mobility other than wheelchair users, the horizontal gap shall not be greater than 300 mm [4].

Recommendations:

- The maximum horizontal gap that doesn't require a gap bridging system shall not be greater than 75 mm (preferably 50 mm), assuming the vertical gap is smaller than 50 mm and wheelchairs wheels dimensioned according to [11].
- When using any type of gap bridging or gap reducing system, the remaining horizontal gap shall be not greater than 75 mm (preferably 50 mm),.
- In any case, horizontal gap of more than 300 mm is not recommended at all, since this is the limit for people with severe walking difficulties, and this limit value is still comfortable for all other people.

2.2.1.2 Gap reducing devices

Gap reducing devices are fixed extensions fitted onto the vehicle or sometimes onto the platform, with the aim to reduce the existing gap between the vehicle and the platform. In the case of railways where larger gaps are present (see subchapter 2.2.2.2), the gap reducing device as shown in figure 2.18 reduces the gap to an acceptable value for railway applications. The remaining gap is still inappropriate for wheelchair users, but more comfortable for people with walking difficulties and all other passengers.

In the case of closed systems like trams or metros, gaps can be regularly kept smaller than on railways, but still not small enough for wheelchair users. In this case an extension on the vehicle which is normally made of rubber or plastics decreases the gap to acceptable limits for wheelchair users, as shown in figure 2.19. In rare cases, when some contact with the platform edge occurs during the train motion, the elastic material of the gap filler prevents severe damaging of the vehicle.

Figure 2.18: Gap filler in railway application

Figure 2.19: Gap filler in tram application

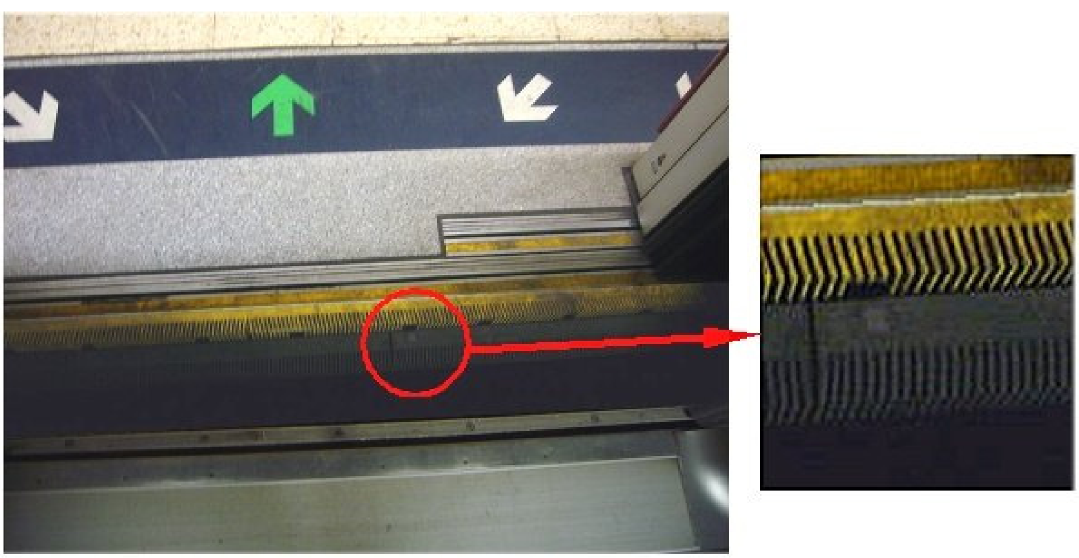


Figure 2.20: Gap filler, metro Hong Kong

One successful solution of gap reduction is the example as used on the metro in Hong Kong. As shown in the figure 2.20 the gap filler is made of rubber in the form of a comb. By fitting the filler onto the vehicle as well as onto the platform the gap at the entrances can be held very low. At the same time the elastic material and the shape makes the filler very resistant and almost insensitive to occasional contacts during train passage.

Recommendations:

-The gap reducing devices (gap fillers) are recommended in case of level boarding for tram and metro systems as the simplest solution for decreasing the gap to an acceptable level for wheelchair users. In case of railway systems, these devices can significantly improve the entrance comfort for people with walking difficulties and all other passengers, but often not for wheelchair users

2.2.1.3 Gap bridging systems

In case of small horizontal gaps, automatic bridging systems activated by the door control unit have advantage compared to manual ramps. These devices are integrated in the coach floor, are always deployed along with door opening, not interfering with movement of passengers. They are used by all passengers.

As a result of lowering the vehicle under load, there is a possibility that an expanded bridging plate above the station platform gets stuck. In order to avoid this situation there are two possibilities:

- it is necessary to provide additional rotation along the longitudinal axis using articulated support (as it is a short automatic ramp), or
- to prevent overlapping at all.

The first solution (figure 2.21) is a more complex design than the second one.

Figure 2.21: Bridging plate with rotational mechanism

Alternatively, a gap bridges can move only laterally to the vehicle, and will be stopped by the vertical limiter and appropriate sensing devices stopping the bridge when coming into contact with the edge of the station platform. The height of the limiter should be greater than the maximum expected value of the height difference between the station platform and vehicle floor, which is in the case of level boarding up to 50 mm. The principle of the vertical limiter for preventing overlapping is shown in figure 2.22.

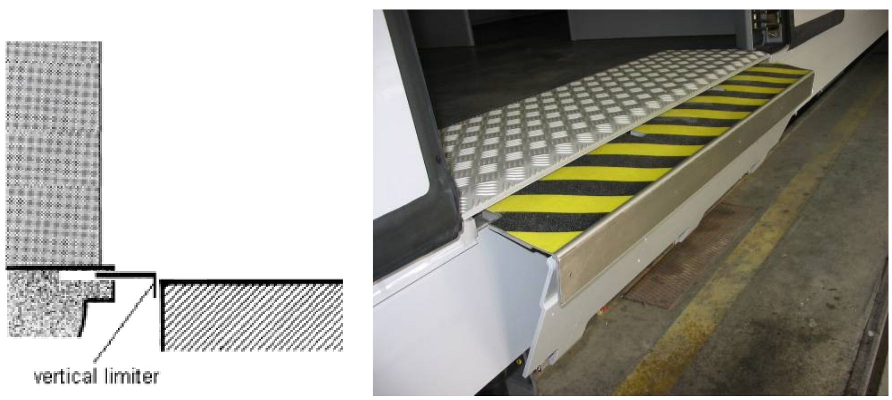


Figure 2.22: Principle of the mechanical limiter at the end of the bridging plate

In any case the movement of the bridging plate should be monitored and held stopped in position if the plate is loaded. Measured values should be compared with the expected logical values. In case of malfunction of the bridge plate, after the released signal has been given the door should remain in locked position for a preset time in order to obtain time to warn the passenger. Warning sound and light signal should be activated, clearly indicating the bridging plate malfunction.

Recommendations:

- In case of relatively small horizontal gaps, the automatic bridging system has advantages compared to ramps.
- If the bridging plate is designed to overlap the station platform, it is necessary to provide additional rotation along the longitudinal axis to avoid getting stuck.
- It is recommended that the bridging plate design prevents overlapping with station platforms using a mechanical limiter or sensors for gap measurement. The height of the mechanical limiter should be greater than the maximum expected height difference between the station platform and the vehicle floor.
- The movement of the bridging plate should be controlled along with the door system, and remain standstill if the plate is under load.
- In case of bridging system malfunction, the door should remain locked for a preset time and the warning sound and light signal should warn passengers.

2.2.1.4 Platform based vs. vehicle based gap bridging systems

The vehicle based bridging plates are more suitable compared to the platform based type, because at long station platforms only segments under the doors should be equipped with bridging plates. Vehicle based bridging plates do not require precise stop positioning of the train to the platform.

Figure 2.23: Korean PS Link Metro

In some metro systems the position of doors is standardized in distance over the full train length. This allows a precise stop of the train and mounting gap fillers only at segments of the existing station platforms in front of the expected position of the entrance doors. An application of the platform based gap bridging systems is justified in the case of an application of platform screen doors or a fence protection at station platforms (figure 2.23). It is also possible to apply a platform based gap bridging systems only in the stations within curves where larger gaps do occur.

Recommendations:

- The bridging plate location is more suitable on the vehicles than on station platforms.
- In case that only few stations are located in curves where bigger gaps occur, fitting the gap bridging systems on the platform can be an efficient solution.
- An application of the platform based bridging systems is justified in the case where there are platform screen doors or a fence protection with a predefined position of the doors relative to station platform.

2.2.2 One or two step upwards boarding and downwards alighting

This case includes boarding/alighting situations with platforms up to approximately 400 mm lower than the vehicle floor. This scenario allows solving the boarding/alighting for people with reduced mobility applying different types of ramps, but does not exclude the possibility of using lifting devices if such devices are available.

An access ramp may be either positioned manually by staff whether stored on the station platform or on the vehicle, or deployed semi-automatically by mechanical means, operated by staff or by the passenger [11].

The possibility of applying ramps for bridging height differences up to 400 mm, and not for greater ones, is determined by the defined length of the ramp needed to meet the criterion of the allowed ramp slope.

2.2.2.1 Ramp slope

Small ramp slopes are more appropriate for people with reduced mobility than higher slopes. Many passengers in manual wheelchairs will not be able to use a ramp when its gradient is too steep and therefore require assistance. For the majority of other groups of people with reduced mobility who can enjoy the benefits of using ramps as a Boarding Assistance System, a slope of more than 5-8% represents a difficulty.

On the other hand, a smaller slope for the same height difference involves longer ramps. Ramps that extend more than approximately 1200mm from the side of the vehicle when deployed will be impractical to use in most operational environments. In case of a bigger height differences a higher ramp gradient is the result.

There are more reasons for limiting the maximum slope of the ramp. The first one regarding safety is illustrated in figure 2.24. The leg support of some wheelchairs can touch the ground at the end of the ramp and cause the overturn of the wheelchair.

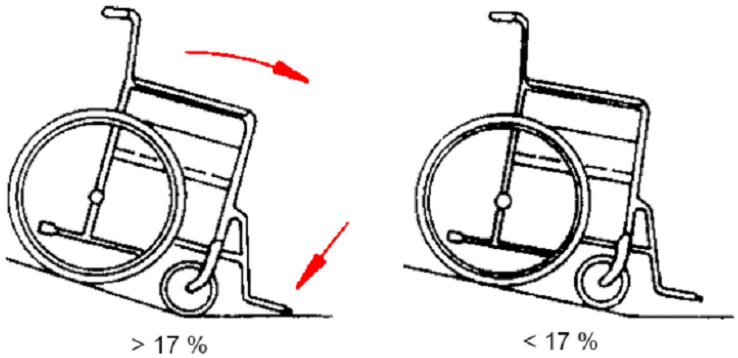


Figure 2.24: Overturn hazard in connection of high ramp slope [12]

On the downward movement on the steep ramps there is potential risk exists for the wheelchair user to fall down, see figure 2.25. Under these circumstances the wheelchair user potentially fills unpleasant and fear. It might be possible to propose a backwards down ride to the wheelchair user, but that involves an additional risk for the assistant person to stumble.

For assisting personnel, high ramp grades involve use of more force for pushing the heavy wheelchair up, fig 2.26. The intensity of this force depends on the slope percentage multiplied by the wheelchair weight. At a ramp grade of 18% and a mass of 100 kg of an occupied wheelchair, the required push force is about 200N. Approximately the same force should be used by the personnel as a "braking" force during downhill assistance. This is acceptable only on very small lengths and if not needed frequently.

Table 2.6 shows the limit values of the ramp slope according to different sources.

Figure 2.25: Potential risk for wheelchair user to fall down on steep ramps

Figure 2.26: Required push (brake) force increases with the ramp slope

Table 2.6 Ramp slope according to different sources

Reference	Recommended (desirable) slope up to	Maximum slope	Comment
[11]	8% longer than 1000mm* 15% 600-1000mm* 18% not longer than 600*	18% (may require assistance)	*ramps in the train
[12]	5-12%	17% (assistance is condition)	
[18]	8%		>8% operator must provide assistance
[4]	8% longer than 1000mm 13% 600-1000mm	18% not longer than 600 mm (assistance)	interior ramps in railway vehicles
[5]	5% over 8% with assistance		
[6]	9%	17% (powered wheelchairs)	
[7]	5% 8% acceptable up to 2m 10% up to 1m		Urban communications

Recommendations:

- Maximum ramp slope gradient shall be not greater than 17%.
- Ramp slopes up to 8% are recommended for both, self-propelled wheelchair user and other people with mobility impairments.
- For ramps with a slope greater than 8% assistance is obligatory. However as best practice, assistance should be available regardless of the ramp gradient.
- For ramps with high gradients it is recommended to propose to the wheelchair occupant to descend with assistance backwards.

2.2.2.2 Maximum horizontal gap between platform and vehicle

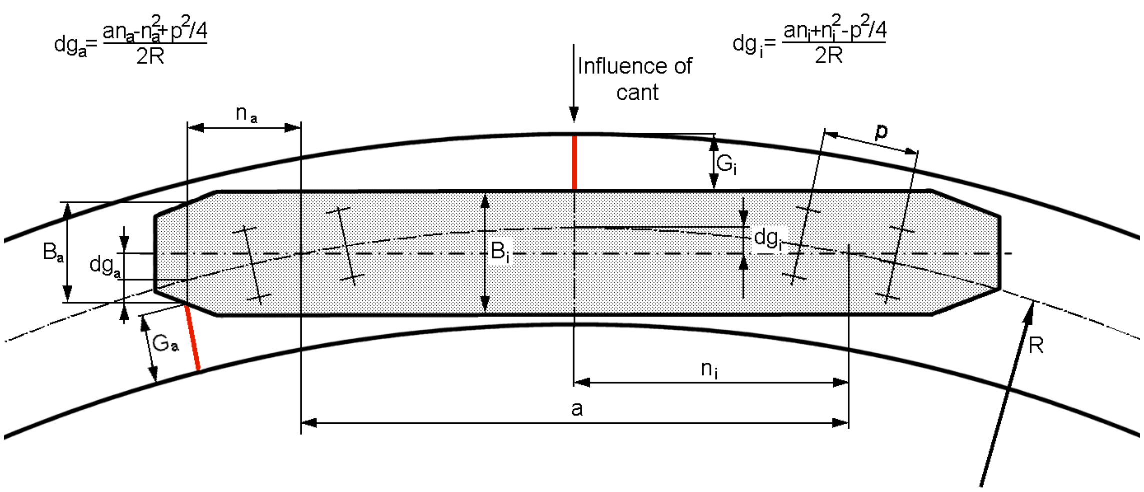
At railway lines horizontal gaps are bigger than at tram, metro or commuter train lines. In Europe, the nominal distance from the platform edge to the centre of the normal gauge track for railways, according to [13] is given by the formula:

$$L_p = 1650\text{mm} + \frac{3750}{R} + \frac{I - 1435}{2}$$

Here R denotes the radius of the track in meters, whereas I denotes the track gauge in millimetres. Track gauge in curves caused by side wear of rails can increase to a maximum of 1465^{+5}mm. Platforms should not be placed in track with a radius less than 500m, or, in exceptional cases, 300m. A cant of up to 60mm in curved sections of station platforms is preferred, and a cant of more than 100mm should be avoided [13].

The distance Lp shall be respected for heights between 400 and 550mm. For higher platforms the increase of the distance Lp must include possible inclination of the vehicles in the curve on cant track as well as other reasons.

According to [11] the same formula, but without the last term (influence of gauge) is given, for platform heights of 550 and 760mm. Additional influences such as the track gauge widening in curves, cant, switches and crossings, quasi-static inclination, construction and maintenance tolerances that are not included in the formula, shall be taken into account according to [14].



	dg_i (door in the middle)		dg_a (door at the vehicle end)	
curve radius R [m]	300	500	300	500
geometric overthrow [m]	0.153	0.092	0.101	0.061

Figure 2.27 Geometric overthrow in curves

Depending on the position of the doors along the coach, and geometrical proportions of the vehicle, the actual gap may be far greater than the nominal gap that can be conducted from the previous formula. The figure 2.27 presents the additional lateral overthrow of different cross sections of the vehicle in a curve. The associated table shows typical values for coaches like UIC type Z.

The width B of the rail coaches depends on the length of the vehicle, the boogie axle base etc. The typical width for UIC Z type coaches is B_i=2825mm. Shorter coaches can be wider, typically up to B_i=3000mm. At the ends, the vehicles are normally a little bit narrower. The typical width in the middle of the end doors for UIC Z type coaches is about B_a=2725mm, and B_i=2825mm in the middle of the coach.

Taking into account all previous elements, a horizontal gap G between the edge of the platform and vehicle side can be approximately between 150mm (like ICE1 on the straight track) and:

$$G_i = L_p + dg_i - \frac{B_i}{2} = 1650\text{mm} + \frac{3750}{300} + \frac{1465 - 1435}{2} + 153 - \frac{2825}{2} = 418\text{mm}$$

for a coach like UIC Z type, with a side door in the middle of the vehicle, staying in curve of R=300m. In such a case, some additional deploy in direction towards the curve centre caused by cant slightly augments the gap.

Let it be noted that in some European countries along which railway network Russian coaches are running, the distance between the track axle and the platform edge is not 1650mm, but 1750mm. This additionally enlarges the gaps between platform and vehicle entrance.

According to TSI PRM [11] for rolling stock designed to stop in normal operation only at platforms of one height, i.e. 550mm or 760mm, the horizontal gap to be considered is 200mm on the platforms along strait track and 290mm along track of radius of 300m. For rolling stock designet to stop at both platform heights, i.e 550mm and 760mm. and having two or more access steps: the respective horizontal gaps are 380 and 470mm.

Recommendation:

- For BAS applications at railway lines, a maximum horizontal gap up to approximately 450mm from the platform edge to the vehicle side should be taken into account. Additionally, internal steps can increase the gap.

2.2.2.3 Height difference for the ramp application

The application of the ramps is highly connected with acceptable ramp lengths. Based on the maximum slope gradient of 18% for assisted or motor driven wheelchairs, and a maximum slope of 8% for self-propelled wheelchairs (see 2.2.2.1), figure 2.28 shows necessary ramp lengths versus height differences.

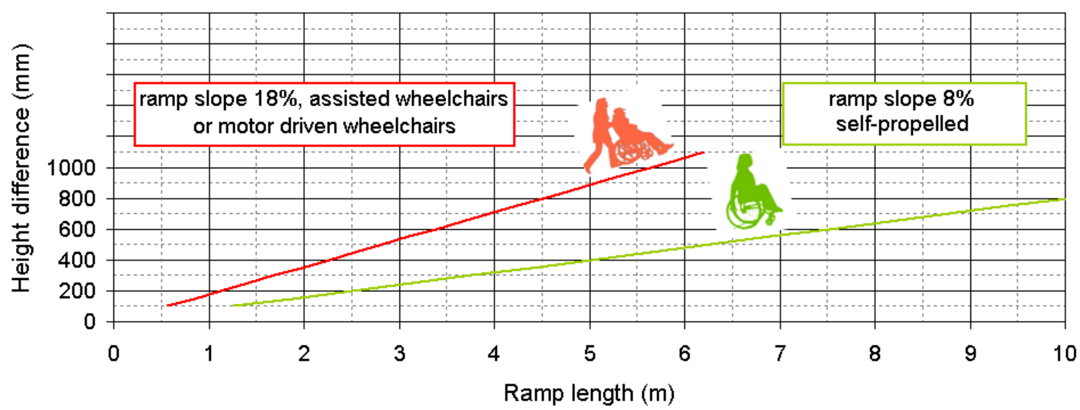


Figure 2.28: Ramps length for overcoming existing height differences

The available place perpendicular to the vehicle for placing the ramp and for allowing a wheelchair to descend the ramp is limited. For new platforms, normally, the minimum width is 2,5m for the single side platform, and 3,3 m for the island platform. [11]. But there is a lot of old infrastructure with narrower platforms. Anyway, if the ramp spans over more than 1,5 to 2 m perpendicular to the train, the passenger flow on the platform can be disturbed. The way out of the wheelchair from the ramp to the platform can be a problem (see 2.2.4.11).

In the case where the ramp enters partially the vehicle like shown in figure 2.26, the ramp occupies less space on the platform (L_{eff}), than in the case of the coach without steps (figure 2.25).

Entrances with steps, require a cut in the coach structure and the gap that must be bridged in that case is bigger (G', see figure 2.29 b), than in the case of a coach without steps (G, figure 2.29 a).

The majority of all ramps analyzed in the deliverable 2.2 are for height differences up to 200 mm. This is approximately the height of one step. The majority of these ramps have a slope that allows self-propelled wheelchair use. From the figure 2.28 can be gathered that for the height difference of 150mm the ramp length for self-propelled use is 1875mm. Such a ramp occupies $L_{eff} \approx 1{,}65$m on the platform, which is very acceptable, bearing in mind that ramps can be used not only by wheelchair users, but also by other people with reduced mobility as well as by all other passengers. There is a positive response from all passengers expressed. Disturbance of the passenger flow along the platform is also very little.

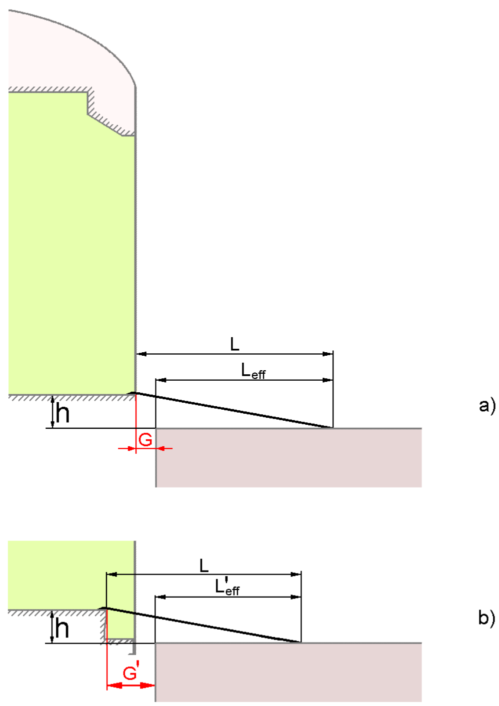


Figure 2.29: Required space L_{eff} for the ramp on the platform

There are several examples of the ramps where a height difference of 400-450mm exists. (Deliverable 2.2, pages 22, 27, 28, 29). All this ramps have a slope near or at the upper limit for assisted or powered wheelchairs. If positioned perpendicular to the vehicle this ramp can causes a disturbance of the passenger flow along the platform. They are applicable only on platforms wide enough. The boarding/alighting for other people with disabilities the usage of steep and relatively long ramps is difficult. Long ramps are also not appropriate for assisted personnel when frequently used.

To reduce some of the mentioned problems the application of ramps parallel to the vehicle is recommended. In any case long ramps are appropriate only with slopes up to 8%. This kind of ramps are heavy, requires a large space in stowed position and are therefore mainly suitable as platform based solutions. Although the usage by all passengers can be allowed, long ramps do not allow a passenger flow in two directions at the same time.

Recommendations:

- To provide barrier free entrance for height differences up to 150 mm it is recommended to use ramps with a slope not greater than 8%. This allows the use of self-propelled wheelchairs, facilitate boarding/alighting of all people with disabilities, and minimally disturbs the passenger flow.
- To provide barrier free entrance for height differences from 150 up to 300 mm it is recommended to use ramps with a slope not greater than 17%, to have a ramp length that does not disturb the passengers flow too much. This slope requires assistance from the personnel.
- If the ramps are used for height difference of more than 300mm it is recommended to apply the ramp parallel to vehicle.
- Ramps higher than 300mm shall have handrails.
- For height differences of more than 450 mm it is not recommended to use the ramps. Lifts are a better solution in this case.

2.2.2.4 Clear width of the ramp and ramp surface properties

Ideally, the ramp should have a similar width as the doorway where it is applied. The absolute minimum width of the ramp is defined by the wheelchairs dimensions, the distance between wheels and the safety margin for preventing entrampment or perhaps falling off the side of the ramp. Taking into account the above-mentioned items, a ramp shall have a minimum width of 800mm and a maximum width equal to the width of the clear door width [18].

The ramp surface should be flat and should not include any excessive upstands at either side. Based on the fact that the doorway form one entity and that the minimum clear width of the doorway is set to 800 mm, in some relevant regulations [11, 4] it is prescribed that the effective or clear width of the ramp shall be at least 760 mm.

Ramps made of two separate tracks (figure 2.30) are not recommended, although there are some advantages regarding their weight and suitability during the winter period. The main reason for not recommending them is that the surface area is not continuous, which is dangerous and unsafe for a wheelchair user and very useless for the assisting person.

Figure 2.30 Ramp consisting of two separate tracks

Surfaces of boarding devices and mobility aids shall be slip resistant and shall have anti-reflecting properties [11, 18, 4]. 'Slip resistant' means that the surface finish used should be sufficiently rough or otherwise specially formulated so that friction between the surface, and a person's shoe or a mobility aid, is maintained at an acceptable level in all the weather conditions.

According to [18] it shall be sufficient to demonstrate that the static coefficient of friction between a designated 'slip resistant' surface and a rubber soled shoe for everyday wear in the member states of the European Union achieves a minimum value of 0,35 regarding EN ISO 14122-2 even when the surface is wetted by clean water, as measured using a nationally, or internationally, recognized testing method. Existing valid ENs should be used to fulfil this purpose.

Anti-reflecting properties means that the surface finish does not produce glare or dazzle which could affect people with visual impairments and disturb all others.

Recommendations:

- The effective or clear width of the ramp must be at least 760 mm.
- For safety reasons it is not recommended that ramps are made of two separate tracks, although there might be some advantages in the winter period.
- Surfaces of all obstacle-free routes including all boarding devices and mobility aids shall be slip resistant and shall have anti-reflecting properties.

2.2.2.5 Safety against unintended movement of the manual ramp during boarding/alighting

When in use the ramp must be fixed securely to the vehicle and must have solid support on the station platform [11]. It is not recommended that ramps are simply laid on the vehicle floor, since friction might not be sufficient to prevent slipping or other unintended movement during use.

If the ramp is manually fixed, it is required to use simple and safe securing devices so that the ramp can be positioned and removed again within a short time. A plug type fixing (like one in the figure 2.31) may be the most efficient [18].

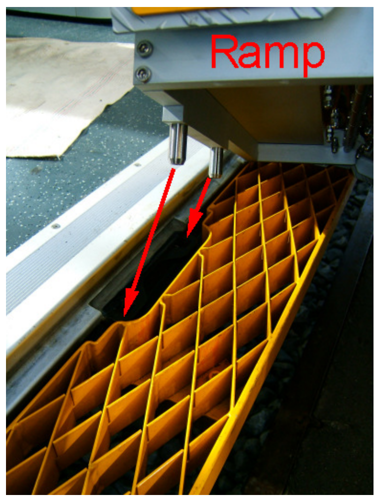


Figure 2.31 Ramp fixing example

Recommendations:

- When in use the ramp must be fixed securely to the vehicle to avoid unintended movement during boarding/alighting.

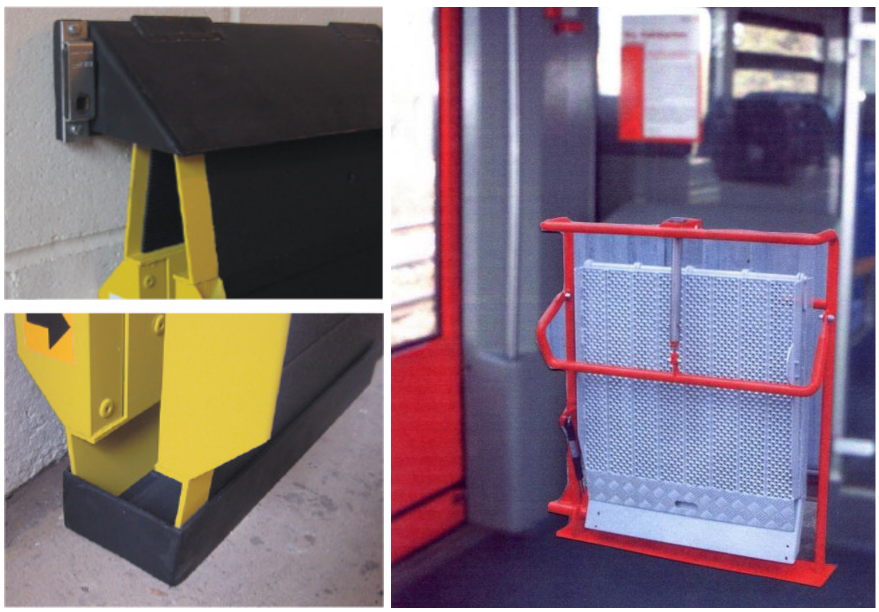
2.2.2.6 Safety and security measures on automatic ramps

Operation of the ramps must be safe, with respect to deployment, securing, raising, lowering and stowing.

An automatic ramp shall be fitted with a device capable of stopping the movement of the ramp if its front edge comes in contact with any object or person whilst being in motion [11]. In such a situation, additional warning acoustic signal can be added. The stopping force should not be dangerous or unpleasant for person's legs. Usually the maximum force is less than 150N. After a few seconds of standstill, an attempt may be repeated. If the deployment cannot be finished after a preset number of attempts (depending on operator's need), the ramp should be retracted or wait for further commands.

For the safe operation of an automatic ramp, the control system shall not allow the ramp activation if the doors have not received the release signal and while the train is in motion.

The ramp shall be incapable of movement in any direction if the surface of the ramp is loaded with 15 kilograms or more [18]. This load corresponds to a child that can use the ramp without the assistance of adults.



a) Platform based ramp – Portaramp b) Vehicle based ramp - Medivent

Figure 2.32: Ramps in the stowed position

The ramps shall be stowed securely in the vehicles or on the station platforms (fig. 2.32), so not to cause any obstruction to passengers. If stowed in the vehicle, the ramp should be fixed and secured to withstand the inertial loads in the event of an emergency stop or similar service conditions.

The train or tram shall be prevent of movement if the door is not closed and locked or the ramp is not securely locked in the stowed position

It should be mentioned that an automated system must have safety devices (e.g. sensitive edges, light barriers) to prevent any hazards or injuries of passengers or operators. Such devices are usually expensive and would increase the difficulties regarding trouble-shooting.

Recommendations:

- Control must ensure that an automatic ramp cannot be operated until the vehicle is stopped and the doors are released, and also that the vehicle cannot be moved if an automatic ramp is not securely locked in the stowed position
- An automatic ramp shall be fitted with a device capable of stopping the movement of the ramp if its front edge comes in contact with an object or a person whilst being in motion. An acoustic signal in such a situation can be added [11].
- The ramp shall be incapable of movement in any direction if the surface of the ramp is subjected to a load of 15 kilograms or more.
- A secure storage method shall be provided to ensure that ramps, including portable ramps, when stored do not cause an obstruction to passengers or pose any hazard to passengers in the event of an emergency stop, or similar service condition [11].
- The train shall be prevent of movement if the door is not closed and locked or the ramp is not locked in the stowed position.

2.2.2.7 Fall-off-the-ramp protection measures

It is recommended that ramps should have upstands on both sides to prevent mobility aid wheels from slipping off. According to [11] a ramp less than 900 mm wide shall have raised edges on both sides to prevent mobility aid wheels from slipping off. The possibility of a wheelchair and in particular a high-powered electric wheelchair, accidentally overriding the raised edges of a ramp must be taken into account [4]. The height of the raised edges along each side which is not to be crossed by the wheelchair shall be at least 50 millimetres higher than the surface of the ramp [18], see figure 2.33.

Figure 2.33 Ramp with raised edges in contrast colours – Souteastern Rail, UK

The upstands at both ends of the ramp shall be bevelled and shall not be higher than 20 mm [11]. They shall have contrasting hazard warning bands. Good practice is to highlight vertical outer sides of the raised edges with a colour that is bright and contrasts with the surrounding surfaces. This will help to prevent people with visibility impairments from colliding with the ramp.

Recommendations:

- Ramps less than 900 mm wide shall have raised edges on both sides to prevent wheelchair wheels from slipping off. It is good practice to raise the side edges regardless of the ramp width [11].
- The height of the raised edges along each side which is not to be crossed by the wheelchair shall be at least 50 millimetres higher than the surface of the ramp [18].
- The upstands at both ends of the ramp shall be bevelled and shall not be higher than 20 mm [11].
- The upstands at both ends shall have contrasting hazard warning bands. Good practice is to highlight vertical outer sides of the raised edges with a colour that is bright and contrasts with the surrounding surfaces.

2.2.3 Step down boarding and upwards alighting

This case includes the boarding/alighting situations with platform up to approximately 200mm higher than vehicle floor level. This scenario can be solved with specific ramps or vehicle based lifts. Common platform based lifts are not suitable for this boarding/alighting scenario.

There is an on-going project of TU Kaiserlautern with the aim to develop a platform based lift which can be used in such a cases [30]. Figure 2.34 shows the idea of this project.

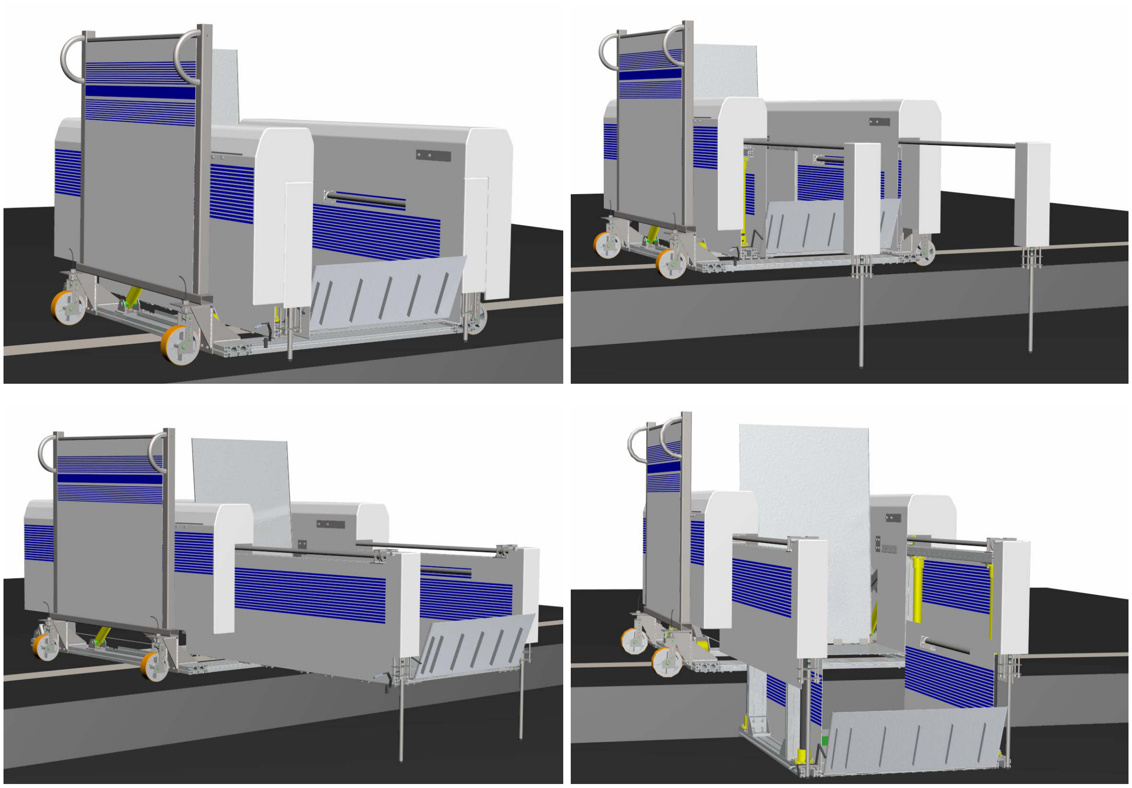


Figure 2.34 TU Kaiserlautern project of platform based lift for step-down boarding [30]

MBB Palfinger realized projects with an extendable ramp into the vehicle, figure 2.35. The limited space in the vehicle entrance requires the maximum slope of 18% (10,2^{o}).

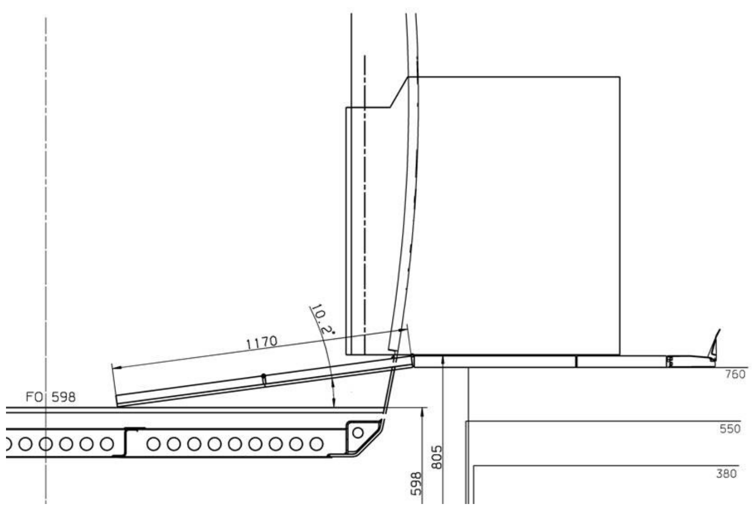


Figure 2.35 MBB Palfinger ramp extendible into the vehicle

2.2.3.1 Requirements for using the BAS in the case of a high platform and a low coach floor

According to [13] there are three recommended nominal platform heights: 550mm, 760mm and 960mm. For existing platforms, acceptable is also the height of 300mm (and for upgraded platforms 380mm) according to older standards. Only two cases of boarding and alighting of low coach floors from recommended high platforms are possible: an access from a 760mm high platform into vehicles having floor height of approximately 600 mm, and from a platform of 960 mm height into vehicles having floor height of approximately 800 mm (figure 2.36).

Boarding from the platform of nominal 960 mm height to coaches having floor height of 600 mm is considered dangerous for passengers (figure 2.36, left), and therefore not acceptable.

In TSI PRM [11] only platform heights of 550mm and 760mm are considered. For both of them vertical gap between platform and first step is maximum upwards 230mm and downwards 160mm.

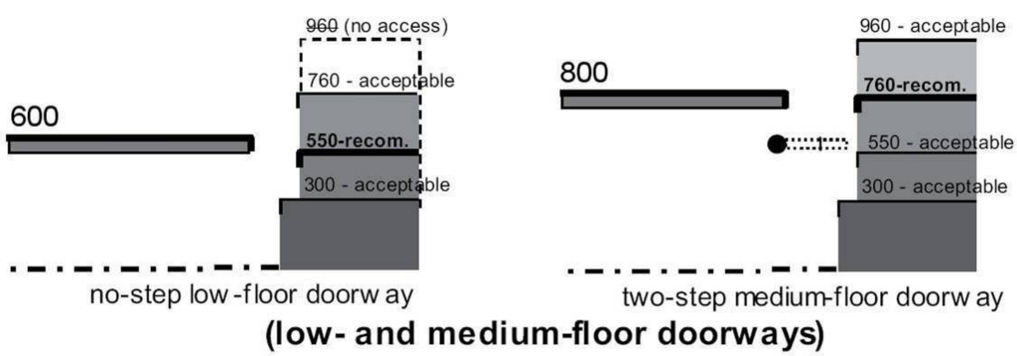


Figure 2.36: Low and medium floor doorways and various platform heights [13]

The double-deck coaches are a typical example for downward boarding. The entrance level of double-decker coaches is usually at approximately 600 mm from top of rail (TOR). From the platform height of 550 mm entrance area can be reached as level boarding. Lower deck, which use people with walking disabilities is accessible by stairs, for example in TGV Duplex (figure 2.37) or inclined floor, for example in DABpbzf 764 coach (figures 2.38 and 2.39).

An internal wheelchair lift for access within the vehicle to and from the entrance area can be a good solution to board and alight wheelchair users in such a situations. In TGV Duplex the internal BAS lift up wheelchair users from the coach floor height to the entrance level when alighting, and lift down wheelchair users to the vehicle floor level when boarding. The users are provided with a fully accessible level-boarding-alighting situation, with the possibility to operate the BAS by themselves.

Such design would not lead to delays or influence the passenger flow as regular abled passengers can easily make one or two small steps down when boarding and one or two steps up when alighting. The only difference in the case of use of the internal vehicle lift would be that those steps would not be between platform and vehicle but inside the vehicle, when already boarded or before alighting. This process enables not to wait for the downward movement of the lift to vehicle floor level and not to extend dwell time..

External small height difference between entrance level and the platform level in this case can be bridged by a ramp (figure 2.37b).

a) Lift in lowered position (default)   b) lift in position for wheelchair boarding/alighting

Figure 2.37

A possible universal solution for platforms height of 380 to 760 mm can be the designed as applied at coach type DABpbzf 764 as shown in figure 2.39, and allows one step down boarding. The main principle of the design is that the vehicle floor level of the doorway is approximately equal to the mean height of the station platform, in this case 600 mm and the floor is initially inclined. For different boarding situation a part of the floor and the ramp may be adapted, either forming a continuous ramp or a broken shape as shown in figure 2.39.

For all passengers without reduced mobility the different platform height between 380 and 760 mm and a vehicle door way height of 600mm provide either level boarding, or one step-up or one step-down boarding. For wheelchair users and other PRMs such a design allows boarding using a ramp of variable shape and slopes. Not all new double-deckers are equipped with such a ramp system due to the high ramp slope, which requires assistance.

Figure 2.38: Ramp at double-deck coach type DABpbzf 764

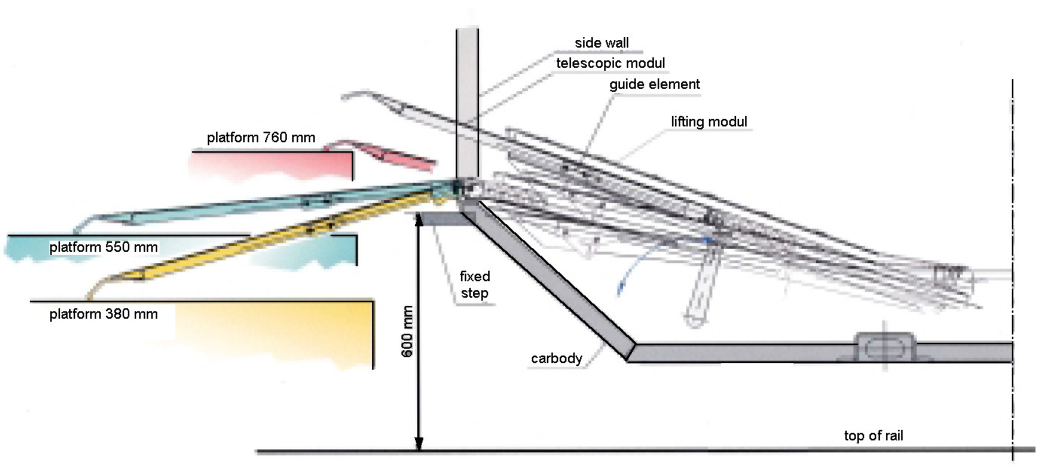


Figure 2.39: Universal ramp solution for various platform height [4]

Recommendations:

- Boarding/alighting in the case of a higher platform than the vehicle doorway level for more than 250 mm is considered dangerous for passengers and is not recommended.
- Internal vehicle lifts can provide comfortable level boarding for wheelchair occupants if the vehicle entrance and vehicle floor do not provide the same floor level.
- An adaptable ramp with an initially inclined vehicle floor or the ramps extendible into the vehicle can be applicable for step-down boarding only in the case when the ramp slope can be retained in acceptable limits.

2.2.4 Boarding/alighting in the case of height difference greater than 400 mm

In the case where the height difference between vehicle floor and platform level is greater than 400 mm, the best solutions for boarding/alighting are lifts. The lift can be platform based or vehicle based integrated into the doorway of the respective coach.

2.2.4.1 Automatic versus assisted usage of lifts

The most common practice is that the lifts for boarding and alighting are to be assisted by train or platform staff (figure 2.40). Safety concerns require that they should be operated by railway staff, where there are significant vertical or horizontal gaps [6]. Since the lifts are complex systems, it is difficult to think about allowing idnependent use by passengers, especially passengers with disabilities. Several operators highlights that even trained personnel can involve problems with lift usage. In case of any malfunctions the presence of well trained staff is inevitable.

Figure 2.40: Platform lift Switzerland

On the other hand, lifts inside the vehicles as in TGV Duplex, figure 2.37 or SJ (Sweden) vestibule lift, figure 2.41 [2], provide a much higher level of passenger safety, and even in case of malfunctions will not cause train delays. It is recommended to allow passengers to use such automatic solutions by themselves.

Figure 2.41: Operation – SJ-Regina Lift

Fixed installed platform based lifting devices are very common overseas. Travellers can easily locate them every time of travel, which offers a great advantage. Such lifts can also be operated by the users themselves (figure 2.42) [2].

User operated lifts offer comfort for wheelchair users, providing them a less dependent feeling.

Figure 2.42: Platform based, permanently installed train-lift, U.S.A.

The disadvantage of such lifts is that the respective vehicle door position shall be at the exactly same position every time.

In order to prevent misuse of the user operated lifts train drivers can de-activate the device, e.g. on board lifts, or platform based permanently installed lifts should be activated just before train arrival.

Platform or vehicle based lifts regardless if they are activated by train or platform staff are satisfactory or very satisfactory for users, while manually operated lifts can provoke undesirable feelings of staff misuse among passengers in wheelchairs as described in Deliverable 2.1 [1].

The dwell time do increase when lifts are used for boarding or alighting is more or less equal for all lift types and it is approximately 120 seconds [4, 2].

Recommendations:

- Movable platform based lifts and vehicle based lifts used as BAS from platform to vehicle, should be operated only by well trained personnel.
- For internal lifts and fixed platform boarding lifts which present acceptable automatic low risk solutions, it is recommended to be operated by users themselves.

2.2.4.2 The operation of powered lifts

In the case of powered lifts the control for lowering, raising and stowing the lift will require continuous manual pressure by the operator and shall not allow an improper lift sequencing when the lift platform is occupied. To avoid contradictory commands the master control place should be at one side only. The possibility of contradictory or unintentionally commands should be excluded. This can be achieved by using recessed or covered buttons, two hand controls, etc.

In case of power fault the lift must stop accordingly. An additional movement of maximum 100mm can be tolerated. A self-descent of the lift platform in case of power failure is allowed but with a speed not higher than 0,165 m/s [17]. But this situation can be considered also as potentially dangerous, as there is no more possibility to stop the movement until reaching the ground.

Each lift device shall incorporate an emergency scenario of deploying, lowering to the ground level with a lift occupant, and raising and stowing the empty lift if power fault or any failure occurs.

In case of overloading more than 25%, a protection should be activated to avoid any lift movement.

An emergency stop button within reach of the user (on the lift) and on the vehicle (e.g. assistance) should be provided. Release of an activated emergency stop button should only be possible by personnel.

Additional protecting and safety measures like an obstacle detector, foot entrapment protection, visual and optical indication signals etc. are recommended although the lift is operated and supervised by personnel.

Recommendations:

- The control of the lift should be based on the principle hold-to-run.
- It is recommended to control the lift from one place only.
- Any unintentionally or contradictory commands shall be avoided.
- The lift should have a protection against overload.
- The emergency stop button shall be available for the lift user and for the staff.
- Additional protecting and safety measures such as obstacle detector, foot entrapment protection, visual and optical indication signals, etc. are recommended.

2.2.4.3 Security on the lift platform

The lift platform must be unobstructed and must be slip resistant.

The lift shall permit both boarding and alighting in the direction of the wheelchair in order not to arouse feelings of discomfort [11]. Many people could feel unsecure while using a platform lift and that feeling can cause undesirable body movement and consequently even a wheelchair movement [18].

The design of the boarding lift must take into account the possibility of a wheelchair, and in particular a high-powered electric wheelchair, accidentally overriding the raised edges of lift platform [4].

Each side of the lift platform which extends beyond the vehicle in its raised position shall have a barrier of a minimum 25 mm high [11]. Sometimes this height is regarded as insufficient and a minimum height of 50 mm is recommended. Such barriers shall not interfere with manoeuvring into or out of the aisle (figures 2.43).

Figure 2.43: Linear lift (U-Lift) side barriers

The loading-edge barrier (outer barrier) which functions as a loading ramp when the lift is at ground level, shall be sufficient when raised or closed (figure 2.44), or a supplementary system shall be provided [11], figure 2.45, to prevent a wheelchair from riding over or defeating it. Unless the lift-platform is in its fully lowered position the wheelchair shall be prevented from rolling off the platform by a device with a height of not less than 100mm above the surface of the lift-platform [17,18].

Figure 2.44: Pivoting lift roll-off barrier (MBB Palfinger Trainlift TR 1)

Figure 2.45: Rolling off security - platform ramp

A barrier or inherent design feature shall prevent a wheelchair from rolling off the edge closest to the vehicle until the lift is in its fully raised position [18].

The lift platform must be equipped with a handrail on one side, 650 to 1100mm or better 750 to 900 mm high, for use by the person standing or in a wheelchair [11] (figure 2.46).

Figure 2.46: Handrail - Linear lift (Ratcliff Palfinger Trainlift RVT 300)

Recommendations:

- The lift platform must be unobstructed and must be slip resistant.
- The lift platform shall be equipped with side barriers at least 25mm high (50mm is advisable), to prevent any of the wheels of a wheelchair from rolling off the lift platform during its operation.
- To prevent a wheelchair from rolling-off the lift the barrier at least 100mm high should be provided at the front and rear platform end.
- Handrails at least on one side of the lift platform should be provided.

2.2.4.4 Lift overall security measures

The lifting process using platform lifts should not start before the train is at standstill. Preparatory activities for lifting are allowed to be done even before train arrival.

Lowering to ground level, raising and stowing the lift shall not allow an improper lift sequencing when the lift platform is occupied [11].

When the lift is activated the break system of the coach must be activated also, and still applied until the lift is stowed.

Hydraulic boarding and alighting lifts powered for moving up and using gravity for moving down should use aero-grade oil [2] capable for use in all ambient temperatures and should provide enough internal friction during the downward movement in order not to exceed speed of 150 millimetres per second.

Recommendations:

- Lift operation should be possible only at zero speed of the vehicle.
- A control shall ensure that the vehicle cannot be moved when a lift is in use.
- Boarding aid shall incorporate an emergency scenario of manual operation in a case of power fault or system fault.
- Wheelchair users should be able to board and alight from the vehicle in the event of a boarding device power failure.

2.2.4.5 Warning signals

The surface of the lift-platform should be marked by a strip of colour on the surface edges [18], not less than 50mm wide and in contrast with the remainder of the surface. The platform should be coloured on each side with that colour (figure 2.47).

Figure 2.47: MBB Palfinger Railjet lift

Currently the deployment of a boarding aid, whether on the platform or on board, requires staff supervision. In case of a vehicle based lift, it may also be necessary to install visual and audible warning signals especially if the staff member deploying the device does not have a full view of the operation [4].

<u>**Recommendations:**</u>

- Regardless of staff involvement visual and audible signals during lift operations are recommended.
- Lift platform surface edges should be appropriately marked to be well recognisable for all people with disabilities.

2.2.4.6 Place for lifts in stowed position

The place for lift stowing depends on the type and the design of the lift.

Lifts should be stowed so that they do not significantly obstruct the flow of passengers inside the vehicle or at the station platform.

A boarding device which is carried by a rail vehicle and that is not in use shall be fixed securely to that vehicle so that it does not endanger the safety of passengers in that vehicle, figure 2.48. Unexpected and undesired unfolding of stowed on-board lifts at any in-service condition is unacceptable [18].

Figure 2.48: Stowed lift at Stadler train (MAV Hungarian Railway)

Platform based boarding aid should be stowed in a secure stowage area that would prevent the risk of damage (possibly from dust and dirt) and vandalism [4] and provide short time of response.

Platform based lifts should be operated by station staff and on-board lifts should be operated by train personnel to avoid long delays due to the time consumption for the preparation of the lifts and to clearly define who is responsible for the lifts operation.

Recommendations:

- Lifts should be stowed so that they do not significantly obstruct the flow of passengers inside the vehicle or at the station platform.
- A boarding device must be stowed-in securely in all in-service condition, so that it does not to endanger the safety of passengers.
- Platform based lifts should be stowed in a secure stowage area that would prevent the risk of damage and vandalism, to provide a short time of response as well as protection against weather influences.

2.2.4.7 BAS performances

Lift platform's dimensions

The lift platform's dimensions for standard self propelled or motor driven wheelchairs should be at least 1200 x 760 mm [4] (1200mm long measured at a right angle to the side of the vehicle and not less than 760mm wide measured parallel to the side of the vehicle [18]).

As an exception for lifts applied on narrow doors platform width of 720 mm is permitted [11].

If the platform is ramped at one end, a slope steeper than 13% may require help from the staff for a manual wheelchair [4].

The up stands at both ends must be bevelled. If they are higher than 20 mm, help from the staff may be required [4].

Load capacity

The need to increase the capacity of lifts is caused by the increasing weight of modern powered wheelchairs. The following diagram provides an overview of the percentage distribution of weight of a wheelchair with occupant (figure 2.49) [19]

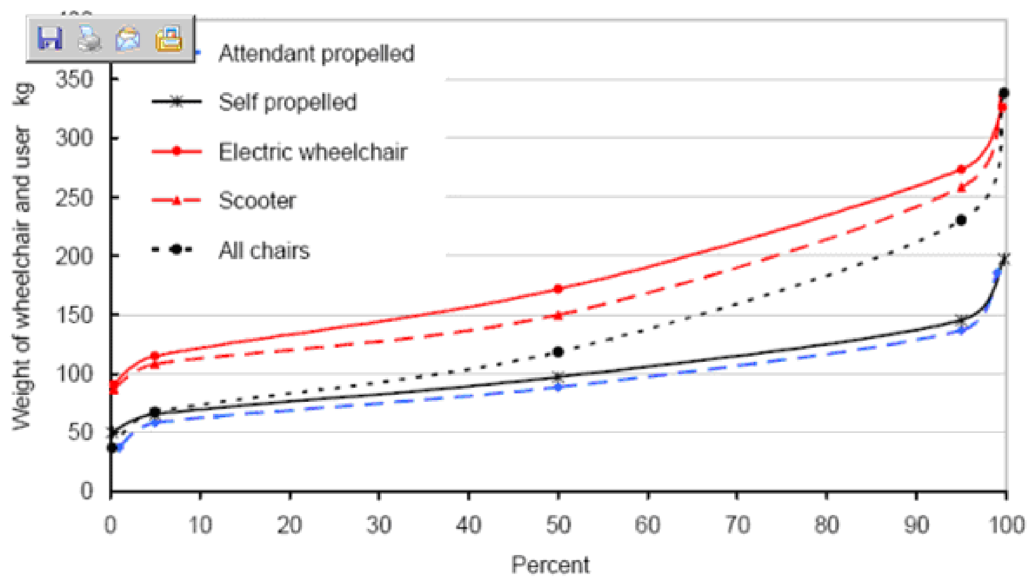


Figure 2.49: Weight distribution of wheelchairs with users

The diagram shows that 98% of wheelchairs with user sitting in them have a weight up to 250 kg, 99% have a weight up to 300 kg and all wheelchairs with user sitting in them have a weight less than 350 kg.

Based on these facts, in all relevant regulations [11, 18, 4] is set that a lift device shall withstand a weight of at least 300 kg (excluding its own weight).

The device shall withstand a weight of at least 300 kg, placed at the centre of the device distributed over an area of 660 mm by 660 mm [11].

Lift speed

No part of the lift platform shall move at a rate exceeding 150 mm/second [18, 11,17] during lowering and lifting an occupant, and shall not exceed 300 mm/second during deploying or stowing (except if the lift is manually deployed or stowed). If additional barrier recognition devices exist the speed without load can be up to 0,6m/s [17]. The maximum lift platform horizontal and vertical acceleration, when occupied, shall be 0,3 g.

The lift-platform shall be fitted with sensors capable of stopping the movement of the lift-platform if it comes into contact with any obstacle or a person whilst the lift is in movement [18]. An acoustic signal in such a situation can be added.

Duration of the loading/unloading

The duration of the entire cycle of loading/unloading should be such as to permit the boarding/alighting the vehicle within the anticipated dwell time in stations.

The main factors affecting the duration of the process are:

- responding time,
- level of staff training,
- limit speed of device elements during lifting should not create discomfort to users.
- capability/ limitation of the wheelchair user

Duration of the loading/unloading should be about 2 minutes each time [4].

<u>Recommendations:</u>

- The lift platform's dimensions for standard self propelled or motor driven wheelchairs should be at least 1200 x 760 mm.
- The lift-platform shall be capable of supporting a weight of not less than 300kg (excluding its own weight).
- The lift-platform shall not travel up or down at a speed in excess of 150mm per second.
- Duration of the loading/unloading should be about 2 minutes each time.

2.2.4.8 Maximum height difference between platform level and coach floor level

The lift as a boarding assistant system shall be able to compensate the maximum height difference between the vehicle floor and station platform.

The vehicle based lift-platform shall be supported on the surface of the station platform when it has been fully lowered [18].

Platform movable lifts shall be designed in order to fulfil all requests regarding the height difference between platforms and coach floors. There are some examples of the lifting heights.

The manually operated movable platform lift Herkules WG 300 is designed for lifting up to 1005 mm [20].

Herkules powered lifts MB 1000 and MB1300 are designed for lifting up to maximum heights of 1.000 mm and 1.280 mm.

The electric platform lift Guldmann LP11 is designed for lifting up to heights from 180 to 950 mm [21].

I Italian mobile electric vehicle employed as a platform lift has a maximum lifting height of 1100 mm [6] (figure 2.50).

Figure 2.50: Trenitalia mobile electric platform lift

Platform heights can vary from 150 mm to 960 mm and floor heights can be up to 1255 mm high as in X, Y, Z type of coaches [22, 23]. Some old designs have floor height of 1385 mm. In the table 2.7 and 2.8 an overview of existing platform and floor heights in different countries is given [4].

Table 2.7: Overview of existing platform and floor heights in different countries – 1 [4]

Country	Austria	Switzerland	France	Germany	Finland	Denmark	Sweden
Boarding Aids Used	Platform lift, ramps, vehicle based lifts	Platform lift	Platform lift Platform ramp Lift on TGV duplex	Platform lift On board lift Bridging ramp	On board lift On board bridge	Platform lift Platform ramp	On-board lift Platform lifts (few)
Platform height-Mm	550, 380, and less	550, 350	550, 350 900 (IdF region)	380, 550, 760, 900	265, 550	550	580 (all new stations) 730 (few suburban systems)
Floor height-mm	590 to1255	1160	900, ~950, 1190	600, 800, 1100	~550, 1200	900-950	1150

Table 2.8 : Overview of existing platform and floor heights in different countries – 2 [4]

Country	Hungary	Italy	Norway	Spain
Platform height Mm	300	250 to 550	700-570-350 and less	550 (main), 280, 700, 900
Floor height mm	1 100	500 to 1100	1320-1150-920-750	650 (Talgo), 850, 950 (high speed)

Recommendations:

- Having in mind that in Europe there are various height differences between platform and vehicle floor, it is recommended that lifts should have capability of overcoming height differences up to 1300 mm. This is necessary in emergency cases in which the BAS system should be used out of the station areas as well.
- In the fully lowered position the lift platform of vehicle based lifts shall be supported on the station platform.

2.2.4.9 Requirements on reparability and reliability

Boarding assistance systems must be reliable in order to fulfil their task successfully. Therefore any mechanical and electrical components must be designed taking into account the environmental conditions likely to be encountered in service, dust and objects which may cause damage to the device. Vandalism is a concern of operating companies, more and more of them are installing protection systems in the stowage area. The UIC-report (Mobility for All - The missing millions, 1996) indicated the complexity of on-board BAS and therefore more pronounced problems that are likely to cause train delays [4]. For example, the failed platform based lift can be easily removed from the train not causing significant delay, while the difficulties in stowing on-board lifts can in some cases cause a long unscheduled train stop.

Pivoting/Swing vehicle based Lifts are permanently installed inside the vehicle. This system scores between a good and very good reliability when in operation according to [1].

Linear Lifts, Single and Dual Parallel Arm (DPA) Lifts are providing good service to passengers in wheelchairs but some operators are not very satisfied concerning the lifts' reliability [1].

The reliability of user operated on-board and permanent platform lifts is assessed as good by the operators due to its self-service operation ability [1].

The reliability of manual and powered movable platform lifts is very good if permanent maintenance and adequate storage are provided.

Recommendations:

- Permanent maintenance and adequate storage are necessary to achieve good reliability of movable platform lifts.
- Vehicle based lifts can in some fail cases cause remarkable train delays and therefore must be highly reliable and, in case of malfunction, easily stowable manually.

2.2.4.10 Entrance area of the railway coach for wheelchair users

After boarding the train using a BAS, the wheelchair user in the entrance area of the coach has to perform a 90^{o} turn to longitudinal corridor. The consideration of this problem is given in regulations dealing with the passage of an angled corridor. According to ISO [10] for this case, figure 2.51, typical and maximum recommended limit measurements are given in table 2.9.

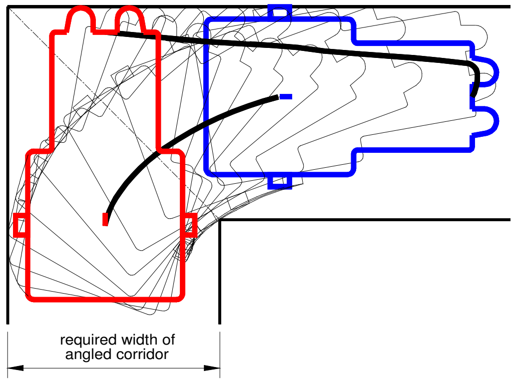


Figure 2.51: Passage sequence at the angled corridor. [24]

Table 2.9 Typical required width of the angled corridor (in mm)

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

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

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

*For dimensions of classes A, B and C, see table 3.1

As can be seen, a corridor of approximately 900 mm width must be available at both parts of the angled corridor. In this case, the same minimum corridor width of 900mm is required [25]. According to figure 2.51 this passing scenario assumes the partial gliding of the wheelchair along the wall. It is normally impossible to do s in the entrance area of passenger coaches because the stairs at the opposite doorway form a hole in the floor that has to be avoided. Figure 2.52 shows a small cover for the stairs corner used on Serbian Railways coach in order to reduce the fall-in danger for the wheel during manoeuvring. Therefore a little bit larger corridors are needed.

UIC regulations [12] consider the possibility of different widths at the two sides of angled corridor, figure 2.53, according to table 2.10. This is a very common case by coaches. It is recommended to round the inner corner as much as possible. For example it is possible to make a 90^o manoeuvre from corridor of 1100mm width to the corridor of 850mm width. These widths should be taken into account when designing or adapting the entrance area of the coaches in order to be accessible for wheelchair users.

Table 2.10: Minimum angled corridor dimensions according to [12]

Corridor width a (mm)	1100	1000	900
Clearance width of door or corridor width b *mm	850	900	1000

Figure 2.52 Permanent cover for dangerous stairs corner on the coach of Serbian Railways

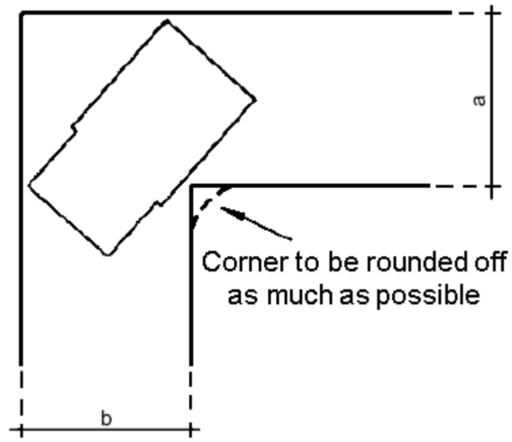


Figure 2.53 UIC recommendation for angled corridor

Recommendation:

- The entrance area of passenger coaches adapted for wheelchair users should have angled corridor widths preferably 1000/1000mm, but not less than 1000/900 or 1100/850mm. The cut for the stairway must be considered. The inner corner should be rounded off as much as possible.

2.2.4.11 Landing area on the platform

The use of BAS is tightly bound with the available area on the platform. To access a ramp or lift, the wheelchair must previously come in the position in line with the boarding direction. In principle if the BAS is placed perpendicular to the train and station platform, a 90^o wheelchair turn precedes the wheelchair entry the ramp or lift platform. In case of alighting the necessary space must be available in extension of the ramp or lift platform for safe drive out, again with a 90^{o}turn.

As a base, data given in the previous subchapter can be considered. However, in this case there are no surrounding walls that interfere in the corridors with wheelchair user hands and specially elbows, so it is possible to perform a sharper turn. On the other side there has to be some safety distance from the adjacent platform edge, to prevent a fall onto that track.

In case of ramps, due to the ramp slope, the wheelchair must complete the descent from the ramp before it start the turning, figure 2.54. It is the same case for lift platforms with fixed side barriers. To define the minimum required platform width a turning radius of about 1500mm is necessary. According to TSI PRM [11] this value shall be provided to the opposite danger area. The danger area is defined as the area where passengers may be subject to dangerous forces due to the slipstream effect of moving trains at an adjacent track. This area shall be in accordance with national regulations.

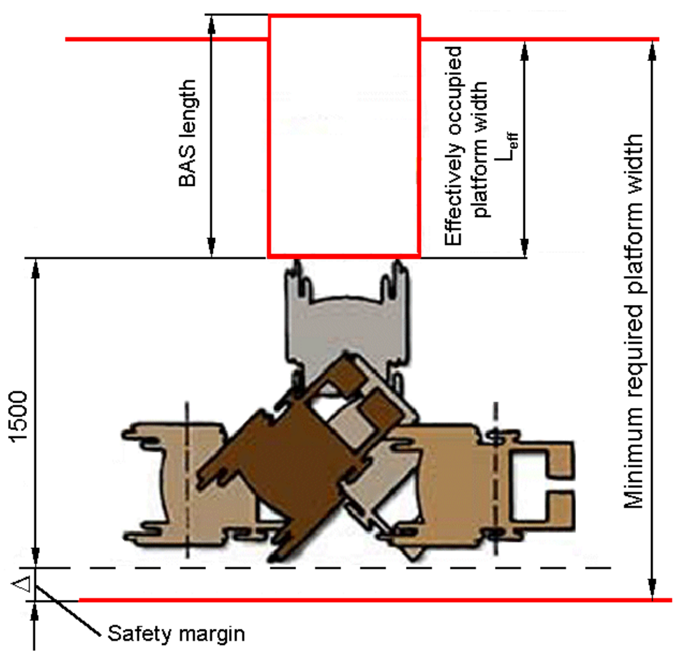


Figure 2.54: Landing area 1

The effectively occupied platform width L_{eff} in case of ramps is lower than the ramp length (see Chapter 2.2.2.3). In the case of lifts the effectively occupied platform width depends on how far from vehicle side the lift platform lands. In principle this can be more than the lift platform length used for the wheelchair, as in figure 2.56. As an example, if we take into account typically L_{eff}=1200mm, then the minimum platform width should be not lest than approximately 3 m.

In the case of lift platforms with collapsible side barriers, where side barriers can be lowered to the ground (see figure 2.55), the wheelchair can start the turning movement immediately from starting position on the platform. In that case the necessary landing area is significantly smaller, and boarding/alighting can be performed on narrower platforms, figure 2.56. Let's assume the worst case, where the wheelchair is in starting position aligned with front line of the ramp. In this case the difference between L_{eff} and the wheelchair length should be added to the turning radius and the safety margin Δ. As an example, assuming L_{eff}=1500mm, and a wheelchair length of 1350mm, the minimum required platform width is about 1,9m.

The most convenient and the most universal solution is to use ramps or lifts that allow boarding/alighting parallel to the vehicle. The example of this kind of ramp is shown in figure 2.57.

If the lift design allows the turn of lift platform parallel to the vehicle, the minimum required width of the station platform is equal to L_{eff} + Δ. In this case, the safety margin Δ is needed to avoid interference with the train on the neighbouring track. It can be estimated that such lifts could be used on the platform of approximately 1,6m width. This corresponds to the distance between two neighbouring tracks of about 5m.

Figure 2.55: Collapsible side barrier-BraunAbility Milleniun Series lift

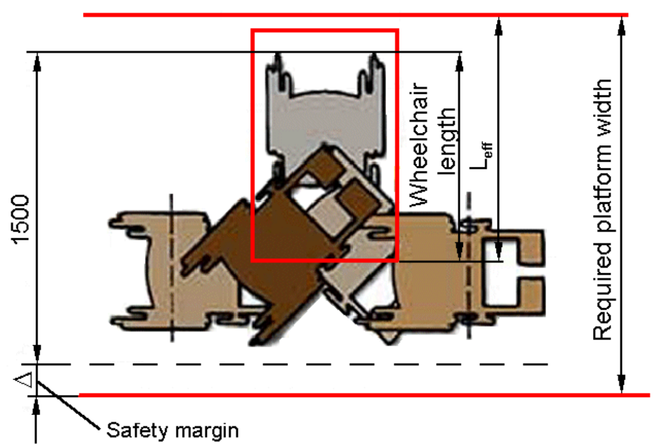


Figure 2.56: Landing area 2

Figure 2.57 Platform based ramp parallel to the coach (NS)

Recommendations:

- It is recommended to use ramps or lifts for boarding/alighting parallel (or occasionally at some angle smaller the 90^o) to the vehicle, in order to allow the usage of the BAS on very narrow platforms.
- In case of lifts, it is recommended to use lifts that land as close as possible but not less than 75mm to the plane of vehicle side wall. If necessary the lower turning step on the coach stairway (if it exists) should be uplifted before the use of the BAS, to allow landing close to the vehicle side, and the use of the BAS on narrow platforms.
- In the case of lifts with the platform perpendicular to the vehicle, it is recommended to use side barriers that can be turned down to allow wheelchair roll-off sideward, and make the use of BAS on narrow platforms possible.

3 Design Recommendations for Improved BAS

The Description of work of the PubTrans4All Project defines as the main goal of the project to "Develop a prototype for a standard BAS that can be retrofitted into all types of existing rail vehicles or installed on all types of platforms". Also, "The minimum goal for the PubTrans4all project is to develop a BAS that works for wheelchair users; the ultimate goal is to develop a BAS that works for other groups of persons with reduced mobility and all other users."

In the previous work of the PT4All Consortium research that had been conducted in Deliverable 2.1 (see point 5.1.3) led to the conclusion that a technical access solution (new development) is required for high floor vehicles. Among them (see D.2.1, point 8.1.3) high speed trains and long distance trains (high floor vehicles) do have the highest priority for a BAS application, according to the DOW, page 5:

"...current research supports development of a standardized vehicle based BAS, however the project will assess the potential for a platform based BAS as well, and will develop a platform based prototype if it is found that this would lead to an optimum solution." In deliverable D.2.2 (point 5.2) it was assessed that "For the PubTrans4All project especially vehicle based systems are playing a major role for the future, based on the findings of the surveys of deliverable 2.1 amongst the great part of operators and users."

The discussion at the second full consortium meeting showed that a vehicle based solution has advantages over a platform based solution, as they are permanently present and available always right in time and at the right place – fitted in the special coaches designed for wheelchair users. Therefore it cannot happen that in a given station that there is no BAS available to board or alight a wheelchair user or other PRMs to or from such a dedicated coach. Therefore the decision of the consortium was to develop the vehicle based BAS prototype, and all further activities on the project, are focused on seeking an appropriate vehicle based BAS solution.

This part of the deliverable is meant primarily to support the work of the Prototype Development Group of the project PubTrans4All. In the first part of this section various technical constraints for UIC coaches will be analysed. In the second part, the general recommendations for the improvement that could be included in the development of the prototype of the new BAS will be summarised shortly.

3.1 UIC coaches – technical conditions for BAS fitting

3.1.1 Why UIC coaches?

Within the passenger railway transportation, two main-concepts do exist:

- classic, locomotive hauled trains
- electro motor units (EMUs) or diesel motor units (DMUs)

In the first case the train consists of locomotive and different types of coaches. This concept allows a very flexible train composition according to the different needs. The train typically consists of a different number of first class or second class coaches, a restaurant car or sleeping cars. The train composition can be split or changed by adding or subtracting some coaches in intermediate stations along the line.

As the coaches can sometimes be combined in trains with wagons, they are equipped with classic European draw and buff gears. The strength of these coaches must be in accordance with UIC 566 and EN 12663-1, and must be able to withstand longitudinal draw forces of 1500 kN and buffing forces of 2000 kN, 1000 kN on each buffer, figure 3.1.

Figure 3.1: Classic UIC coach

s from the figure 3.1 can be seen, the side doors of the UIC coaches at the car ends are placed immediately behind buffers. In order to transfer concentrated force of 1000 kN along the coach, a beam in line behind the buffer is needed. This beam makes at the same time limit to what can be cut the structure of the underframe for mounting the steps.

Until a few years ago the UIC regulations were the only international regulations for passenger coaches in Europe. Practically all coaches for international passenger traffic for decades had been built according these regulations. Due to a long service life, this type of coach will stay in service also in coming decades.

On the other hand, electro motor units (EMUs) and diesel motor units (DMUs) are independent units, not requiring classic buffing and drawing gear. They do have milder service conditions compared to classic caches i.e. they are exposed to lower longitudinal forces. According to UIC566 and EN 12663-1, these vehicles must withstand a draw force of 1000 kN and buff force of 1500 kN acting on the central coupler (fig. 3.2) Therefore DMUs and EMUs have a lighter design than UIC coaches and are usually more economic in service. The Development in the last twenty years led to a rapid share rising of EMUs and DMUs.

Figure 3.2: Coach of EMU with central coupler

As shown in figure 3.2 the absence of side buffers makes the entrance cut in the structure simpler and without restrictions. Side doors at coach ends of 900mm width are common instead 800 mm by UIC coaches. The central coupler is normally placed at some lower height from top of rail (TOR) comparing to the classic draw/buff gear of UIC coaches, allowing the floor level to be lower than by UIC coaches.

Based on these facts **it can be concluded that vehicle based BAS that can be operated at a narrower door, from a higher floor level over the platform, and at place that is constraint by the buffer position, will be the most unfavourable. A BAS solution for UIC coaches can certainly be installed (fit) in DMU and EMU.** Therefore the conclusion of the PubTrans4All consortium was to continue to search for and find a solution for a BAS that is able to be fitted into UIC coaches.

3.1.2 Technical constraints caused by the vicinity of the buffers

Figure 3.3 shows the position of the buffers in accordance with UIC 528 [26]. As mentioned, this position limits the possible cut in the bearing structure that is needed for the stairs to approximately 420mm from the coach side walls. The typical floor level (FL) above TOR (top of rail) is 1255mm or may be even a higher than that.

In order to utilise as much space as possible, the carbody is partially extended over the buffers, as shown in the side view in figure 3.3.

According to the UIC code, several types of coaches do exist: X, Y, Z, A, B, M [22, 23,27,28,29]. In relation to the PT4All BAS project, the interesting is position of the side entrance doors, toilets for wheelchair user as well as wheelchair user compartment.

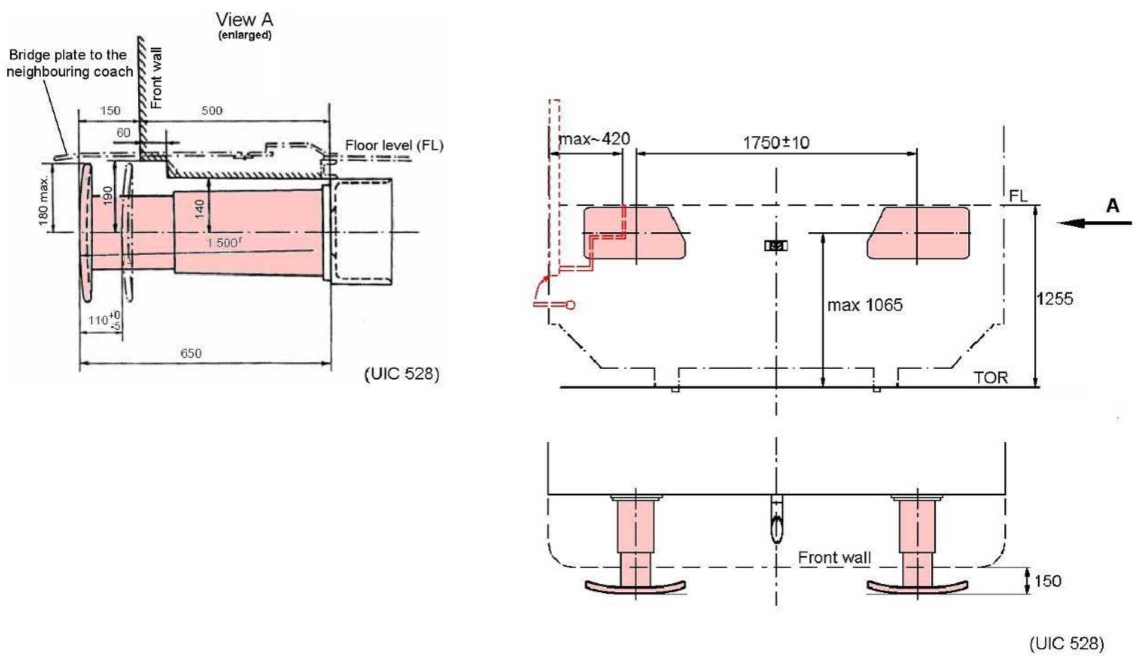


Figure 3.3: Influence of side buffers position

Approximately 80% of all types of UIC coaches do have the entrance doors are located directly in the buffer-zone. Two examples taken from the UIC regulations showing the toilet and the compartment for wheelchair users are shown in figure 3.4.

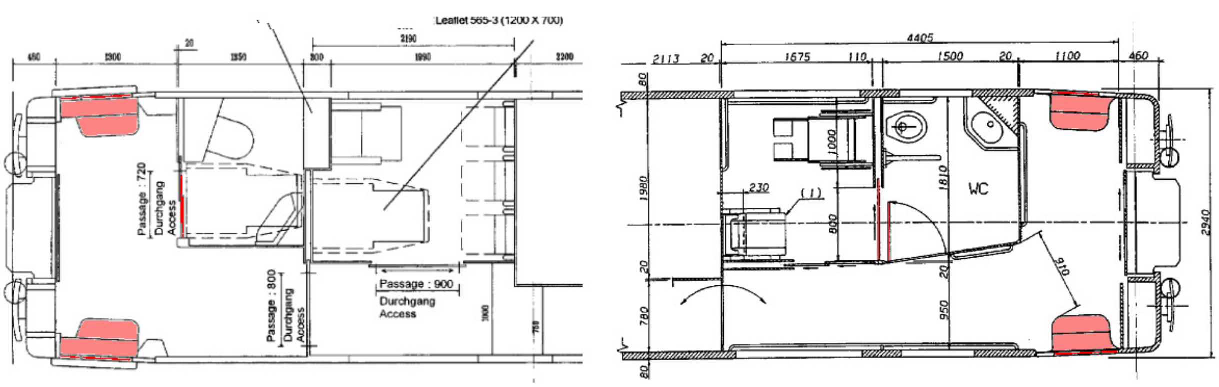


Figure 3.4: UIC coaches with doors in the buffers-zone

The Minority of UIC coaches have the entrance doors approximately 1,2m behind the buffer fitting plane, as shown in figure 3.5.

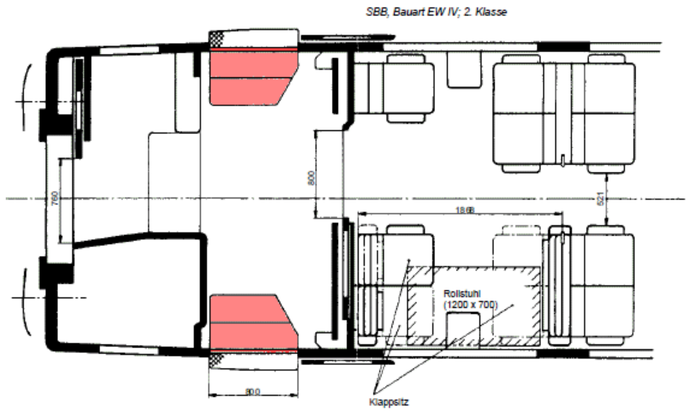


Figure 3.5: UIC coach with side doors away from the buffers

The main difference between the two variations is the cut-in of the under-frame for the stairway. In the first case situation the given conditions are worse. Due to the buffer position, the upper step must be narrower than the lower steps (see figure 3.6). At the right-hand side in figure 3.6 is a photo of the stairway of the BDŽ (Bulgarian state railways) UIC coach, which is foreseen for the fitting of the BAS prototype in the project PubTrans4All. The option as shown in picture 3.5 is much better in terms of stairway cut-in.

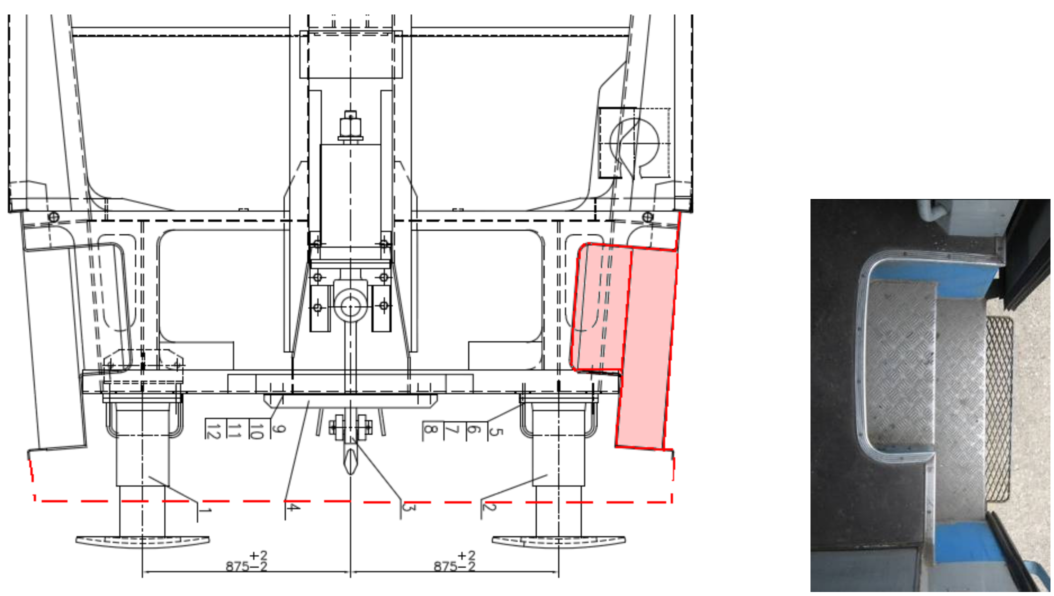


Figure 3.6: Stairway influenced by buffer position

The PubTrans4All consortium has chosen the most frequently used, and at the same time the most complicated version of an entrance in terms of installation as a basis to develop the BAS prototype, convinced that this solution will well cover all other options and versions.

Keeping in mind that research trough all over Europe whose results were presented in Deliverable 2.2 had brought only one vehicle based BAS on a coach with an 800mm door-width. This solution, which is used in service on Sweden Railways is presented in figure 3.7. As can be seen from the pictures, the BAS mechanism – M uses small slits -S at both sides of stairway. This is possible in a given situation with stairways being constant in width of all of their steps.

Figure 3.7: BAS of SJ coach with 800mm door-width

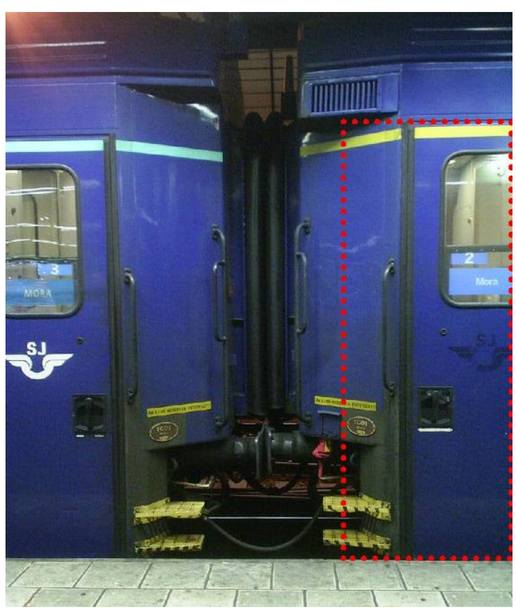


Figure 3.8: Position of the SJ doors compared to UIC coach doors

Figure 3.8 shows that the doors by SJ coach are far away enough from the buffers, allowing a constant width of the stairway. This allows the positioning and fitting the mechanism for BAS drive at both sides of the stairs. **Figure 3.8 shows, marked with doted red line, the corresponding position of the door of a typical UIC coach (similar to BDŽ coach shown figure 3.6), that does not allow this type of technical solution for the BAS.**

It can be concluded that no vehicle based BAS was found during research amongst all over European railway operators, applied at the entrance with a 800mm door-width, positioned in the buffer-zone, as it is the case with the majority of UIC coaches. This means that the PubTrans4All consortium has chosen a very complex task.

3.1.3 Technical constraints caused by the main electric line

To find sufficient space for fitting the BAS mechanism and the BAS itself, all equipment around the entrance area of the UIC coaches must be taken into consideration. Figure 3.9 shows the standard UIC position [30] of the main electrical line sockets and connecting cables. The electric main line provides electrical energy along the train at voltage from 1000 to 3000V. The sockets are positioned under the buffers. Behind them, the electric line continues covered in metal pipes that cannot be bended at sharp angles.

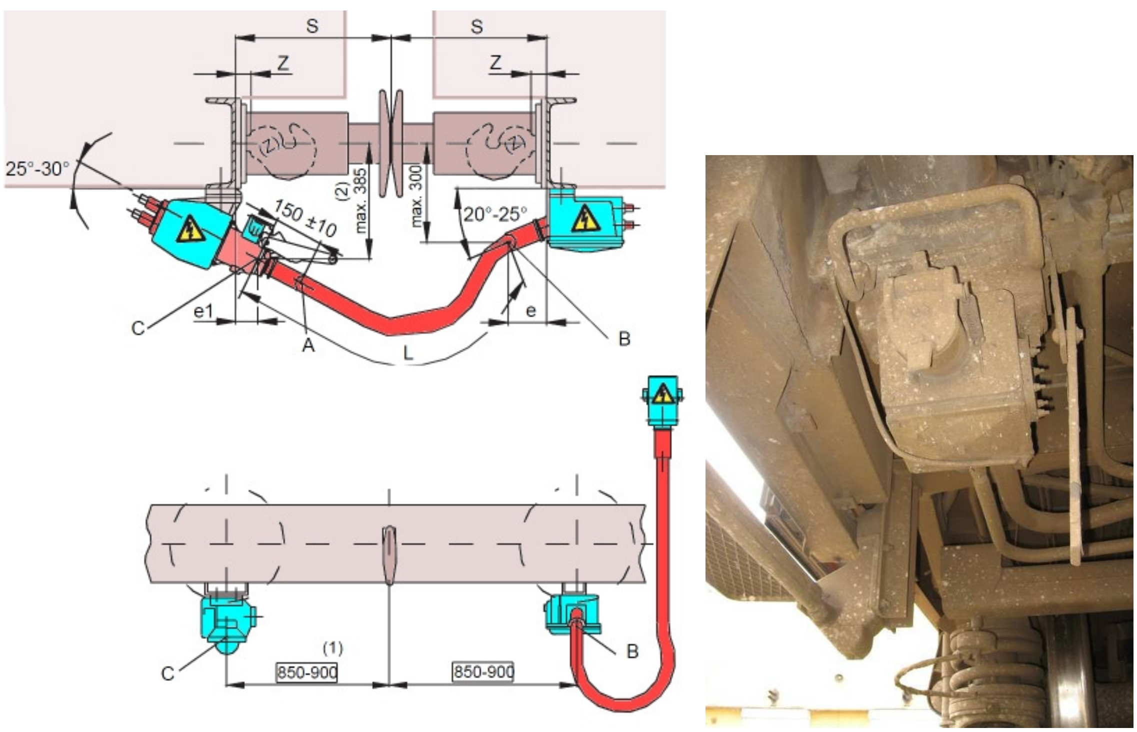


Figure 3.9: Electric sockets under stairway

The picture in figure 3.9 shows that the socket and continuing pipe with the electric main-line occupy the space behind the steps and under. There is no possibility to move the socket from the prescribed position. **It is clear that there is not enough space for the stowing position of the BAS under the stairs.**

3.1.4 Rails for door guiding

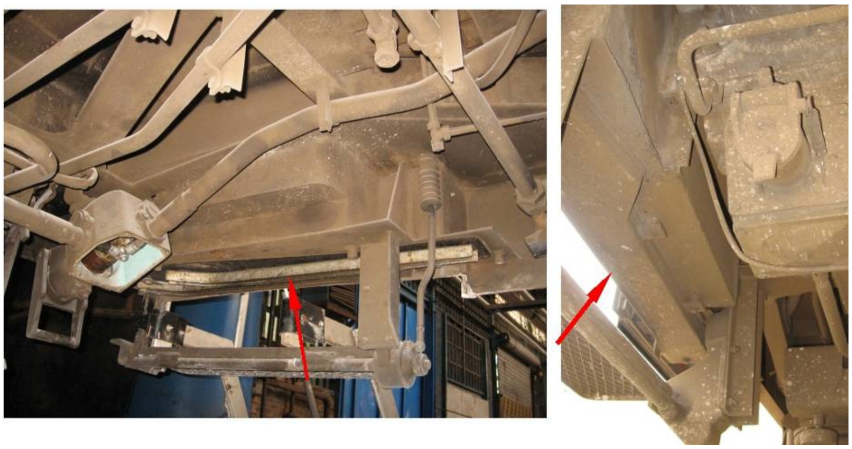


Figure 3.10: Rails for door guiding

As a rule, at the bottom side of the second step of the stair, a guiding rail of the door is positioned. Two examples from UIC coaches are shown in figure 3.10 (left - uncovered, right - covered). Along these rails a part of the door mechanism is gliding along. **There is practically no possibility to make use of the bottom side of this step for the BAS installation.**

3.1.5 Available space in the entrance area

Figure 3.11 is showing the equipment around the doors inside the BDŽ coach, showing the: hand brake wheel -1, cover of the toilette fittings -2, fire extinguisher -3, door closing switch for personnel -4, push buttons for door opening/closing -5, door pneumatics release handle -6, door unlock handle -7, sliding end doors – 8, handrails-9 and door locking mechanism -10. **All these fittings must be accessible and should not be covered by the BAS.**

3.1.6 Space behind the end wall

Figure 3.12 is showing the space behind the end wall which is used for different types of equipment. Usually parts of the door pneumatics or door electrics, end lights etc are located there. Moreover, this space is accessible only when the end sliding doors are closed. **The space behind the end walls cannot be used to stow the BAS.**

Figure 3.11: Inside fittings around the entrance doors

Figure 3.12: Equipment behind the end wall

3.1.7 Space under and over the ceiling

The space under and over the ceiling may be interesting for the application of some technical solutions of the BAS. Figure 3.13 is showing the uncovered door mechanism which occupies the space over the door. The same space for the head doors mechanism is shown in figure 3.14. Both places must be accessible.

Above the ceiling in the entrance area the space can be used for different features. Figure 3.15a shows the example of using this space for air conditioning equipment. Figure 3.15 b shows another example (BDŽ coach) where only small part of the available space is used for the ventilation outlet. The water supply reservoir can also be partially placed here, as well as the lighting.

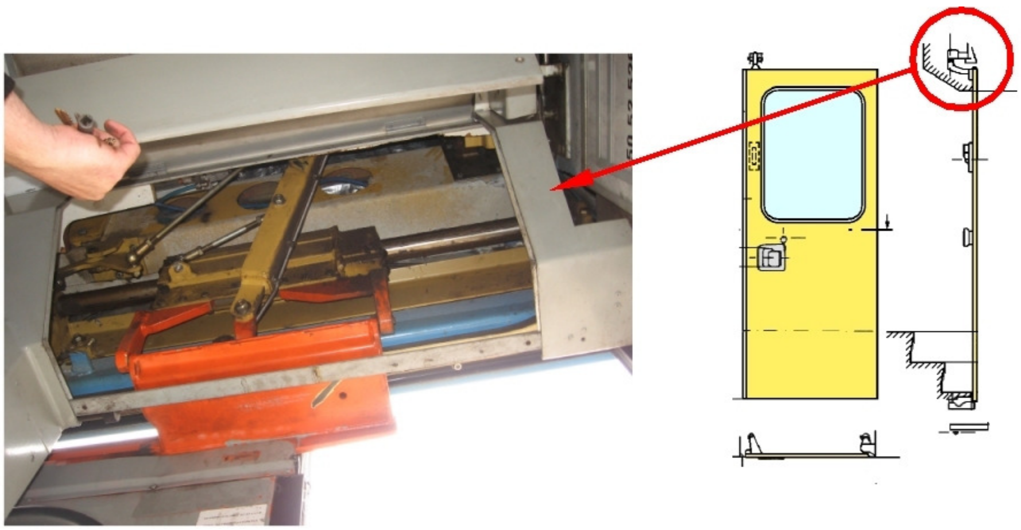


Figure 3.13: Space over the side door for door mechanism

Figure 3.14: Space over the end door for door mechanism

Generally some space over the ceiling could be available for parts of the BAS mechanism, but the situations differ from one to another coach design. The accessibility of the other features in this space must be accessible by opening the corresponding covers.

a) b)

Figure 3.15: Space over the ceiling

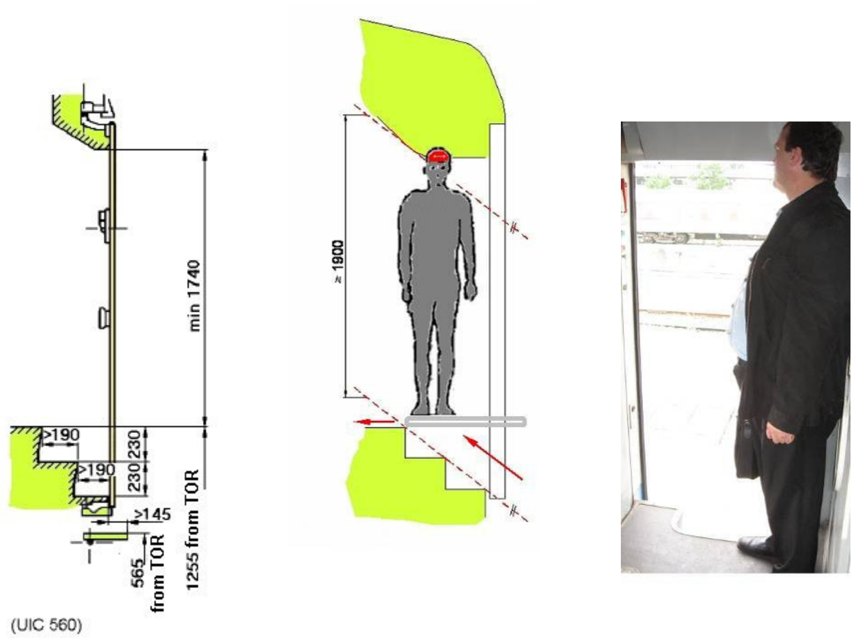
3.1.8 Door height for standing passengers

The BAS could be used not only by wheelchair users, but also by other people with walking disabilities. In that case some constraints must be taken into account. The entrance of the UIC coaches assumes passenger ascending the steps. Therefore the height of the ceiling above the steps follows the stairway inclination accordingly as shown in figure 3.16a. The vertical clearance measured from the floor level shall be at least 1740mm.

In EN 14752:2005 the unrestricted passage height of 1900 mm minimum is required except where the infrastructure, the gauge or car profile, does not allow that. This EN also applies for new vehicles and high speed vehicles. Figure 3.16a defines the measuring method. Practically these two measurements (from UIC and EN) are consistent with each other.

Figure 3.16c gives a view of the situation inside the BDŽ coach. The vertical space of just over 1700mm is not sufficient enough for the transferring a person using a BAS parallel to floor level. Even if the BAS platform is moving parallel to the slope of the stairs, the person cannot be transported in the standing position as shown in figure 3.16b. Based on the previous findings, **railway vehicles with side doorways meeting only the minimum requirements of the EN [16], cannot be entered by a standing person on the BAS.**

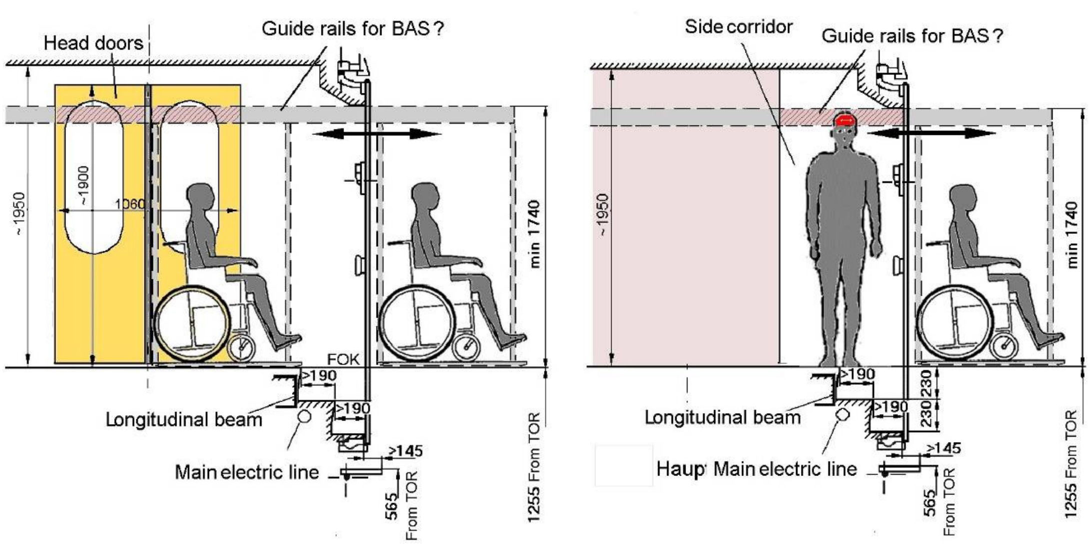
Some of the ideas for design of a BAS are based on the use of upper sliding rails, as presented schematically in figure 3.17a. The rails must be long enough to slide the BAS into the vehicle. This can violate the clearance of the end doors as shown in red (hatched) in figure 3.17a.



a) b) c)

Figure 3.16: Available door heights

On the opposite side toward the side corridor, the problems of the insufficient height for passenger passage do arise during the operation of the BAS, as shown in figure 3.17b. **It can be concluded that due to the relatively small height of the upper edge of the door opening, it is practically almost impossible to implement a BAS design with upper guiding rails to UIC coaches.**



a) b)

Figure 3.17: BAS idea with upper rail guides –clearance restrictions

3.1.9 Door width constraints

Figure 3.18 is showing the dimensions of the manual wheelchair according to ISO 7193 [9]. The width of 700 mm according to [19] covers requirements of approximately 96% of wheelchair users. The ISO 7176-5 standard [10] defines dimensions for occupied wheelchairs for different wheelchair categories according to table 3.1.

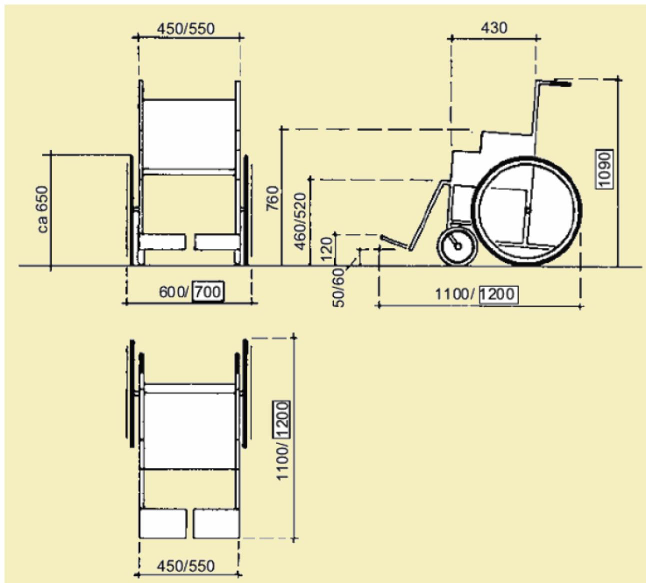


Figure 3.18: Manual wheelchair dimensions according to ISO [9]

Table 3.1 Dimensions of occupied wheelchair [10]

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

It is worth mentioning that the width of the occupied electrical powered wheelchair, according to this standard, is smaller than the width of the manual wheelchair, which takes into consideration the extra space for the wheelchair user's hands for operating the wheels of a manual wheelchair. If transferred by a BAS, this additional space can be neglected and only the net manual wheelchair width of maximum 700mm according to ISO 7193 shall be taken into account.

During the passage of the manual wheelchair trough the door of 800mm using a BAS, it needs to be taken into account that additional space is needed to cover door width tolerances and side tolerance required for the positioning of a wheelchair. If a minimum of 10mm is taken into account on both sides, 780mm remain for the wheelchair-passage and spacious requirements of the BAS mechanism.

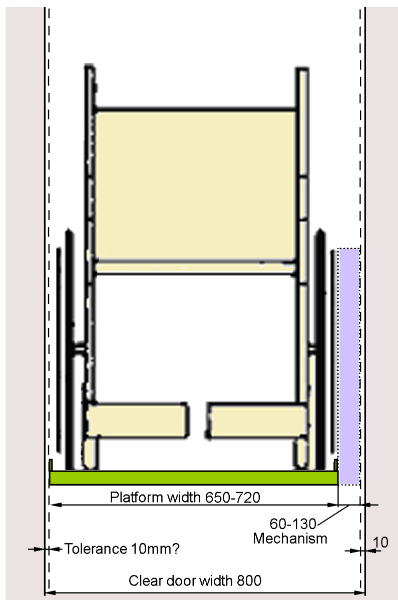


Figure 3.19: Manual wheelchair passage through an 800mm door

If we consider a one side mechanism, and supposing their width is in the range from 60 to 130mm, 650 to 720mm remains for the wheelchair-passage and the BAS platform. The recommended clear width of the wheelchair lift platform is usually 760mm. The minimum clear width of the platform according TSI PRM [18] is 720mm (see 2.2.4.7). If we add now a minimum of 10 mm to the clear width for both fixed raised side edges, and a minimum of 20 mm for collapsible, 40 to 50 mm remain for the lifting mechanism.

The limited available width for the mechanism makes the majority of the lifting solutions unfeasible for the UIC coaches. Therefore the lift platform's clear width, feasible for UIC coaches, needs to be built a little less in width than the minimum recommendations, in order to be retro-fitted in existing UIC wagons. Still the vast majority of wheelchairs would be covered by that approach, meaning a major improvement to the current situation.

3.1.10 Available space for the BAS in the entrance area

All previous considerations led to the conclusion that in the entrance area of the UIC coaches there are severe constraints that makes it very difficult to find an appropriate place for vehicle based BAS in a the stowed position. Moreover, the possible differences in the entrance layout of UIC coaches do complicate the possibilities to find a standard BAS solution that can be retrofitted in the all existing UIC (and other) vehicles. This is quite clear shown within three UIC coach examples presented in figures 3.4 and 3.5.

On the other hand, a vehicle based BAS implementation makes sense only if the coach has an accessible entrance corridor in combination with an accessible toilet and a compartment adapted according to the needs of a wheelchair user. In the situation of existing coaches, the BAS implementation is normally a part of refurbishment with some internal adaptations for providing the space for a BAS in stowing position.

The BDŽ coach intended for the installation of the prototype of the new BAS within the PubTrans4All project, is adapted for wheelchair users, and has some space available, that could be used for a stowed BAS with some adaptation. Figure 3.20 shows the plan of the BDŽ coach entrance area. The space and position that could be potentially available for the BAS in stowed position is green hatched.

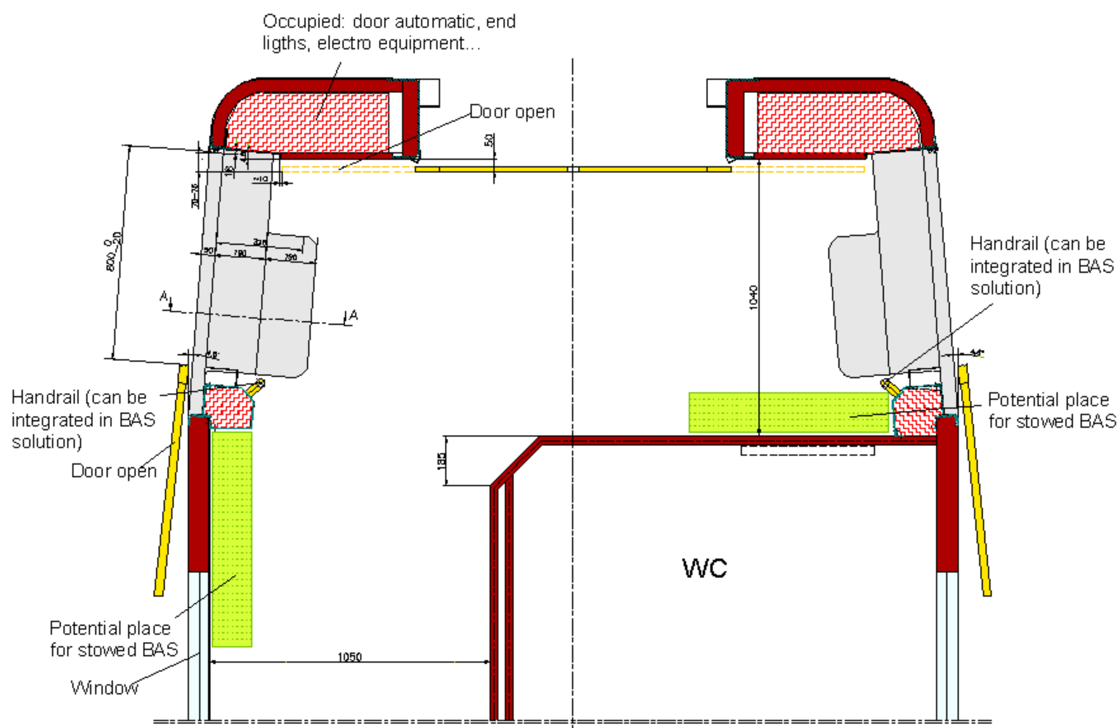


Figure 3.20: BDŽ coach entrance area

This place could be available under the following conditions:

1. The wheel of the hand brake must be shifted as shown in figure 3.21, within acceptable reconstruction works.

2. The cover 2 of the toilet fittings, figure 3.21, must be accessible only for maintenance purposes.

3. In case of the other BAS stowed in the side corridor, free corridor width of 900mm for wheelchair passage must be left. If necessary additional 40 mm can be obtained by removing the outer part of double wall on the toilet side.

4. Partial covering of the first window in the corridor is needed.

In this case the BAS should be thin enough to be placed into the planned space. The BAS mechanism should have two options: one for the left, another for the right side. These two solutions will cover almost all possibilities in other UIC coaches. For example, the BAS for coaches with a central longitudinal corridor can be solved with one of these mechanisms for both sides.

Figure 3.21: Necessary hand brake wheel shift

One of the remaining problems may be the space for door locking mechanism and for the connection of the door mechanism with a lower movable step. This space behind the handrail is hatched red in figure 3.19. The handrail on the cover of this space can be incorporated into the BAS solution. If the BAS mechanism should use some part of this space a further analysis is necessary.

3.2 Design recommendations for new BAS

This subchapter gives an overview of the recommended features for the new boarding assistance systems that can be retrofitted in the existing UIC type coaches. The next overview takes technical conditions into account as described in the previous subchapter 3.1, and the recommendations as described on the previous chapters corresponding with lift-solutions.

The features recommended for the new BAS are given in table 3.2.

Table 3.2 Recommended features for the new BAS

Characteristic	Value	Comment
Carrying capacity	300kg	Covers 99% of wheelchair users, see chapter 2.2.4.7
Minimum clear width of lift platform	720mm	Covers 96% of wheelchair users, see chapter 2.2.4.7
Minimum platform length	1200mm	
Maximum working height difference vehicle floor-platform	1300mm	
Distance from the side of the coach when the lift platform is in lowered position:	As small as possible, but not less than 75 mm	The lowest foldable stair required to be lift up before descending of the lift platform.
Boarding/alighting parallel to the vehicle	Recommended	Alternatively, exit sideways through lay down of the side fenders (required for narrow platforms)
Handrail bound to the platform on one side, should be at the high	650 to 1100mm from platform level	
Integrated folding seat for categories of users other than wheelchair users	Recommended	
Finger force to activate control buttons	≤ 5N	≤ 20N (regarding WG44 PRM)
Manual force to operate the lift by staff	≤ 200N	For example for emergency mechanical activation.

Characteristic	Value	Comment
Manual force to operate the lift by staff at movement start	≤ 250N	Allowed only for short period at the start. For example for emergency mechanical activation.
Vertical speed in the operation	≤ 0.15 m/s	Movement should be smooth
Operating speed variation: empty-maximum loaded	±10%	
Speed of any point of BAS without load	≤ 0.2 m/s	Up to 0,6m/s is allowed by EN 1756-2 only in the case where security measures (proximity sensors or similar) are present to recognize obstacles and stop the movement. To meet TSI PRM, maximum speed without load no more than 0,3m/s is recommended.
Acceleration during operation with load in any direction and at any point of the lift platform	≤0.3 g	
Tilting speed of the lift platform	≤ 4°/s	In case of automatic adaptation to the relative angle between the vehicle and platform, for example, at superelevated track by platforms in curves.
Automatic roll-off protection height	≥100mm	The barrier in front and at rear side of the wheelchair lift platform should be automatically erected during lift operation.
Lateral side guards height:	≥25mm min ≥50mm preferred	Prevention of the wheelchair side roll-off from the lift platform

Characteristic	Value	Comment
End of travel mechanical limitation devices	Yes	Lift platform touching the ground should be automatically stopped.
Prevention of any unauthorized operation in the absence of the operator	Yes	Locking and unlocking by a key or a code or similar.
Overload protection of the main power electrical circuit		Fuse, an overload cut-out or similar
In stowed position BAS must be safe against uncontrolled displacements. Mechanical securing devices dimensioning according to the accelerations:	$a_{longitudinal}$=5g $a_{lateral}$=1.5g $a_{vertical}$=1g	This accelerations can arise in the exceptional case of occasionally buffing impact at coach staying in yard (without passenger) (UIC 566)
Activation possible only at:	V = 0 km/h.	
Activation of the BAS should introduce activation of the coach brake system.	Yes	Any moving of the train during BAS usage shall be prevented
Minimum safety coefficient against yield strength	2.1	
The lift platform surface should be smooth and must have slip-resistant surface	Yes	Slip resistance i.e. according to EN ISO 14122-2. (WG 44 definition in process)
Easy removal of ice and snow must be possible	Yes	Unobstructed operation under certain environmental conditions is required
Gaps or holes in the platform area shall not accept a probe greater than:	15 mm diameter	
Illumination of the lift working zone	Yes	Including entrance area
The warning devices should be fitted at edges that can come in contact with persons or injure passengers or personal.	Yes	light / reflective stripes / reflective markings, visible at night also
Visual and audible warning signals during the lift movement must be activated	Yes	

Characteristic	Value	Comment
The operation control should be of type hold-to-run.	Yes	Lift shall stop moving and remain motionless after the control is released.
Movement no more than 100mm for any part of the lift platform after release of the control is tolerable to slow lift down	Yes	Mechanical drives with self-braking capability or with independent direct acting brakes, or hydraulic systems with normally closed valves etc. should be used.
Controls shall be designed to avoid unintentional lift actions.	Yes	Recessed or covered buttons, etc.
One control position is recommended	Yes	Conflicts of commands must be avoided (Slave/Master)
Safety devices shall preferably operate through active positive action.	Yes	
A stop in overload protection should be present at overload more than	25%	Overload shall prevent the moving of lift.
An emergency stop button within reach of the user and staff (vehicle and lift based) should be present	Yes	Release of the emergency stop button should only be possible by the personnel
Additional protecting measures like obstacle detector, foot entrapment protection etc.	Recommended	Although control of hold-to-run principle is used additional measures are recommended
During lift platform closing the risks of crushing or shearing of the arms or head must be avoided.	Yes	Limitation of the closing force, security cut-off, etc.
Other technical details not covered in this table preferably should be based on:	TSI PRM, EN 1756-2, RVAR, EN14752 and prEN of WG44	

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