International Best Practice Guidelines

BPG1
Transportation of People Seated in Wheelchairs

Use of this document

As a code of practice, this Best Practice Guideline (BPG) takes the form of guidance and recommendations. It should not be quoted as if it were a specification, and particular care should be taken to ensure that claims of compliance are not misleading.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Background

This Best Practice Guideline (BPG) document is one of a series of documents prepared in advance for discussion at the 4th International Interdisciplinary Conference on Posture and Wheeled Mobility, held in Glasgow in 2010. It is the outcome of over two years of work and two public consultation processes, including two workshop sessions. Over 40 people attended each of the two workshop sessions.

The BPG has been compiled by an international committee, comprising the following people:

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The purpose of the document is to gather knowledge and experience from a range of related disciplines to present commonly accepted solutions to maximise safety and minimise risk levels pertaining to passengers transported in wheelchairs as vehicle seats during road transport.

In the determination of the issues to be primarily considered the following key topics were identified:

- Wheelchairs for Use in Transport
- Seating Systems for Wheelchair Occupants
- Wheelchair Tie-downs and Occupant Restraint Systems
- Vehicle Types and Operational Characteristics
- Appendices: Legislation and Standards

With limited national regulations regarding wheelchair seated passenger transport, the guidelines presented are intended to provide a broad comprehension of the subject for clinically-oriented stakeholders engaged in the provision of wheelchairs and seating systems. Wherever possible, supporting regulations and standards are cited throughout the document.

A Risk Management approach has been adopted throughout the drafting process because risk control measures applied for a broad range of non-disabled vehicle seated passengers have limited application to individuals with a disability of a nature that they must use a wheelchair as a mobility aid.

Introduction

Generally, the choice of a wheelchair for a person is based on their clinical need and their requirements for comfort, postural support, tissue integrity, and general mobility. Use of a wheelchair as a seat in a motor vehicle is an important additional consideration to be addressed by wheelchair manufacturers and equipment prescribers when taking into account a wheelchair occupant's many differing social and medical needs.

Safe transport is a key element in a wheelchair occupant's ability to access medical facilities as well as to improve quality of life through participation in education, work, and leisure. Equipment prescribers should consider transport needs at an early stage in the wheelchair and/or seating assessment process, and should make use of the transport safety information available from respective wheelchair and seating manufacturers, as this may influence the choice of wheelchair and/or seating to be prescribed.

Generally, when travelling in a motor vehicle, it is safest for wheelchair occupants to transfer out of their wheelchair to a vehicle seat and to use the vehicle seatbelt system or a child safety seat that complies with local legislation. It is therefore strongly recommended that wheelchair occupants transfer into a vehicle seat where possible and practical. This is especially true in the case of scooters, which are not intended to be transported occupied, and buggies. Where an occupant transfers out of their wheeled mobility device, the device should be safely secured in the vehicle as an item of luggage.

When transporting children whose body mass is below 22kg, transport providers should always be encouraged to transfer the child from their seating system into an appropriate child restraint system intended and approved for use in motor vehicles [1, 2, 3, 4]. Having transferred out of their wheelchair or buggy, the wheelchair or buggy should be secured in the vehicle as an item of luggage. Some buggies are suitable for occupied use in transport, and where such a situation arises, the buggy manufacturer's guidelines should be followed. When it is not possible, or safe, for an individual to transfer out of their wheelchair or buggy, then the wheelchair or buggy must become the vehicle seat, which necessitates that additional safety concerns be addressed.

While it is the objective of each stakeholder to seek reasonable levels of safety for people who remain seated in their wheelchairs, there are bound to be variances in the risk of injury posed to the two groups. Wheelchair occupants will frequently have reduced skeletal strength due to injury or disability, and contractures or physical deformities may lead to reduced injury tolerance. Such characteristics may also create difficulties with the accommodation and application of occupant restraint systems. Careful selection of the wheelchair and seating system by prescribers will play an important role in reducing risks to acceptable levels during transport.

At times, the relevant recommendations and available equipment for safe transport may contradict the individual's seating and positioning needs. In such cases risk assessment (incorporating a risk/benefit analysis and evaluation) will play an important part in the decision making process, as well as careful documentation thereof. International Standard *ISO 14971:2007* specifies a process to identify the hazards associated with the use of medical devices to help estimate and evaluate

the associated risks, to control these risks, and to monitor the effectiveness of the controls [5].

Decisions taken at the time of issue to a person of a piece of equipment should be reviewed over time to take account of the person‘s changing presentation, changing needs, or alterations to their equipment configuration. Changes with time to the condition of equipment also need to be considered, and a system put in place to manage maintenance, and replacement of worn parts, straps, etc.

The purpose of this document is to gather and describe relevant standards and regulations, as well as to describe commonly accepted solutions to maximize safety and minimize risk levels pertaining to passengers transported in wheelchairs as vehicle seats during road vehicle transport.

National and International standards and codes of practice, as well as professional experience, change over time, and the intent is that this document shall be updated from time to time. This document is therefore being placed on a publically available website (www.pmguk.co.uk) where individuals can place their comments, and updates can be posted: ultimately these will be considered for inclusion in the next edition of these International Best Practice Guidelines for Transportation of People Seated in Wheelchairs.

References:

[1] Economic Commission for Europe ECE - R44 *Uniform Provisions Concerning the Approval of Restraining Devices for Child Occupants of Power-driven Vehicles*.
[2] Code of Federal Regulations, Title 49, Transportation, Part 571.213; *Child restraint systems*. Washington, DC 2003 National Archives and Records Service, Office of the Federal Register.
[3] Canadian Standards Association, CMVSS 213*Child restraint systems*, Ottawa, Canada.
[4] AS/NZS 1754:2010 *Child restraint systems for use in motor vehicles.*
[5] ISO 14971:2007 *Medical devices -- Application of risk management to medical devices.*

Abbreviated Terms

EN – European Standard generated by the European Committee for Standardisation

IFU – Information for Users

ISO– International Organisation for Standardisation

OM – Owner’s Manual

RESNA – Rehabilitation Engineering and Assistive Technology Society of North America

WTORS – Wheelchair Tie-down and Occupant Restraint System

Summary

General

- Transport considerations should be factored into the initial phase of the wheelchair and seating assessment process.

- Manufacturers of wheelchairs and seating systems should make information relating to the safe transportation of their products readily available and easy to understand.

- With the desire to provide the safest possible transport environment for wheelchair-seated passengers, and other vehicle occupants, all stakeholders must engage in a multi-disciplinary approach to ensuring transport safety, involving the wheelchair occupant with their families, carers, equipment prescribers, and transport providers.

Securement and Restraint

- When properly used, a wheelchair tie-down and occupant restraint system (WTORS) allows a wheelchair to be secured to the vehicle floor and the passenger in the wheelchair to benefit from a properly fitted seatbelt system.

- A proven crashworthy wheelchair, used in conjunction with a proven WTORS, is fundamental to the provision of safe transport for people who remain seated in their wheelchairs in a motor vehicle, and for other vehicle occupants.

- Exceptions to the requirement for use of WTORS exist on certain high-mass, low-speed urban public transport vehicles that allow standing passengers where the likelihood of a crash situation and the severity thereof are low. Large intra-city transit buses, for example, in which passengers often travel while standing, offer a safer transport environment because their large mass, combined with slow travel speeds, greatly reduces the frequency and severity of crash events. In these situations, use of a rear-facing wheelchair containment station may be appropriate.

- Powered and manual wheelchairs offer a large variety of seated postures through their tilt, recline, and other mechanisms. Guidelines should be given by manufacturers with respect to use of these mechanisms during transport.

- Wheelchair manufacturers should highlight in their pre-sale literature any special requirements relating to the use of their wheelchair with WTORS. The configuration of the specific representative wheelchair which underwent the crashworthiness test should be provided so that informed decisions can be made with respect to wheelchair selection and configuration.

Seating

- The combination of a crashworthy seating system, that accommodates the proper fit of the occupant restraints, and a crashworthy wheelchair base frame, serve to indicate to the prescriber that the risks of equipment failure when exposed to crash conditions during transport have been reduced as far as reasonably possible.

- To minimise injury risk for wheelchair occupants, prescribers shall seek to ensure that the means of attachment of the seating system to the wheelchair (the wheelchair to seating interface) is suitable for use in transport. It is imperative that the manufacturers' instructions for use and fitting instructions for seating systems are carefully adhered to.

Risk Management

- Due to the individual nature of disability, prescribers may at times be faced with the need to request modification to a wheelchair or off-the-shelf seating system (Class 1 medical devices) in order to maximise medical benefits, and to address the postural and functional needs of a wheelchair occupant. In such cases access to transport should not be denied. Rather, necessary modifications should be undertaken and documented in line with relevant medical device legislation, and a risk management process should be followed.

- Stakeholders should have a working comprehension of a documented risk assessment process (incorporating a risk/benefit analysis and evaluation) and understand the relevant risk/benefit analysis and evaluation undertaken for each case.

- Prescriber awareness of the type of transport environment and the facilities available to assist vehicle entry and egress is highly beneficial in the risk management process.

- Informed risk/benefit analysis can only be undertaken on the basis of sound evidence. There should be an aim to create an open climate around the safety issues such that incidents and injuries must be reported back to the transport companies, with formalised reporting procedures that facilitate the collation of facts without seeking to assign blame to individuals.

Roles and Responsibilities

According to the Convention on Road Traffic, the driver of a vehicle will always be responsible for the safe carriage of passengers, and for taking necessary precautions to avoid any risk of accident [1]. That said, persons associated with the transportation of a person with a disability have a "duty of care" i.e. *a requirement to take reasonable care of a person to avoid acts or omissions which he or she could reasonably foresee are likely to injure that person".* This duty of care is shared over a number of people engaged in the supply of equipment. The responsibilities of these people are listed as follows [2, 3]:

Wheelchair Occupant or his/her Advocate:

- Understands principles of, and advocates for, his/her own safe transport
- Understands the necessity for the use of the prescribed equipment and, where possible, oversees the correct and safe use on an on-going basis
- Liaises with stakeholders to undertake risk assessments as appropriate
- Offers feedback on difficulties or problems with the postural support seating, wheelchair occupant restraint, and/or wheelchair restraint

Clinician

- Works within his/her area of expertise
- Keeps abreast of current and new information relating to transportation safety
- Understands and applies applicable transport safety guidelines
- Informs stakeholders of their responsibilities
- Provides up-to-date information to stakeholders
- Provides relevant documentation and training to those involved in the transportation of the wheelchair occupant, bearing in mind physical and cognitive abilities
- Verifies that the wheelchair occupant and support team understand the function of WTORS
- Liaises with stakeholders to undertake risk assessments as appropriate
- Feeds back problems and difficulties with transportation to his/her supervisor
- Works with other specialists in the design and development of custom-made equipment, bearing in mind factors relating to transportation safety, and takes a key role in relevant risk management.

Technical Support

- Has access to, understands, and applies appropriate guidelines, standards and design rules as they relate to transport safety
- Works with other specialists in the design and development of custom made equipment to meet the client's and caregiver's needs
- Optimises safety requirements in the design and development of custom equipment
- Reviews new developments and designs, both custom-made and commercially available, in the light of the appropriate standards and design rules, and informs clinicians of the suitability of the product's use and risks involved
- Liaises with stakeholders to undertake risk assessments as appropriate.

Family/Caregiver

- Maintains equipment as recommended in the IFU/OM

- Understands their role in sharing responsibility for the wheelchair occupant's best interests
- Uses the prescribed equipment correctly and safely, and understands the necessity for its use on an on-going basis
- Liaises with stakeholders to undertake risk assessments as appropriate
- Offers feedback on difficulties or problems with the postural support seating, wheelchair, occupant restraint, and wheelchair securement systems.

Wheelchair Manufacturer

- Provides clear information on the safe transportation of their wheelchair – both in the pre-sales literature and in the IFU/OM
- Clearly discloses which of their wheelchairs comply with relevant international standards
- Ensures tie-down points on wheelchairs are clearly marked and easily accessed
- Provides information in an appropriate and timely manner, and rectification where possible in the event of a product recall.

Seating Manufacturer

- Provides clear information about the safe transportation and limitation of use of their seating system(s), both in pre-sales literature and IFU/OM
- Clearly discloses which of their seating systems comply with relevant international standards.

Equipment Supplier/Retailer

- Works within his/her area of expertise
- Keeps abreast of current and new information relating to transportation safety
- Understands and applies applicable transport safety guidelines
- Provides up-to-date information to stakeholders
- Provides relevant documentation and training to those involved in the transportation of the wheelchair occupant
- Provides clear information on the safe transportation of their product – both in the pre-sales literature and in the IFU/OM
- Ensures tie-down points on wheelchairs are clearly marked and easily accessed
- Clearly discloses which of their products comply with relevant international standards
- Is prepared to engage with stakeholders in the undertaking of risk assessments as appropriate
- Provides information in an appropriate and timely manner, and rectification where possible in the event of a product recall.

Vehicle Conversion Company

- Ensures that wheelchairs and their occupants can be adequately accommodated in vehicles following the technical requirements given in road vehicle Type Approval regimes
- Ensures WTORS are crashworthy and suited to the wheelchair to be transported
- Ensures that wheelchair tie-downs are installed in the adapted vehicle in such a manner that they can be easily attached to the wheelchair in accordance with ISO 10542-1
- Ensures that the occupant restraint can be used in accordance with the manufacturer's instructions

- Provides relevant documentation and training to all involved in the transportation of the wheelchair occupant, bearing in mind physical and cognitive abilities.

Transport Provider

- Provides vehicles that are suitably equipped to transport individuals using a variety of wheelchairs, and equipped for safe access/egress of same
- Provides relevant training to all staff involved in the transportation of individuals with mobility impairments, and participates in the risk management process
- Maintains and replaces as necessary components of the vehicle integral to the correct functioning of the WTORS
- Develops and implements systems of monitoring and reporting on transport safety issues.

Contract Transport Personnel

- Undertakes relevant training on the safe transportation of those with mobility impairments, and participates in the risk management process
- Uses the prescribed vehicle access, and wheelchair and occupant securement equipment correctly and safely, and understands the necessity for its use on an on-going basis
- Keeps WTORS tracking free of debris to maximise lifespan of equipment
- Regularly checks the restraint systems for wear and/or damage and liaises with the appropriate person for their repair or replacement.
- Liaises with stakeholders to undertake risk assessments as appropriate
- Offers feedback to appropriate agency on difficulties or problems with the postural support seating, wheelchair occupant restraint, and wheelchair securement.

References:

[1] UNECE (1968) *Convention on Road Traffic,* Vienna.
[2] Disability Services Commission, Australia (1998) *Reducing the Risk.*
[3] UK Medicines and Healthcare Regulatory Authority (2001) *Guidance on the Safe Transportation of Wheelchairs,* DB 2001(03).

1. Wheelchairs for Use in Transport

Section Summary:

- 'Crash testing' of representative wheelchairs is only one aspect of enhanced occupant safety: prescribing practitioners, transport professionals, wheelchair and seating manufacturers and suppliers, wheelchair occupants, their families, and caregivers, need to consider numerous matters when determining acceptability for transport of a given wheelchair and seating configuration.
- The benchmark approach to wheelchair validation allows a certain amount of flexibility to achieve a 'reasonable' level of safety for the occupant when in transport.
- Not all conditions of product usage can be directly represented in a crash test, as it is not possible to test all possible product permutations.
- Information relating to the safe transportation of wheelchairs should be provided by wheelchair manufacturers/suppliers in their pre-sales literature and IFU/OM.
- Crashworthy wheelchair models - intended to be occupied in vehicles - should show designation of passing a dynamic crash test in order to demonstrate crashworthiness.
- Wheelchair tie-down securement points should be clearly labelled using the karabiner symbol.
- IFU/OM should include instructions on how to transport the wheelchair when unoccupied.
- Where concerns exists with respect to the use in transport of a given equipment configuration, a thorough interdisciplinary risk assessment needs to be carried out.

Suitability for Transport

The suitability of a wheelchair for use when occupied as a seat in a vehicle should be clearly indicated in a statement by the wheelchair manufacturer's pre-sale literature and IFU/OM [1]. It is the responsibility of the wheelchair manufacturer to state the intended use of its product, to specify any limitations in usage, and to provide warnings of conditions of usage that may lead to increased risk of injury to an occupant.

Information supplied by the manufacturer [2, 3] should include:

- A description of the intended use and intended environment for use
- A description of the intended occupant of the wheelchair (as a minimum this will include occupant mass plus any specific requirements for functional capability, visual ability, and cognisance, to operate the wheelchair safely in its intended environment)
- Instructions as to how to transport the wheelchair when unoccupied
- That the wheelchair is - or is not - suitable for use as a seat in a vehicle
- If it is suitable for use as a seat in a vehicle, the method of attaching wheelchair tie-downs and occupant restraint systems (WTORS)
- Recommendation of suitable wheelchair tie-downs and occupant restraint systems.
- Any actions to be undertaken with respect to add-on components during transport (e.g. tray or head support)
- Affects of additional mass attached to, or carried by the wheelchair, on wheelchair stability

It is advisable that information relating to seating orientation (e.g. forward or rearward) and any limits on the settings of adjustable elements of the wheelchair when used in transport (e.g. tilt or recline angles) be made readily available.

Images of mechanical settings and wheelchair securement points should be clearly illustrated in the IFU/OM, and tie-down points should be clearly marked on the wheelchair frame by a karabiner symbol (Figure 1). The means of illustrating the tie-down attachment point on the wheelchair frame needs to be durable, bearing in mind that it may be subject to abrasion during the fitting and removal of tie-downs.

Where securement loops are fitted to a wheelchair to facilitate the attachment of wheelchair tie-downs, it is recommended that these loops are coloured in a manner that makes them easily identifiable.

Figure 1. Karabiner Symbol

The presence of a karabiner symbol does not mean that a wheelchair is approved for use with any or all docking-type securement systems.

Testing for Transport Safety

To determine if a wheelchair is suitable for use as a vehicle seat in transport, the manufacturer will subject the wheelchair to a dynamic crash simulation following the test method given in a voluntary standard, such as ISO 7176-19 or ANSI/RESNA WC19 [4, 5].

The most common means of assessment is a dynamic crash test that exposes a forward-facing wheelchair and surrogate occupant to a simulated severe crash event [4]. This means of assessment requires the wheelchair to be subjected to the dynamic test to be secured with a four-point system, as the most common means of wheelchair tie-down. If a wheelchair manufacturer wishes to use another type of tie-down such as a docking system, then the wheelchair should be re-tested accordingly.

The frontal crash severity chosen is similar to that used in the automotive industry for the evaluation of child restraint systems, car seat anchorage validation, and luggage retention devices, and is accepted as being representative of a typical small passenger vehicle such as a private car or multi-person vehicle-type (MPV) in a moderate-to-severe frontal collision.

In conducting the test, the wheelchair to be assessed is secured to a sled test rig using a four-point tie-down system according to the instructions provided by the manufacturer, where two webbing straps attached to the front of the wheelchair, and two webbing straps with tensioning mechanisms are attached to the rear, at the designated tie-down securement points.

A surrogate occupant, or Anthropomorphic Test Device (ATD) representing the appropriate occupant mass is seated in the wheelchair in a ‘normally upright seated position’ and fitted with a three-point lap and diagonal restraint system of design and function similar to a seatbelt system used for automotive drivers or passengers.

The secured wheelchair and the restrained occupant are then exposed to a dynamic crash simulation. Measurements are made of ATD and wheelchair movement during the crash event and, when combined with post-test observations, are compared with written pass/fail criteria to determine the outcome of the test. Measurements taken during the crash simulation include a means to ensure that an occupant is not subjected to injurious loads by the wheelchair pushing the occupant into the restraint system.

Post-test observations require that no structural failure of the occupant seat support occurs, and that if sharp edges have been created that they are not contactable by the seated passenger. A certain amount of vertical collapse of the wheelchair is allowed and may in fact provide a means of energy absorption thereby reducing injury potential. Some parts may detach during a test, but their allowable mass is limited to a very low level.

The frontal impact test method serves as a ‘benchmark’ for product performance. Not all conditions of product usage are directly represented, as there are countless possible wheelchair set-up conditions to suit the wide range of individuals’ requirements.

Wheelchair manufacturers should provide detailed information on the configuration in which the wheelchair may be used whilst in transport, and, in as far is possible, these configuration details should to be adhered to.

It is important to note that wheelchairs of an older design and those designed for specific target groups (such as active occupants who are able to transfer out of their

wheelchairs) may not comply fully with the securement point recommendations contained within relevant standards.

Furthermore, due to the individual nature of wheelchair configurations and seating system combinations, it is not possible to test all possible product permutations. The benchmark approach to wheelchair validation allows a certain amount of flexibility to achieve a 'reasonable' level of safety for the occupant when in transport.

Crash testing of representative wheelchairs is only one aspect of enhanced occupant safety. Prescribing practitioners, transport professionals, wheelchair occupants, their families, and caregivers, need to consider numerous matters such as vehicle type, vehicle access and egress, WTORS type, use of accessories, etc. when determining acceptability for transport of a given wheelchair and seating configuration.

Where concerns exist with respect to the use in transport of a given equipment configuration, a thorough interdisciplinary risk assessment needs to be carried out to highlight, consider, and address the risks associated with transport of the wheelchair occupant.

References:

[1] Council Directive 93/42/EECof 14 June 1993 concerning medical devices, OJ L 169, 12.7.1993, p.1.
[2] EN 12183:2009 *Manual wheelchairs. Requirements and test methods.*
[3] EN 12184:2009 *Electrically powered wheelchairs, scooters and their chargers. Requirements and test methods.*
[4] International Standards Organisation ISO 7176-19:2008 *Wheelchairs -- Part 19: Wheeled mobility devices for use as seats in motor vehicles.* Geneva, Switzerland.
[5] ANSI/RESNA WC19: *Wheelchairs Used as Seats in Motor Vehicles.*

2. Seating Systems

Section Summary:

- Loads experienced through a seating system during a severe impact can be considerable.
- Where a seating system is an integral part of a wheelchair supplied by a wheelchair manufacturer, the wheelchair and seating combination should comply with a relevant crashworthiness performance standard.
- If a separate seating system is fitted to the wheelchair, the wheelchair base frame should comply with ISO 7176-19 and the seating system and attachment mechanism should comply with ISO 16840-4.
- A back support should ideally be set at shoulder height, but definitely be no lower than the spine of the highest scapula.
- A head support may offer protection primarily in low speed rear vehicle impacts.
- To determine the requirement for Postural Support Devices (PSDs) during transport, an appropriate risk/benefit assessment should be undertaken and documented.
- Wheelchair cushions to be used in transport should be of minimal weight and secured to the wheelchair using hook and loop or straps.
- Where more complex disabilities are presented it will become necessary to accept that a wheelchair occupant may be exposed to a higher risk of injury whilst in transport.
- It is recommended that trays and other ancillary items should be removed from a wheelchair during transit, and secured/stowed separately.
- Risk management processes should be used by equipment prescribers to record and support decisions made and actions taken.

Seating System Requirements

The objective of transport-approved wheelchair seating is to meet the wheelchair occupants' medical and positioning needs. Minimizing injury risk to the occupant in the event of a motor vehicle crash or adverse event, such as abrupt braking or high-speed vehicle manoeuvres is also an important factor to be considered. Since the loads through the seating system during a severe impact can be considerable, the seating system is required to have the structural integrity to support and contain the occupant so that the restraint systems can fit properly around the passenger's body and function to prevent occupant ejection and harmful contact with any internal parts of the vehicle or other occupants or objects.

Where a seating system is an integral part of a wheelchair supplied by a wheelchair manufacturer, the wheelchair and seating combination should comply with a relevant crashworthiness performance standard (see Section 1). If a third party seating system is fitted to the wheelchair, the wheelchair base frame should comply with *ISO 7176-19* [1], while the seating system and attachment mechanism should comply with *ISO 16840-4* [2], to ensure a minimum recognised safety standard for the occupant. In this case, seating systems that comply with the standard will be labelled with a statement that it complies with *ISO 16840-4*.

Regardless of whether the seating system is already part of the wheelchair or has been tested separately, there are certain requirements of seating systems that are preferred, to maximise safety.

Back Support

A back support should ideally be set at shoulder height, but definitely be no lower than the spine of the highest scapula. The back support angle should allow the occupant to achieve an angle of 30° or less from the vertical (no less than 330°, using the *ISO 16840-1* convention) [1, 2, 3].

Head Restraints and Head Supports

Although rear impact accounts for only 5% of fatalities, this crash mode results in 30% of automotive related trauma in the general population and low severity rear impact accounts for more long term injury than any other crash mode. A head restraint is a device fitted to an automotive seat and is intended to prevent occupant neck hyper-extension in rear impact situations. A head restraint will act to limit head rearward excursions, and thus reduce injury potential in low speed rear impact scenarios. The function of an effective head restraint relies on its being mounted to a seatback with known minimum strength. There is currently no control or requirement for the seatback strength of a wheelchair or seating system in transport situations.

A head support is a postural support device intended to help maintain a person's head in a desired position. The presence of a head support will be a decision based on the assessment of a wheelchair occupant's clinical requirement. The occupant's need for head support may be increased when in transport as vehicle motion, tiredness, or the effect of medication may create drowsiness in the passenger, or muscle weakness may result in the passenger being unable to handle the forces of cornering or changes in speed. The design of the head support used must be based on the occupant's clinical requirements, and may be at odds with the design requirements of a head restraint. Under such situations a comprehensive risk assessment must be undertaken by competent individuals.

Some commercially available head supports have been shown to reduce the potential for neck injury in rear impact scenarios, i.e. act as a head restraint [4]. In cases where wheelchairs will be used regularly in transport, a head support capable of offering a degree of head restraint should be considered necessary. Care must be taken to ensuring that the head restraint does not present any sharp edges, shafts, or adjustment screws that could cause injury to a passenger seated behind the wheelchair occupant. In instances where such a hazard does exist it would be advisable to ensure that the wheelchair seated passengers sit at the rear of the vehicle or have additional free space behind to prevent head contact from a passenger travelling behind them.

Where a head support is prescribed with the intention of also providing a degree of head restraint, the top of the head support should be no lower than the most prominent point on the back of the head (above the top of the person's ears). It should be positioned as close as possible to the back of the head, be well padded, firmly attached to the seating system, and be able to withstand a substantial horizontal load to the front contact surface of the head support.

Vehicle-mounted back and head restraints are commercially available, some with combined occupant restraints and wheelchair tie-downs integrated into their structure. Where viable, the option of vehicle mounted systems should be considered.

The fact that a typical wheelchair back support is likely to deform somewhat during rear impact loading is possibly a positive factor in most rear impacts, since the forces on the neck are reduced when there is some deformation of the seatback. In this regard, it is important not to install a vehicle-anchored head support system without including additional vehicle-anchored support for the wheelchair back support, since a strong rear head restraint without strong back support could result in injurious loading to the neck in a rear impact. The primary challenge in providing effective rear head and back support using a vehicle-mounted system is achieving close positioning of the support surfaces to the back support of the wheelchair and head of the occupant. This is not easily accomplished when a wheelchair space in a vehicle is used by a wide range of wheelchair occupants, with different types and sizes of wheelchairs. Specific documents relating to head support/head restraint use are currently being developed.

Integrated Postural Support Devices (PSDs)

It is preferable that postural support devices (such as lateral trunk supports, medial knee supports, etc) be integrated into seating systems such that they maintain a continuous surface with the seating surface and be appropriately padded. Integrated PSDs that have not been tested for crashworthiness as part of ISO 16840-4 compliant seating systems are not recommended to be used while travelling.

However, at times, an occupant may be at greater risk of injury travelling without these PSDs than the potential risk of an accident. To determine their requirement during transport, an appropriate risk assessment should be made and carefully documented [5].

Minimum Mass Seat Cushions

As well as the clinical requirements of seating components, the mass of seat cushions, and any attachments to the seating system that could potentially come

loose, should be a consideration. The higher the mass of a component, the greater the load generated during an accident that could cause it to break free.

Accessories
It is recommended that trays and other ancillary items and equipment should be removed from a wheelchair during transit, and secured/stowed separately. To prevent confusion, items that should be removed should be labelled as such by the manufacturer.

Exceptions to this recommendation may exist. For example, if a tray is required to provide postural support (benefit) and the potential for injury is increased while travelling without the tray (risk), it may be preferable to include the tray for transport, i.e. the benefit outweighs the risk. In such a situation, use of additional padding on the tray would be advisable. Other circumstances may arise where it is necessary to carry life-support equipment attached to some component of the wheelchair/seating system. Under such circumstances it is critical that every effort is taken to protect both the wheelchair occupant and other vehicle occupants against the risks associated with transporting such equipment - without compromising the wheelchair occupant's right to access to their community.

Custom Modifications

An off-the-shelf crash test-compliant seating system may not be practical or meet all the needs of a client, and custom modification or custom manufacture of a seating system may be necessary. Such alterations to a seating system should only be made by duly qualified and technically competent individuals, with the manufacturer's consent, or else by specialist workshop units that are equipped for, and experienced in, the custom modification and manufacture of seating systems, and that meet the relevant medical device regulatory requirements. Since such modifications may affect the crashworthiness of the wheelchair they may affect the original chain of responsibility and place additional responsibility on the modifier. Consequently, a full risk assessment should be carried out before any modified seating equipment is issued to a client with the intention of being used in transport, and the modifications should be documented in line with applicable medical device regulations.

As previously mentioned, in instances where more complex disabilities are presented, it will become necessary to accept that a wheelchair occupant may be exposed to a higher risk of injury whilst in transport. In such cases, the employment of a full risk management process should be used by equipment prescribers to record and support the decisions and actions taken to address a wheelchair occupant's needs, bearing in mind the manufacturer's responsibilities as outlined in ISO 16840-4.

In undertaking risk management, all options should be considered in an effort to provide transportation that is as safe as possible for all occupants of the vehicle. This may involve modification to a vehicle to secure oxygen cylinders, or an increase in the size of the vehicle, or a reduction in the number of passengers being transported in the vehicle, in order to reduce risk to an acceptable level.

Attaching Seating Systems to a Wheelchair Base

If a seating system has been designed specifically for a wheelchair base, it must be used with that wheelchair base using the attachment hardware provided. When a

seating system is intended to be used with a range of host wheelchair bases it is essential to use the attachment hardware for the compliant seating system as supplied and instructed by the seating manufacturer.

The wheelchair frame shall not be drilled, welded, or modified to attach seating hardware. A thorough risk assessment should document any deviation from this recommendation.

Postural Support Devices

Postural support devices (secondary supports), such as pelvic belts, should be assumed that, and be clearly marked to indicate, they are **not** a substitute for, or suitable for use as, crashworthy occupant restraints.

All occupant restraints should comply with required standards [6]. Postural support devices may have a secondary purpose in supporting the occupant during severe vehicle manoeuvres. Postural supports can also help the passenger maintain a seated posture that allows crashworthy occupant restraints to fit the passenger properly and load the strongest parts of the body during a crash.

The seating system should to be designed in accordance with relevant standards to facilitate ease of fitting and routing of crashworthy occupant restraints so as to contact the load bearing parts of the occupant's skeletal structure, especially with the occupant lap belt section. The use of a wheelchair-integrated crashworthy lap belt can provide a vastly improved restraint solution for complex seating needs [1].

References:

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3. Wheelchair Tie-down and Occupant Restraint System (WTORS)

Section Summary:

- Vehicle occupant restraints are the primary means of providing effective occupant protection in a wide range of crash conditions.
- The most common type of wheelchair tie-down uses a four-point strap system to secure the wheelchair to the vehicle floor.
- The use of four-point strap tie-downs is easier if the wheelchair occupant is using a crash-tested wheelchair that complies with ISO 7176-19 or ANSI/RESNA WC19.
- Not all wheelchair tie-down systems are suitable for all wheelchairs – consult the wheelchair manufacturer's IFU/OM.
- The pelvic or lap-portion of a crashworthy wheelchair occupant restraint system generally anchors to structural regions of the vehicle, or to the wheelchair tie-down straps.
- Some crash-tested wheelchair designs feature an integrated crashworthy lap belt that anchors to the wheelchair and has connector hardware to attach to a vehicle mounted shoulder belt
- The upper anchor point of the shoulder should be attached to a point above and behind occupant shoulder level.
- Anchoring the upper end of the shoulder belt to the floor has been shown to increase, significantly, harmful downward loading on the occupant's torso and spine in the event of a crash and is strongly discouraged.
- Docking-type wheelchair tie-down is another type of wheelchair securement system in commercial use, but is generally wheelchair-, and vehicle-specific.
- In certain passenger transport environments alternative wheelchair containment and occupant retaining methods, such as rear-facing wheelchair spaces, may be appropriate.

Passenger Securement

While the vehicle seat is an important part of the occupant protection system, vehicle occupant restraints (i.e. seatbelts) are the primary means of providing effective occupant protection in a wide range of crash conditions and have an overall effectiveness between 40% and 50% in reducing crash-related fatalities [1]. To work well together, seats must allow the proper fit of the seatbelt systems and they must support the occupant throughout the crash so that the seatbelts remain properly positioned [2, 3, 4]

For those wheelchair occupants who cannot transfer to a vehicle seat or child safety seat without compromising their medical or positioning needs, safe transport requires the use of after-market equipment to:

- Secure the occupied wheelchair firmly to the floor facing forward in the vehicle
- Provide effective, crashworthy occupant restraint for the person in the wheelchair

Commercial products that accomplish both goals are called Wheelchair Tie-Down and Occupant Restraint System, or WTORS. Testing WTORS involves passing a dynamic crash test, similar to the tests for crashworthiness of child restraint systems, standard vehicle seats, and standard occupant restraint systems [5, 6, 7, 8, 9, 15, 16]. There are also several national WTORS standards [10, 11, 12]. These standards are similar to ISO 10542 in spirit and requirements. WTORS systems that comply with these similar standards may also comply with ISO 10542.

In certain passenger transport environments where the likelihood of a high-severity vehicle crash is low, alternative wheelchair containment and occupant retaining methods may be appropriate, such as rear-facing wheelchair spaces. Large intra-city transit buses, for example, in which passengers often travel while standing, offer a safer transport environment because their large mass, combined with slow travel speeds, greatly reduces the frequency and severity of crash events. For these vehicles, the provision of safety for wheelchair-seated passengers focuses on keeping the wheelchair in place and keeping the occupant in his or her wheelchair during normal travel and emergency events, such as sudden stops and turns. These systems are considered part of the vehicle and are described in Section 4.

Four-point Strap Tie-down

The most common type of wheelchair tie-down uses a four-point strap system to secure the wheelchair to the vehicle floor. These wheelchair tie-downs are very effective and can be used to secure many types and styles of wheelchairs, but usually require another person to attach and tighten the straps. For these systems to work properly, all four straps must be used as instructed by the manufacturer.

The use of four-point strap tie-downs is much easier if the wheelchair occupant is using a crash-tested wheelchair that complies with *ISO 7176-19 or ANSI/RESNA WC19* (see Section 1), since these standards require wheelchair frames to include four designated points for attaching the four tie-down straps.

If the wheelchair does not comply with ISO 7176-19 or WC19, the prescriber should advise that it is not suitable for use in transport. However, in situations where tie-down points are not indicated on a wheelchair frame, and occupied transport must occur, a documented risk assessment should be undertaken.

Tie-downs should never be attached to removable elements like arm supports, foot supports, lower leg support assemblies, or to the wheels.

When using a typical four-point wheelchair tie-down (see Figure 2), it is best to position the wheelchair so that the floor anchor points for the rear tie-down straps are directly behind the securement points on the wheelchair. A side-view angle of 30° to 45° relative to the horizontal is desirable. If pos sible, attach the front wheelchair tie-down straps to floor anchor points that are wider than the wheelchair to avoid interference with wheelchair foot supports and also increase lateral stability during vehicle movement.

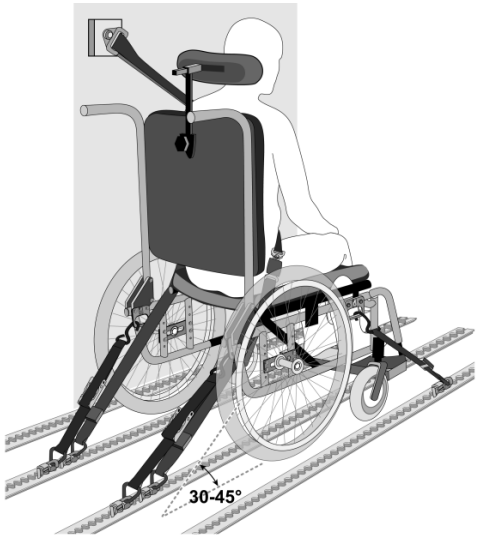

Figure 2. A 4-point strap type wheelchair tie-down system
(Illustration courtesy of University of Michigan, used with permission)

Not all wheelchair tie-down systems are suitable for all wheelchairs. For example, some wheelchairs exceed the weight limits for which most wheelchair tie-downs are intended. In these cases, the wheelchair manufacturer's instructions will indicate when a different type of tie-down is needed or how to use double sets of wheelchair tie-downs for these wheelchairs. Other wheelchairs have over-sized tubing and special additional straps are required in order to fit the wheelchair tie-down. The requirements for the wheelchair tie-down system should be specified in the wheelchair manufacturer's pre-sales literature as well as in the IFU/OM.

Wheelchair Docking Systems

Another type of wheelchair securement system in commercial use, is a docking-type wheelchair tie-down (see Figure 3), whereby components on the wheelchair engage with a docking station mounted to the vehicle floor when the wheelchair is moved into position in the vehicle.

The advantages of the docking-type wheelchair tie-down are that it is quick to use, does not require manual effort, and allows the wheelchair occupant to secure and release his or her wheelchair independently. The primary disadvantages are higher cost and the need to attach wheelchair tie-down and securement adapters to the wheelchair, which will lock into the docking station mounted in the vehicle. The added hardware on the wheelchair increases the overall mass and can reduce ground clearance.

Because of the need for a specific hardware match, docking-type securement is not currently practical in public transport vehicles where a single wheelchair station must accommodate many types of wheelchairs. However, docking tie-downs are extremely helpful for wheelchair-seated drivers who want to operate a private vehicle independently. Universal docking system geometry has been specified in *ISO 10542* [5] in the hope that it will lead to systems in a wide range of public transport vehicles that allow people to dock their wheelchairs independently. Docking systems used on specific wheelchairs should follow the wheelchair manufacturer and docking system manufacturer's recommendations, or else a thorough risk assessment must be undertaken.

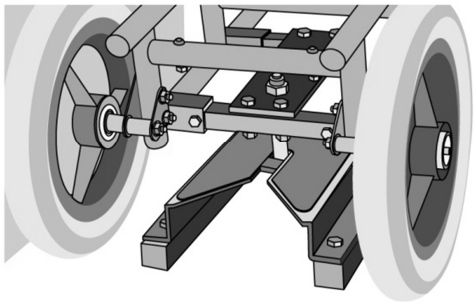

Figure 3. A docking type wheelchair tie-down system
(Illustration courtesy of University of Michigan, used with permission)

Note: the presence of a karabiner symbol does not mean that a wheelchair is necessarily suited for use with a docking-type tie-down system.

Protecting the Occupant

Having secured the wheelchair, the next task is to protect the wheelchair occupant effectively with a crashworthy lap and shoulder occupant restraint system.

Postural support belts and harnesses used to position a person in the wheelchair are intended for postural positioning, and it should be assumed that they are **not** strong enough to withstand the forces of a crash. As posture positioning supports, they are often not positioned in such a way as to apply the necessary forces to the strong parts of the skeletal system and thus restrain the occupant safely. They should not therefore be relied upon for occupant restraint during travel, but can be used in conjunction with a crashworthy lap/shoulder belt system.

The pelvic or lap portion of a crashworthy wheelchair occupant restraint system anchors to structural regions of the vehicle, or to the wheelchair tie-down straps [5]. The upper anchor point of the shoulder belt is attached to the structural points on the sidewall of the vehicle with the lower end of the shoulder belt connecting to the pelvic belt near the hip. The system anchors at three separate points in order to provide a lap and diagonal shoulder belt for the wheelchair seated passenger.

Anchoring the upper end of the shoulder belt to the floor has been shown to increase, significantly, harmful downward loading on the occupant's torso and spine in the event of a crash and results in poor upper body restraint [13]. Floor-anchorage for the upper end of shoulder belts does not comply with ISO 10542, and is unlikely to be compatible with the wheelchair manufacturer's instructions for use. Such a configuration is therefore strongly discouraged, and should only be considered as a last resort when a correct location for the shoulder belt upper anchorage that is both above and behind the shoulder is not available. Under such circumstances a risk

assessment should be undertaken and documented in advance of selection of the floor-mounted shoulder anchorage points.

Some crash-tested wheelchair designs feature an integrated crashworthy lap belt that anchors to the wheelchair, and has connector hardware to attach to a vehicle-mounted shoulder belt. Greatly improved pelvic restraint fit can be achieved with a wheelchair-anchored lap belt and this scenario can reduce the need for a third party to invade the personal space of the wheelchair occupant. However, a wheelchair-anchored pelvic belt will increase loads applied to wheelchair tie-downs which may become an issue when heavier wheelchairs are used in transport. In these cases, it may be desirable to use more than two rear tie-down straps or a four-point tie-down system with an appropriate load-bearing capacity.

Effective routing of the occupant restraint is often difficult to achieve for wheelchair occupants. The lap belt should fit low over the hips, touch the top of the thighs and, ideally should be angled between 45° and 75° to the horizontal when viewed from the side [14]. Some wheelchair hardware, such as arm supports, can interfere with good lap belt fit of vehicle anchored restraints by holding the belt away from the occupant. It is essential to avoid routing the lap belt over the arm support. It may be necessary to feed the lap belt carefully between the arm support and the passenger to achieve an effective fit of the occupant restraint.

A shoulder belt should first cross the collarbone (the clavicle), then cross the centre of the chest, and finally connect to the lap belt near the opposite hip. It should have a straight run from the point of contact with the occupant to the upper anchorage point, which should be at or above the level of the shoulder (see Figure 4). The occupant restraint webbing should be at least 25mm away from any sharp edges along the full length of its path.

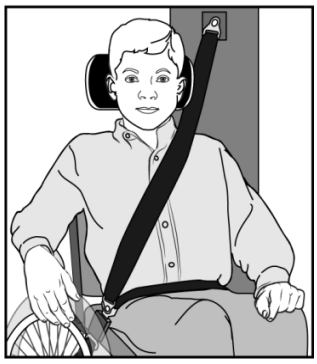

Figure 4. Good fit of a lap/shoulder belt system
(Illustration courtesy of University of Michigan, used with permission)

Maintenance of Securement Devices

The transportation provider is responsible for the safe transport of passengers. It is the responsibility of the driver to maintain WTORS in a clean and fully functioning state, and to replace WTORS that have become worn or damaged. Webbing should be regularly inspected in accordance with the manufacturer's instructions.

Upon arrival at a destination, WTORS should be removed and stowed to avoid theft, vandalism, soiling, or damage caused by wheelchairs rolling over them during access and egress. Loose items of equipment can also become dangerous missiles in the event of a crash.

Where floor tracking is used as the means of anchorage of the WTORS to the vehicle floor, rails should be kept clean of debris.

In the event of a crash of such severity that the vehicle must be towed away, WTORS equipment should be quarantined for deep inspection and considered for replacement.

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[16] ADR 5/05 (2006) *Australian Design Rules for Road Vehicles – Anchorages for Seatbelts*

4. Vehicle Categories

Section Summary:

- Vehicles can be categorised into M1, M2, or M3 categories according to size (capacity), intended use, and mass.
- Each vehicle category requires different technical provisions to ensure that appropriate levels of safety are achieved.
- Entry to, and exit from, vehicles should be safe, quick and effortless, and vehicle entrances should facilitate this.
- The method used to access a vehicle e.g. platform vs ramp vs channel ramp can influence the accessibility of the vehicle to different types of wheelchairs.
- There are minimum clear space requirements around a wheelchair occupant in a vehicle.
- WTORS anchorages must be installed only into structurally suitable vehicle components, and should be adequately reinforced.
- M1 vehicle accessibility is categorised into Type 1 and Type 2 vehicles, and fleets of taxis used for regular services should be composed of a combination of these two types of vehicles.
- It is recommended that wheelchair passengers should avoid using a rear-facing seating orientation in an M1 category taxi.
- A wheelchair seated passenger travelling in an urban bus that allows standing passengers may travel in a purpose-made rearward facing wheelchair passenger space (RF-WPS), where the occupant backs up to a padded barrier that stops the wheelchair from rolling forward and may offer additional head and back support.
- An RF-WPS offers independence for wheelchair users and faster boarding because wheelchairs don't need to be secured by bus drivers.

Vehicle Types

Passenger vehicles can be intended for private or public use:

- A wheelchair accessible private use road vehicle may be a family-owned converted car, van, or multi-purpose vehicle (MPV) intended to satisfy the specific needs of a family member
- Public Service Vehicles (PSVs) include taxis, minibuses, larger urban buses, or long distance coaches or buses.

In many regions of the world national equality regulations mean that most PSVs will need to be designed so that wheelchair occupants can travel in reasonable comfort and safety.

Vehicles may be categorised in a number of ways, and one system adopted in Europe categorises vehicles based on the type of use, capacity, and vehicle mass (Table 1).

Table 1: Directive 2007/46/EC [1], Annex II, Definition of vehicle category

Category	Description
M_1	Vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat
M_2	Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass not exceeding 5 tonnes
M_3	Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass exceeding 5 tonnes

Each vehicle category requires different technical provisions to ensure that appropriate levels of safety are achieved. Safety considerations include wheelchair stability, boarding and alighting, manoeuvring on board, seating orientation, securement of the wheelchair, and restraint of the occupant. Further details are available in Appendix A.

Ingress, Access, and Egress

Entry to, and exit from, vehicles should be quick and require minimal effort. Once inside, the wheelchair must be well secured for safety. For PSVs, each wheelchair vehicle entrance door should have a minimum vertical height, a minimum clear door opening width, have no or a very small lip or protrusion at the door, and be equipped with straps/locking devices to hold the door open when a lift is in use [3].

When considering vehicle access it is important to consider the means of access from the ground to the vehicle entrance. Portable ramps, hoists, and platform lifters may be used. While the latter options require less manual handling than the former, they are usually more costly. During ramp use, assistance may be needed for passengers using a wheelchair, and other considerations relating to ramps include:

- Fixture of the ramp to a vehicle surface (European regulations dictate that if buses are designed for easy access for passengers with reduced mobility and wheelchair occupants, boarding devices must be vehicle-mounted [4])
- Ramp width
- Weight and ease of use
- Load capacity

- Required length to ensure a manageable slope
- Slip resistance
- Edge barriers
- Storage space in the vehicle, and anchor points for storage

When selecting a wheelchair, it is important to consider the types of vehicles on which it will be used, and the means of access and egress. For example, some mid-wheel drive powered wheelchairs have rear castors that are not in alignment with the other four wheels, and can therefore not access vehicles using channel or track ramps. It is also important to be aware that some abrupt slope changes can cause contact with the wheelchair foot supports, anti-tip wheels, and/or the underside of chairs with low ground clearance.

Clearance/Interior Space

A longitudinally central location in which a person is seated as close to the vehicle chassis as possible, i.e. as low in the vehicle as possible, is considered to be the most comfortable position in which to be transported in a vehicle. The field of vision and visibility of the wheelchair occupant, for communication or attendance, are also important considerations when choosing the wheelchair position within a vehicle.

When selecting the wheelchair position and WTORS mounting points, priority should be given, where possible, to a location within the vehicle where a ceiling or side-wall mounted upper torso restraint anchorage allows the occupant restraint system shoulder belt to pass over the centre of the occupant's shoulder.

It is a requirement of EU Type Approval that all passengers travelling within a vehicle must have free access to a door or an emergency exit in the case of emergency. This has particular relevance for vehicle layouts where maintaining free gangways for evacuation in the case of an accident, or in case of a fire when toxic fumes may occur in a confined space.

A forward and rearward clear zone, based on details given in ISO 10542, should be provided to reduce the potential for injurious head impact with the vehicle interior or other passengers or objects in a crash (see Figure 5).

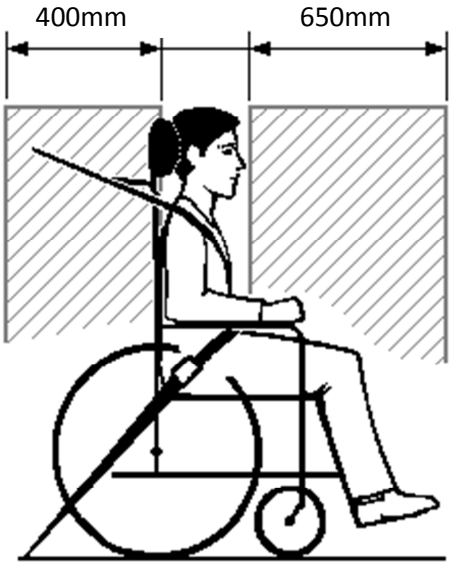

Figure 5: Clear space requirements.

If a head restraint is anchored to the vehicle rather than to the wheelchair, a vehicle-anchored back restraint must also be provided to minimize rearward deflection of the wheelchair seatback to reduce the risk of neck injury [5]. Energy absorbing and flame retardant padding should cover vehicle structures near the wheelchair securement station [5, 6].

Securement Points/Anchorages

WTORS anchorages must be installed only into structurally suitable vehicle components and should be adequately reinforced. The WTORS manufacturer should indicate anchorage strength requirements in their installation instructions [7, 8].

In order to achieve a flexible floor layout, and to maximise the usage of a vehicle by removing vehicle seats to allow an additional wheelchair space, vehicle integrated tracking or rails may provide a means to lock down both seats and/or wheelchair tie-downs to the vehicle floor.

Accessible M1 (Taxi/Converted MPV) Vehicle Design

M1 vehicle accessibility is based on two design levels for passenger vehicles:

- Type 1 - Wheelchair Accessible Taxis which are accessible for wheelchair-seated passengers as well as people with other disabilities and require forward-facing WTORS

- Type 2 - Standard Accessible Taxis which are designed for easier use by disabled people and wheelchair occupants who can transfer to a vehicle seat.

In order to achieve accessibility for all passengers, fleets of taxis used for regular services should be composed of a combination of these two types of vehicles [8].

It is recommended that wheelchair passengers do not ride rear-facing in a taxi. Passengers are not to ride side-facing in any vehicle.

Accessible M2 (Minibus) Vehicle Design

M2 vehicles, typically referred to as minibuses, will carry fewer than 22 passengers. Wheelchair seated passengers will generally be forward facing and provided with an occupant restraint system of design equivalent to those provided for vehicle seated passengers.

Accessible M3 (Low Floor Urban Bus) Vehicle Design

In all cases the wheelchair space in an accessible low floor urban bus should be clearly marked. It should be a flat surface without obstacles and provide space to manoeuvre. A call-bell push is required to be within easy reach of the wheelchair passenger.

Rear-facing Wheelchair Occupant Stations

One approach to wheelchair occupant travel on city buses is the rear-facing wheelchair occupant space (RF-WPS). It is accepted that on low-floor buses, which allow standing passengers, a rearward-facing occupied wheelchair placed against a reaction barrier, with suitable hand rails, does not need to be secured with a WTORS.

To use the RF-WPS, the wheelchair occupant backs up to a padded barrier. This barrier stops the wheelchair from rolling in the direction of travel, and may offer additional head and back support. A horizontal handrail is mounted on the sidewall of the wheelchair space, and on the gangway or aisle side. There should be a device (for example a stanchion) to prevent the wheelchair swinging into the aisle during vehicle manoeuvres.

The primary advantages of the RF-WPS include independence for wheelchair occupants and faster boarding because the wheelchairs don't need to be secured by the bus drivers. A disadvantage is that facing rearward may be difficult for some people to tolerate due to problems with motion sickness, and may result in the rider being unable to see upcoming stops.

In addition, there are currently few detailed standards for RF-WPS so the level of safety offered varies considerably [9, 10, 11].

Accessible Coach Design

Unlike low floor bus design, wheelchair access onto a high-floor single-deck (in the US known as an 'over the road') coach is generally made by a passenger lift. There are however some double-deck coaches where access to the lower deck can be accessed by a ramp.

The wheelchair space should be designed so that the wheelchair occupant is facing forward. In coaches and long distance buses where seat belts are required, ISO 10542 compliant WTORS must be provided within the wheelchair space and attached to anchorages of proven strength [10]. It is preferable that a head-and-back restraint also be provided.

Passenger Lifts

Use of passenger lifts for access to vehicles has proven to be a high risk activity where wheelchairs and their occupants have suffered injury as a result of falling from a lift platform. Adequate training of all staff engaged in the operation of passenger lifts is paramount in ensuring safe operation and practice in their use.

Passenger lifts are required by EU law to undergo a critical safety inspection every 6 months.

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Appendix A

Vehicle Size Specifications

Table 1: Ideal Dimensions for a wheelchair accessible M1 Vehicle (Oxley, 2007)

Item	Dimension
Doorway	
- height	≥ 1595 mm (≥1500mm)**
- width	≥ 850 mm
Entrance step	≤ 100 mm
Boarding aid	
- width	≥ 800 mm
- ramp gradient	≤ 7°(less than 1-in-8,unassisted)** ≤ 14°(less than 1-in-4, assisted)
Wheelchair space*	
- width	≥ 1300 mm (≥800mm**)
- length	≥ 1340 mm (≥1300mm**)
Roof height	≥ 1625 mm (≥1410mm**)

* side-entry taxi
** Australian Disability Standards for Accessible Public Transport 2002

Table 2. Dimensions for a wheelchair accessible low floor bus (2001/85/EC, UNECE Reg 107.02 and ECMT (2006)

Item	Dimension
Door	
- height	1800 mm*
- width	1200 mm**
Entrance step	≤ 250 mm
Boarding Aids	
- kneeling system	
Or	
- powered lift	
- length	≥ 1200 mm
- width	≥ 800 mm
- capacity	≥ 300 kg
or	
- ramp (powered/manual)	
- width	≥ 800 mm
- gradient	≥ 12 %
- capacity	≥ 300 kg
Gangway	
- min.	750 mm
- preferably	> 800 mm
Wheelchair space*	
- width	≥ 750 mm
- length	≥ 1300 mm
Wheelchair back rest	
- lower end	350 mm
- upper end	1400 mm
- width	300 mm
Horizontal rail, wall-mounted	
- height	850-1000 mm

* Class I
** Double door