Use of Mobility Devices on Paratransit Vehicles and Buses

DETAILS

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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 171

Use of Mobility Devices on Paratransit Vehicles and Buses

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions,* published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), Transportation 2000, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

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The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

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FOREWORD

By Gwen Chisholm-Smith
Staff Officer
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TCRP Report 171: Use of Mobility Devices on Paratransit Vehicles and Buses describes the current and emerging issues which limit the use of mobility devices in paratransit vehicles and buses, and includes a separate guidance document to assist transit systems, manufacturers, and transit users in the implementation of potential accessible design and accommodation solutions for the short and long term. This report also addresses potential safety improvements and the level of service of public transport for larger and heavier occupied mobility devices in paratransit vehicles and buses.

Regulations issued by the U.S. Department of Transportation (U.S. DOT) implementing the transportation provisions of The Americans with Disabilities Act of 1990 (ADA) defines a "common wheelchair" as being no more than 30 in. wide and 48 in. long, measured from 2 in. above the ground. In addition to transporting persons using common wheelchairs, the ADA requires transit operators to provide lifts and ramps that are able to accommodate 600 pounds, although transit agencies can choose to provide service for larger wheelchairs with lifts and ramps that accommodate more than 600 pounds. However, some mobility devices may not fit into the layout constraints of paratransit vehicles and buses. Travelers using wheelchairs and scooters can face a serious problem when trying to board a transit vehicle if their mobility device does not fall into the common wheelchair envelope of 48 in. long, 30 in. wide—a problem in both rural and urban areas.

Also, the dimension challenge is compounded by the lack of designated, safe attachment points on mobility devices. This, combined with the increased weight beyond the design parameters of common securement systems, can lead to attaching securement devices at points which are not safe or structurally sound to protect the passenger, especially those on scooters.

K.M. Hunter-Zaworski of Oregon State University and Uwe Rutenberg of Rutenberg Design Inc., prepared this report under TCRP Project C-20. The primary objectives of this research were to identify and assess the current and emerging issues which limit the use of mobility devices in paratransit vehicles and buses and to develop guidance and options to assist transit systems, manufacturers, and transit users in the implementation of accessible design and accommodation solutions for the short and long term. To accomplish this objective, a comprehensive literature review was undertaken to identify challenges and opportunities that result from the transport of persons using mobility devices. In addition, a workshop was conducted to engage vehicle lift manufacturers, transit vehicle manufacturers, manufacturers of mobility devices, manufacturers of securement devices, and transit operators who represented entities of various sizes and utilized a variety of vehicle types. The purpose of the workshop was to discuss the common issues and potential solutions related to the compatibility of the individual component designs and the extent to which these component designs interact effectively in a transit application.

After gathering this information and conducting surveys, the research team worked to produce a Final Report and Guidance Document that may help the wide variety of stakeholders including: transit agencies; transit users; and manufacturers (of vehicle lifts/ramps, transit vehicles, securement systems, mobility devices, and fare collection systems) understand and address the demands of oversized mobility devices as well as those with larger passenger weights.

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Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

SUMMARY

Use of Mobility Devices on Paratransit Vehicles and Buses

The Americans with Disabilities Act of 1990 (ADA) defines a common wheelchair as being no more than 30 in. wide and 48 in. long, measured from 2 in. above the ground. In addition to transporting people using common wheelchairs, the ADA requires transit operators to provide lifts/ramps that are able to accommodate a combined weight of an occupant and the mobility device of 600 pounds. The change in population demographics, including the increased number of elderly and people who are obese together with the changes in mobility device technologies have resulted in many people and mobility devices exceeding the space available and weight to accommodate a wheeled mobility device (WhMD).This creates problems for customers and for operators of low floor buses, lift equipped buses and paratransit vehicles. This situation is further compounded by the lack of designated points on wheelchairs and scooters to provide safe attachment points for belt-type securement systems. The objective of this project was to research and identify potential improvements for the safe transportation of WhMDs including wheelchairs and scooters on public transit vehicles.

Phase 1 of the project included an international literature review, surveys and a workshop involving the diverse stakeholders. The key results of the literature review are summarized in Table 1.

The surveys were carried out with key stakeholders, such as transit users, transit agencies, manufacturers of mobility devices, vehicles, lift and ramps and fare payment system. In addition a workshop was held with representatives of key stakeholders and government agencies. The recommendations resulting from these activities are summarized in the Table 2.

The project team analyzed and assessed the outcomes of the research activities to identify potential design criteria and new concepts. These include design parameters for WhMDs, specifications for lifts, bridging plates and ramps, fare payment systems, vehicle lay-outs, and insurance reimbursement revisions.

To improve the safe transport of WhMD on paratransit vehicles and buses the following recommendations and suggested best practices as shown in Table 3 were developed.

While final report includes details that support the project options, supporting reports from the research activities are available on the Project C-20 website at apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3085. These include a PowerPoint presentation for a webinar, a literature review, and notes from the project workshop. The accompanying Guidance Document was developed to help the transit industry address the changing demands of demographics and oversized mobility devices.

Table 1. Key results of the literature review.

United States
Changing demographics—increase in population that is older and more obese
The United States (U.S.) permits more types of wheeled mobility devices including scooters
Few accommodations for service animals
U.S. is much more prescriptive than other countries in requirements for securement systems
Low floor paratransit vehicles entering the market
United Kingdom, Australia, and Europe
Do not permit the transport of scooters
Are much more restrictive on the transport of oversized mobility aids
Use of four-belt securement on smaller vehicles is wide spread, and is consistent with U.S. practices
Canada, Europe, and Australia
The same level of acceleration force exposure is used for standing passengers and those in wheeled mobility devices
Wide spread use of rear-facing securement
Spain and Australia allow side-facing securement on large vehicles
Most Countries
Footprint of wheelchairs: 30” x 48”
Minimum payloads for ramps and lifts 600 pounds

Table 2. Summary of recommendations derived from research activities.

Wheeled Mobility Devices
The maximum mobility device size (maximum length, width, weight and turning radius) for public transportation should be specified
WC 19 or similar standard should be the basis for securement system attachment points that are located at structural safe points of mobility devices
Medical insurance agencies should require securement system attachment areas or “transit safe” devices
Vehicles
Large vehicles:
Reduce dwell times by center boarding and rear facing for travelling position
Research use of side-facing securement as an option in the U.S.
Increase interior maneuvering space
Small vehicles:
Locate securement positions between front and rear axle,
Require public transport vehicles to be structurally strong to support securement systems and weight of mobility devices
Training
Require recurrent and new employee training for all operators on use of equipment, e.g., lifts, ramps, securement systems
Increase sensitivity awareness by transit operator staff of the needs of persons with disabilities
Coordination
Require more coordination between securement systems standards development group and domestic mobility device manufacturing industry
Encourage transit agencies to communicate with local Durable Medical Equipment(DME) dealers about mobility device size limitations
Require DME dealers to indicate to customers which mobility devices are transportable on public transport vehicles
Require Allied Health professionals to consider client’s transportation needs when prescribing wheeled mobility devices

Table 3. Summary of recommendations and best practices.

Paratransit Vehicles and Buses
Increase lift/ramp payload to 800 pounds
Revise ramp slope to a maximum of 1:6
Increase length of lift platform from 48 to 54 in.
Increase WhMD footprint from 30 in. wide x 48 in. long to 30 in. wide by 54 in. long
Specify minimum turning radius of 38 in.
Paratransit Vehicles
Use of low floor vehicles
Securement (20 g): 4 belt securement/lap and shoulder belt occupant restraint
WC-19 compliant WhMD with attachment points for securement systems
Location of securement space to maximize occupant safety—between front and rear axle of vehicle
Flexible layout: seats/wheelchair positions
Bench seats for obese passengers
Large Transit Vehicles
Fare collection: off vehicle or smart/touch/touch less card
Cantilevered fare box to maximize turning area in vestibule
Center door WhMD access for large vehicles
3 g in rear-facing environment
Rear-facing securement near center door
Space for service animals

CHAPTER 1

Background

Currently public transportation operators are faced with two emerging factors, the change of demographics, which is reflected in an increasingly older and more obese population, and an increase in the use of mobility scooters for mobility out of doors or as a substitute for not being able to drive a car. These issues are straining public transportation resources and in addition, regulations and standards, have not kept up with these new developments.

To set the stage for discussion, some key definitions are used. Table 4 shows those derived from Chapter 11 of the 3rd Edition of the Transit Capacity and Quality of Service Manual (TCQSM) [Kittelson, 2013].

The current regulations and standards for the mobility device footprint and payload, and the accommodation of passengers with disabilities do not address the recent changes in passenger demographics and WhMD technologies. As a result on some fixed-route transit systems, passengers and their equipment are left stranded. There is an urgent need to address basic issues, resulting from the increase in the size, weight, and maneuverability of mobility devices, particularly scooters. Specifically, because of the increasing number of people who are obese and use scooters for outdoor mobility, there is a need for heavier payload considerations for lifts and ramps and increased maneuvering and travel space.

Table 4. TCQSM definitions of common terms.

Paratransit—forms of transportation services that are more flexible and personalized than conventional fixed-route, fixed-schedule service but not including such exclusory services as charter bus trips. The vehicles are usually low- or medium-capacity highway vehicles, and the service offered is adjustable in various degrees to individual users' desires. Its categories are public, which is available to any user who pays a pre-determined fare (e.g., taxi, jitney, dial-a-ride), and semi-public, which is available only to people of a certain group, such as the elderly, employees of a company, or residents of a neighborhood (e.g., vanpools, subscription buses).
Paratransit, Complementary—paratransit service required within a certain distance of any local fixed-route transit service to accommodate passengers whose disabilities prevent their independent use of the fixed-route service. Required by the Americans with Disabilities Act.
Demand-Response Transportation System—a form of public transportation characterized by flexible routing and scheduling of small- to medium-size vehicles (passenger cars, vans or small buses typically less than 25 seats) operating in shared-ride mode between pick-up and drop-off locations according to passengers' requests. A demand-responsive operation is characterized by the following: (a) the vehicles do not operate over a fixed route or on a fixed schedule except, perhaps, on a limited basis to serve specific origins or destinations; (b) passengers make a personal request for a reservation or service consideration (the reservation may be required several days in advance of the requested trip or on board the vehicle depending on the type of demand responsive operation), and (c) typically, the vehicle may be dispatched to pick up several passengers at different pick-up points before taking them to their respective destinations and may stop en route to these destinations to pick up other passengers. The following types of operations fall under the above definitions provided they are not on a scheduled fixed-route basis: many origins-many destinations, few origins-few destinations, many origins–one destination, one origin-many destinations, and one origin-one destination.
Transportation System, Dial-a-Ride—a demand-responsive system in which passengers call the transportation operator, who then dispatches a vehicle to pick up the passengers and take them to their destinations. It is also known as dial-a-bus when buses are the vehicles used.
Transportation System, Fixed-Route—service provided on a repetitive, fixed-schedule basis along a specific route with vehicles stopping to pick up and deliver passengers to specific locations; each fixed-route trip serves the same origins and destinations, unlike demand response. Includes route deviation service, where revenue vehicles deviate from fixed routes on a discretionary basis.
Transportation System, Non-Fixed Route—service provided along a specific route to specific locations but not provided on a repetitive, fixed-schedule basis. Demand response is the only non-fixed-route mode.
Transportation System, Urban—the system of transportation elements (both private and public) that provides for the movement of people and goods in an urban area. The components include transit systems, paratransit services, and highway or road systems, and includes both private vehicles and pedestrians

CHAPTER 2

Objectives

The objectives of this project were to examine the use of WhMds on paratransit vehicles and buses, and to identify potential improvements that could increase the safety and level of service of public transportation agencies that transport larger and heavier occupied wheelchairs and scooters on paratransit vehicles and buses. The existing regulations originated in 1991 just after the Americans with Disabilities Act (ADA) was enacted and were primarily focused on users of manual wheelchairs. There have been many developments in the past 20 years that warrant re-examination of the use of mobility devices to be responsive to changes in technology and population demographics. The two key issues that are underpinnings of the project are:

1. the increasing size and age of the overall population and
2. the increasing size and weight of wheeled/powered mobility devices. These issues have significant impact on transit operations and governing regulations.

The project was divided into two phases. Phase 1 involved the investigation of the factors that impact the access and safety of WhMds on paratransit vehicles and buses. Phase 2 involved the identification and development of new design concepts and other changes that would contribute to improvements in the safe transport of people using WhMDs. These safety improvements impact both passengers and operators and, also, produce improvements in safety, reduction of risk, and increased level of service for transit agencies.

CHAPTER 3

Motivation

There are two key motivations for this project: the changing population demographics and the increase in size and weight of WhMDs.

Demographics–Passenger Profiles

As the population of the U.S. ages, it is becoming more obese and more people have disabilities that impede their access to public transportation. Transportation is essential for all aspects of a quality of life including employment, education, and social interaction. The demand for accessible public transportation is rapidly increasing.

Age Trends

In the report entitled "The Changing Demographic Profile of The U.S." the forecast of the proportion of the population over age 65 and older in the U.S. is projected to be 17.9% in 2015 and over 20% by 2050 [Shrestha and Heisler, 2011].

Disability Trends

According to current statistical data from the Centers for Disease Control, Table 5 shows the number and percentage of people in the U.S. with mobility and sensory limitations [FastStats, 2013] (http://www.cdc.gov/nchs/fastats/disable.htm).

In the U.S., 32.9% of adult Americans have at least one disability with 7.6% having mobility challenges [FastStats, 2013]. Of the population with mobility impairments, some will use walkers and wheelchairs to facilitate mobility, but the trend to use three- and four-wheel mobility scooters appears to have gained significant momentum. It is foreseeable that the demand for these types of mobility devices will continue to increase over the next decade, which will have a severe impact on transportation systems and travel.

Obesity Trends

During the past 20 years, there has been a dramatic increase in obesity in the U.S. Obesity is defined as a body mass index (BMI) of 30 or greater. In the U.S. the percentage of adults who are obese is 35.9 and the percentage who are overweight including obesity is 69.2 [FastStats, 2013] (http://www.cdc.gov/nchs/fastats/overwt.htm).

The U.S. Federal Transit Administration has recognized the increased weight of passengers and was proposing for vehicle testing to (a) increase passenger weight requirement from 150 to 175 pounds, and (b) increase the average occupied floor space from 1.5 to 1.75 square feet. This requirement was withdrawn because the Federal Transit Administration is developing new pass/fail standards that require a more comprehensive review of its overall bus testing program.

Traveler Profiles

The following section is a characterization of travellers and alternative equipment that is used for travel:

People Who Use Manual and Sports Chairs

People using manual wheelchairs may propel themselves, or they may be pushed by an attendant. They also may transfer to and from their chair either with or without assistance. However people who use sports type wheelchairs typically have very strong upper body and upper extremity strength. They usually propel themselves and accomplish transfers to and from their chair without help.

People Who Use Power Wheelchairs

People with little upper extremity strength and or agility often use power wheelchairs. In order to operate their device, they use joysticks or similar features to maneuver their powered

Table 5. Number and (percent) of people in U.S. with sensory or mobility limitations.

Number (percent) of adults with any physical functioning difficulty: **37.4 million (16.2%)**
Number (percent) of adults unable (or very difficult) to walk a quarter mile: **17.6 million (7.6%)**
Number (percent) of adults with hearing trouble: **37.1 million (16%)**
Number (percent) of adults with vision trouble: **21.2 million (9.2%)**

chairs. They typically cannot transfer independently from their WhMD and often need assistance. Power wheelchairs may also include postural support systems with head, arm and leg supports and tilting mechanisms.

People Who Use Bariatric Wheelchairs

People using bariatric wheelchairs may have the same features as manual or power wheelchairs, but the distinguishing feature is the wider seat for the accommodation of people who are obese. It should also be noted that this part of the population often has the ability to transfer themselves using very short periods of standing and walking on their own.

People Who Use Mobility Scooters

People who use mobility scooters can typically walk for short distances, get in and out of their device independently, and maneuver the scooter on their own. An increasing segment of the aging population are using scooters as a substitute for a car when they are not able to drive a car or as a substitute for a second vehicle. Scooter users are often elderly, semi-ambulatory or people with limited mobility. Scooters are typically battery powered, have a swivel seat and a handle bar for steering.

They come in a variety of types and sizes, smaller 3- and 4-wheel scooters are mostly used indoors, due to their instability on outdoor terrains. The larger 4-wheel scooters are more stable and mostly used outdoors. These devices are more robust and often have larger tires, and may be equipped with canopies and other accessories.

People Who Use Wheeled Walkers

People who use wheeled walkers often have stamina, balance, hip, knee or back problems. The walker provides support and stability. Some walkers are equipped with casters, seats, brakes and large removable baskets.

People Who Use Crutches and Canes

People who use crutches or canes can stand on at least one lower limb. Many people with crutches are using them only temporarily due to surgery or accidents. Others may use them in addition to their mobility devices such as wheelchairs or scooters because it is easier to negotiate steps with crutches and canes.

People Who Are Blind/Vision Impaired

People who are blind may use a cane or a trained guide dog. They may also require tactile, audio and olfactory cues. When using transportation the service animals should have access to a designated space away from the aisle to avoid conflicts with other passengers.

People Who Are Deaf/Hard of Hearing

People who are deaf or hard of hearing require a visual/text alternative to audio modes for information. They may use dogs or other animals to alert them to audio cues. People who are hearing impaired require assistive listening technologies to enhance their hearing.

People Who Are Obese

People who are obese typically exceed the 99 percentile human model in body width and weight. Some may use mobility scooters or other equipment for travel. They may require a wider and stronger seat.

People Who Use Segway® Type Devices

Often people who have difficulty with stamina or must stay vertical use a Segway® or similar device for mobility. Many public transit agencies accept these devices and treat them as WhMDs.

People Using Strollers

Many families use strollers for transporting children and small adults with disabilities. These devices are generally more robust and larger than typical infant and young children's strollers.

Mobility Device Characteristics

The following types of mobility devices, commonly found in the U.S., were studied for their suitability for transport on transit vehicles. Table 6 shows the dimensions of representative

Table 6. Dimensions of generic types of WhMDs.

Mobility Device Type	Length (inches)	Width (inches)	Weight (pounds)	Turning radius (inches)
Manual wheelchairs  Source: http://www.dimensionsinfo.com/wp-content/uploads/2010/03/Wheelchair-size.jpg	42	24–26	30–120	36
Bariatric Manual Wheelchair  **Source:** http://mobilitybasics.ca/wheelchairs/bariatric.php	42	26–34	30–120	36
Sports chairs  Source: https://www.ilcnsw.asn.au/items/9771? Topic header=dimensions	35–40	32	20–80	36 or less
Extreme sport chair (for illustration only)  Source: http://www.popularmechanics.com/outdoors/sports/technology/wheelchair-racing-boston-marathon	60–78	32	80–110	70+

(continued on next page)

Table 6. (Continued).

Mobility Device Type	Length (inches)	Width (inches)	Weight (pounds)	Turning radius (inches)
Power chairs  Source: http://www.spinlife.com/Invacare-Pronto-M94-Heavy-Duty/High-Weight-Capacity-Power-Wheelchair/spec	38–43	23–25	150 or more	20–28
Power wheelchair with Tilt Features  Source: http://www.beracah.us/powered_wheelchairs.htm	44–55	23–25	200 or more	30–48
3-wheel scooters regular size  Source: http://www.topmobility.ca/images/products/PRIDE-VICTORY-ES-9-3-	42–48	24–25	100–110	40
3-wheel scooter oversized  Source: http://youalreadyknowwhoitis.files.wordpress.com/2010/04/ev-rider-royale-3-wheel-scooter.jpg	49–54+	30	200	55

Table 6. (Continued).

Mobility Device Type	Length (inches)	Width(inches)	Weight (pounds)	Turning radius (inches)
4-wheel scooter regular size  Source: http://www.1stseniorcare.com/images/goldproducts/Golden-2012/1stSeniorCare-Buzzaround-XL-GB146-4-wheel-electric-scooter-huge.jpg	48	20	100	50
4-wheel scooter over sized  Source: http://www.1800wheelchair.ca/product/3774/osprey-extra-large-4-wheel-scooter	54.5	24.5	212	54 or longer
Wheeled walkers  Source: http://thumbs3.ebaystatic.com/d/l225/m/m7Qn_zIU7c1UjGixhG1gsGg.jpg	25	30	30	25
Segways  Source: http://www.segway.com/compatibility/	26.5	33	120	20

types of WhMD according to manufacturer/supplier information and this shows that most devices are less than 32 in. wide, however many exceed 48 in. in length and the unoccupied weight is less than 300 pounds.

- Manual wheelchairs
- Sports chairs
- Power chairs
- Power chairs (with special features)
- 3-wheel scooters
- 4-wheel scooters
- Wheeled walkers
- Segways®

Descriptions of Wheeled Mobility Devices

Manual Wheelchairs

Manual chairs were the most common mobility devices in the past decades. They are light, some are foldable, have large rear wheels, small front casters, and are still mainly used by persons with strong arms to propel themselves. They have push bars at the rear for those occupants who cannot propel themselves and are pushed by another person, typically in hospitals, transportation terminals, and institutional places. The "common manual wheelchair," measuring 25 in. wide and 42 in. long when occupied, was for many years used as a base for regulations and standards with a recommended footprint of 30 in. × 48 in. and a turning radius of 36 in. With the advent of making private and public transportation accessible, systems were developed to secure the wheelchair to vehicles, mainly by tie-downs to prevent forward and rearward movement. These were rated for an acceleration of 20 g which corresponds to a force of 20 times the weight of the chair. Most wheelchair frames are not strong enough to withstand these acceleration forces without proper structural integrity and attachment points for securement systems.

Sports Chairs

Sports chairs are made of lightweight materials, have large rear wheels with a camber to allow for greater stability and small front casters when used at sporting events. Small sports chairs typically have a width of 32 in. at the large wheel camber, and the chair's length can range from 35 to 40 in. Their turning radius is less than 36 in. Sports chairs can easily board public transportation vehicles but are very difficult to secure effectively. There are a great variety of other sports chairs depending on their purposes; some of these such as extreme sports chair, have two large wheels, with a long front extension and one large front wheel. Due to their length they cannot be transported on public transportation vehicles.

Power Wheelchairs

Power wheelchairs are powered by batteries and operated by joysticks or other control means. They may have special postural control systems or cushioned seats and back, a headrest, and padded armrests. These devices typically measure about 25 in. wide by 38 to 43 in. long, and can weigh up to 300 or even 400 pounds depending on their power pack and accessories. They are usually very nimble and have a small turning radius of about 28 in., and their footprint can easily be accommodated on public transportation vehicles, provided the user is capable of maneuvering in and out of their position on-board a vehicle. Some manufacturers are complying with WC-19 to equip these chairs with attachment points for securement. In addition there are powered chairs with added features to tilt the chair and also provide extended leg and upper body supports. As a result of the additional features these chairs can vary in length and weight, and can easily exceed the standard foot print of 30 × 48 in., thus making transport on public vehicles difficult.

Bariatric Chairs

Bariatric chairs can be either manual or power chairs, and they are often distinguished by the width and added design strength of the mobility aid. These chairs are usually wider than 34 in. and designed for users who weigh up to 500 pounds. Users of bariatric chairs often are transported on paratransit vehicles.

3-Wheel Scooters

Indoor 3- and 4-wheeled scooters typically have small wheels, and their narrow width (usually about 20 in.) makes them more prone to tipping. However, these devices often are used in environments that they are not designed for and as a result tip over. These scooters should never be occupied during transport, and they are not equipped with designated attachment points as specified by WC-19.

Oversized 3-wheel scooters have been developed for the outdoor environments. These devices have three large wheels and can be powered by batteries or gas engines. The may measure from 49 to 54 in. or longer and can also weigh over 200 lbs. With their size, weight, and turning radius of 70 in. they cannot generally be accommodated onboard public transportation vehicles.

Large 4-Wheel Scooters

Large 4-wheel scooters may have a footprint of 30 in. wide by 48 in. long and provide a more stable geometry, but the two front wheel steering increases their turning radius to over 50 in., which makes it difficult and sometimes impossible,

Figure 1. 3- and 4-wheeled mobility devices designed for outdoor use only. (Source: X-Treme Scooters; http://electricbikeandscooterstore.com/ebssxtreme420.htm.)

for example, to negotiate the entry to urban buses. Most of these scooters are also not equipped with designated attachment points according to WC-19, resulting in unsafe securement.

Oversized 4-wheel scooters were developed for the outdoor environment and are also used as a substitute for persons who cannot drive their car anymore. These scooters have four large wheels and can negotiate modest uneven terrain. They are powered by batteries, exceed a length up to 54 in. and have a turning radius of 64 in. and can weigh between 200 and 300 lbs. They cannot be accommodated on most public transportation vehicles, except a few paratransit vehicles. Most of these scooters are not equipped with designated attachment points according to WC-19, resulting in unsafe securement.

Non Transportable Mobility Devices

There are models of wheeled mobility devices on the market, specifically designed for outdoor use. However their size, turning radius, and weight exceed the footprints of wheeled mobility aids that are used indoors. These models are either 3-wheel or 4-wheel scooters and may be used in place of a car and cannot be transported on public transportation modes. Two examples are shown in the Figure 1.

Wheeled Walkers

The walkers are built of lightweight materials, have four small casters, a seat and hand brakes. They can sometimes be lifted by their occupants to get over small obstacles, but need even surfaces due to their small casters. Occupants with walkers typically transfer to a seat when using public transportation.

Other Devices

Table 7 shows the footprint of other types of devices.

Table 7. Footprints from other types of mobility aids.

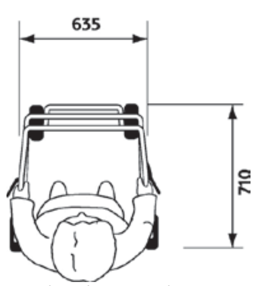
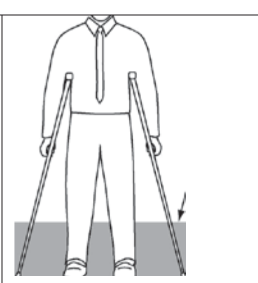
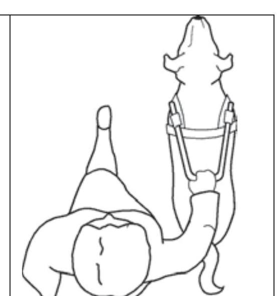
		
25" (635) x **30"** (710 mm)	**31.5"** (800 mm) – **36.25"** (920 mm) width	**47.25"** (1200 mm) width
Person using walker	**Person using crutches**	**Person with guide dog**
Source Illustrations: CAN/CSA B651		

Table 8. Weight (lbs.) of occupied wheeled mobility devices (N = 135).

Type	N	Mean	Minimum	5th	10th	50th	90th	95th	Maximum
Manual	72	225.2	125	143.6	158.6	217.6	296.2	350.9	488
Power	54	422.1	228	251.8	305.5	420.3	562.6	591.3	642
Scooter	9	408	260			396			660

Mobility Device Weights with Different Occupant Weights

Mobility Devices—Weight and Dimensions

This section discusses the trends in weights and dimensions of wheeled mobility devices, and is supported by anthropometry studies conducted in North America and the United Kingdom.

The Idea Center at the University of Buffalo has completed a significant evidence-based research study for the US Access Board. Its final report "*The Anthropometry of Wheeled Mobility*" has a number of findings that are directly relevant to the use of WhMDs on paratransit vehicles and buses. Of particular significance are the findings in the study that suggest that a number of participants in the study would not be accommodated by the current U.S. standards for clear floor space, especially in length [Steinfeld, et al. 2010]. The results of this study produced similar results to those observed in the United Kingdom. Table 8 shows the weight of occupied WhMD in a sample of 135 mobility device users [D'Souza, 2012].

Table 9 shows the mass/weights of different mobility devices with occupants in kilogram and lbs. The 95 percentile weight for most of the occupied mobility devices meet the current regulations. However the maximum for the powered wheeled mobility devices exceed 600 pounds.

Table 10 shows a comparison of wheeled mobility device dimensions that are based on manufacturers' specifications. The imperial measurements have been rounded up or down to the next quarter inch; weights to the next quarter pound.

Figures 2 through 4 are from the IDeA Center—Anthropometry Study [Steinfeld, 2010]. These illustrate the standards from various countries and the mean, 80th, 90th and 95th percentile as well as the maximum for unoccupied and occupied wheeled mobility devices.

Table 9. Comparison of mass/weights of adult device & occupant, from 1999 and 2005 (kg/lbs.).

Device Type	**Survey Year**	Mean kg/**lbs.**	Min kg/**lbs.**	Max kg/**lbs.**	5%ile kg/**lbs.**	50%ile kg/**lbs.**	95%ile kg/**lbs.**
Self-Propelled	1999	96.0 **211.2**	46.6 **102.52**	184.4 **405.68**	67.2 **147.84**	93.0 **204.6**	131.4 **289.08**
	2005	99.7 **219.34**	50.0 **110.00**	197.2 **433.84**	65.6 **144.32**	97.0 **213.4**	145.2 **319.44**
Attendant-Propelled	1999	89.0 **195.8**	58.0 **127.6**	181.0 **398.2**	68.0 **149.6**	83.0 **182.6**	127.0 **279.4**
	2005	91.9 **202.18**	36.8 **80.96**	185.6 **408.32**	58.2 **128.04**	88.4 **194.48**	136.7 **300.74**
Electric Wheelchair	1999	168.0 **369.6**	94.0 **206.8**	384.0 **844.80**	116.0 **255.2**	158.8 **349.36**	258.0 **567.6**
	2005	180.1 **396.22**	90.6 **199.32**	326.2 **717.64**	114.8 **252.56**	171.6 **377.52**	273.4 **601.48**
Electric Scooter	1999	166.0 **365.2**	79.0 **173.8**	314.0 **690.8**	109.0 **239.8**	159.2 **350.24**	222.0 **488.4**
	2005	162.5 **357.5**	86.6 **190.52**	338.6 **744.92**	108.0 **237.6**	149.8 **329.56**	258.4 **568.48**
All Chairs	1999	120.5 **265.1**	47.0 **103.4**	384.0 **844.8**	70.0 **154.0**	108.0 **237.6**	206.0 **453.2**
	2005	130.7 **287.54**	36.8 **80.96**	338.6 **744.92**	67.0 **147.4**	118.4 **260.48**	230.2 **506.44**

[Source: UK Survey of Occupied Wheelchairs, 2005]

Table 10. Equipment dimensions based on: ISO 7176-2009; US ICC/ANSI A117.1; Canada CAN/CSA B651-04; UK BS8300:2001; manufacturer's products specs.

Models	Length	Width	Turning Clearance 90 degrees	180 degrees	360 degrees	Weight
Adult wheelchairs without occupants						
Manual standard – manufacturer specs	Min.39.5" (1000 mm) Max. 51" (1300 mm)	Min. 21.25" (540 mm) Max. 26" (660 mm)			59" (1500 mm)	Min. 24 lbs (11 kg) Max. 48 lbs. (22 kg)
Standards – wheelchair floor space:						
ISO	47.25" (1200 mm)	27.5" (700 mm)				
UK	51" (1300 mm)	29.5" (750 mm)		59" (1500 mm)	59" (1500 mm)	
Canada	47.25" (1200 mm)	29.5"-31.5" (750 -800 mm with person)	36.25" (920 mm)	59" (1500 mm)	59" (1500 mm)	
US	48" (1220 mm)	30" (760 mm)	36" (915 mm)	60" (1525 mm)	60" (1525 mm)	
Sports chair standard (does not include racing sport chairs)	Min. 22.5" (570 mm) Max. 25.5" (650 mm)	Min.22.75" (580 mm) Max.26.75" (680 mm)				Min. 14.5–21 lbs. (6.6–9.5 kg)
Power chair	Min.34.5" (880 mm) Max. 43.25" (1100 mm)	Min.20.5" (520 mm) Max.24" (610 mm)	30" (760 mm) 40" (1020 mm)	88.5" (2250 mm)	88.5" (2250 mm)	213 lbs.–242 lbs. (97 -110 kg with batteries)
Mobility scooters with person (without front or rear accessories)						
Large 4 wheel	Min.44" (1118 mm) Max.56" + (1422 mm)	25.5" (650 mm)	Min.42" (1070 mm) Max. 84.5" (2150 mm)	124" (3150 mm)	124" (3150 mm) 4300 mm	138.5 lbs.–286 lbs. (63–130 kg)
Person with Guide dog		47.25" (1200 mm)				Dog weight: 26.5.–44 lbs. 44 lbs. (12–20 kg)
Space for large dog	950 mm	15.75" × 13.75" (400 mm width × 350 mm height when laying down)				
Person with Walker		25" (635 mm)				
Person with Crutches		36.5" (930 mm)				

(continued on next page)

Table 10. (Continued).

Models	Length	Width	Turning Clearance 90 degrees	180 degrees	360 degrees	Weight
Obese Persons		Up to 29.5” (750 mm)				Up to 440 lbs. (200 kg) (est.)
Strollers plus person						
Single	57.5” (1460 mm)	20.75” (530 mm)				
Single Jogger	75.5” (1920 mm)	24” (610 mm)				
Twin side by side	58.75” (1490 mm)	27.5” (700 mm)				
Twin Tandem	75.5” (1920 mm)	24” (610 mm)				
Triple side by side	72.75” (1850 mm)	43.25” (1100 mm)				
Triple Tandem	90.5” (2300 mm)	23.75” (600 mm)				

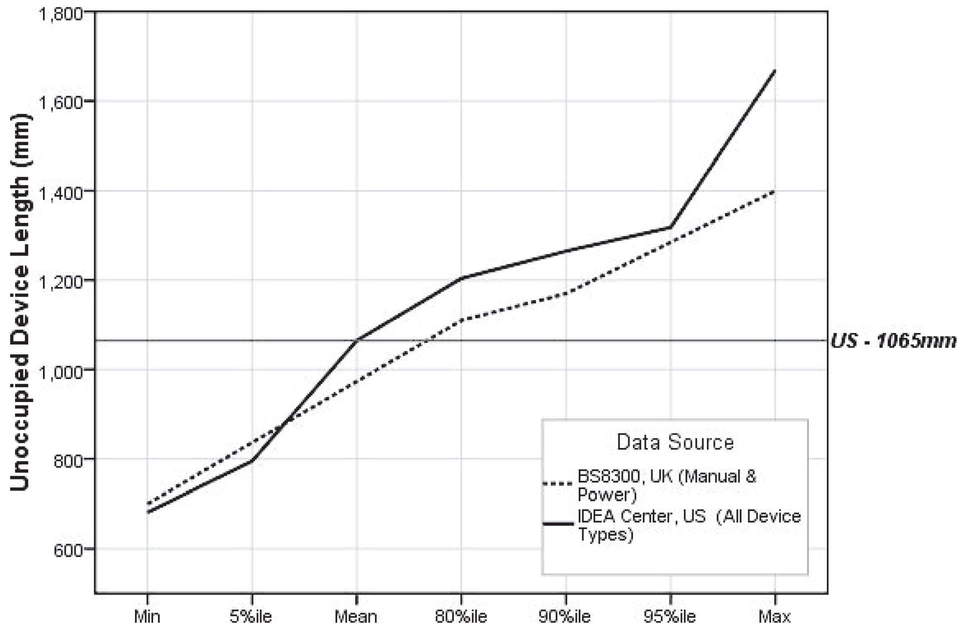
Securement Environment

The level of securement and the operating environment encountered by people who use WhMDs depends on the characteristics of the transport vehicle. As discussed in other sections, WhMDs and occupants will all react differently to applied forces or loads. This section discusses the findings of the securement environment as a function of the transport vehicle and not the WhMD.

For this study the securement environment has been characterized in general terms by the longitudinal forces encountered during severe operating and some crash (conditions) situations. There are three different securement environments that are a function of the type of transport vehicle. These are characterized by 1 g, 3 g, and 20 g, where “g” refers to an acceleration or deceleration of 32.2 feet per second^2 (9.81 meters per second^2). This illustrates a disconnect with previous research. Research has shown that large massive transport vehicles experience accelerations of 3 g or less in crash scenarios and in extreme maneuvering the accelerations for all vehicles is less than 1 g. For this study the transport vehicle is characterized by the “g” force. The design basis for securement in large Bus Rapid Transit Vehicles, where the curb weight exceeds 35,000 GVW and the possibility of a head on crash is substantially lower is suggested to be 1 g. For vehicles between 25,000 and 30,000, this is increased to 3 g and for any transport vehicle with a GVW less than 25,000 pounds it is 20 g. For some large paratransit type vehicles this is excessive, however, paratransit operators may also use small minivans which certainly require the use of securement systems that operate in the 20 g range.

The 3 g environment has been successfully applied for large mass/weight vehicles with a rear-facing system in Europe and Canada for over 20 years. Performance tests carried out by Transport Canada in 2008 confirmed that it is safe to transport persons in different mobility devices onboard large low floor buses in a rear-facing position [Rutenberg U. et al. 2007; Zaworski, J., et al. 2007].

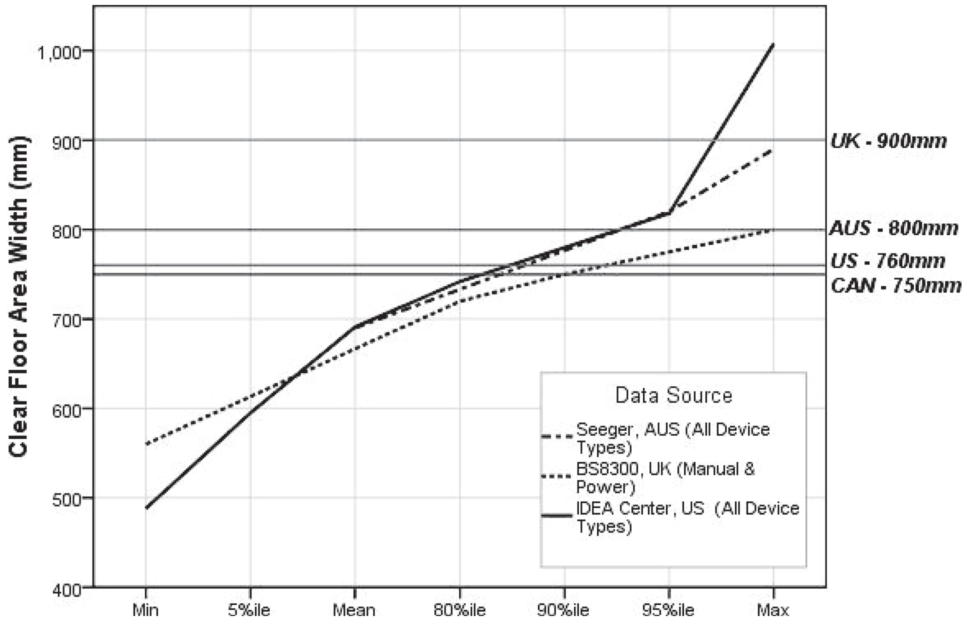
The 20 g environment applies for small, low mass/weight vehicles under GVW of 30 000 lbs. The US DOT Standards for Accessible Vehicles, differential the required design load based on GVW of 30,000 pounds, but this does not reflect actual vehicle accelerations and decelerations. This is very conservative for vehicles in the 25,000 to 30,000 GVW range. The ADA differentiates securement requirements for number and orientation based on the length of the vehicle, and 22 feet in length is the break point. For vehicles less than 22 feet, the securement orientation may be either forward or rearward facing, for vehicles longer than 22 feet at least one of the securement orientations must be forward facing. It is typical to use forward facing securement and passenger occupant restraint in compliance with WC-19 to protect the passenger using a mobility device. Forward facing systems with the use of two belt straps in the front and two at the rear take up considerable space due to the location of the anchor points on the floor. This has an impact on the number of passengers that can be accommodated. Table 11 shows three different types of securement systems and the transport vehicles that they are used on.



Data Source	Sample Size	Min	5%ile	Mean	80%ile	90%ile	95%ile	Max
BS8300:2001, U.K.								
Manual chairs - self propelled	54	700	-	-	1090	1124	-	1200
Power chairs	27	700	-	-	1160	1190	-	1400
Manual and Power chairs*	81	700	-	-	1110	1170	-	1400
Electric scooters	5	1170	-	-	-	-	-	1500
IDeA Center, U.S.								
Manual chairs	276	686	774	1012	1169	1223	1264	1600
Power chairs	189	681	900	1117	1244	1297	1340	1669
Scooters	30	1025	1035	1208	1283	1369	1435	1439
All Device Types*	495	681	795	1065	1204	1265	1318	1669

* Indicates data plotted in the graph.
[Steinfeld, 2010].

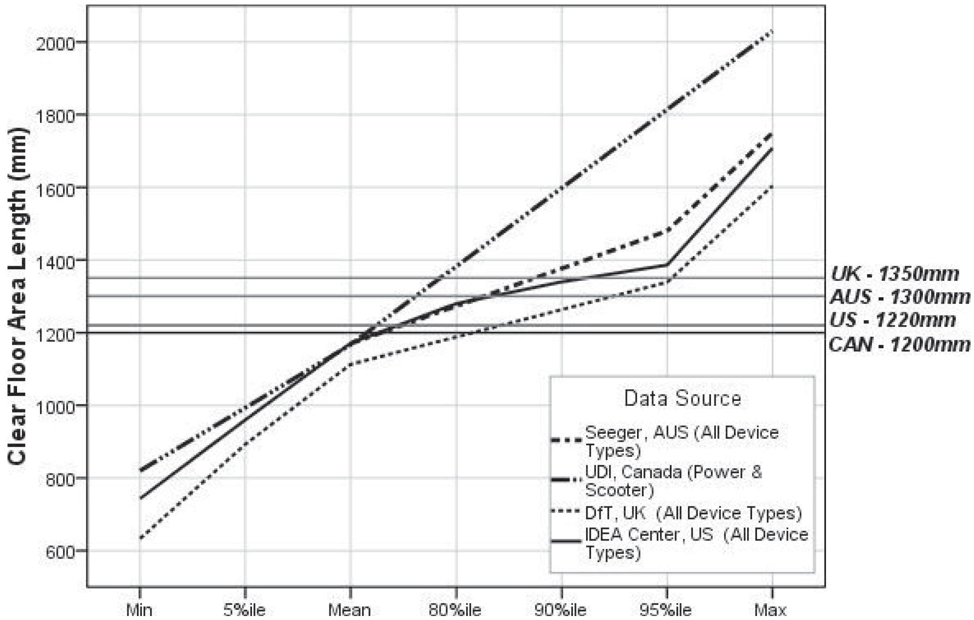
Figure 2. Unoccupied wheeled mobility device lengths (mm) versus U.S. standards [Steinfeld, 2010].



Data Source	Sample Size	Min	5%ile	Mean	80%ile	90%ile	95%ile	Max
Seeger et al., AUS								
All Device Types*	240	-	-	690	-	-	820	890
BS8300:2001, U.K.								
Manual chairs - self propelled	54	560	-	-	696	720	-	800
Power chairs	27	560	-	-	750	760	-	800
Manual and Power chairs*	81	560	-	-	720	750	-	800
Scooters	5	630	-	-	-	-	-	700
IDeA Center, U.S.								
Manual chairs	276	508	595	685	725	761	786	992
Power chairs	189	574	607	707	765	802	827	1008
Scooters	30	488	516	643	732	810	837	857
All Device Types*	495	488	595	691	742	780	818	1008

* Indicates data plotted in the graph.
[Steinfeld, 2010].

Figure 3. Clear floor width (mm) (occupied): research versus standards [Steinfeld, 2010].



Data Source	Sample Size	Min	5%ile	Mean	80%ile	90%ile	95%ile	Max
Seeger et al., AUS								
All Device Types*	240	-	-	1170	-	-	1480	1750
UDI, Canada								
Power chairs and scooters*	50	820	-	1168	-	-	-	2030
DfT, U.K.								
Self-Propelled Wheelchair	458	776	864	1068	-	-	1254	1534
Attendant-Propelled Wheelchair	106	951	1003	1123	-	-	1344	1375
Electric Wheelchair	294	633	955	1142	-	-	1339	1604
Electric Scooter	240	828	956	1168	-	-	1416	1503
All Device Types*	1098	633	893	1113	-	-	1339	1604
IDeA Center, U.S.								
Manual chairs	276	743	934	1150	1255	1314	1362	1625
Power chairs	189	831	977	1196	1313	1360	1415	1708
Scooters	30	1025	1035	1208	1283	1369	1435	1439
All Device Types*	495	743	960	1171	1280	1340	1386	1708

* Indicates data plotted in the graph.
[Steinfeld, 2010].

Figure 4. Clear floor length (mm) compared (occupied length) research versus standards [Steinfeld, 2010].

Table 11. Three securement environments.

Vehicle Type	Large Vehicle environment	3 g environment	20 g environment
			
Paratransit vehicles, Less than 30 000 lbs. GVW			Forward facing, tie-down, occupant restraint -WC19 Rearward facing with padded barrier
Small vehicles, taxis, personal vehicles, vans; less than 30 000 lbs. GVW			Forward facing, tie-down, occupant restraint-WC19 Rearward facing with padded barrier
Fixed route large buses-over; 30 000 lbs. and more GVW		Rear-facing, with aisle side containment device; BRTs in the US also require a forward facing securement system, when using rear-facing is provided	
Very large vehicles over 35 000 lbs. and more GVW	Side-facing, with aisle side containment device (not approved)		

CHAPTER 4

Key Stakeholders

To address the objectives of this project, it was essential to inquire about technical, operational and regulatory experiences. To this end, a number of diverse stakeholders were identified to provide input on these issues. The seven groups of key stakeholders are as follows:

1. Transit users
2. Transit agencies
3. Vehicle manufacturers of small and large vehicles
4. Equipment manufacturers
5. Mobility device manufacturers
6. Funding Agencies

Transit Users

Transit users with disabilities can be divided into two categories, (1) those able to use fixed route transit, and (2) those unable to use fixed-route transit and require special transportation services for at least some of their trips. Transit users use a variety of equipment for their mobility, ranging from wheeled walkers and self-propelled wheelchairs to power chairs, scooters and Segways®. They also include persons with vision/hearing problems who travel with a service animal. People who are obese also face challenges using either fixed-route or paratransit vehicles. People who use mobility scooters are sometimes left stranded since they cannot access either fixed-route or paratransit vehicles. Most consumers are not informed at the time of purchase whether or not their WhMD is transportable based on its footprint, weight and maneuverability. People who use power chairs and scooters are often exposed to undue hazards as a result of a lack of designated attachment points on their devices for forward facing securement systems.

Transit Agencies

Transit agencies may operate public transportation services in urban areas, rural areas, or both. These operations include fixed-route services and on-demand special services. The large fixed-route operators generally use low floor large transit buses that are 35 ft and longer. However some high floor vehicles that are equipped with wheelchair lifts are still in service. Intercity and long distance commuter service is often provided by large high floor Over the Road Buses. These vehicles, if they are accessible, have a lift that is usually located in the center of the bus and is operated by the driver, who must get out of the bus to deploy the lift.

Many low floor transit buses can kneel and use a flip ramp for access, which is operated by the driver from his/her seat. Several countries use rear-facing securement systems. In the U.S., they are only allowed to have rear-facing securement if a forward-facing system is provided at the same time. Dwell times with rear-facing systems have shown to be reduced to about 1 minute. Many users prefer rear facing for its independent use. In the United States most fixed route vehicles use forward facing securement systems that are operated by the driver. Deploying and undoing the securement and occupant restraint system can take up to 3 minutes or more which impacts dwell times. Transit agencies on fixed-route services are facing problems with oversized mobility devices that are unable to access vehicles due to increased length, weight and turning radii.

Most paratransit vehicles have a high floor and are equipped with a lift, however new low floor kneeling vehicles with a ramp are entering the market. Forward facing securement and occupant restraint systems are required to safely transport passengers using mobility devices. All operations to board/deboard and secure the passenger are the responsibility of the driver. Risk of injury to the driver or the passenger is possible during the deployment of securement systems. The location of wheelchair positions behind the rear axle increases the risk of injury for passengers seated in mobility devices due to the vertical acceleration forces [Hunter-Zaworski et al. 2009].

Transit Vehicle Manufacturers

Large transit vehicle manufacturers include those producing transit buses, and bus rapid transit (BRT) vehicles with a Gross Vehicle Weight (GVW) over 30 000 pounds. Fixed-route vehicles are typically low floor and the Over The Road

Buses (OTRB) are high floor, both range in length from 35 feet to 45 feet. Articulated buses measure about 60 feet in length, and many BRT vehicles can be 60 feet and longer.

Small vehicle manufacturers produce small buses, vans, taxis with a GVW under 30,000 pounds. On-demand paratransit vehicles are shorter and typically range in length from 22 feet to 28 feet. In the last decade, almost all new vehicle procurements for fixed-route vehicles are low floor, due to safer and faster access for all passengers including those with mobility devices. The interior lay-out of vehicles is typically determined by the transit agency for the number, type and orientation of seats, lifts or ramps, and wheelchair positions.

Transit Equipment Manufacturers—Interiors

Manufacturers of transit equipment include those who produce ramps, lifts, seats, securement systems and fare payment systems.

Lifts and Ramps

Lifts are used for high floor vehicles and have a minimum platform size of 30 inches by 48 inches, with front and rear safety stops, side guards and hand rails on both sides. In recent years many transit agencies are procuring lifts with longer platforms that are 52 inches or even 56 inches long. The minimum payload for the lifts is 600 pounds although some models are available that can carry a load of 800 or even 1,000 pounds. When not in use, lifts are stowed inside above floor or under floor.

Ramps are used for low floor vehicles and are single flip or bi-fold, or sliding/telescopic ramps. Ramps have guards on each side and a non-slip surface. Depending on their length the slope ratio is either 1:4 or 1:6. Their minimum required payload is 600 pounds. There is a challenge for transit operators and ramp manufacturers to provide ramps that have lower slope ratios than 1:6. Many of the ramps are designed for payloads of 800 pounds or more.

Seats

Seats for fixed-route transit vehicles are typically molded as single, double or multiple seat models. They may be upholstered, have armrests and are designed for a vertical load of 450 pounds. Flip seats or seats that fold out of the way are commonly used in wheelchair securement locations.

Seats used in paratransit operations are often upholstered; some may have a head rest and pivoting armrest to assist with transfers in and out, and also have a passenger seat belt system.

Securement Systems

Securement systems are either forward or rear facing. Traditional forward facing systems consist of four floor based anchor points with securement belts that are hooked to the mobility device, two at the front, and two at the rear. For vehicles that are less than 30,000 pounds GVW, the four-point securement system is still the best option. For larger vehicles over 30,000 pounds GVW, the forces encountered by a person sitting in a wheeled mobility aid are much lower. New proposed ADA regulations indicate that "*The design force is reduced from 4,000 pounds to 2,000 pounds based on research showing the "g" loads generated on wheelchairs and their occupants in large vehicles under the following conditions: Maximum acceleration (0.2g), maximum braking (0.85g), rapid turning (0.5g), and frontal collision (3g). Wheelchair securement systems that are designed to restrain a force of 2,000 pounds in the forward longitudinal direction in large vehicles would provide an appropriate level of protection based on these "g" loads*" [ADA, 2009].

For larger vehicles, other securement options include rear-facing systems which consist of a fixed padded back panel. The person in the mobility aid maneuvers the mobility aid with the back to rest against the back panel. The back panel is designed to absorb and attenuate some of the energy produced by the deceleration forces. There is no need for securement straps, but the tilting or turning into the aisle must be restricted. Manufacturers are presently developing a number of different approaches to address this issue. Research has shown that a 3 g protection provides for a safe environment for large mass transit buses. In other countries, such as Spain and Australia, side facing systems have been used on large BRT type vehicles over GVW 35,000 pounds. Further research is required to determine the safety of such a system in the U.S. operating environment.

Fare Payment

Fare payment manufacturers provide cash fare boxes, and these are still used by many transit agencies. New fare payment technologies that use touch or touch less credit/debit smart card systems are becoming more common. Prepaid or debit fare systems facilitate payment for persons with mobility devices, agility and sensory problems.

Wheeled Mobility Device Industry

The industry for WhMDs is comprised of manufacturers, suppliers, dealers and importers. The range of products include manual and sport chairs, power chairs, bariatric chairs, 3- and 4-wheel scooters and wheeled walkers. These devices are designed to meet the diverse needs of people with mobility impairments who require assistive technology. The diversity of WhMDs has caused challenges for the transport industry. There is no simple or single definition of wheeled mobility devices. However, a general characterization of these devices was adopted when the ADA and associated regulations were first enacted. The early definition of a wheelchair was in terms of the static footprint, and it was 30 inches wide by 48 inches long, and the minimum lift payload of 600 pounds. A number of considerations are missing, in particular the key measure of maneuverability. In this study the turning radius is suggested as a measure of maneuverability. Since most WhMDs are not recommended for use on public transportation, many manufacturers and suppliers are not aware of the limitations of transporting an occupied WhMD onboard transit vehicles such as urban buses, BRTs, and paratransit vehicles. Such limitations include the length, the weight, the turning radius and the attachment points of a securement system to the mobility device.

In the current retail environment in the U.S., many scooter-type wheeled mobility aids are bought at general retail outlets or on line. In these situations there is no involvement of Durable Medical Equipment (DME) professionals. Purchasers of these devices are not aware or even consider the use of the device in an outdoor environment or on a transit vehicle. In addition, there are no opportunities to provide any user training. If the WhMD is purchased through a DME supplier or dealer, then some basic training might be provided. It is in the rare circumstance that any conversations about transportability or use in outdoor environments take place between a dealer and a new customer.

Manufacturers of WC-19 Compliant Devices

There has been widespread recognition of the need for standards for WhMDs that are occupied during transport. The North American Standard is referred to as WC-19 and it is a voluntary industry standard for designing, testing and labeling a wheeled mobility device that is ready to be used as a seat in a motor vehicle. The standard was developed by the RESNA (now SOWHAT) Subcommittee on Wheelchairs and Transportation. RESNA is designated as a standards-setting organization by ANSI, the American National Standards Institute. The designated WC-19 wheeled mobility device has:

- Four permanently attached and labeled securement points that can withstand the forces of a 30 mph, 20 g impact.
- Specific securement point geometry that will accept a securement strap end fitting hook.
- A clear path of travel that allows proper placement of vehicle-mounted occupant safety belts next to the skeletal parts of the body,
- Anchor points for an optional WhMD anchored pelvic safety belt, that is designed to withstand a 30 mph, 20 g impact that has a standard interface on it that allows it to connect to a vehicle-anchored shoulder belt.

The WC-19 standard was created to address a number of concerns about the lack of crashworthiness of mobility devices that are occupied during transport on public transportation vehicles. A few manufactures/suppliers adhere to this regulation. This is particularly important when power chairs and scooters are transported occupied or unoccupied and must be safely secured onboard a vehicle. Not all mobility devices are manufactured to be used in a 20 g environment such as those encountered onboard paratransit vehicles, small vehicles, vans and taxis.

Funding Agencies

During Phase 1 of the project, many attempts were made to engage the Durable Medical Equipment industry and agencies that provide funding for DMEs as participants in the project survey and workshop activities. Two wheelchair manufacturers participated in the workshop and several others in the online survey. The public and private insurance agencies appeared reluctant to participate in most conversation or other data collection activities. It was also noted that several DME suppliers who started the survey that was targeted at them did not complete it.

CHAPTER 5

Key Findings

Sources

A summary of the research findings are presented in this section. The key findings were derived from the following sources: a literature review, national surveys, workshop and contributions from panel members and the transit industry.

Literature Summary

An extensive review of the U.S., Canadian and international literature was performed. There are a few key findings of interest. The U.S. and Canada permit a greater range of sizes of wheeled mobility devices to travel on paratransit vehicles and buses, than most other countries. The UK, Australia and the European Union do not permit the transport of scooters, and in general these regions are much more restrictive on the transport of oversize mobility aids. In addition, the U.S. is much more prescriptive with regards to mobility aid securement. In the other countries the frame of reference for securement on large transit vehicles is that people in wheeled mobility devices are exposed to the same level of acceleration as standing passengers, and this is reflected in the wide spread use of rear-facing securement and in some countries side-facing securement. Since the diversity of WhMD is much more restrictive, the use of four belt securement on smaller vehicles is wide spread, and is consistent with US practices. In most countries the standard footprint for a transportable mobility aid is approximately 30 inches wide by 48 inches long and the minimum payload for lifts and ramps is 600 pounds.

Survey Summary

The TCRP Project C-20 Research Team worked with the Oregon State University Survey Research Center to develop the survey instruments for all the diverse stakeholders involved with the project. All of the survey materials were submitted for approval by the OSU Institutional Review Board (IRB) for the Protection of Human Subjects as well as comply with the requirements of NAS/TCRP. The IRB documents were submitted for an “exempt” review, and final IRB approval for the surveys was received on April 30, 2012.

The survey instruments were designed to be used in several survey modes. The survey instruments included cover letters that meet the requirements of TCRP and the OSU IRB. The Surveys of Transit Agencies, Transit Users and Wheeled Mobility Device (WMD) industry were online surveys. The five instruments addressed the items suggested by the project panel as well as other items that the research team had also identified. The audiences for the surveys included (1) transit agencies, (2) transit users, (3) transit equipment manufacturers, (4) WhMD industry, and (5) funding agencies. The (1) Survey for the Transit Agencies, and the (2) Survey of Transit Users were reviewed by subject matter experts and as a result a number of modifications were made to these instruments.

The three online surveys required OSU IRB approval before they could be programmed for the web. The survey of transit equipment manufacturers (3) was hardcopy and phone survey and most of the surveys were conducted by phone. The Survey for Mobility Device Industry (4) was also an online survey. Online surveys by the OSU Survey Research Center (SRC) were activated on July 9, 2012, and concluded September 7, 2012. The survey of funding agencies was the most challenging survey to conduct and was designed to be conducted by telephone. A short interview survey was prepared for this population group. Despite repeated referrals and attempts at recruitment, this population declined to be interviewed.

In addition to the formal surveys a number of conversations in a number of different formats were held with stakeholders to identify the issues, problems, and potential solutions related to the transport of persons using mobility devices. As a result of organizing the workshop, a number of additional stakeholders were identified and interviews and conversations were carried out to determine issues that have not been identified to date. Telephone interviews have been conducted with

Table 12. Key findings from surveys by stakeholder groups.

Transit operators Desire for strong regulations that mandate the following: Training and refresher programs for all operators on the safe use of equipment; e.g., lifts, ramps, securement systems Wheeled Mobility Devices: • maximum length, width, weight and turning radius of **transportable** wheeled mobility devices • attachment points for securement systems located at structural safe points this includes scooters
Transit Users Require DME dealers to indicate which mobility devices are **transportable** on public transport vehicles Revise funding models and insurance payment policies for mobility devices to include securement attachment points or WC-19 compliant devices Encourage transit agencies to communicate with local DME dealers about mobility device size limitations
Mobility Device Manufacturers Require public transport vehicles to be structurally strong to support securement systems and the weight of mobility devices Require more coordination between securement systems standards development group and domestic mobility device manufacturing industry Require mobility aids to have securement attachment areas Require WC 19 standards to be mandatory Require funding agencies to mandate securement system attachment areas

a number of transit vehicle and transit equipment manufacturers. The structured interviews were concluded when it was determined by the research team that no new information was being gained. The complete Survey Report is available on the project website.

Key Findings from the Surveys

There were a number of common themes in the responses from the diverse stakeholder groups. It was consistent from all surveys, that oversize wheeled mobility aids are challenging for transit operators, passengers and many users. Many respondents noted the challenge of securing WhMDs particularly those with "shrouds."

Some surprising comments were received from transit operators and the transit industry. Both entities requested more regulations pertaining to transportable WhMDs that have built-in and easily identifiable securement system attachment points. There was also a comment about the need to develop specifications for the minimum structural strength for vehicles transporting WhMDs.

Interviews were conducted of transit operators in certain markets. One operator reported that since they switched to new belt securement system on their paratransit vehicles they had not had any operator injuries. The comments in the transit user survey that pertain to roadways and intersections were unsolicited. The number of comments on accidents that occurred off the transit vehicle and in the roadway was unexpected. The key outcomes from each stakeholder group are summarized in Table 12.

The Transit equipment industry also had a number of recommendations, and these are shown in Table 13.

Detailed summary of all the surveys are in the survey report. The survey report provides a full description of all

Table 13. Transit equipment industry survey summary responses.

Transit equipment industry Require regulations to control the size, weight and turning radius of mobility devices Size of transit vehicle is restricted - loss of seating capacity, if increase width of seat or space for mobility devices
Lift and ramp manufacturers Many lifts and ramps are already designed for higher 800 pound loads Many new lifts and ramp platforms are now designed for longer mobility devices, however WhMD cannot board vehicle due to tight turning radius at front of bus and restricted interior maneuverability
Seating manufacturers Seats are designed for 450-pound vertical load Wider seats may reduce seating capacity of vehicle
Securement manufacturers Forward facing in bus and paratransit in U.S. In favor of developing improved standards and safety that are based on engineering research
Fare payment suppliers Move towards smart fare payment systems Redesign mounting hardware to make sure fare box does not encroach into vestibule area

Table 14. Findings from survey.

	Transit Operators	Transit Users	Transit Equipment Manufacturer	WhMD Manufacturers
Regulations that mandate max size of WhMD	X		X	
Regulations that mandate securement system attachment points	X			X
Require regular & refresher training for drivers	X			
Provide Space for service animals	X	X		
Require DME dealers to indicate WhMD that are transportable on public transit		X		
Revise WhMD funding to include securement attachment (WC-19)		X		X
Encourage transit agencies to work with local DME Dealers on size limitation of transportable WhMD		X		
Require more coordination between DME industry and securement standards groups				X
Develop securement standards that are based on engineering			X	

the methodology, surveys and results. Table 14 summarizes the key findings from the surveys.

Workshop Findings Summary

A report that summarizes the results of the workshop that was held on June 26, 2012 and includes materials submitted by some of the workshop participants is available on the project website. A short summary of the key findings is outlined below.

Workshop Objectives:

- Demonstrate the impacts of changes in population demographics and wheeled mobility devices technologies and the impact on the transportability of WhMD
- Identify technical, operational and regulatory issues associated with the transport of wheeled mobility devices on-board paratransit vehicles and urban buses
- Convene an opportunity for key stakeholders from the transit vehicle, WMD, and securement industry, to meet with transit operators and regulators to discuss the transport of WMD on paratransit vehicles and larger buses.
- Synthesize and evaluate the workshop discussions, and prepare a workshop report.

The workshop was organized into four modules to facilitate full participation and discussion.

Module 1 Framing the Conversation

The significant issues were introduced, and the framework of the discussion was presented

Module 2 Technical Issues

The technical issues were categorized according to manufacturers' perspectives and included: wheeled mobility devices, bus and paratransit vehicle, lift/ramp, securement, fare payment and transit seat.

Module 3 Operational Issues

The operational issues were introduced from the perspectives of transit operators, transportation consultants, regulators and trade association. A discussion of regulatory issues was also included in this module.

Module 4 Balanced and Sustainable Solutions

This module was a facilitated discussion that identified key areas of change to improve the accommodation of wheeled mobility devices on paratransit vehicles and buses. Suggested changes would impact all the stakeholders. In addition there was a discussion on short term and long term changes and implementation strategies.

Technologies

Mobility Device Industry

The WhMD industry is comprised of manufacturers, suppliers, dealers and importers. The range of products include manual and sport chairs, power chairs, bariatric chairs, 3- and 4-wheel scooters, and wheeled walkers. These devices are designed to meet the diverse needs of people with mobility impairments who require assistive technology. The diversity of WhMD has caused challenges for the transport industry.

Most manufacturers/suppliers are not aware of the limitation for a transportable mobility device, and therefore cannot inform the purchaser of the device accordingly. First time purchasers of scooters are often not familiar with the operation of such a device and require some training. Since these devices are often purchased through the Internet there are no provisions for appropriate sizing or training. Scooter users are especially not accustomed to boarding a bus, and maneuvering in and out of the securement position. The size and lack or maneuvering capabilities of the scooter user make them very difficult to use on a bus. Some suppliers/dealers provide a basic training but others do not. Scooters in particular require attention because of their size, weight and turning radius. Table 15 is a summary of the transportability of WhMD onboard low floor fixed-route buses and paratransit vehicles.

Transit Vehicle

Large vehicles are considered those that have a GVW of 30,000 pounds and more. They include urban transit buses ranging in length from 35–60 feet, and extra-long articulated vehicles that are over 60 feet long and often used in BRT service. These vehicles can be standard urban buses, low floor or high floor, single axle, double axle, articulated, double

Table 15. Summary of WhMD transportability on-board fixed route low floor buses and paratransit vehicles.

Person with equipment	Transportable on fixed route low floor bus/BRT Y/N	Requires WC-19 Y/N	Transportable on paratransit vehicle Y/N	Requires WC-19 Y/N	Comments
Manual and sports chairs	Yes	Yes	Yes	Yes	
Power chairs	Yes	Yes	Yes	Yes	
Bariatric power chairs	**No**	NA	Yes	Yes	
3-wheel scooters	Yes	Yes	Yes	Yes	
4-wheel scooters 30” x 48 “	Yes	Yes	Yes	Yes	If turning radius does not exceed 36”
4-wheel scooters 30” x 49” – 54”	**No**	NA	Yes	Yes	
Wheeled walker	Yes	NA	Yes	NA	
Crutches and canes	Yes	NA	Yes	NA	
Persons who are blind/vision impaired	Yes	NA	Yes	NA	Require a space for service animal
Persons who are deaf/hard of hearing	Yes	NA	Yes	NA	Require visual mode for information
Person using Segway	Yes*	NA	Yes*	NA	*If operator policy allows
Person using stroller	Yes*	NA	Yes	NA	*Only if envelope does not exceed 30” x 48” and a turning radius of 36”
Person who is obese	Yes	NA	Yes	NA	May require wider seat

decker, or as BRTs with several cars. Users of fixed-route transit are those who are able to enter, exit and maneuver their mobility device on their own.

Most commonly used large urban vehicles for fixed-route operations are now low floor. The low floor section is accessible for mobility devices either via the front door or the center door. Most operators use a flip ramp at the front door for access with a slope of 1:4 from vehicle floor level to the road. Some operators use a bi-fold ramp which allows for a 1:6 slope. Ramp loads are presently limited to 600 pounds for an occupied mobility device. Today's demands can exceed this limit with the growing weight of both mobility devices and occupants. Entry through the front door has its physical restrictions due to the space for a fare box which limits the turning radius for a mobility device to 36 inches. Front door ramp operations are under the direct visual control of the driver, as is fare payment. The width of the aisle through the wheel wells is limited to 36 inches. Front door access may also have an impact on seating types and capacities since the area around the securement systems require a large maneuvering space for mobility devices to get in and out, thus 2 + 1 seating or bench seats on one side are usually applied. Entry via the center/rear door allows for a greater turning radius and more maneuvering space. The operation of the ramp located at center or rear doors is controlled by the driver via interior/exterior mirrors or video cameras. There are trade-offs between the two access door systems. Front access is under the drivers' direct control, but access is limited by the size of mobility devices and longer paths and maneuvering space to get to the securement position; center door access allows for larger mobility devices, larger maneuvering space and shorter distance to the securement position, but direct visual control by the driver is more difficult.

It is required that at least one of the securement systems in large fixed-route vehicles must be forward facing with both an occupant restraint and mobility device securement system as required by ADA regulations. Forward facing securement systems often require the driver to deploy the systems which increases dwell time. Research has shown that 3 g protection is safe to transport persons in mobility devices on large transit buses such as those with a GVW over 30,000 lbs. Several countries in Europe, Asia, Australia and Canada use rear-facing systems. Rear-facing systems in the U.S. are permitted as long as a forward facing system is provided at the same time. Rear-facing does not require driver involvement and reduces dwell times significantly. It is also preferred by users of mobility devices since rear-facing securement provides more independence and dignity.

Cash fare boxes are the most common fare payment system in fixed-route operations. However, the position and size of the fare box mounting hardware can limit the vestibules' maneuverability space. They can also present a barrier to persons with agility and cognitive problems. Many transit agencies are opting now for touch or touchless smart card systems which are easier and more convenient to use, and also reduce the space for a fare box, thus permitting a larger turning radius in the vestibule and longer mobility devices to access the vehicle.

Small Vehicles

Small vehicles are those with a GVW under 30,000 lbs. They range in length up to 28 feet and are mostly high floor, although low floor vehicles are becoming increasingly popular. Users of paratransit services are typically those who are unable to use fixed-route transit. Small vehicles less than 22 feet are required to provide one securement location and devices, and the securement may be forward or rear-facing; all vehicles over 22 feet are required to provide at least two securement locations and devices and at least one must be forward facing.

Most paratransit operators are still using high floor vehicles that are equipped with lifts, which can be located at the rear of the vehicle, at the side behind the rear axle, or at the side in front. Their typical payload is 600 pounds, but some lift manufacturers now supply lifts with a payload capacity of 800 pounds, and more due to the increase in combined weights of mobility devices and occupants. Longer lift platforms, originally measuring 30 inches wide by 48 inches long, are also now available for the same reasons. Lifts are operated by the driver/operator and are stored inside the vehicle when not in use. In paratransit operations these are the only vehicles that can accommodate some mobility devices which exceed the typical 30 inches × 48 inches foot print and a larger turning radius. The interior lay-out of these vehicles varies according to the demand of local operations for the number of seats and securement positions. The positioning of seats and securement locations allows for greater flexibility and larger maneuvering space to move mobility devices in and out of their positions. Unfortunately in many cases occupants in wheelchairs are positioned behind the rear axle, where the suspension provides higher vertical acceleration forces resulting in discomfort and injuries to the occupant. Due to the smaller mass of these vehicles, a belt type securement system is required to protect in a 20 g environment.

In most cases the driver/operator maneuvers the mobility devices in and out of their securement positions, and must deploy the securement and occupant restraint, which can result in injuries to the operator and undignified close physical contact with the occupant. Some persons are able to transfer from their mobility device to a seat, and this is strongly recommended for all scooter users. Most seats are upholstered, have a headrest and pivoting armrest to facilitate transfers, as well as a three point belt system for protection.

One safety issue has been identified for operations which are the boarding and alighting with lifts and ramps on roadways with high cross sections (cambers) or side slopes and this increases the risk of incidents.

Low floor small vehicle use is increasing due to the recent availability of such vehicle types and the demand for safer and more convenient operations. These vehicles are accessed via the front door with a ramp, which requires less involvement from the operator and provides a more dignified access for all passengers. The ramp also reduces many of the risks encountered on high lift platforms. Some manufacturers are providing an angled ramp design which allows for longer mobility devices to enter the vehicle. Forward facing securement systems are used and their locations are at the front behind the driver station, with a short distance from the entrance to reduce maneuvering space. Positioning behind the rear axle should be avoided. It should be noted that there are some operating environments where a high floor vehicle equipped with a lift is to be preferred.

Other Transit Equipment

Lifts

Transit operators use lifts for high floor vehicles to provide access from the road level to the vehicle floor level for persons who cannot negotiate steps/stairs. Lifts require a significant space when stored, either inside a vehicle above the floor or under floor. Capital and maintenance cost for lifts are high. Currently, payloads and platform sizes cannot always accommodate heavier or longer mobility devices and heavier occupants. Some manufacturers provide longer platforms and lifts for payloads of 800 pounds. Under the U.S. Department of Transportation (DOT) Americans with Disabilities Act (ADA) regulations at 49 C.F.R. Section 38.23(b) (1), wheelchair lifts must accommodate a design load of at least 600 lbs., with a safety factor of at least six (3,600 lbs.) for working parts, such as belts, pulleys, and shafts that can be expected to wear, and a safety factor of at least three (1,800 lbs.) for nonworking parts, based on the ultimate strength of the material. For vehicles equipped with ramps, the design load must be at least 600 lbs. for ramps in excess of 30 inches in length, with a safety factor of at least three (1,800 lbs.). There is nothing in the regulations preventing the procurement of lifts that accommodate larger and heavier mobility aids.

When the vehicle is parked on a road with either a vertical slope or a cross slope there is a danger for both lifts and ramps because of their may not be full contact between the end of the lift or ramp at the interface between the lift and ramp and the sidewalk. There are only a very few locations where a high floor vehicle would be preferred over a low floor vehicle and this would include vehicles that cover very long trip lengths such as over the road buses.

Ramps

Ramps are used for low floor vehicles, usually positioned at the front or center doors. They are typically hydraulic or electric powered flip ramps operated by the driver from his/her driving position. When not in use the ramps are folded flush with the vehicle's floor. Ramps should be hinged at the edge with the bus floor and folding out onto the sidewalk/road. Transit operators typically require the ramps to be cycled every day before the vehicles start operation. Single flip ramps with a length up to 48 inches may exceed a slope of 1:4 when deployed to the road, which can make access for some mobility devices difficult. There are new bi-fold ramps with longer lengths and slopes of 1:6 on the market. Often the vehicle is knelt to achieve a 1:6 ramp slope. Unimproved stops that do not have a sidewalk or curb are challenging for ramp operations. The driver from his driving position can visually control the operation of the ramp at the front door location; ramps at the center door require visual control by mirrors or video cameras.

Seats

There are a variety of seat types used on fixed-route vehicles. The type of seat is a function of the operating environment, the culture of the transit agency and the type of operations. This is reflected in the combination of seated and standing passengers, and the number of positions for wheelchairs. Commuter operations for longer distances typically require more seats, short distance urban operations allow for more standees. Although seats are designed for a vertical load of 450 pounds heavier persons exceeding this weight may need stronger and wider seats.

Single, double and bench fixed seats can be in combinations of 2 + 2 and 2+ 1, or side facing. Flip seats are used in the positions for wheelchairs. Sometimes the flip seats in the wheelchair location are also designated as Priority Seats for elderly, pregnant women or other persons with disabilities. This should be avoided since it can lead to conflicts when these seats are occupied and a person in a wheelchair is boarding. A bench seat does not reduce the number of seats if not occupied by a person requiring a wider space. Seat lay-outs are typically determined by local transit agencies, for example, for longer distance service more seats are provided with few or no standees, on shorter routes fewer seats are required and more standees are allowed.

Fare Payment

Most fare payment systems are still on-vehicle, using a cash fare box. One of the most rapidly evolving technological areas in public transportation is new fare payment systems. Both large and small U.S. public transit agencies are currently planning or implementing open (standards) payment systems, in which contactless credit/debit cards or near-field communications (NFC)-enabled devices are accepted directly at fare gates in rail stations and at fare boxes on buses. The Chicago Transit Authority (CTA) launched an open payments system in late 2013, and the Southeastern Pennsylvania Transportation Authority (SEPTA) will roll-out open payments in 2014. Similarly, other transit providers are pursuing fare collection systems in which riders pay using smartphone applications. Portland's TriMet recently launched a pilot program for smartphone payments, and Dallas Area Rapid Transit (DART) plans to provide mobile ticketing options. Transit agencies in North America are planning and implementing new fare payment systems at an extraordinary pace. While new fare payment systems have the potential to deliver many benefits to transit agencies and transit riders—including reduced costs to collect fares and increased customer convenience—one key issue that must be addressed is how to meet the needs of riders who do not have or do not want to use open standards-based fare media. In many transit agencies, the fare boxes are positioned at the front vestibule of a bus, where they impact the maneuverability/turning radius of a mobility device in the vestibule. In cases where the fare box is still required, the researchers propose that the box be cantilevered, or mounted above the floor and thus providing more space for maneuvering.

Operations

The discussions at the workshop and the voluntary comments as part of the surveys indicated that the physical infrastructure and operating environment can create barriers and challenges for people who use WhMDs. It was noted that the dwell time is significantly impacted by lift and ramp deployment and that roadways with large cross slopes or cambers create significant challenges for the safe deployment of ramps. Bus Rapid Transit with level boarding by a bridge plate at a center door had the lowest dwell time. Other comments were received on the need to insure safe and sufficient space for service animals. At the workshop, fare boxes were mentioned as a common impediment during the boarding process, and that off vehicle fare payment or smaller fare collection devices would also help to promote shorter dwell times.

A common theme from both transit operators and passengers was the need for more recurrent training on sensitivity awareness for operators.

Technical

The fixed-route transit industry has moved almost exclusively to low floor buses. Low floor buses are easier for all passengers. Recently, several models of low floor paratransit vehicles are being procured. It is anticipated that over time more and more models of low floor paratransit vehicles will become available. In the meantime, high floor paratransit vehicles are being procured with lifts that have longer platforms and heavier payload ratings. This is to accommodate the increased length and weight of wheeled mobility devices.

Transit agencies, transit operators, transit industry and people who use WhMDs indicated that there should be standards that define a transportable mobility device. Almost universally there was a desire for securement attachment areas or devices to be made available for all mobility devices. In addition there was recognition that the ADA "footprint" of 30 inches wide by 48 inches long did not satisfy the current WhMD market, thus there was a desire to redefine a footprint for a WhMD and also include a measure of maneuverability.

During the literature review and workshop activities, the change in ramp slope from 1:4 to 1:6 was identified as having unintended consequences. The operations staff at several transit agencies, worked directly with vehicle manufacturers and ramp manufacturers to solve most of the challenges that the new slope and designs had created, and this resulted in new models of ramps that meet the new 1:6 requirement.

Regulations

There are three main topics that pertain to regulations and standards: (1) the recent changes in the definition of a wheeled mobility device, (2) the use of voluntary standards, (3) and the changes in reimbursement for durable medical equipment.

Recent Changes in WhMD Definition

There has been modification in the definition of a wheelchair. Both the Departments of Justice and Transportation have made modifications. The term "common wheelchair" has been removed. This concept was originally developed to provide a set of parameters for designers and manufacturers to use in the process of designing and building accessible vehicles and equipment. The original DOT ADA regulation created an operational use of this design concept, saying that transportation operators were required to transport "common wheelchairs." Over time, transit operators began to apply this concept to exclude wheelchairs that did not fit into the common wheelchair weight and dimension "envelope" regardless of whether their vehicles and equipment could accommodate them. The definition of a wheelchair is modified to include "three or more wheeled devices;" this is in recognition that some powered wheelchairs have more than four wheels. Transit operators and part of the transit industry have expressed a desire to have a new definition of wheeled mobility devices that will establish new parameters with respect to size, weight and maneuverability. Under the new definition, transit agencies that have vehicles that can accommodate larger mobility devices that exceed the definition of the common wheelchair are required to transport those passenger if the vehicle and lift/ramp can physically accommodate them, unless doing so is inconsistent with legitimate safety requirements. There is recognition that the previous footprint of a "common" wheelchair does not reflect the current market.

Changes of Standards/Regulations

The survey results and the input received at the workshop also indicated a desire by some of the stakeholders for the establishment of mandatory rather than voluntary standards for wheeled mobility devices. In particular the current ANSI/RESNA and corresponding ISO standards are voluntary. The standards of interest are: ANSI/RESNA Standards WC18/ISO 10520 (SAE J2249); and WC19/ISO 7176-19 WC19/ISO 16840-4. There are a few wheelchair manufacturers who manufacture their products to meet these standards, but there are many WhMD that are distributed in the US that do not meet any of the voluntary standards.

Reimbursement for Wheeled Mobility Devices

In the past 5 years there have been changes in the rules for Medicaid reimbursement by the Centers for Medicare and Medicaid Services (CMS), which has resulted in making it much more difficult to prescribe wheeled mobility devices that are designed to be used out of doors. In addition, it is very difficult to get reimbursement for wheeled mobility devices that are "transit safe" or WC-19 compliant. This raises a dilemma for many people with disabilities and their families. Assistive technology and accessible transportation facilitate independent living, access to education, and employment on the one hand, and yet the reimbursement policies for wheeled mobility devices confine people to an indoor environment.

Summary of Phase 1 Findings

Table 16 summarizes the findings of the project in terms of topical themes, sources and impacts.

Table 16. Summary of project findings.

Theme \ Source	Literature Review	Survey	Workshop	Technical Impacts	Operation Impact	Regulatory Impact
Wheeled Mobility Devices(WhMD)	X	X	X			
1. Standards/Regulations						
a) Weight- establish maximum weight of occupied WhMD	X	X	X	Y	Y	Y
b) Length- establish maximum length of WhMD to be accepted for transport	X	X	X	Y	Y	Y
c) Turning Radius- establish standard turning for vehicle access		X	X	Y	Y	Y
d) Securement systems- require securement system attachment points of all WhMD.		X	X	Y	Y	Y
e) Scooters- mandatory for scooters to have securement system attachment points if they are transported		X	X	Y	Y	Y
f) CMS and Insurance- require reimbursement for WC- 19 or equivalent securement system attachment points on WhMD			X		Y	Y

(continued on next page)

Table 16. (Continued).

Theme \ Source	Literature Review	Survey	Workshop	Technical Impacts	Operation Impact	Regulatory Impact
Large Transit Vehicles						
Access doors- consider use of center door boarding for WhMD-reduce dwell time			X	Y	Y	
WhMD orientation- consider use of side facing for large transit vehicles	X				Y	Y
Ramps - flat level area inside vehicle, ramp start at threshold	X		X	Y	Y	Y
Lifts /ramps - minimum payload 800 pounds	X	X	X	Y	Y	Y
Platform lifts -increase minimum length to 54 inches	X	X	X	Y	Y	Y
Ramp slope 1:4 or 1:6		X	X	Y	Y	Y
Seats for obese passengers			X	Y		
Fare payment	X	X	X	Y	Y	
Small Transit Vehicles						
WhMD location- place WhMD securement between front and rear axle	X		X	Y	Y	
DME Dealers						
Transportable WhMD	X	X	X	Y	Y	Y
Revise funding/reimbursement model		X	X			Y
Transit Operators						
Training		X	X		Y	Y
Risk management			X		Y	
Funding Agencies		X	X		Y	Y

X: Source
Y: Impact

CHAPTER 6

New Concepts in Design and Operations

This section on new concepts in design and operations is divided into three major divisions: the design of transit vehicle equipment and layouts, design of transit safe mobility devices, and innovations in transit operations to reduce risk to operators and passengers.

Designs of Vehicle Equipment

Low Floor Transit Vehicles

The low floor bus layout has certain limitations for boarding/exiting with a mobility device, accessing the travelling position, and maneuvering into and out of the wheelchair position. A balance must be achieved between the space requirements for the mobility device and the seating/standing spaces for the other passengers. Most low floor transit buses use front door access for persons with mobility devices, requiring a 90 degree turn out of the vestibule, passing through the wheel wells and maneuvering into position. Turning in the vestibule is often limited due to the space taken up by the fare box, and or vestibules that are sloped to accommodate a 1:6 ramp. It is suggested that consideration be given to an alternative access door, namely the center or rear door. This permits the wheelchair positions to be adjacent to the door, which in turn permits space for larger turning radii and shorter dwell times. Access through the front door and maneuvering into the wheelchair position through the wheel wells may result in fewer seats because of the required maneuvering space. Center door access may result in a more favorable seat capacity due to less space required for maneuvering. Flip seats in the wheelchair space location can avoid seat loss. Accommodation for persons travelling with a service animal should be provided. Figures 5 and 6 show lay-outs of low floor paratransit and transit buses. Figures 7 and 8 show flex seating and flip seat seating arrangements

Ramps

Most of the ramps for low floor buses that are older than 3 years have a slope of 1:4, which works well if boarding takes place from a curb and the vehicle can kneel. When boarding directly from the road, the steeper angle can create a safety problem, thus a 1:6 slope is recommended to reduce the problem. The recent changes in ramp slopes from 1:4 to 1:6 had some unintended consequences. However the ramp manufacturers worked with the bus manufacturers and some transit agencies to develop solutions that address the problems encountered in early deployment. It has been suggested that the maximum slope should be 1:8, while this is commendable it is far from practical for either paratransit or fixed-route operations [ESPA, 2009]

There are some new design elements for ramps that must be considered. The transition point for the ramp should be at the door edge of the vestibule. A number of designs for a 1:6 ramp start the slope of the ramp in the middle of the vestibule. This makes it much more challenging for a wheeled mobility device to make the turn and keep all the wheels in contact with the floor. Figure 9 depicts a 1:6 ramp for low floor bus in kneeling position. The Table 17 shows the difference in the length of the ramp for ground to door heights of 14 and 7 in. respectively.

Any slope of the ramp should only start at the edge of the bus floor, not inside the vehicle. The 1:6 slope also has consequences for the landing space infrastructure, extending the depth to 90 in. or 7½ feet for a 7-in. curb and 11 feet for an unimproved surface (Figure 10). In addition, a cross or vertically sloped road at accessible stops should be avoided to prevent tipping when the ramp would be angled laterally. Due to the increase in weight of mobility devices plus heavier occupants, the payload should be increased to 800 pounds. Figure 11 shows an extended bi-fold ramps and a single flip ramp from a kneeling low floor bus.

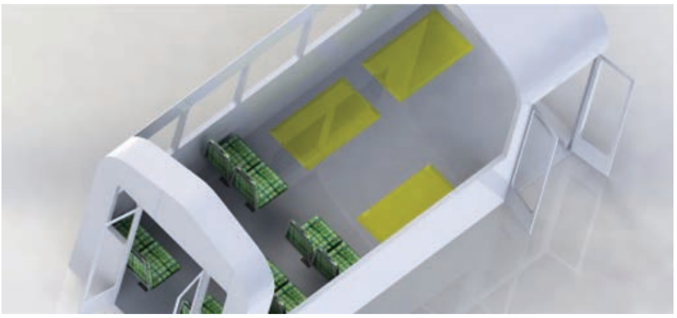


Figure 5. Low floor Paratransit vehicle with front ramp and wheelchair position between axles.

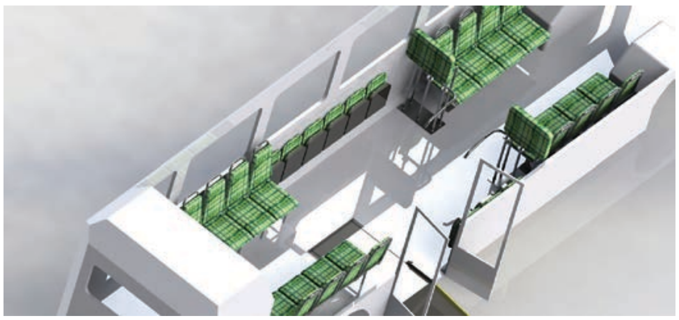


Figure 6. Low floor bus with center door ramp and wheelchair position(s) opposite/adjacent door.

Lifts

The recent changes in wheelchair lift design pertain to the increase length of the platform from 48 inches to 54 inches or longer, and an increase in minimum payload from 600 to 800 pounds or more. There are many transit operators who are specifying the larger lifts on new vehicle procurements. Lift platforms should be equipped with handrails on both sides, safety guards on both sides, and front and rear stops to prevent the mobility devices from rolling off the platform. Lifts should accommodate payloads of 800 pounds or more. Figure 12 depicts the platform of a platform lift with the recommended width of 30 inches and length of 54 inches and a payload of 800 pounds. Figure 13 shows a lift on a high floor inter city bus.

Figure 7. Flex seating with extra wide seat.

Figure 8. Seating with flip seats in securement area.

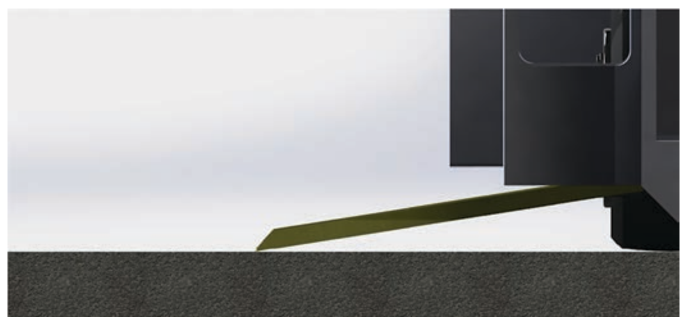


Figure 9. Ramp for vehicles with 1:6 slope.

Bridge Plate

In Bus Rapid Transit(BRT) operations it is common for the station design to include level boarding. If the horizontal gap between the platform and the vehicle exceeds 3 in. (75 mm), and the vertical gap between the platform an the vehicle floor exceeds ⅝ in. (16 mm), a bridge plate should be used for

Table 17. Chart of different ramp lengths and ramp slopes.

	Vertical height (inches)	Ramp Slope			48-in. landing space		
		1:4	1:6	1:8			
Length of ramps(ins)	14	58	85	113			
Horizontal distance(in)	14	56	84	112	104	132	160
Length of ramps(ins)	7	29	43	56			
Horizontal distance(in)	7	28	42	56	76	90	104

Bi-fold ramp for low floor bus, extended ramp length, Ricon Corp
Source: Ricon Corporation.

Single flip ramp, front door, kneeling bus at 7 inch height.
Source: Rutenberg Design Inc.

Figure 10. Two examples of ramps on low floor transit buses.

Figure 11. Bi Fold ramps on transit bus (DART) and low floor paratransit vehicle (ARBOC).

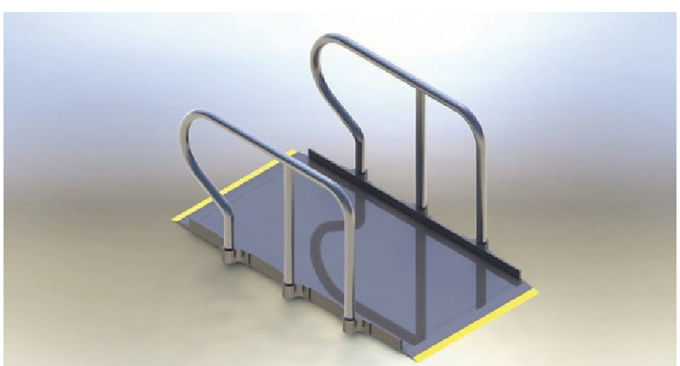


Figure 12. Platform Lift—Platform 30" wide x 54" long, 800 lbs. payload.

boarding. Bridge plates can be movable or be attached to the vehicle or the platform. Bridge plates are common in urban rail operations and more recently in bus rapid transit operations. Figure 14 shows a manual bridge plate between a railcar and the platform.

Securement Systems

The prevailing securement system on urban buses is forward facing with the mobility device secured by four belt straps, two in the front, two at the rear.

Although some WhMD manufactures voluntarily provide attachment points according to WC-19, others do not, which can result in damage to the mobility aid, especially to scooters

Figure 13. Wheelchair lift for intercity/OTRB high floor coach (NJ Transit).

Figure 15. Forward facing securement with four belt securement [Source: www.travelsafer.org/].

when belt straps cannot be applied safely. Recent innovations in securement include the use of fully integrated wheelchair securement stations and adaptable securement systems that have been shown to reduce driver injuries (Figure 15). A challenge for operators is the increasing size of the wheeled mobility aids and the challenge of having enough space and appropriate securement locations to secure these mobility devices. An alternative to be considered is a docking system, similar to the ones used in cars and vans, without straps (Figure 16). To assist drivers with securement, many transit agencies provide tether straps to their customers. It is very important that these straps are attached correctly otherwise the wheeled mobility aid can be damaged and the occupant could be injured.

Rear facing securement is gaining popularity with wheeled mobility users due to the increase in the number of Bus Rapid Transit services and fixed-route operators who are offering this type of securement systems. Initially there were reservations, but once people use rear facing systems it becomes the mode of choice. There are now transit agencies trying to add more rear facing securement stations to their buses to accommodate the increase demand. This has prompted the development of the "flex space" concept. There are double decker vehicles with two rear-facing systems in a row.

Figure 14. Manual bridge plate for use in rail cars (VIA Rail Canada).

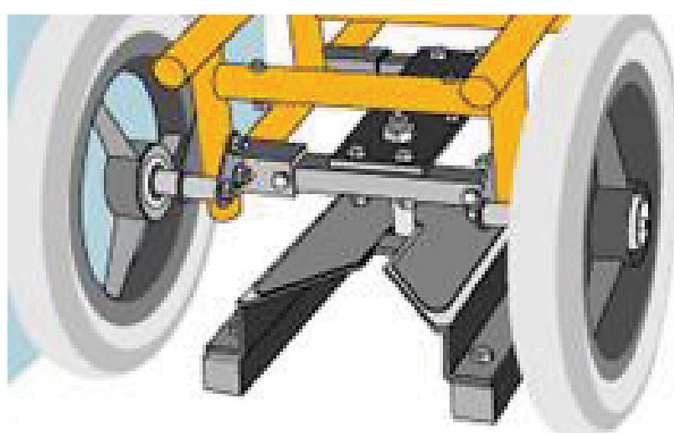


Figure 16. Example of docking system. [Source: https://www.google.ca/#q=docking+system+for+wheelchair]

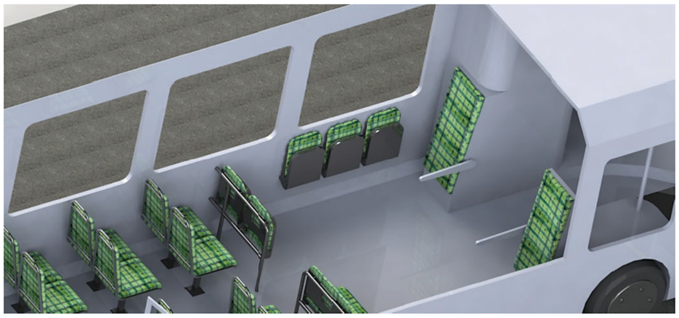


Figure 17. Rear-facing securement with back panel and pivoting aisle arm rest (3g) environment.

Rear-facing systems do not require belt straps or occupant restraints, the WhMD occupant's forward movement is prevented by applying the brakes and resting his/her back against a back panel, which absorbs the deceleration forces. Experience with the system in many countries have shown that it works well in vehicles over 30,000 pounds GVW. One of the challenges with rear facing is the aisle side containment to prevent tipping into the aisle. The basic systems include the curved stanchion, retractable side arms and several other concepts that are under intellectual property protection.

Side facing securement has not been approved for use in the U.S. Research is needed to determine if side facing securement would be an option for BRT type operations. Figure 17 shows a rear facing securement area with a back panel and a pivoting aisle arm, and Figure 18 shows an oversize scooter in a rear facing road side position. There is a drop down arm that restricts sideway motion. Figure 19 shows a rear-facing securement system on the curb side of the bus.

Figure 18. Example of rear facing on road side of bus (BC Transit, Canada).

Figure 19. Rear facing on the curb side of bus with pivoting aisle arm rest to prevent tipping (BC Transit Canada).

Figure 20 shows a rendering of the extended width back and aisle side restraint that was developed by a transit agency for use on the BRT vehicles. The BRT vehicles use center door loading and the aisle restraint remains down.

Figure 21 Depicts two rear-facing securement positions on a double decker bus.

Fare Payment

Many Transit operators use cash fare payment systems, however the industry is moving towards advanced fare payment technologies both on and off the vehicle. Two options for on-vehicle fare payment systems are suggested. These options will increase the amount of space available in the vestibule for the turning radius in the vestibule thus accommodating larger mobility devices. The first option is the complete removal of the fare box floor mount and the second option is to cantilever the fare box. Touch and touchless fare payment systems are being increasingly used by many transit operations. Figure 22 shows a cantilever fare box adjacent to the vestibule.

Figure 20. Extended width back panel and aisle side restraint for rear facing on BRT vehicles (center door loading).

Figure 21. Two rear-facing positions on double decker bus [BC Transit, Canada].

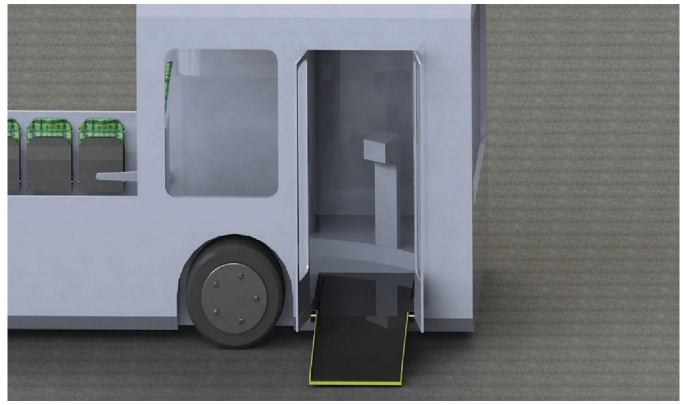


Figure 22. Cantilevered fare box near front vestibule.

Transit Safe and Transportable Mobility Devices

This section addresses the need to identify and describe potential design concepts for "transit safe" and or "transportable" mobility devices.

Transit Safe Mobility Device

Transit safe is a way of boarding, transporting and exiting a passenger in a mobility device on a transit vehicle, such as an urban bus in a safe way without the risk of injury for the occupant of the mobility device, other passengers, the operator, or damage to equipment.

Transportable Mobility Device

A mobility device for public transit can only be transported if it fits within the technical limitations of a transport vehicle, in this case, an urban bus. This includes that the occupant must have a safe operational device and he/she must be capable of entering and exiting with this device on their own. With the present design of urban low floor buses, the WhMD length cannot exceed 48 inches, the turning radius cannot exceed 36 inches, and the weight of the WhMD plus its occupant cannot exceed 600 pounds. If a forward facing securement is used, all WhMD should be equipped with attachment points for belts, such as meeting the requirement of WC-19. Some mobility devices that are larger than 48 inches can be transported on paratransit vehicles, which often have larger interior maneuvering spaces, and the passenger is assisted for boarding, maneuvering and securing by the driver/operator.

Design Concepts for Mobility Devices That Impact Safe Transport

The common element for all transportation is the mobility device and its occupant. As a benchmark, the occupant of a mobility device should be provided with the same level of safety as any other passenger in the bus, seated or standing.

Condition of Wheeled Mobility Devices

The mobility devices must be in good and safe operating conditions, and the occupant should be able to maneuver the device in and out of the vehicle on his/her own when using fixed-route buses. Factors include working brakes, charged batteries, properly inflated tires, and attachment points for securing the device during transportation.

Turning Radius

The geometry of urban buses restricts the turning radius in the vestibule, thus transportable mobility devices must comply with these limits if they are to be transported. On most transit buses, the maximum turning radius is presently limited to 36 in. Manual wheelchairs and power chairs have no difficulty complying with this requirement, but many 3 4-wheel scooters have turning radii that exceed 36 in.

Attachment Points

Attachments points must be mandatory for all WhMDs to secure the device safely in a forward facing position or for stowage as an unoccupied device such as a scooter.

Length of Wheeled Mobility Devices

Wheeled mobility devices exceeding 48 inches in length can have an impact on the turning radius, the space to be occupied during travel on a bus, and the ability to maneuver in and out of the wheelchair position. WhMD length is independent of turning radius. Many large power wheeled devices have a much smaller turning radius than a scooter (Figure 23).

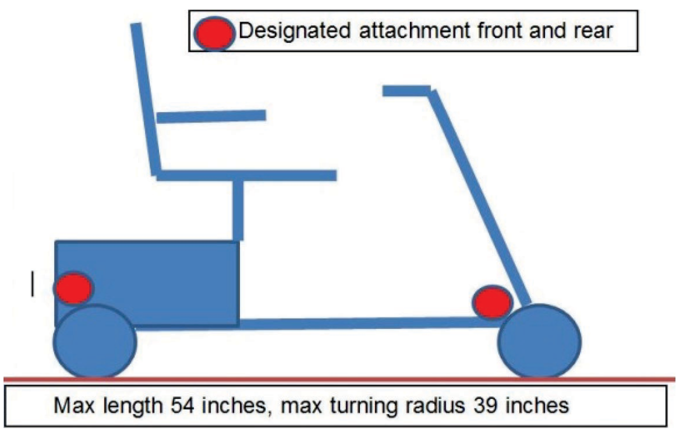


Figure 23. Mobility Device defined length, turning radius and attachment points.

Lightweight Materials

Lighter weight materials that do not compromise the strength of the mobility device should be used as much as possible to reduce the overall weight of WhMDs. Aluminum and carbon fiber materials are used widely now in the automotive and the aircraft industry and now are being used to make WhMDs.

Wheeled Mobility Device Users

The users of a WhMD must ensure that when using public transportation, his/her equipment does not exceed the length of the device by adding front or rear baskets, or other equipment such as canopies. The user must be capable of operating his/her equipment independently to board/deboard a fixed-route vehicle, and maneuver in and out of the securement position. For users that cannot use fixed route transit, they are usually eligible for complimentary ADA paratransit or other paratransit services. Paratransit vehicles, which are generally smaller than transit vehicles may be easier to access, but they almost always require a four point belt securement system.

Prescribers/Dealers/Suppliers Information

The allied health professionals, durable medical equipment dealers and suppliers need to be made aware of the transportation needs of the person who is acquiring a wheeled mobility device and make informed decisions about the wheeled devices and any accessories to insure the safety of the wheeled mobility device user during all aspects of the transport chain.

Transit Agencies

The transit agency should inform the general public about the limitations of transporting a WhMD on fixed-route and paratransit vehicles. Transit agencies should publish information that describes transportable devices including information on the maximum length, turning radius, and weight. In addition, transit agencies should strongly advise their WhMD customers to have transportable WhMDs that are either WC-19 compatible or have obvious attachment points for their securement systems. Transit Agencies that have high ridership of people in WhMDs often provide extended outreach services to provide open door and training sessions for their WhMD clientele to familiarize them with the vehicle lay-out and operations. Some agencies provide complimentary tether straps at public events where trained personnel apply the tether straps at structurally safe locations on WhMDs. In some communities, the transit agencies provide training to the durable medical equipment dealers so that the dealers and suppliers are informed which products can be safely transported. Not surprisingly, these same agencies also partner with the rehabilitation facilities to provide ongoing transit training and this in turn helps to educate the allied health professionals on transportable mobility aids.

Within the transit agency it is the operator who has the responsibility for the safe deployment of the equipment, such as the ramp, the securement systems, and at the same time to be respectful of their passengers and safely operate the vehicle. For the operators there are a number of opportunities for increased risk of injuries in the deployment of forward facing securement systems. These risks for the operator stem from bending, kneeling, reaching and pulling four belt straps and connecting them to the mobility device. During this process, physical contact with the occupant can sometimes not be avoided, which can impose on the dignity of the occupant. Only when the occupant of the mobility device is securely positioned should the operator start driving the vehicle in a manner that avoids jerking, and severe accelerations and decelerations.

There are new securement technologies that lower the injury risk to operators. On large transit vehicles, this includes the use of rear-facing securement systems which are safe, do not require belt straps, and provide greater independence for the mobility device user, and require shorter dwell times. They do require an aisle side means to prevent tipping/moving into the aisle. On paratransit vehicles, there are new four belt securement systems with automatic retractors, and these new systems have been shown to reduce risks to operators.

Transit Agencies and Transit Industry

Characteristics of Accessible and Inclusive Transit Agencies

Transit agencies that are accessible and inclusive often have a culture of innovation and citizen advisory committees that operate collaboratively to make continual improvements for all passengers.

Culture of Innovation

There are several transit agencies that have created a culture of innovation at all levels of the agency. The transit equipment industry in partnership with innovative transit agencies have shown leadership in developing technologies and operational policies that have promoted safer transport of WhMDs on paratransit vehicles and buses. In many instances products that increase access for WhMDs are available, but it is up to the transit agencies to specify them during the procurement process. In other instances, innovation often begins in the transit agency maintenance facility, and then proceeds through collaboration with vehicle and equipment manufacturers.

Advisory Committees

The transit agency's citizen advisory committee on accessible transportation is often the first place that problems or challenges are identified. Transit agencies that provide the most inclusive service also appear to have citizen advisory committees that are highly engaged, collaborative and not adversarial. Members of these committees are often very involved in leading edge developments, procurements and general problem solving which lead to service enhancements, improvements in risk management or cost savings for the agency.

Best Practices

Many of the best practices and innovations that have led to changes in the transit industry started as a result of a problem identified by a consumer. One transit agency had challenges with the first prototypes of 1:6 ramps. There were unexpected consequences, however through a collaboration between the transit maintenance facility staff and ramp manufacturers solutions were developed, tested and now in regular service and marketed by the ramp manufacturer. Another example was the need for better aisle side containment for rear-facing securement systems. There are two innovative approaches for aisle side containment that do not involve stanchions that block the aisle. The new approaches are side restraint systems that can easily be rotated out of the way. One of these approaches is proprietary and is marketed by a vehicle manufacturer; the other is manufactured in house in the transit agency's maintenance facility. An additional new concept on aisle side containment will be released in the near future.

One innovative development for paratransit operations is the use of new low floor vehicles. There are several manufacturers of these vehicles. These vehicles are popular for semi mobile passengers as well as users of WhMDs. The adoption of low floor paratransit vehicles is gaining momentum in the industry. As with any new technologies, there were minor issues with early deployment, but more manufacturers have entered the market and more and more transit agencies are purchasing low floor vehicles.

L.A. Metro has recently reported it has taken a number of steps to improve accessibility through new bold signage, forward facing seats as priority seating, a dedicated spot for walkers that is not in the wheelchair space, and the use of the new three-point securement systems that is intended to make securement easier for the driver or the wheelchair users. In addition L.A. Metro is procuring new 40-foot vehicles that have 1:7 ramps and rear-facing option without securement [Transit Access, 2013].

CHAPTER 7

Research Results

Guidance Document Summary

The accompanying Guidance Document provides a summary of technical and engineering changes in transport vehicles, equipment and WhMDs, and also suggests operational and regulatory changes that together will improve safety for all. New advances in technology are described as well as operational and regulatory changes. New concepts are suggested to help the industry to improve the safety for all passengers and operators. The document is structured on the securement system operating environments of 20 g to 3 g.

Demographics

People who use WhMDs are not homogenous; they are unique in their requirements and use of WhMDs. Some people can use their upper body, others cannot; some can stand and walk for short distances, and some can transfer from their device to a seat. Changing population demographics include: aging, obesity, and the increased use of scooters.

Wheeled Mobility Devices (WhMDs)

Challenges

There is a great variety of WhMDs, from manual self-propelled chairs to power chairs, bariatric chairs, walkers, 3- and 4-wheel mobility scooters and Segways®. Oversized mobility devices are wider than 30 in., longer than 48 in., and have a turning radius of more than 36 in., and often cannot be accommodated on most fixed-route buses. The size of the transit vehicle vestibule and available turning radius is compromised by fare box position, and onboard ramps. Many times the oversized WhMD is transported on paratransit vehicles. However, some WhMDs are even too heavy for paratransit and transit bus lifts and ramps. There are several manufacturers who produce WhMDs that comply with WC-19, and are deemed "Transit Safe." Most durable medical equipment insurance providers do not fund accessories to make WhMDs transit safe or compliant with WC-19.

Suggestions

The suggested parameters for describing the physical attributes of a transportable mobility device will permit the accommodation of about 90% of WhMD in common use, including many of the larger scooters. The recommended parameters are:

- Footprint: 30 in. wide, by 54 in. long
- Maximum turning radius: 39 in.
- Maximum weight including occupant: 800 pounds

In addition, all WhMDs that are occupied during transport should be designed to resist a 20 g acceleration and meet the requirements of WC-19. These provisions will accommodate WhMDs transported in smaller minivans and accessible taxis. The new parameters would permit more WhMDs to be transported and the parameters would provide a common framework for design and operations. Using the common parameters for WhMDs, would establish the physical limits of oversized WhMDs for paratransit vehicles and buses. Information should be shared with the durable medical equipment and allied health community to insure that consumers who purchase or procure WhMDs are properly informed about the physical limits of their equipment with respect to access paratransit vehicles and buses.

Impact of the Suggestions for Parameters for WhMDs

Several other changes would need to be done if the expanded parameters of WhMDs with a width of 30 in., a length of 54 in., and a turning radius of 39 in. were accepted. These changes include:

- Center or rear door boarding with adjacent wheelchair locations or
- Front door access; the removal of the fare box or the use of a cantilevered fare box to accommodate the larger turning radius; flat vestibule area
- Larger maneuvering space to get in and out of the wheelchair position, and or
- Flex space that will accommodate two more wheelchair securement spaces and other passengers; this will likely impact seat type and capacity
- Consideration of staggered or tandem configurations for wheelchair securement areas
- Increase ramp or lift payload to 800 pounds or more.

Transit Agencies

Challenges

The biggest challenges for transit agencies are both the size and diversity of WhMDs, and many of these devices cannot be secured with the available securement technologies. Transit agencies also face the challenge of maintaining adequate seating capacity and providing enough interior space to accommodate larger wheeled mobility devices. Transit agencies are also encouraged by risk management to reduce operator injuries and still maintain schedules.

Suggestions

Vehicle Layout

The use of low floor vehicles for both paratransit and transit operations benefits all passengers especially those who use wheeled walkers. Vehicle interiors that have the option for "flex space" can increase the number of WhMDs that can be transported. Flex space on transit buses can be used by standees or accommodate passengers with luggage. Flex spaces on paratransit vehicles that have appropriate securement systems will accommodate oversize WhMDs.

Lifts and Ramps

All platform lifts and ramps should be rated for at least 800 pounds. Platform lifts should be at least 54 in. long and 30 in. wide. Where possible the ramps should have a maximum slope of 1:6, however the ramp slope should be continuous and start at the door so that the vestibule is flat.

Paratransit vehicles are still mainly high floor, and they are equipped with lifts at different locations such as the rear, rear curbside or front curbside.

Securement Systems

The securement area should be located between the front and rear axle because the passengers are much more vulnerable to injury from the vertical accelerations when the securement area is located behind the rear axle. The stairs in high floor vehicles are a challenge for many passengers. Some paratransit providers have reported difficulties with very heavy occupied WhMDs on the lifts, and on the vehicle suspension system. Forward facing wheelchair securement systems are the most common systems used on paratransit vehicles in the United States. They require two front and two rear belts and a three point belt occupant system for a 20 g environment. The driver is responsible for their deployment. Not all WhMDs can be secured and many passengers refrain from using occupant restraint devices. There is a need to provide operators with options for the safe securement of oversize WhMDs. It is recommended that the forward facing securement systems that are easier for the operators to attach to WhMD be used. These new systems reduce operator risk and are more dignified for the WhMD user. It is also recommended that some of the seats have pivoting armrests for easier transfers and that space should be identified for service animals.

Fare Payment

It is recommended that for transit buses the tapered fare box platform be used when fare payment devices are required to optimize clear space in the vestibule. When possible, transit agencies should strive to develop smart and off-vehicle fare payment systems that minimize the space required in front vestibule. New fare payment systems should also accommodate people with sensory and cognitive impairments.

Number of WhMD positions

Several transit agencies, particularly those operating large articulated vehicles in regular and BRT service have expressed interest in providing space for 3 or more WhMDs. The use of forward and rear-facing securement systems provide more than 2 spaces. In the U.S., forward facing securement must be provided, and rear facing is an option. Forward facing securement systems require the use of 3 or more belt securement systems. In transit buses operating in a 3 g environment, rear-facing securement with aisle side containment is safe and more dignified.

Access Doors

In large transit buses such as articulated and BRT vehicles, center door boarding with WhMD accommodation adjacent to door will accommodate large WhMDs. In Australia and

Spain, side-facing securement is used. The use of side-facing securement should be studied for U.S. applications.

Flip Seats

Flip seats/benches are typically located in the wheelchair locations. One seat manufacturer is providing flip seats that are designed for obese passengers.

Transit Operators

Challenges

Risk Management and Training

Risk management for driver/operators is an ongoing issue due to the need to physically assist passengers with disabilities and physically attach many of the belt type securement systems. Recurrent training for operators is needed to address the evolving changes in demographics, WhMDs and securement technologies. There is a need for the allied health and durable medical equipment industry to take responsibility to inform consumers of WhMDs about the transportability of these devices on public transportation vehicles.

Suggestions

Operators who provide passenger assistance for vehicle access or for the deployment of securement and occupant systems should be trained in risk avoidance and risk management. Training and refresher courses should also be in place for operators. Eligibility centers that provide opportunities for passengers to practice accessing vehicles and maneuvering in the interior of the vehicle enhance travel training, and increase the safety of both passengers and operators.

Standards

The quality of life and independent living are dependent upon access to both private and public transportation. People riding in accessible private vehicles or accessible taxis are generally more vulnerable than people riding a transit bus, and this is simply due to the mass of the vehicle. Requiring WhMD that are occupied during transport to be compliant with WC-19 protects everyone. The risk of exposure in small vehicles that operate in a 20 g environment are significantly higher than those of a large buses and BRT type vehicles that operate in a 3 g environment. Recommending that all WhMD are WC-19 compliant or transit safe, will ensure that occupied WhMD users are protected during transport in an accessible taxi and also on regular transit and BRT vehicles.

Challenges

The research reported in the final report for this project shows that the multiple stakeholder groups involved with the transport of WhMDs on paratransit vehicles and buses would like new regulatory parameters for WhMDs. These parameters described will improve the safety and security of passengers and operators. In addition, it has been suggested that there is a need to change some voluntary standards such as the WC-19 into mandatory (i.e., not voluntary) standards or regulations.

Suggestions

A key suggestion is to acknowledge that WhMDs have increased in size and accordingly, to set new parameters for length, width, turning radius and width for WhMD that are transported on vehicles. Across the stakeholder groups there was recognition of the need to require securement attachment points on all WhMD that are occupied during transport. In addition there are recommendations that insurance programs cover the costs of WC-19 compliance.

Education of Allied Health Professionals

Challenges

The Allied Health Professionals are very important stakeholders in the procurement of WhMDs. It is rare that transportation modes and operating environment are considered in the prescription and procurement of WhMDs. In addition, many WhMDs are procured by family members and the key stakeholder is the durable medical equipment dealer, or an online vendor. It is important to raise awareness through advocacy and public information, as well as changing the insurance process to ensure that Transit Safe WhMD become the norm and not the exception.

Suggestions

The key suggestion is to insure that allied health professionals receive training on the prescription of Transit Safe Wheeled Mobility Devices and that the professional certification process include education on the safe transport of WhMD on private and public vehicles. In addition, the training and certification for durable medical equipment dealers should also include training and education on the safe transport of WhMDs. Risk Management and Liability Insurance programs that support the training and certification of allied health professionals and durable medical equipment dealers can require and support the importance of prescribing transit safe wheeled mobility aids.

CHAPTER 8

Implementation Plan

Research Product

It is anticipated that a significant result of this research project will be a "roadmap" to harmonization of standards that impact the use of mobility devices on paratransit vehicles and buses.

Product Market

Harmonized standards pertaining to the size and use of mobility devices on paratransit vehicles and buses as well as other modes of public transportation will benefit all stakeholders, including:

(i) people who use mobility devices;
(ii) mobility device manufacturers;
(iii) retailers, government and insurance agencies that fund mobility devices;
(iv) allied health professionals, who prescribe mobility devices;
(v) transit agencies (local, regional and state);
(vi) manufacturers of vehicles;
(vii) vehicle access technologies including lifts, ramps and boarding devices;
(viii) manufacturers of mobility device securement and occupant restraint systems;
(ix) fare collection devices; and
(x) agencies that regulate or oversee regulations and standards for mobility devices.

Implementation Challenges

The project team recognizes that there are institutional, operational and technical challenges that need to be overcome. The team also acknowledges that due diligence must be applied in implementation to insure that professional ethical standards are maintained.

Engaging WhMD Industry and DME Dealers

The survey respondents completed only a few questions on the survey. Currently, a small number of U.S. wheelchair manufacturers participate in providing wheeled mobility devices that are compliant with WC-19 standards.

Engaging Funding and Insurance Agencies

There is a need to raise awareness of the transportation needs of WhMD users during the prescription process. Transportation is an essential element for independent living, education and employment. There is a need to expand collaborations between local DME providers, insurance and funding agencies as well as the Allied Health Community. These collaborations may have more of an impact in small- and medium-sized communities. Agencies that fund WhMDs should be strongly encouraged or required to pay for modifications that make the WhMD WC-19 compliant and or "transit safe" if the user will remain seated in their devices during transport. This effort would not include walkers.

Leadership for Implementation

Leadership for change comes from stakeholder groups, the government and insurance agencies that fund mobility devices and the allied health professionals who prescribe them. Manufacturers of vehicles, equipment, and mobility devices can initiate and lead changes in their respective fields. Professional Organizations of allied health professionals may assist in the prescription of and development of voluntary standards for WhMDs. All the stakeholders must be included in the implementation process.

Implementation Steps

The roadmap should be implemented in steps that include activities in the short term (1–3 years), medium term

(3–5 years), and long term (over 5 years). In the short term, the best practices provide evidence for short term changes and opportunities for stakeholders to adapt or adopt immediately. For the medium term, the research results suggest the need for regulatory reform. In addition, the transit industry is already producing and marketing technologies that make transit safe for all transit users, but the transit agencies need to procure them. The involvement of key stakeholders will bring about improvements in recommended practice, while being mindful that reform will also require staged implementation. In the long term, it is anticipated that the transit vehicles, mobility devices and related technologies will comply with standards that are harmonized across the U.S. and Canada, and the results will be public transportation that is safe, seamless and dignified.

New Opportunities: Collaborations/Partnerships

Short Term. There are several recommendations that are low cost and have immediate impact. Many transit agencies host open houses and invite people who use WhMDs to come and practice boarding transit vehicles. Some of these agencies also offer free "tether straps" and free installations by trained professionals. These straps help vehicle operators attach belt type securement systems to WhMD that are not equipped with WC-19 compliant attachment points. Most power chairs have areas where the tether straps can be safely attached; however many three- and four-wheeled scooters do not have any safe attachment areas for either tether straps or securement systems.

Other events involve collaboration between transit agencies and local durable medical equipment dealers. These events provide an opportunity for familiarization of the durable medical equipment (DME) dealers with the access challenges of public transportation vehicles. In turn, these can help the dealers provide more informed advice to clients who purchase WhMDs to use on public transport vehicles. Providing DME dealers with the opportunity to try boarding different models of WhMDs on transit buses is an education for all.

In some cities, transit agencies reach out to local chapters of allied health professional groups and provide educational seminars on access to paratransit vehicle and buses. This also provides an opportunity to impact the rehabilitation process and ensure that WhMDs that will be used in private and public vehicles are safe for transport. Mobility training as part of the rehabilitation process also improves the success of independent community living.

There are a number of larger transit agencies in North America that construct a mock-up that uses the front section of a transit vehicle and for orientation and training purposes. Often the mock-up is combined with an ADA eligibility center and permits potential customers the opportunity to practice maneuvering on and off a bus without an audience.

There are emerging best practices that will in time impact access to paratransit vehicles and buses. For paratransit, these include low floor paratransit vehicles that include access at the front door with large vestibules that accommodate larger WhMDs and provide seating and securement space between the two axles.

There are some models of transit buses that have larger vestibules with up to 38 in. for a turning radius, other vehicles have flat vestibules and the fare box is cantilevered to minimize impact on the turning area. There are also transit vehicles that use rear-facing securement and provide two or more wheelchair locations on the vehicle. On large transit buses such as articulated vehicles that operate in BRT service, center door access accommodates oversize WhMDs. Some operators with rear-facing securement have developed aisle side containment systems that are fixed to the padded rear board. This increases interior circulation by removing an aisle stanchion.

Research has also shown that new belt securement systems that are specifically designed for transit buses and are equipped with retractors reduce driver involvement and driver accident claims. In addition, new belt securement systems that have been designed for paratransit vehicles are popular with drivers as they also reduce driver involvement during the securement operation.

Medium and Long Term. The research activities related to TCRP Project C-20 showed a strong desire for more definition of transportable WhMDs. This included realizing that WhMDs are larger, and heavier than the common WhMD that was defined in the original ADAAG, and that the current broad definition is a challenge for many stakeholders. The project suggests increasing the length of the footprint to 54 in., increasing the weight of the occupied WhMD to 800 pounds and including a turning radius of 39 in. as a measure of maneuverability. In addition, it is strongly recommended that all WhMD that are occupied during transport meet the WC-19 requirements.

Other long-term recommendations include, designing low floor paratransit vehicles and buses that have flat vestibules that permit a 39-in. turning radius. Paratransit operators who provide securement systems that minimize driver involvement are experiencing a reduction in operator injury claims that have been attributed to the new securement technology.

Table 18 shows the suggested short-, medium- and long-term implementation strategies.

Roadmap to Change Vision of the Future

Partnerships

- Encourage local and regional partnership between DME dealers, rehabilitation centers and public transportation

Table 18. Suggested short-, medium- and long-term implementation strategies.

Item	Implementation Short term 1-3 years	Implementation Medium term 3-5 years	Implementation Long term Over 5 years
Paratransit layout	Increase use of low floor vehicles with ramp. Wheelchair position between front and rear axle. Place for service animals.	Provide seats for obese passengers; Increase floor area for forward facing with 4 anchor belt type securement.	Comply with standards that are harmonized across the U.S.
Users	Develop training manuals and websites for scooter users to access public vehicles		
Fixed route vehicle Lay-out	Use of cantilevered fare boxes to increase turning radius in vestibule.	Use of center door access to reduce maneuvering floor space	Use of 3 g securement environment
Mobility devices	Develop definition for mobility devices for length, weight, turning radius		Implement standards for transportable mobility devices for all public transportation
Mobility device manufacturers	Install hardware for attachment points, WC-19. Advise customers of mobility devices about the limits of transportability on public vehicles	Provide basic training for use of motorized mobility devices in public transportation	
Operations	Carriers to publicize widely policies for the safe transport of WhMD. Reduce risk for assisting person with mobility devices, e.g., boarding, securement	Establish risk management policy; Provide open doors, rodeos for access practice by users	Implement risk management policies for operators/users
Training	Establish training policy; provide regular Training and refresher for operators	Develop training manuals, and websites	Implement training manuals
Lifts	Increase length of lift platforms to 54 inches; increase payload to 800 pounds plus	Implement for all lift equipped vehicles	Implement standards
Ramps	Low floor vehicles with 1:6 ramp slope; increase payload to 800 pounds plus	Implement 1:6 slope for all situations where boarding from road level may occur	Implement standards
Fare payment	Cantilevered fare boxes; touch or touch less systems; develop standards	Implement touch or touch less systems in addition to cantilevered fare boxes	Implement standards
Securements	Apply securement in 3 g environments	Develop new forward facing systems without tie-down straps	Comply with standards that are harmonized across the US and Canada
Public forums/Advisory Committees	Organize regular public forums with manufacturers, users, regulators and funding agencies to discuss common issues	Update guidelines based on forum outcomes	Update guidelines based on forum outcomes
Standardization	Harmonize standards for all public transportation modes	ongoing	ongoing

providers to clearly delineate size and types of WhMDs that can safely be transported
- Work to develop "ADA eligibility centers" that provide opportunities for travel training including boarding and securing on buses

Standards

New and defined parameters for WhMD that are transported on paratransit vehicles and buses will bring consistency for WhMD users and the transit industry.

Transit Industry

- Low floor paratransit vehicles and transit buses, with sufficiently large vestibules that accommodate a 39 in. turning radius or the use of center loading doors
- Development and deployment of driver friendly securement systems for 20 g vehicles including small minivans
- For rear facing securement systems, wider deployment of aisle side containment devices that don't impede interior circulation or standee passengers
- For large BRT transit vehicles research the feasibility of side facing securement

WhMD Industry

- Encourage design and marketing of WhMD that meet or exceed WC-19 requirements

Institutional Change

- Train allied health professionals and DME dealers to consider clients transportation needs when prescribing WhMD
- Work with insurance industry to fund WC-19 and other enhancements for transit safe WhMD

Table 19 provides a Checklist for Operators to examine compliance.

Table 19. Checklist for operators.

	Compliance Status		
Elements/Items	**Paratransit** ***Yes*** ***No*** ***Partial*** ***Not Applicable***	**Fixed route** ***Yes*** ***No*** ***Partial*** ***Not Applicable***	**Comments**
Transportable WhMDs 30" x 48", turning radius up to 36"			
Transportable WhMDs oversized 30" x 54", turning radius over 36"			
Lift platform size 30" x 48"			
Lift platform size 30" x 54"			
Lift payload 600 lbs.			
Lift payload 800 lbs. plus			
Ramp slope1:4 (not recommended)			
Ramp slope 1:6			
Securement 20 g: Forward facing			
Securement 3 g Rear facing			
Securement large vehicle : Rear facing; Side facing (To be considered)			
Occupant restraint, 3 belt			
Single Seats			
Double Seats			
Bench Seats			
Flip seats			
Seat for obese			
Fare payment cash fare box (-cantilevered)			
Touch card fare payment			
Touch less card Fare payment			
Eligibility policy			

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Abbreviations and Acronyms

ADA: Americans with Disabilities Act

ADAAG: ADA Accessibility Guidelines for Buildings and Facilities

ADD: Automatic Docking Device

ANSI: American National Standards Institute

Anthropometric: Science dealing with measurement of the size, weight, and proportions of the human body

Attachment points: Fixed and designated points on a mobility device to attach tie-down straps to secure the mobility device onboard vehicles against movements.

BRT: Bus Rapid Transit

CSA: Canadian Standards Association

DDA: Disability Discrimination Act (Australia)

Deceleration: The rate of change of decreasing velocity of movement

Demand Responsive: refers to public transportation that operates on request, may include Complementary ADA and paratransit services. May also include community shuttles

DfT: Department for Transport, United Kingdom

DME: Durable Medical equipment

DSAPT: Disability Standards for Accessible Public Transport (Australia)

DVLA: Driver and Vehicle License Agency (UK)

ED: Emergency Department

Footprint: the static two-dimensional area occupied by a wheeled mobility device.

Forward-facing securement: Securement of wheelchairs facing forward in the driving direction of the vehicle

G force: a measure of the force resulting from acceleration measured in m/sec^2 or ft/sec^2

GVW: Gross Vehicle Weight, a term used to describe vehicles.

ISO: International Standards Organization

Lift platform: the two-dimensional flat floor space of a lift to accommodate a wheeled mobility device.

Low floor buses: buses which have at least one section of their bus with a low floor

Maneuvering: Performing or causing to perform a movement or series of moves with a mobility device in a vehicle requiring skill and care such as in vehicle boarding

NPRM: Notice of Proposed Rulemaking

Occupant restraint: System to restrain the movement of a mobility device occupant while travelling onboard a vehicle. A separate system from the wheelchair tie-down anchorage, typically a three point belt system consisting of shoulder and lap belts.

Paratransit vehicles: Vehicles transporting passengers who are disabled and cannot use public transportation

Payload: (design load) is the maximum rated weight of a lift or ramp.

People who are obese: People are considered obese when their body mass index is greater than 30.

Project ACTION: Accessible Community Transportation In Our Nation

Rear-facing containment/securement: An area in a vehicle where the passenger in a wheeled mobility device travels facing rearward or backwards from the direction of travel

RESNA: Rehabilitation Engineering and Assistive Technology Society of North America

SAE: Society of Automotive Engineers

Securement: System to secure the movement of a mobility device against vehicle forces

Service animal: A trained animal used by people with disabilities.

Side-facing containment: An area in a transit bus where the mobility device is facing perpendicular to the direction of travel

TCQSM: Transit Capacity Quality of Service Manual

Tie-down: Belts/straps to be used to attached to a mobility device and the vehicle floor to prevent the mobility device from moving

Urban buses: In general, vehicles that operate on fixed routes and scheduled service and may range in length from 24 to over 60 ft. BRT and Articulated vehicles may be longer

WC-19: Voluntary Industry Standard, requiring fixed attachment points on a mobility device to secure the mobility device onboard vehicles

Wheeled Mobility Device (WhMD): wheeled mobility devices, also referred to as mobility devices, include manual wheelchairs, three and four wheeled scooters, power wheeled mobility devices, walkers, and other wheeled devices such as the Segway**. Of primary concern are manual, power wheelchairs and mobility scooters.**

ATTACHMENT
Guidance Document

Use of Mobility Devices on Paratransit Vehicles and Buses

Oregon State University
Corvallis, Oregon

in collaboration with

Rutenberg Design Inc.
Ottawa, Canada

November 2013

Purpose

The purpose of this document is to provide a concise guide for achieving a vision of more accessible public transportation vehicles for more people, and a guide to changes that range from low cost and short term to long-range structural changes to federal regulations and standards.

Background

The project final report documents background, research findings and recommendations. This is a practical guide for practitioners. Details are in the final report. The problem being addressed is the safe transport and accommodation of large wheeled mobility devices (WhMD) on paratransit vehicles and buses. This problem has been exacerbated by recent changes in the definition of WhMD and changes in the population demographics. Transit agencies are faced with providing transport for devices that are too large to safely access the vehicle or cannot be secured in a safe manner. As a consequence vehicle operators are being exposed to higher levels of risk. This guide provides a summary of the technical and engineering changes in transport vehicles, equipment and WhMD, and also suggests operational changes that together will improve safety for all. All the recommended technical changes are already available. Several of the new advances in technology will only be described in general terms to not compromise intellectual property. The operational changes span the time line from immediate (and low cost) to much more long term.

In this project the operating environment is described in terms of the needs for WhMD securement. The paratransit maximum operating environment is 20 g and includes vehicles that range in size from small mini-vans up to large twenty five foot coaches. The transit buses are assumed to operate in a maximum 3 g environment and include vehicles with GVW of 30,000 pounds and over. These vehicles can be a 25-foot transit bus up to a long articulated bus or Bus Rapid Transit (BRT) vehicles. In this study, the BRT vehicle has also been considered a maximum 3g environment.

Issues/Challenges from Research Results

The following (Table 1) is a summary of issues/challenges resulting from the research via literature search, surveys, web investigations and interviews. Detailed information is provided in the final report and project documentation.

Impacts

Table 2 uses a level of importance of High, Medium, Low and Not Applicable to summarize the impact of WhMD of Paratransit vehicles and buses in terms of the Guidance principles.

Description of Innovative Concepts: Prototypes/Production/Operations

Concept Criteria

The following criteria were established for new concepts, based on issues identified from research. Some prototypes are described in very general terms as most are still in testing phases and protected by intellectual property restrictions. Many of the recommended changes that involve transit equipment are already available and many transit agencies are procuring this equipment. The research phase of the project clearly indicated a desire by many stakeholders to return to a more precise definition of a transportable mobility device. Transit agencies and the transit equipment industry clearly would like specific parameters for wheeled mobility devices (See Figure 1). Suggested parameters include the following and are based on research that is reported in the Project Final Report.

Wheeled Mobility Devices (WhMD)

The suggested parameters will permit the accommodation of about 90% of WhMD in use. This includes larger scooters.

- Footprint: 30 in. wide by 54 in. long
- Maximum turning radius: 39 inches
- Maximum weight including occupant: 800 pounds

Table 1. Summary of challenges.

Topic	Description	
Demographics	People who use wheeled mobility devices are not homogenous; they are very unique in their requirements and use of WhMDs. Some people can use their upper body, others cannot; some can stand and walk for short distances, and some can transfer from their device to a seat. Changing population demographics include: aging, obesity, and an increased use of scooters.	
Wheeled Mobility Devices (WhMD)	There is a great variety in WhMDs, from manual self-propelled chairs to power chairs, bariatric chairs, walkers, 3 and 4 wheel mobility scooters and Segways®. Oversized mobility devices are wider than 30 in., longer than 48 in., and have a turning radius of more than 36 in. and as a result, cannot be accommodated on most fixed route buses. The size of the vehicle vestibule and available turning radius is compromised by fare box pedestals, and on board ramps. Most oversized WhMDs are transported on paratransit vehicles. Some WhMDs are too heavy for paratransit and transit bus lifts and ramps. Most WhMDs currently do not comply with WC-19, and are not deemed "Transit Safe". Bariatric chairs accommodate heavier persons and those who require a wider seat. Clearance between wheel wells on low floor transit buses is typically 36". The width of a bariatric chair typically does not exceed 32", and can be transported on-board a transit bus.	
Funding	Most Durable Medical Equipment (DME) Insurance providers do not fund accessories to make WhMDs transit safe or compliant with WC-19.	
	Paratransit	**Fixed Route Transit**
Vehicle lay-out	Vehicle lay-outs that have flex space with different seat configurations depending on the local provider.	The geometric lay-outs of fixed route buses can accommodate WhMDs with a maximum turning radius of 36 inches at the front entrance, and turning radius larger than 36 inches if there is a center door access. WhMDs with large turning radius cannot be transported on most fixed route transit buses. Most transit vehicles can only accommodate two WhMD.
High floor	Paratransit vehicles are still mainly high floor, equipped with lifts at different locations, rear, rear curbside or front curbside. Increased passenger vulnerability when the securement area is located behind the rear axle as a result of vertical accelerations in high floor vehicles. The stairs in a high floor vehicle are a challenge for many passengers. Some providers have reported difficulties with very heavy occupied WhMDs on the lifts, and on the vehicle suspension system.	Most urban buses are now low floor with a ramp at the front or center door. Some high floor buses are intercity vehicles that are defined as Over the Road Buses (OTRB) and these are used for commuter services.
Lifts	Lift payloads are limited to 600 lbs., and do not accommodate heavier weight occupied WhMDs. Many lift platforms cannot accommodate WhMDs over 48 in. in length, and this leaves a number of WhMD passengers at the curb.	
Ramps	Ramps can be single flip ramps, telescopic ramps or bi-fold. Ramps for low floor vehicles have a slope of 1:4 (14 degrees), but a slope of 1:6 (9.5 degrees) or less is recommended, as long as the ramp slope does not start in the vestibule area, and slope is continuous. Payloads are limited to 600 lbs. and cannot accommodate heavier WhMDs combined with user.	
Securement	Forward- and rear-oriented wheelchair securement belt systems based on the voluntary WC-19 standard are the most common systems used in the US. They require two front and two rear belts and a three point belt occupant system for a 20 g environment. The driver is responsible for their deployment. Not all WhMDs can be secured and many passengers refrain from using occupant restraint devices.	In the U.S., forward-facing securement must be provided, and rear facing compartment with a padded back barrier is an option. Forward and rearward oriented securement systems require use of 3 or more belt type securement systems. In large vehicles over 30 000 lbs. GVW, a rear facing compartment, with aisle side containment is safe for a maximum 3 g environment.

(continued on next page)

Table 1. (Continued).

Topic	Description	
Seats	Seat configuration and capacity on vehicles depend on the number and positioning of wheelchair locations.	Seat combination can be 2+2, 2+1 and side facing. Some operators only provide perimeter seating with space for many standees. Flip seats/benches are typically located in the wheelchair locations. There are no designated or specific seats for obese passengers, except where there are benches without center armrest. Few vehicles have designated areas for people traveling with service animals.
Fare payment	Not Applicable	Fare payment methods range from in-vehicle (cash fare box), to off-vehicle (prepaid tickets and passes), to touch and touch less smart cards. The trend is going toward cashless smart cards. Fare box pedestals/bases impact on the turning radius of larger WhMDs in the vestibule and can be a barrier to access by WhMDs.
Risk management and Training	Risk management for driver/operators is an ongoing issue due to the need to physically assist passengers with disabilities and physically attach many of the belt type securement systems. Recurrent training for operators is needed to address the evolving changes in demographics, WhMD and securement technologies. There is a need for the allied health and durable medical equipment industry to take responsibility to inform consumers of WhMDs about the transportability on public transportation vehicles of these devices.	
Regulations	ADA Part 1192.21	ADA Part 1192.21 and 151

Table 2. Impacts on paratransit vehicles and buses.

Guidance principles	Impact on small paratransit vehicles less than 30 000 lbs. (20g)	Impact on large Transit vehicles 30 000 lbs. and over (3g)	Comments
1 Passenger Characteristics			
1.1 Uses Manual WhMD	Low	Medium	
1.2 Uses Powered WhMD	Medium	Medium	
1.3 Obese	Medium to High	Medium	
1.4Travelling with service animal	High	High	Space available for service animal
2.Wheeled Mobility Device (WhMD) Characteristics			
2.1 Length, 54 in., (increase % of WhMD accommodated)	Medium	Medium - High	Depends on lift or ramps design
2.2 Weight 800 pounds (increase % of WhMD and Occupant accommodated)	Medium	High	Depends on lift/ramps payloads. Industry moving toward heavier payloads
2.3 Turning radii: 39 in. (Addresses scooter needs)	Medium	High: (few vehicles with turning radius larger than 38 inches)	Note: Many paratransit operators transport occupied scooters
2.4 Transit Safe WhMD-(WC-19)	High	Medium	
2.5 Funding of transit safe WhMD	High	High	Insurance providers should fund accessories to make WhMD transit safe
3.Transit Vehicle			
3.1 Interior configuration	High	High	
3.2 Access front door	High	High	Vestibule space may present access barrier
3.3 Access center door	Medium	Medium	Center door access avoids vestibule and is more accessible
3.4 Vestibules	Medium	High	
3.5 Fare payment	NA	High	
4.Transit vehicle equipment			
4.1 Lifts	High	NA	
4.2 Ramps	Medium	High	

4.3 Seats	Medium	High	
4.4 Bridging plate	NA	NA	
5.Securement Types			
5.1 Forward and rear orientation (4 point belt systems)	High	High	
5.2 Rear facing compartment with padded back barrier	NA	High	
5.3 Side facing	NA	NA	Research is needed to identify impact of side facing securement in US operating environment
5.4 Occupant restraint – 3 point lap and shoulder belt	High	Medium	
6.Transit Operations			
6.1 Driver involvement	High	Medium-Low (rear facing does not require driver involvement)	Depends on type of securement systems
6.2 Driver risk	High	High	
6.3 Dwell times,	Medium	High	
6.4 Seat capacity	Medium	Medium	Depends of agency standards for mix of seated and standing passengers
7. Standards Access			
7.1 Increase lift/ramp payload to 800 pounds	High	High	Industry is manufacturing and selling heavier lifts in many procurements
7.2 Revise ramp slope to 1:6	High	High	Industry has taken action to make improvements to mitigate problems in early deployments
7.3 Increase length of lift platform from 48” to 54”	High	NA	Industry is moving to producing longer lifts
7.4 Increase WhMD footprint from 30” x 48” to 30” x 54”	Medium	High-Medium	Interior design and seating configuration directly impacted

Note: According to USDOT: In vehicles 22 feet in length or less, the required securement device may secure the wheelchair or mobility aid either facing toward the front of the vehicle or facing rearward, with a padded barrier as described. Additional securement locations shall be either forward or rearward facing with a padded barrier.

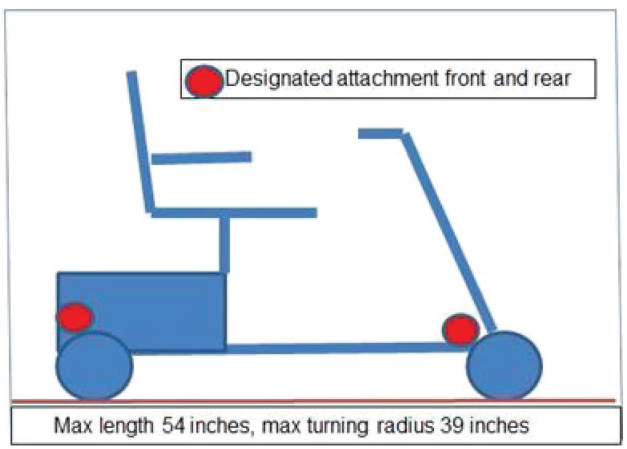

Figure 1. Mobility device with defined length, turning radius and attachment points for securement.

In addition all WhMD that are occupied during transport should be designed to remain intact during a 20 g deceleration from 30 mph and meet the other requirements of WC-19. These provisions will accommodate WhMD transported in smaller minivans.

Lifts and Ramps

All lifts and ramps should be rated for at least 800 pounds and platform lifts should be 30 × 54 in. Ramps should have a maximum slope of 1:6 (9.5 degrees). Figure 2 depicts a lift, and Figure 3 depicts a 1:6 ramp.

Fare Payment

In transit buses, cantilever pedestals should be used when fare payment devices are required to optimize clear space in

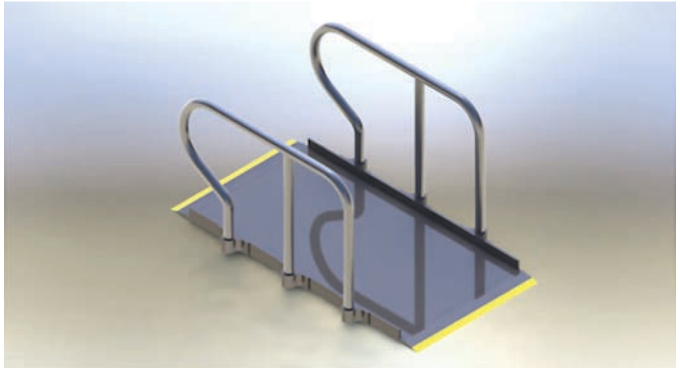

Figure 2. Lift platform size of 30" wide × 54" long with 800 lbs. payload.

the vestibule. When possible, transit agencies should strive to develop smart and off-vehicle fare payment systems that minimize the space required in the front vestibule. New fare payment systems should also accommodate people with sensory and cognitive impairments. Table 3a and b is a summary of key concepts. Figure 4 shows a ramp at the front of a low floor bus and a cantilevered fare box without floor pedestal.

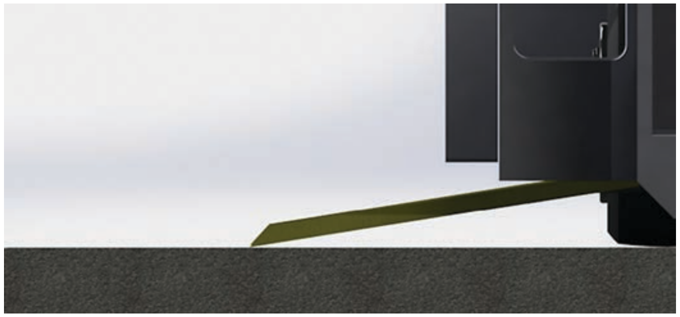

Figure 3. Ramp with 1:6 slope.

Access

In Figure 6 note that there are three spaces for wheelchairs, two rear facing and one forward facing (barrier not shown).

Operational Safety and Security

It's necessary to protect both operators and passengers who use WhMDs. In addition passengers and their equipment/

Table 3a. Summary of key concepts.

Access

Paratransit Vehicles	Transit Buses
Low Floor, front door or mid door access, see Figure 5.	Front door with 39 in. turning radius and flat vestibules or center door access adjacent to securement areas. Flex space for securement with rear facing that accommodate more than two or more WhMDs, 30 inch aisles (see Figure 6). Space for service animals. When using public transportation, a service animal requires a space where it cannot be stepped on by other passenger. The place should be in the vicinity of its patron, see Figure 7.

Table 3b. Summary of key concepts.

Paratransit Vehicles (20 g)	Transit Buses (3 g)
Belt type securement that minimizes operator involvement and risk, see Figure 8	Two rear facing positions with one or more forward facing position, see Figure 10
Securement areas located between front and rear axles	Use flex space and flex seating: forward, rear and side facing seats, see Figure 11
Docking securement, see Figure 9	Single flip seats rated for obese passengers, see Figure 12

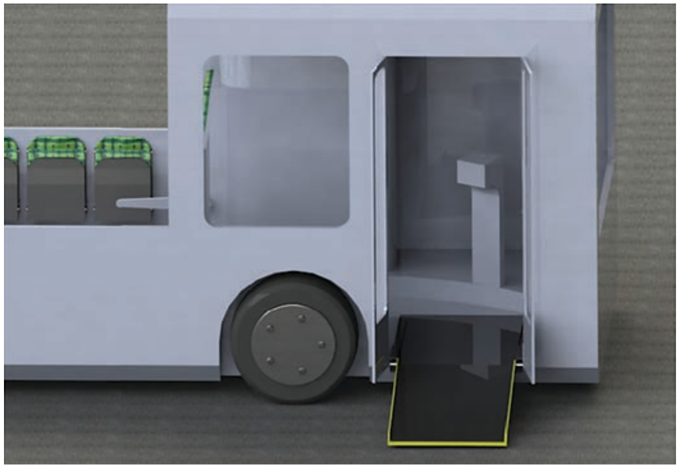

Figure 4. A ramp at the front of a low floor bus and a cantilevered fare box without floor pedestal.

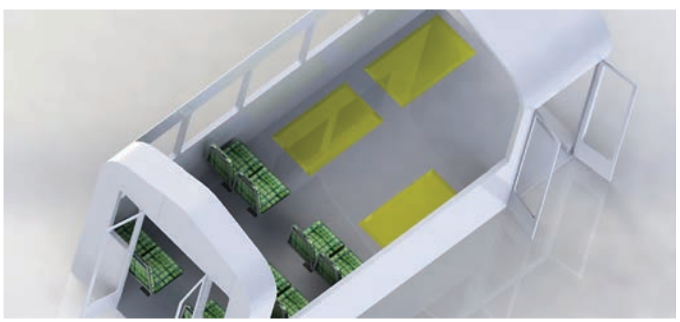

Figure 5. Low floor paratransit vehicle with front door ramp and wheelchair positions between front and rear axles.

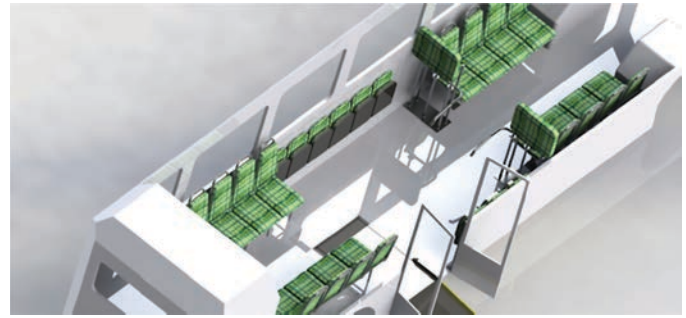

Figure 6. Low floor bus with center door ramp and wheelchair positions opposite/adjacent to door.

Figure 7. Example for space for service dog underneath bench seat [Source: http://www.queenslandrail.com.au/].

Figure 8. Forward facing four belt securement system [www.travelsafer.org].

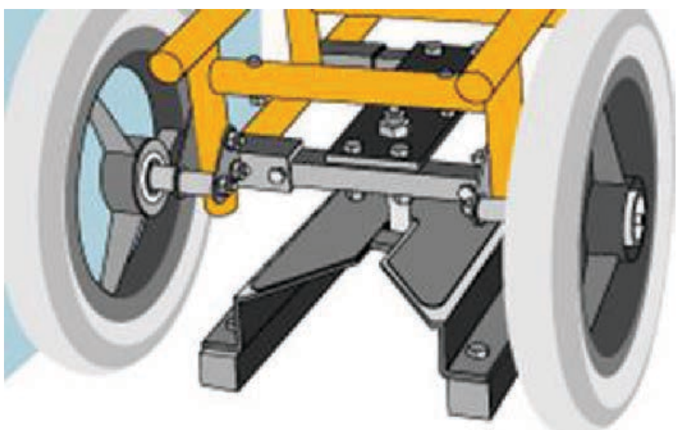

Figure 9. Docking type securement [www.travelsafer.org].

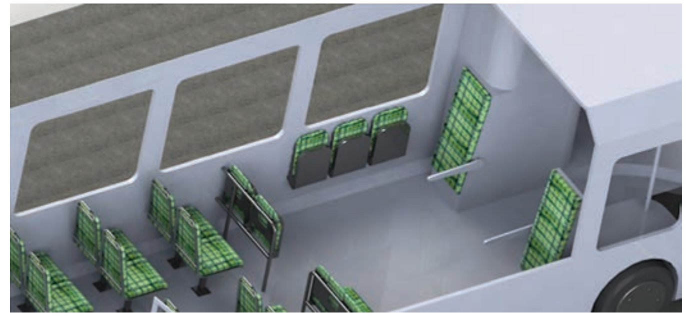

Figure 10. Rear facing securement with pivoting aisle arm.

Figure 11. Seating with flip seat in securement area.

Figure 12. Seating with extra wide seat.

mobility devices must be accommodated both safely and with dignity during boarding, exiting and travelling onboard vehicles. Note that passengers travelling in small paratransit vehicles or accessible taxis are exposed to higher acceleration forces than on larger transit vehicles.

Eligibility

Establish eligibility programs based on equity, mobility assessments, demand, cost, and local legislations. Larger operators can combine an eligibility center with a mock-up of a transit bus. These centers provide a central location for people to practice accessing fixed route transit vehicles and also completing the eligibility process.

Access Policy for Oversized WhMDs

Using the common parameters for WhMDs, establish the physical limits of oversized WhMDs for paratransit vehicles and buses. Information should be shared with the durable medical equipment and allied health community to insure that consumers who purchase or procure WhMDs are properly informed about the physical limits of their equipment with respect to accessing paratransit vehicles and buses.

Risk Management and Training

Operators who provide passenger assistance for vehicle access or for the deployment of securement and occupant systems should be trained in risk avoidance and risk management. Training and refresher courses must be in place for operators. Eligibility centers that provide opportunities for passengers to practice accessing vehicles and maneuvering in the interior of the vehicle, enhance travel training, and increase the safety of both passengers and operators.

Innovation and Best Practices

Culture of Innovation: The transit equipment industry in partnership with innovative transit agencies have shown leadership in developing technologies and operational policies that have promoted safer transport of WhMDs on paratransit vehicles and buses. In many instances, products that increase access for WhMDs are available but it is up to the transit agencies to specify them during the procurement process. In other instances, innovation often begins in the transit agency maintenance facility, and then proceeds outward through collaboration with vehicle and equipment manufacturers.

Advisory Committees: The transit agency's citizen advisory committee on accessible transportation is often the first place that problems or challenges are identified. Transit agencies that provide the most inclusive service also appear to have citizen advisory committees that are collaborative and not adversarial. Members of these committees are often very involved in leading edge developments, procurements and general problem solving which lead to service enhancements or cost savings for the agency.

Best Practices: Many of the best practices and innovations that have led to changes in the transit industry started as a result of a problem identified by a consumer. One transit agency had challenges with the first prototypes of 1:6 ramps. There were unexpected consequences. However, through collaboration between the transit maintenance facility staff and ramp manufacturers solutions were developed, tested, and are now in regular service and marketed by the ramp manufacturer. Another example was the need for better aisle side containment for rear facing securement systems. There are two innovative approaches for aisle side containment that do not involve stanchions that block the aisle. The new approaches are side restraint systems that can easily be rotated out of the way. One of these approaches is proprietary and is marketed by a vehicle manufacturer; the other is manufactured in house in the transit agency's maintenance facility. An additional new concept on aisle side containment will be released in the fall of 2013 by a securement manufacturer.

One of the most innovative developments for paratransit operations is the new low floor vehicles that are entering the market. There are several manufacturers who currently produce these vehicles. These vehicles are very popular for semi mobile passengers as well as users of WhMDs. Transit agencies who have recently introduced low floor paratransit vehicles successfully include Tulsa Transit, fleets in Lubbock, Texas;

and Holland Michigan in the U.S., as well as OC Transpo and BC Transit in Canada. L.A. Metro has ordered a large number of low floor transit buses with innovative features, such as a place for walkers, a 1:7 boarding ramp, a new three-point securement system, a rear-facing option without securement, separate dedicated places for users of wheelchairs, and seats for seniors and persons with disabilities.

New Opportunities: Collaborations/Partnerships

There are several recommendations that are low cost and have immediate impact. Many transit agencies host open houses and invite people who use WhMDs to come and practice boarding transit vehicles. Some of these agencies also offer free "tether straps" and free installations by trained professionals. These straps help vehicle operators attach belt type securement systems to WhMD that are not equipped with WC-19-compliant attachment points. Most power chairs have areas where the tether straps can be safely attached, however many three- and four-wheeled scooters do not have any safe attachment areas for either tether straps or securement systems.

Other events involve collaboration between transit agencies, and local durable medical equipment dealers. These events provide an opportunity for familiarization of the durable medical equipment (DME) dealers with the accessibility challenges of public transportation vehicles. In turn, these can help the dealers provide more informed advice to clients who purchase WhMDs to use on public transport vehicles. Providing DME dealers with the opportunity to try boarding different models of WhMDs on transit buses is educational.

In some cities, transit agencies reach out to local chapters of allied health professional groups and provide educational seminars on access to paratransit vehicle and buses. This also provides an opportunity to impact the rehabilitation process and ensures that WhMDs will be used in private and public vehicles are safe for transport. Mobility training as part of the rehabilitation process also improves the success of independent community living.

There are a number of larger transit agencies in North America that use the front section of a transit vehicle as an orientation vehicle. This vehicle is combined with an ADA eligibility center and permits potential customers the opportunity to practice maneuvering on and off a bus with coaching but without an audience.

There are emerging best practices that will in time impact access to paratransit vehicles and buses. For paratransit, these include low floor paratransit vehicles that include access at the front with large vestibules that accommodate larger WhMD and provide seating and securement space between the two axles.

There are some models of transit buses that have larger vestibules with up to 38 in. for a turning radius, other vehicles have flat vestibules and the fare box pedestal is cantilevered to minimize impact on the turning area. There are also transit vehicles that use rear-facing securement and provide two or more wheelchair locations on the vehicle. On large transit buses such as articulated vehicles that operate in BRT service, center door access accommodates oversize WhMDs. Some operators with rear facing securement have developed aisle side containment systems that are fixed to the padded rear board. This increases interior circulation by removing an aisle stanchion.

Research has also shown that new belt securement systems that are specifically designed for transit buses and are equipped with retractors reduce driver involvement and driver accident claims. In addition, new belt securement systems that have been designed for paratransit vehicles are popular with drivers as they also reduce driver involvement during the securement operation.

Long Term Outlook

The research activities related to the TCRP Project C-20 showed a strong desire for more definition of transportable WhMDs. This included realizing that WhMDs are larger and heavier than the common WhMD that was defined in the original ADAAG, and that the current broad definition is a challenge. The project suggests increasing the length of the footprint to 54 in., increasing the weight of the occupied WhMD to 800 pounds, and including a turning radius of 39 inches as a measure of maneuverability. In addition, it is strongly recommended that all WhMD meet the WC-19 requirements.

Other long term recommendations include, working to design low floor paratransit vehicles and buses that have flat vestibules that permit a 39 in. turning radius. Paratransit operators who provide securement systems that minimize driver involvement are experiencing a reduction in operator injury claims that have been attributed to the new securement technology.

Roadmap to Change Vision of the Future

Access Standards

- New and defined parameters for WhMD that are transported on paratransit vehicles and buses, this will bring consistency for WhMD users and the transit industry.

Transit Industry

- Low floor paratransit vehicles and transit buses, with sufficiently large vestibules that accommodate a 39 in. turning radius or the use of center boarding doors.
- Development and deployment of driver friendly securement systems for 20 g vehicles including small minivans.
- For rear-facing securement systems, wider deployment of aisle side containment devices that don't impede interior circulation or standee passengers.
- For large BRT transit vehicles, research the feasibility of side facing securement.

WhMD Industry

- Encourage design and marketing of WhMDs that meet or exceed WC-19 requirements.

Institutional Change

- Train allied health professionals and DME dealers to consider clients transportation needs when prescribing WhMD.
- Work with insurance industry to fund WC-19 and other enhancements for transit safe WhMD.

Opportunities

- Encourage local and regional partnership between DME dealers, rehabilitation centers and public transportation providers to clearly delineate size and types of WhMD that can safely be transported
- Work to develop "ADA eligibility centers" that provide opportunities for travel training including boarding and securing on buses

Table 4 suggests solutions for paratransit and fixed route transit and also indicates who is responsible for these solutions.

Table 4. Solutions/recommendations.

	SOLUTIONS/RECOMMENDATIONS		
Elements	**Paratransit**	**Fixed Route Transit**	**Who Is responsible?**
Demographics	Increase awareness of the impact of changing demographics, e.g. increase in elderly population, increase of use for scooters, increase of obesity		Operators, and Relevant Organizations
WhMD	Define transportable WhMD in terms of width, length, turning radius and weight. Require WC-19 compliance.		Manufacturers , Operators, Relevant Organizations
Funding	Insurance providers do not fund accessories to make WhMDs transit safe		Durable Medical Insurance companies
Vehicle Layout	Flex space increases maneuverability and capacity	Consider use of flex space to support use of rear-facing securement. Provide 3 or more securement spaces, Use café seating	Vehicle manufacturer, transit equipment manufacturers, operators
High floor/low floor	Increase procurement and use of low floor vehicles with front ramps for easier access for all; locate all securement spaces between front and rear axles for safer and better ride quality.	Most urban buses are now low floor with a ramp at the front or center door. Some high floor buses are used for commuter services.	Operators
Lifts	Increase lift payload to 800 or more pounds Increases lift platform to length of 54 in. or more.		Manufacturers (most already do this)
Ramps	Use a 1:6 ratio continuous ramp slope, with articulation at door and with flat vestibule where possible.		Manufacturers (most already do this)
Securement	Use advanced forward-facing securement systems for easier operation, and a three-point belt occupant restraint for a maximum 20 g environment.	Consider use of rear-facing systems in large vehicles over 30 000 lbs. GVW. Rear facing is safe in a maximum 3 g environment, and increases independence for users. Use advanced forward-facing securement systems for easier operation Consider side-facing systems for large vehicles over 35 000 lbs.	Manufacturers Operators
Seats	Seat configuration and capacity on vehicles depend on the number and positioning of wheelchair locations. Seat combination can be 2+2, 2+1 and side facing. Flip seats/benches are typically located in the wheelchair locations. Consider designated or specific seats for obese. Consider designated place for persons traveling with service animals.		Manufacturers (most already do this) Operators
Fare payment	Not Applicable	Eliminate fare boxes, or use cantilever pedestals to increase turning radius in front entrance vestibule. Consider the use of touch and touch less smart cards.	Operators Manufacturers
Risk management and Training	Establish risk management policy for driver due to the need to physically assist passengers with disabilities and physically attachmany of the belt type securement systems. Establish training programs and refresher courses for operators and drivers needed to address the evolving changes in demographics, WhMD and securement technologies. Inform and educate the allied health and durable medical equipment industry to take responsibility to inform consumers of WhMD about the transportability on public transportation vehicles of these devices.		Operators, Vehicle and Agency Insurance Industry

Priorities for Implementation

Table 5. Checklist for operators.

	Compliance Status		
Elements/Items	**Paratransit** ***Yes*** ***No*** ***Partial*** ***Not Applicable***	**Fixed route** ***Yes*** ***No*** ***Partial*** ***Not Applicable***	**Comments**
Transportable WhMDs			
Transportable WhMDs 30” x 48”, turning radius up to 36”			
Transportable WhMDs oversized 30” x 54”, Turning radius over 36”			
Lifts and Ramps			
Lift platform size 30” x 48”			
Lift platform size 30” x 54”			
Lift payload 600 lbs.			
Lift payload 800 lbs. plus			
Ramp slope1:4			
Ramp slope 1:6			
Securement			
Securement 20 g; Forward facing			
Securement 3 g; Rear facing			
Securement 1 g; Side facing			
Occupant restraint, 3 belt			
Seats			
Single			
Double			
Bench			
Flip seats			
Seat for obese			
Fare payment			
Cash fare box			
Touch card			
Touchless card			
Funding			
Eligibility policy			

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation