U.S. Department of Transportation

Federal Railroad Administration

Inclusive and Universal Accessible Design Considerations for Next Generation of Passenger Railcars

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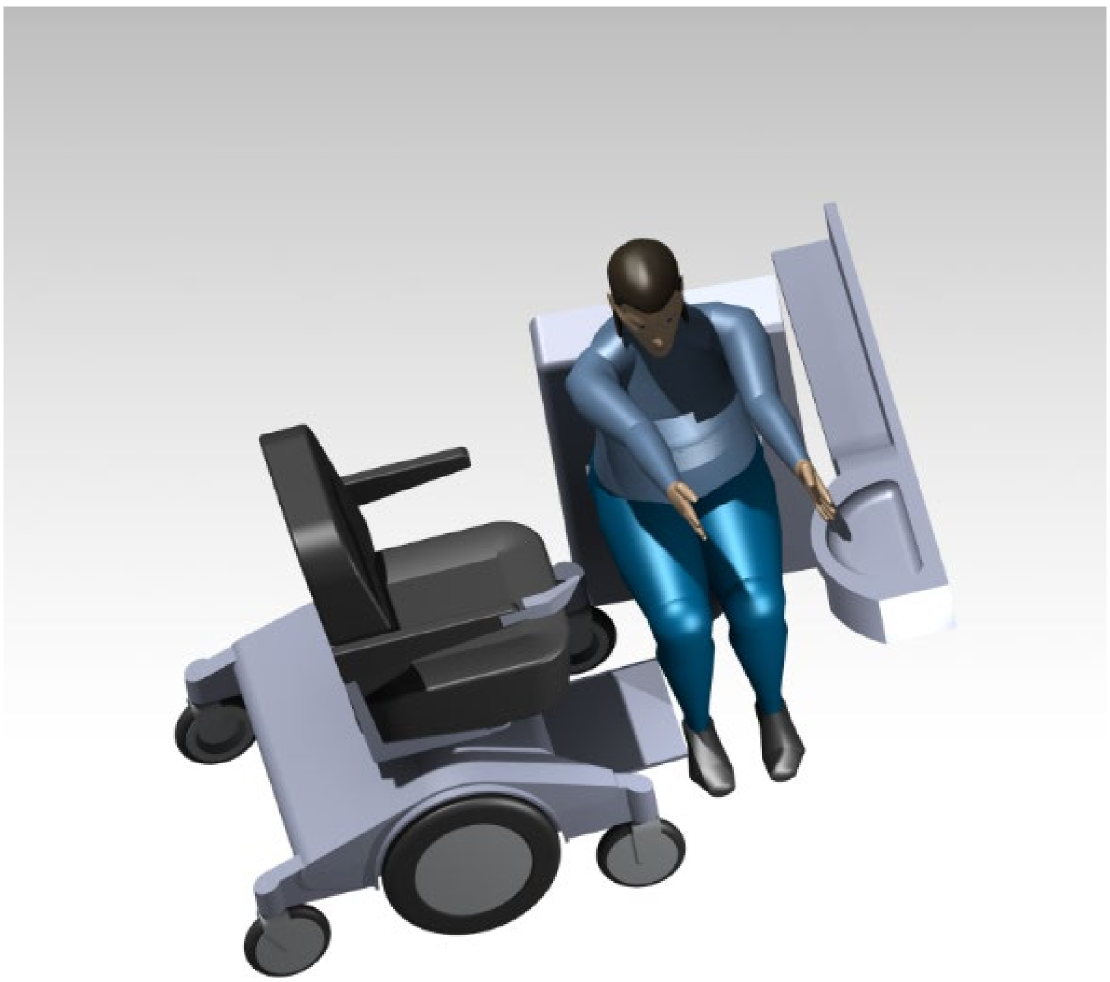

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13. ABSTRACT (Maximum 200 words)
Oregon State University (OSU), with Federal Railroad Administration support, investigated universal, inclusive, and accessible design for the next generation of passenger rail cars. Working with the Next Generation Equipment Committee, OSU developed recommendations for improved accessibility on the next generation of intercity bi-level and single-level passenger trains. The two major recommendations were increased design load of 800 lbs for onboard wheeled mobility device (WhMD) lifts and ramps and a 30-inch by 54-inch platform footprint which accommodates large scooters. OSU conduced additional studies on accommodating larger WhMDs, including an accessible restroom design that accommodates a 180-degree turn; the passageway from the vestibule to the accessible seating area; and an analysis of an accessible seating area for two or more WhMDs. Results showed that containment of WhMDs and occupants must be considered, when more than one WhMD is accommodated on a rail car. Researchers studied railroads that use elevators for passenger access to the upper level in response to the U.S. Access Board, Rail Vehicle Access Advisory Committee (RVAAC) recommendations for access by WhMD to the upper-level on bi-level cars. Further study is needed to develop new technical specifications for equipment that provide access to the upper floor of bi-level cars.

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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

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1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

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1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

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1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

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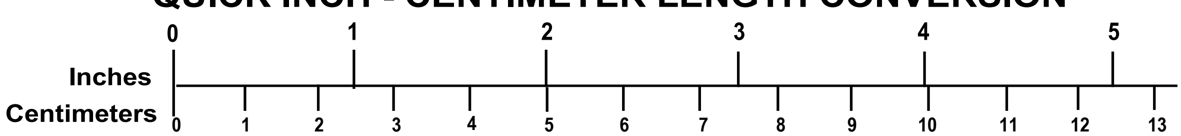

QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

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Executive Summary

The Federal Railroad Administration (FRA) selected Oregon State University (OSU) to investigate universal and inclusive accessible design for the next generation of passenger trains. FRA worked in collaboration with OSU and the Passenger Rail Investment and Improvement Act (PRIIA) Section 305 Next Generation Equipment Committee (NGEC) Accessibility Working Group (AWG) in the development of recommendations for improved accessibility. OSU performed the research from April 11, 2011 to September 15, 2018. In Phase I of the research, an OSU research team developed inclusive and universal recommendations for accessibility in the next generation of high-speed and intercity passenger rail cars. The team developed accessibility recommendations for single-level and bi-level coach cars. The bi-level recommendations, as outlined below, were incorporated into the specifications for the PRIIA bi-level car Section 1.2.1 ADA Requirements, and will ultimately be included in the passenger railcars built to those specifications. Those recommendations include:

- Increase wheeled mobility device (WhMD) accessibility space to 32 inches by 59 inches (minimum requirement is 30 inches by 48 inches).
- Increase vestibule width to 44 inches (minimum requirement is 42 inches).
- Increase design load of car-borne wheelchair lift to 800 lbs (minimum requirement is 600 lbs).
- Increase surface platform of the car-borne wheelchair lift to 30 by 54 inches (minimum requirement is 30 inches by 48 inches).

Phase II of the research studied the feasibility of these recommendations with new recommendations from the U.S. Access Board Rail Vehicle Access Advisory Committee (RVAAC). Researchers used layouts of the Acela first class and business class cars provided by Amtrak as the base to evaluate the proposed recommendations. Initially, other Amtrak vehicles were investigated, but OSU determined the Acela had the best base design characteristics due to its available interior space. Researchers then studied designs of a larger accessible restroom and larger accessible seating area to accommodate a power base wheeled mobility device (WhMD). Phase II research also examined the seat loss associated with accommodating two or more WhMDs and service animals in the seating areas adjacent to the accessible restrooms in both first class and business class cars. Researchers analyzed restroom accessibility to develop a footprint for an accessible restroom that permitted a power base WhMD to enter forward facing, turn 180 degrees, and exit in the forward facing. Other key findings from the analysis and input from the NGEC AWG included insuring that the toilet was longitudinally oriented to the train and inclusion of a small sink accessible from the toilet by a 5th percentile female. Other key dimensions included a wider restroom entry door of at least 40 inches and 42 inches clear opening, which was preferred so as to accommodate restroom entry from a 36-inch wide aisle. In addition, researchers recommended a 12-inch vertical toe and a 27-inch vertical knee clearance and a 17-inch total horizontal clearance under the sink to facilitate access to the sink and general movement about the restroom.

The analysis shows that the tradeoff between inclusion of a larger accessible restroom and the number of WhMDs accommodated is not directly related to seat loss. It is possible with minimal seat loss to accommodate more than one WhMD and larger accessible restroom. Folding seats in accessible spaces may be an option to combat seat loss from improved accommodations. In calculating seat loss, it is also important to consider that passengers who board in manual wheelchairs or scooters will transfer to a regular seat.

This study also investigated RVAAC's recommendation that new bi-level intercity lounge cars built for Amtrak or its successors used on sightseeing routes enable vertical movement between the lower and upper level of the equipment. This access can be provided in non-revenue cars such as lounge or café cars. The research investigated the possible use of elevators to access the upper level on bi-level cars in response to RVAAC recommendations. Three railroads operating bi-level passenger trains with elevators were contacted; they were consistent in their responses. All three railroads have: (1) much higher staffing levels than most regular commuter or intercity passenger services; (2) elevators are operate during train movement as well as when stopped at stations; (3) are operated by trained train crew personnel; and (4) ambulatory passengers who have difficulty negotiating stairs were the most frequent users of the elevator.

Phase III studied the impact on passenger containment from accommodating two or more WhMDs in a passenger railcar. The research showed that there was no one seating configuration that balanced access and containment. The design of passenger railcars to accommodate more than one WhMD must take into account containment of the occupant. Currently, intercity and commuter rail passenger equipment is designed with row-to-row seating configurations. In the event of an accident or derailment, passengers are contained between the seat back in front of them and their seat. This layout provides a safe space for passengers to ride out the accident and minimize injuries from secondary and tertiary impacts. The safety and independence of passengers must be balanced when investigating accessibility and occupant protection.

In summary, the research showed that the next generation of passenger rail vehicles can be designed to be more inclusive and universal, providing accessibility for passengers using WhMD and those with other cognitive disabilities.

1. Introduction

Intercity regional and higher-speed passenger rail (HrSR) service in the U.S. has the potential to be *the* transportation mode of the 21st century to efficiently move passengers across the nation. As such, newly manufactured passenger rail coach cars and trainsets should be designed to be inclusive and universal for all passengers, especially those with cognitive and physical disabilities. Oregon State University (OSU) spearheaded a research effort on behalf of the Federal Railroad Administration (FRA) to investigate universal and inclusive accessible design for the next generation of passenger trains. FRA worked with OSU and the NGEC AWG in the development of the recommendations for improved accessibility. The research was conducted from April 11, 2011 to September 15, 2018.

1.1 Background

The next generation of passenger cars must be designed to accommodate a passenger demographic that is getting older and larger. Existing standards for railcar accessibility do not address the changing population demographic. It is estimated that by 2030, 25 percent of the population will be elderly or have physical, sensory, or cognitive limitations (U.S. Census Bureau, 2012). The project presented an opportunity to develop functional requirements for passenger cars based on inclusive and universal design and also considered the particular constraints of intercity and HrSR operations and vehicles. The project entailed the development of functional requirements for accessible high-speed and intercity passenger railcars. The requirements are based on international research and are responsive to the engineering requirements and market forces of higher- and high-speed rail (HSR).

The U.S. Department of Transportation enforces accessibility standards for public transportation vehicles based on the Americans with Disabilities Act Accessibility Guidelines (ADAAG) for Transportation Vehicles. FRA interprets and enforces the requirements of ADAAG for intercity and commuter rail passenger equipment being operated across the nation. The current standards for accessibility for both are established in 49 Code of Federal Regulation (CFR) Part 38 Subparts E and F, respectively. The research team reviewed the regulations based on current state-of-the-art accessibility and communications amenities and features available for passenger rail coach cars, the types and characteristics of WhMDs being used by rail passengers, and the regulations' ability to provide access to those passengers.

Throughout the project, the rail industry and other stakeholders actively participated in project activities to ensure the functional requirements were balanced across the competing needs of all stakeholders. Early in the project, the NGEC AWG was established and included representatives from a number of Federal agencies inside and outside DOT, the U.S. Access Board, Amtrak, representatives of the railcar equipment manufacturing industry, industrial trade associations, and representatives from advocacy groups. Meetings held in Washington, DC provided a forum for consultation, focusing on the design parameters for interior circulation—specifically the size of the "design" mobility aid and the level of overall access to the train consist. A key outcome of the forum was stakeholder consensus on the size of the mobility aid to be the basis for the functional requirements and a description of the population demographics to be accommodated. The U.S. Access Board hosted the forum that raised the awareness of the need to form the RVAAC.

The research products developed in the project serve as a guidance document for the NGEC and as reference materials for the RVAAC that was convened by the U.S. Access Board.

Demographic trends in the U.S. show a population that is increasingly aged, obese, and disabled. Regardless of their physical or mental condition, all Americans deserve a transportation system that facilitates employment, education, and social interaction. Passenger rail shows remarkable promise as the mode of the future for intercity passenger transportation. Railcars have very limited interior space for passenger accommodation and amenities, and the over-arching need to minimize weight and simultaneously optimize occupant protection and safety. At the same time, there are significant changes in population demographics and the technology deployed in public transportation vehicles. New functional requirements are needed to accommodate all these changes for the next generation of HSR passenger cars.

To ensure access with dignity and accommodation for all people—while maximizing seat revenue generation—researchers balanced the functional requirements. In addition, the functional requirements considered the technical and vehicle operating dynamics characteristics of HSR, and in turn these will directly affect passengers who are seated or moving about in vehicles as well as the protection of mobility device users. Interior designers must be mindful of the horizontal and lateral (side-to-side) accelerations directly experienced by passengers. Unlike air travel, WhMD users have the option of remaining seated in their mobility device. This directly affects restroom design, onboard circulation, and access to other amenities such as the dining car because space is needed to accommodate these features. Typically in current passenger rail operations, WhMDs are not secured or contained.

1.2 Objectives

At the outset of the research project, the OSU team addressed several key questions to meet the competing design requirements. One set of major questions involved the weight, footprint size, and turning radius of the WhMDs to be accommodated on HSR vehicles, considering the diversity of mobility devices used in the U.S. Researchers determined these parameters for developing reasonable functional requirements for aisle widths, door and seating configurations, accessible restroom, other amenity specifications, and the overall level of mobility device access in the train consist.

Working with the AWG and ultimately the NGEC, the OSU team developed accessibility recommendations for PRIIA single-level and bi-level coach cars. The bi-level recommendations, as outlined below, were incorporated into the specifications for the PRIIA bi-level car, and will ultimately be included in passenger railcars built to those specifications.

- Increase WhMD accessibility space to 32 inches by 59 inches.
- Increase vestibule width to 44 inches.
- Increase design load of car-borne wheelchair lift to 800 lbs.
- Increase surface platform of the car-borne wheelchair lift to 30 inches by 54 inches.

The research team conducted an initial assessment of the impact of the recommendations on the interior of a single-level Acela first class coach car. Feedback on the review from the AWG and NGEC Technical Subcommittee (TSC) directed FRA and the OSU research team to conduct more in-depth study of the impact of the recommendations on single-level coach class cars. The study conducted a spatial analysis of the recommendations and also incorporated some of the recommendations from the U.S. Access Board RVAAC.

1.3 Overall Approach

The project used inclusive and universal design principles as the basis for developing the functional requirements—while balancing the level of access for all. The functional requirement focus areas included: restrooms, seats, doors and aisles, access and egress, and real-time passenger information and communication systems. The project focused on the needs of passengers with physical, sensory, and cognitive limitations; passengers with service animals; and also considered the needs of obese individuals, which in some states already represents 33 percent of the population. Researchers used Amtrak drawings of Acela first class and coach class cars as the base for the study of accessible restrooms and corresponding seating areas. The OSU team then converted the new recommended design parameters for WhMDs and the draft functional requirements to 2-dimensional and 3-dimensional renderings and validated them using manikins that represented 5th percentile female and 95th percentile male populations. The mobility devices included sport manual wheelchairs, power wheelchairs, and four-wheel scooters that met the 30-inch wide by 54-inch long footprint. After consultation and analysis, the team used the power base mobility device for both the seating and restroom accessibility analysis. Researchers placed the mobility scooter in the first class seating area but did not use it in the restroom accessibility analysis.

In addition, by using inclusive design principles, HSR cars will also accommodate families traveling with strollers and small children. The functional requirements also incorporate specific recommendations for accessible real-time passenger information and communication systems for next station information, connections and transfers to other modes, and emergency and evacuation information and procedures.

1.4 Scope

Researchers focused on providing access for passengers with disabilities and those using WhMDs on passenger trains. The initial recommendations were for bi-level and single level coach cars. Sleeper cars were not covered in the current functional requirements. The research team conducted initial assessments of the impact of the recommendations on the interior of a single-level Acela first class coach car and other regional trains. Feedback on the review from the NGEC AWG directed FRA and the OSU research team to conduct a more in-depth study of the impact of the recommendations on single-level coach and business class cars that included regional and Acela cars. The researchers conducted spatial analysis of the recommendations developed and on some of the recommendations from the RVAAC.

The team conducted validation studies to examine onboard restrooms and seating areas through virtual models of accessible restrooms and seating areas that incorporate many of the functional requirements.

1.5 Statutory Language and Recommendations

Accessibility requirements for intercity passenger rail services can be found in 49 CFR §§ 37 and 38. Section 2 of the report discusses functional requirements recommendations for accessibility on the next generation of single-level passenger rail cars. The new recommendations provide accommodation for larger WhMDs that exceed the minimum requirements of 49 CFR §§ 37 and

38 (ADAAG, 2006). Aspects of the regulations not specifically discussed in this document are assumed to be adequate and therefore there are no recommendations at this time for them to be updated.

1.6 Organization of the Report

The team conducted the project in two phases. Phase I produced functional requirements and Phase II conducted analysis on some of the key areas identified in Phase I. Section 1 provides introductory and background material for the overall project. Section 2 discusses the Functional Accessibility Requirements for Single Level Passenger Railcars. A reference document that supports the materials in Section 2 is included in Appendix A. Section 3 includes a summary of the rationale for the selection of the major types of WhMDs that were used in the restroom and seating analysis. Section 4 is a summary of the accessible restroom space studies and Appendix B includes supporting materials for the restroom study. The team determined that the layout of the accessible restroom influenced the overall design of the vestibule and accessible seating area. Section 5 is a summary of the seating space studies that evaluated the feasibility of accommodating two or more WhMDs in the accessible seating area. Appendix C includes a seating area analysis. Section 6 highlights the safety concerns and the containment of occupied WhMDs. Section 7 discusses the use of elevators to increase access to bi-level passenger cars, and Appendix D includes all the details of the elevator study. Section 8 is the conclusions of all phases of the project. Section 9 contains recommendations for further investigation. Section 10 includes a list of references used in the report, and Section 11 includes a glossary. The main references for the report are included as part of the Appendix A reference document. Appendix B, Appendix C, and Appendix D include the detailed tasks reports from Phase II.

2. Functional Accessibility Requirements for Single-level Passenger Railcars

The functional requirements for accessibility on single-level passenger trainsets and standalone cars have many commonalities. Appendix A includes background information and technical details. This section outlines the NGEC AWG recommendations for accessibility accommodations on single-level intercity and high-speed passenger railcars.

The functional requirements recommendations are based on recent research regarding the change in demographics (see footnotes 5, 6, and 7 in Appendix A 2.1 and footnote 8 in Appendix A 2.3) and mobility device technologies, and an international literature review as well as best practices from other countries to make train travel as accessible as possible. The functional requirements reflect changes in population demographics; travelers with longer and heavier WhMDs (see footnotes in Appendix A 2.4); people who are blind, deaf, or use service animals; and travelers who require transfer assistance in restrooms. In this document, a WhMD may simply be referred to as a mobility device.

Single-level intercity passenger rail equipment constructed in accordance with the requirements of these recommendations must be fully compliant, at the time of manufacture, with all rules and regulations of the Americans with Disabilities Act of 1990 (ADA), and shall include the following functional requirements that exceed the minimum requirements as outlined in 49 CFR §§37 and 38 (ADAAG, 2006).

2.1 Mobility Device Accessibility

The ADAAG, 49 CFR §38.125 defines the requirements for mobility device accessibility on intercity rail cars. All intercity rail cars, other than level-entry cars, required to be accessible by §§ 38.111 (a) and (e) of 49 CFR §38, shall provide a level-change mechanism or boarding device (e.g., lift, ramp, or bridge plate) complying with either paragraph §§38.125(b) or 38.125(c) and sufficient clearances to permit a wheelchair or other mobility device user to reach a seating location complying with paragraph §38.125(d). PRIIA single-level intercity passenger rail cars should be designed to meet and/or exceed the requirements set forth in §38.125 for access to the rail car.

On-board Mobility Device Lift Design Load

Current Statutory Requirements

49 CFR §38.125(b)(1) requires on-board mobility device lifts to have *"a minimum design load of at least 600 pounds. Working parts, such as cables, pulleys, and shafts, which can be expected to wear, and upon which the lift depends for support of the load, shall have a safety factor of at least six, based on the ultimate strength of the material. Nonworking parts, such as platform, frame, and attachment hardware, which would not be expected to wear, shall have a safety factor of at least three, based on the ultimate strength of the material."* (ADAAG, 2006)

Recommended Requirements for Improved Accessibility

The recommendation is for an increase in the design load of the on-board mobility aid lift to 800 lbs., from the current minimum of 600 lbs. The safety factors and all other applicable requirements in §38.125(b)(1) remain unchanged (ADAAG, 2006). An on-board WhMD lift with a heavier payload of 800 lbs will accommodate more travelers with disabilities (see Appendix A 3.2.1).

On-board Mobility Device Lift Platform Footprint

Increase the platform lift footprint length from 48 inches to 54 inches. This will accommodate 90 percent of the WhMDs in North America. For trains designed for level boarding, the width of the bridging plate should be the width of the door, or at least 32 inches wide.

Current Statutory Requirements

The requirements in 49 CFR §38.125(b)(6) for wheelchair or mobility device lift platform surface states that *"the lift platform surface shall be free of any protrusions over ¼ inch high and shall be slip resistant."* (ADAAG, 2006) Figure 2-1, taken from the ADAAG regulation, shows the lift platform with "*a minimum clear width of 28½ inches at the platform; a minimum clear width of 30 inches measured from 2 inches above the lift platform surface to 30 inches above the surface; and a minimum clear length of 48 inches measured from 2 inches above the surface of the platform to 30 inches above the surface."* (ADAAG, 2006)

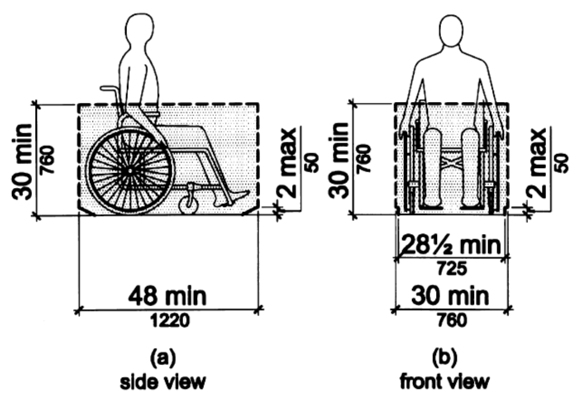


Figure 2-1 Wheelchair and Mobility Device Envelope (ADA CFR Part 38-Figure 1)

Recommended Requirements for Improved Accessibility

The recommended footprint of a clear surface of an on-board mobility lift platform should be 30 inches by 54 inches. The lift platform length shall be increased from 48 inches to 54 inches. This will accommodate 90 percent of the mobility devices used in North America. At a minimum, the existing width requirement of 30 inches must be maintained, but if possible the width should be increased to 32 inches. Maintaining the footprint of 30 inches by 48 inches would limit access to passenger trains for 50 percent of travelers with disabilities; however, increasing the length to 54 inches and increasing the width will accommodate 90 percent of the population of passengers who use a WhMD (see Appendix A 3.2.2).

Level Boarding

Current Statutory Requirements

The current statutory requirements for car ramps or bridge plates can be found in 49 CFR §38.125(c). Car ramp or bridge plate: "*Design load. Ramps or bridge plates 30 inches or longer shall support a load of 600 pounds, placed at the centroid of the ramp or bridge plate distributed over an area of 26 inches by 26 inches, with a safety factor of at least 3 based on the ultimate strength of the material. Ramps or bridge plates shorter than 30 inches shall support a load of 300 pounds.*" (ADAAG, 2006)

Recommended Requirements for Improved Accessibility

For level boarding, a bridging plate must be provided to permit a mobility device user to easily traverse the horizontal gap that is usually present between the car threshold and the station platform. The design load of the bridge plate should be increased to 800 lbs. from the current minimum requirement of 600 lbs. All other requirements of §38.125(c) for bridge plates remain unchanged. (ADAAG, 2006)

Interior Circulation

In an accessible train car, all general passageways within and between cars, as well as from the mobility device's travelling position to the restroom, must be at least 32 inches wide.

Current Statutory Requirements

49 CFR §38.113(b) contains the statutory requirements for interior passageways: *"Doorways required to be accessible by §38.113 (a) of the ADA statute shall permit access by persons using mobility devices and shall have an unobstructed passageway of at least 32 inches wide leading to an accessible seating locations complying with § 38.125(d)."* (ADAAG, 2006) Figure 2-2 shows Fig. 4 from the ADA regulation for an accessible rail car. In cars where such doorways require passage through a vestibule, such vestibules shall have a minimum width of 42 inches.

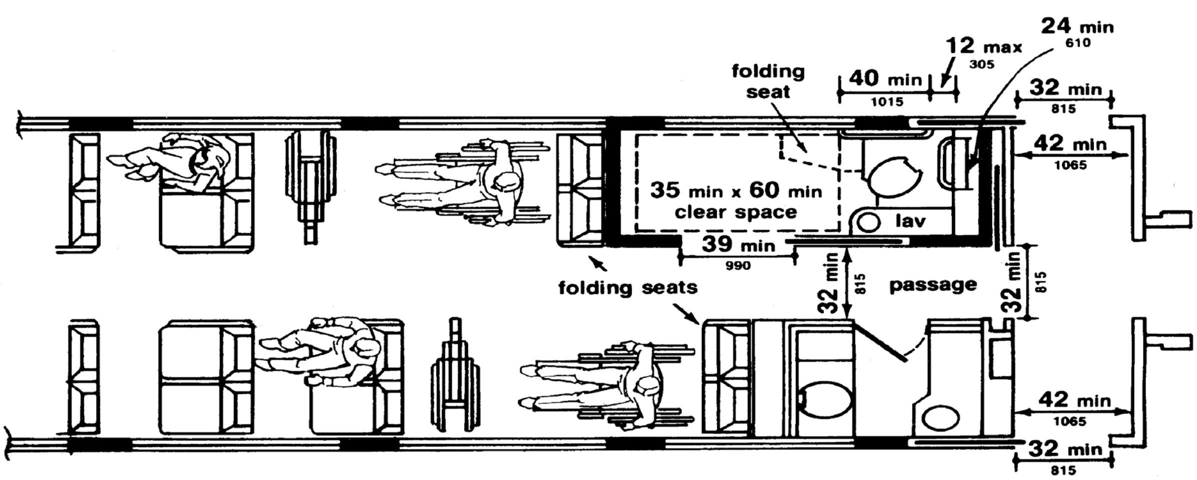


Fig. 4
Intercity Rail Car (with accessible restroom)

Figure 2-2 Intercity Rail Car with Accessible Restroom (ADA CFR Part 38 Fig. 4)

Recommended Requirements for Improved Accessibility

There are several locations where turning clearance is critical; the following turning clearances are recommended:

- A minimum footprint of 32 inches by 59 inches is recommended for maneuvering in and out of the accessible seating position in a coach as well as lounge, café, and dining cars.

For areas where passage through a vestibule is required, the minimum vestibule width shall be 44 inches; a vestibule wider than 44 inches should be considered where appropriate (see Appendix A 3.2.3).

Accessible Seating Position

Current Statutory Requirements

Current regulation 49 CFR § 38.125(d) requires that "*all intercity rail cars required to be accessible shall provide at least one, but not more than two, mobility device seating location(s) per car, which adjoin or overlap an accessible route with a minimum clear width of 32 inches* (ADAAG, 2006). The statute also requires *"a minimum clear floor space of 48 inches by 30 inches for persons who wish to remain in their wheelchairs or mobility devices. Spaces for persons who wish to transfer shall include a regular coach seat or dining car booth or table seat and space to fold and store the passenger's wheelchair."* (ADAAG, 2006)

Recommended Requirements for Improved Accessibility

A minimum of two accessible seats should be provided in each rail car. Each accessible seat should be equipped with pivoting aisle side armrests to accommodate passengers who choose to transfer from their mobility device to the accessible seat. It is recommended that whenever possible the accessible seats should be located adjacent to a window. A footprint of 32 inches by 59 inches is required adjacent to the accessible seating position to accommodate occupied or unoccupied mobility devices. In addition, consideration of the relationship between the location of the accessible seats and the accessible restroom should be considered. On long trip segments, passenger comfort can be compromised when the accessible seats are located adjacent to the accessible restroom doors. A call button should be installed at accessible seating locations. This button should be mushroom style, and should not require the lifting of levers or covers to activate. It should be located forward of the accessible seating location so it is reachable by people who remain in their mobility device or transfer into the accessible seat (see Appendix A 3.2.4).

A new consideration for the next generation of rail cars to have the potential to increase the overall number of available accessible positions per train by placing them so that groups of people using WhMDs can travel together. The overall number of accessible positions per car should be two at a minimum but no more than four per car. Providing more than two accessible seats per car would require a letter of equivalent facilitation from DOT, since this would exceed the requirements of 49 CFR 38.125(d)(2), which limits the number of accessible seating locations to two (ADAAG, 2006). However, providing a minimum of two but no more than four accessible seats per car would increase the overall accessibility of the train to more travelers. This recommendation would be applicable to semi-permanently coupled train consists, such as Acela train consists. This will ensure sufficient accessible positions per train consist. Section 5 discusses the feasibility of accommodating two or more WhMDs and also service animals.

Access to On-board Amenities

To provide equal access to amenities, including the use of café/lounge/dining cars for all passengers, it is essential to provide facilities for those using mobility devices.

Current Statutory Requirements

Current regulation 49 CFR § 38.111(a)(2) requires that *"single-level dining and lounge cars shall have a connecting door with a clear width of 32 inches and be connected to a car that is accessible to people using WhMDs , and at least one space or seating location complying with § 38.125(d)(2) and (3) to provide table service to a person who wishes to remain in his or her wheelchair, and space to fold and store a wheelchair for a person who wishes to transfer to an existing seat."* (ADAAG, 2006)

Recommended Requirements for Improved Accessibility

Access shall be available from the accessible car to the café/lounge/dining car and within the car with a clear passageway of 32 inches. This will require that the café/lounge/dining cars always be connected adjacent to the accessible end of the adjoining cars in the trainset. Designate at least two accessible seating areas in the café/lounge cars. A footprint of 32 inches by 59 inches in the café/lounge/dining cars should be provided at a table as well as a vertical clearance under the table of 30 inches and maximum table height of 34 inches to accommodate passengers seated in WhMDs. In addition, at least one transfer accessible position shall be provided in the accessible café/dining car at a table. Clear space to park unoccupied WhMDs shall be provided adjacent to the accessible transfer seat location (see Appendix A 3.2.11). At accessible seating locations where a table is provided, care must be taken to provide sufficient knee and toe clearance for passengers using a mobility device.

2.2 Accessible Restroom

An accessible restroom with the accessible features and amenities should be provided. Detailed Accessible Restroom Design Recommendations are included in the (see Appendix A reference sections A 6 and A 3.2.7).

Doors

Current Statutory Requirements

ADAAG regulation 49 CFR §38.123(a)(5) currently requires *"32 inches minimum clear opening for doors located on the end of the restroom, and 39 inches for doors located on the side of the restroom."* (ADAAG, 2016) Door latches and hardware shall be operable with one hand and shall not require tight grasping, pinching, or twisting of the wrist.

Recommended Requirements for Improved Accessibility

The minimum door width of 36 inches should be provided if the door is located at the end of the restroom. For doors located on the side of the restroom, the minimum clear width shall be 39 inches. It is recommended that all restroom doors be power-assisted. Doors mounted on the side shall be a sliding/pocket-type. The Phase 2 feasibility study recommends the restroom doors be 40 inches wide to permit increased maneuverability from the aisle to the restroom. In addition, passengers seated in a WhMD should be able to easily reach and operate the door lock without excessive maneuvering if the restroom has limited turning space. A "door lock" indication should be include in close proximity to the door to inform the user that the door is secured.

Clear Space

A clear space to enter and exit forward with a mobility device and turn inside the washroom to access the toilet and vanity should be provided.

Current Statutory Requirements

Current regulation 49 CFR §38.123(a)(1) specifies a minimum clear floor space of 35 inches by 60 inches; however, for some restroom configurations this space is not adequate: *"The minimum clear floor area shall be 35 inches by 60 inches. Permanently installed fixtures may overlap this area a maximum of 6 inches, if the lowest portion of the fixture is a minimum of 9 inches above the floor, and may overlap a maximum of 19 inches, if the lowest portion of the fixture is a minimum of 29 inches above the floor. Fixtures shall not interfere with access to and use of the water closet. Fold-down or retractable seats or shelves may overlap the clear floor space at a lower height provided they can be easily folded up or moved out of the way."* (ADAAG, 2006)

Recommended Requirements for Improved Accessibility

The clear space parallel to the toilet should accommodate independent and dependent transfers to and from WhMDs. A clear space footprint of 35 inches by 60 inches adjacent to the toilet will accommodate most single-person dependent transfers from WhMDs. The smaller footprint accommodates most manual and power wheelchairs, and typically people who require transfer assistance use manual or power wheelchairs.

Laboratory studies show that the clear space must also include space in front of the toilet for the person assisting with a dependent transfer. The size of this clear space is highly variable and is dependent on the transfer technique and size of the person performing the transfer. In the laboratory studies, subjects who were less than 5'6" actually took up more space than taller subjects, as a result of variations in transfer technique. While the recommended space is a simple rectangle, the actual clear space also must include space in front of the toilet. Studies show that a length of 20 inches to 22 inches is required in front of the toilet to accommodate the person performing the dependent transfer. If the total accessible restroom enclosure includes the 35 inches by 60 inches clear space adjacent to the toilet, there is sufficient space in front of the toilet to accommodate most single-person dependent transfers from mobility devices. It is recommended that a clear space footprint of 35 inches by 60 inches adjacent to the toilet be provided.

Phase 2 of this study showed that a larger restroom is needed to accommodate a large power base type WhMD that drives in, rotates 180 degrees, and drives out.

Toilet

Current Statutory Requirements

Requirements in 49 CFR §38.123(a)(2), indicate that *"the height of the water closet shall be 17 inches to 19 inches measured to the top of the toilet seat. Seats shall not be sprung to return to a lifted position."* (ADAAG, 2006)

Recommended Requirements for Improved Accessibility

The toilet shroud shall have clear space adjacent to the toilet for side and frontal approaches for personal hygiene. The toilet seat shall be split. It is recommended that the toilet support a weight of 400 lbs.

Grab Bars

Current Statutory Requirements

Requirements in 49 CFR §38.123(a)(3), indicate that *"a horizontal grab bar at least 24 inches long shall be mounted behind the water closet, and a horizontal grab bar at least 40 inches long shall be mounted on at least one side wall, with one end not more than 12 inches from the back wall, at a height between 33 inches and 36 inches above the floor."* (ADAAG, 2006)

Recommended Requirements for Improved Accessibility

In addition to the requirements in 49 CFR §38.123(a)(3), support bars/armrests should be provided on both sides of the toilet. The support bar(s) on the transfer side may fold down and shall be designed to accommodate a 300-lb design load (see Section 6). All support and grab bars in the accessible restroom should have a cross sectional diameter between 1¼ inches and 2 inches.

Recommended Requirements for Restroom Amenities

Sink

Current Statutory Requirements

There are no statutory requirements.

Recommended Requirements for Improved Accessibility

Additional recommendations, exceeding the minimum standards of 49 CFR §38.123, include locating the sink to be accessible from the seated position on the toilet, by a 5^{th} percentile female. Faucet controls for the sink should not exceed 18 inches as measured from the centerline of the toilet. The sink must not intrude to prevent a frontal approach to the toilet.

Mirror

Current Statutory Requirements

There are no statutory requirements.

Recommended Requirements for Improved Accessibility

An accessible restroom should include a vanity mirror that is accessible from the seated position in a wheelchair. The bottom of a vanity mirror reflecting surface should not be more than 40 inches from the finished floor height if it is located over a countertop. For mirrors that are not over a counter, the bottom of the vanity should be less than 35 inches above the finished floor height. It is recommended that the top edge of the mirror should be at least 74 inches from the finished floor height.

Controls

Current Statutory Requirements

According to 49 CFR §38.123(a)(4), *"faucets and flush controls shall be operable with one hand and shall not require tight grasping, pinching, or twisting of the wrist. The force required to activate controls shall be no greater than 5 lbf (22.2 N). Controls for flush valves shall be mounted no more than 44 inches above the floor."* (ADAAG, 2006)

Recommended Requirements for Improved Accessibility

The accessible restroom should be equipped with automatic touchless braille or raised letters/symbols operating controls for the sink, toilet, and regulated warm water temperature. Faucet and flush controls should be located within easy reach from the toilet position. This recommendation exceeds the minimum requirements in 49 CFR §38.123(a)(4).

Toilet Paper Dispenser

Current Statutory Requirements

There are no statutory requirements.

Recommended Requirements for Improved Accessibility

The toilet paper dispenser should be within easy reach from the toilet position. Dispensers should be located between 7 inches and 9 inches from the front of the toilet, and the outlet of the dispensers should between 15 inches and 36 inches, but should not be behind the grab bars.

Emergency Call Buttons

Current Statutory Requirements

There are no statutory requirements.

Recommended Requirements for Improved Accessibility

Two emergency call buttons shall be located in the accessible restroom. One shall be reachable from the seated position on toilet by a 5th percentile female, and another shall be located 10 inches to 12 inches from the floor, in case the passenger falls and is unable to get up.

2.3 Service Animal Accommodation

Current Statutory Requirements

There are no statutory requirements.

Recommended Requirements for Improved Accessibility

It is recommended that two spaces for service animals be designated in each accessible train car. This space should be adjacent to the accessible seating positions and can be under a double seat or other location, but should be out of passageways. There are no U.S. recommendations for space for service animals. In Canada, the Canadian National Institute for the Blind (CNIB) recommends a space that is approximately 38 inches long by 14 inches wide by 16 inches high to accommodate a service animal, such as a German Shepard or a Labrador (see Appendix A 3.2.10).

2.4 Effective Communication Signage

Current Statutory Requirements

According to 49 CFR §38.113(e), the *"International Symbol of Accessibility shall be displayed on the exterior of all doors complying with this section unless all cars and doors are accessible and are not marked by the access symbol. Appropriate signage shall also indicate which accessible doors are adjacent to an accessible restroom, if applicable."* (ADAAG, 2006)

Recommended Requirements for Improved Accessibility

In addition to the requirements in 49 CFR §38.113(e), all railcar on-board passenger information signage should be accessible. Signage for accessibility should be in accordance with American National Standards Institute (ANSI) 117, as appropriate. When possible both visual and tactile characters should be provided, either one sign with both visual and tactile characters, or two separate signs, one with visual and one with tactile characters. Letters and numerals should be accompanied with Grade 2 braille. Pictograms shall be accompanied by an equivalent verbal description placed directly below the pictogram.

On-board Passenger Information System (OPIS)

Current Statutory Requirements

According to 49 CFR § 38.121 (a), "*Each car shall be equipped with a public address system permitting transportation system personnel, or recorded or digitized human speech messages, to announce stations and provide other passenger information. Alternative systems or devices which provide equivalent access are also permitted.*" (ADAAG, 2006)

Recommended Requirements for Improved Accessibility

US DOT guidelines for communication in airports and on aircraft are currently being developed and should be adopted for onboard passenger information systems on intercity and high-speed passenger trains. These guidelines should be applied to all passenger cars and used for the conveyance of real-time information, including current and next stop, transfers, schedules, and emergency information in audio and visual formats (see Appendix A reference section A 3.2.8 and A 4). Dual-mode communications shall be provided for all communications broadcast to passengers. Dual-mode communication is the provision of passenger information in both audio and visual forms. In normal operations a dual-mode, real-time voice -o-text messaging system, in addition to an audio system, should be made available for communicating with passengers who have hearing loss, those with cognitive impairments, and the elderly. This recommendation exceeds the minimum standards in 49 CFR §38.121(a). In addition, efforts should be made to ensure the source data used for the onboard communication system is available to application developers and others, so onboard information can be shared through smart phone or social media technologies.

Emergency Communication

Current Statutory Requirements

There are no statutory requirements.

Recommended Requirements for Improved Accessibility

Dual mode communications, as defined above, shall be provided for all emergency communications broadcast to passengers. For emergency and evacuation procedures, a real-time voice-to-text messaging system, in addition to an audio system, should be available for passengers who have hearing loss, those with cognitive impairments, and the elderly. This recommendation exceeds the minimum standards in 49 CFR §38.121(a).

2.5 Emergency Evacuation

Current Statutory Requirements

There are no statutory requirements.

Recommended Requirements for Improved Accessibility

On board emergency evacuation chairs shall be located in a train consist and shall be used to evacuate customers with disabilities when applicable (see Appendix A 3.2.6). (ADAAG, 2006)

2.6 Other Items for Consideration

Seating for People Who Are Obese

Obesity is not legally recognized as a disability in the U.S.; however, many people who are morbidly obese have mobility restrictions and use WhMDs (see Appendix A 3.2.9 and A 5). Several seats should be provided to accommodate passengers who are obese. These include double-bench seats with a fold away center arm rest accommodating persons who require a wider seat than 18 inches and those travelling with small children. Pivoting aisle armrests facilitate transfers from mobility devices to train seats. The pivoting center armrest between separate double seats is not usually an adequate solution; thus, and a flat bench seat is also recommended. Molded seats on double seats that are separate are not an adequate solution even if the center armrest folds up.

3. Selection of WhMDs Used in Analysis of Recommended Accessibility Design Guidelines

Researchers conducted spatial analysis of the recommendations and their impact on internal layout of single-level passenger rail coach cars.

3.1 Descriptions of WhMDs

The representative WhMDs used in the spatial analysis included a sport model manual wheelchair, a power base, and 48-inch-long and 54-inch-long scooters.

Manual wheelchairs

Manual chairs were the most common mobility devices in the past decades. They are light, some are foldable, and have large rear wheels and small front casters. They are most often used by people 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 institutions. The “common manual wheelchair,” measuring 25 inches wide and 42 inches long when occupied, was for many years used as a base for regulations and standards with a recommended footprint of 30 inches by 48 inches and a turning radius of 36 inches. With the advent of making public transportation accessible, systems were developed to secure the wheelchair to vehicles, mainly by tie-downs to prevent forward and rearward movement. These securement systems 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.

Manual sports chairs

Sports wheelchairs are made of lightweight materials, have large rear wheels with a camber to allow for greater stability and small front casters for use at sporting events. Small sports chairs typically have a width of 32 inches at the large wheel camber, and the chair’s length can range from 35 inches to 40 inches. Their turning radius is less than 36 inches. Sports chairs can easily board public transportation vehicles but are very difficult to secure effectively in a forward-facing position. There are a great variety of other sports chairs depending on their purposes. Some of the more extreme sports wheelchairs have two large wheels, a 37-inch turning radius, a long front extension, and one large front wheel. Due to their length, they cannot be boarded on public transportation vehicles. Figure 3-1 shows this style of manual sports wheelchair, used by active and independent wheelchair users.

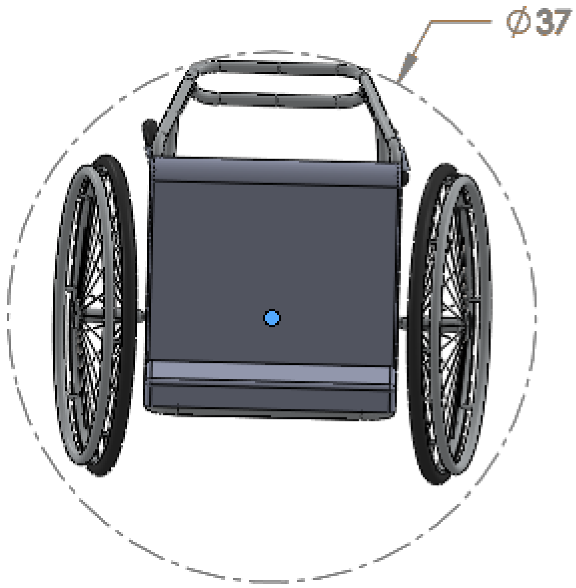


Figure 3-1 Manual Sports Wheelchair, 37-inch Diameter

Powered Wheelchairs

Powered wheelchairs are usually four-wheeled WhMD 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 approximately 25 inches wide by 38 inches to 43 inches long, and can weigh up to 300 lbs or even 400 lbs, depending on their power pack and accessories. They are usually very nimble and have a small turning radius of approximately 28 inches, 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 WC19 standards to equip these chairs with attachment points for securement. WC19 standards are now referred to as ANSI/Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) WC-4:2012 Section 19. These are standards pertaining to wheelchairs that are used as seats in motor vehicles. In addition, there are powered wheelchairs with added features to tilt the chair and also provide extended leg and upper body support. As a result of the additional features, these chairs can vary in length and weight and can easily exceed the standard footprint of 30 inches by 48 inches, thus making transport on public vehicles difficult.

Power Base WhMD

A power base WhMD may have four or more wheels and a seat that may be on a pedestal. These devices have all the power equipment located below the seat and have a relatively lower center of gravity. They have a large power base, and the footprint accommodates a 90th percentile male with legs slightly extended. This footprint is more reflective of the population of WhMD users. 40 inches long by 32 inches wide. The device also includes additional toe space for the occupant. The power base spatial footprint was modified to include toe clearance for a manikin representing the 90th percentile male. The addition space required for toe clearance was used for the spatial analysis. Figure 3-2 shows the spatial area required by a power base for a 180-degree turn, an area 66 inches wide by 84 inches long. The space includes a 9-inch extension for toe clearance and slightly extended footrests for knee flexion that is more natural and greater than 90 degrees. For the restroom studies, the power base was the representative WhMD. Researchers assumed that a scooter may be used to access the passenger railcar, but would be stowed during transport and not used to access the restroom.

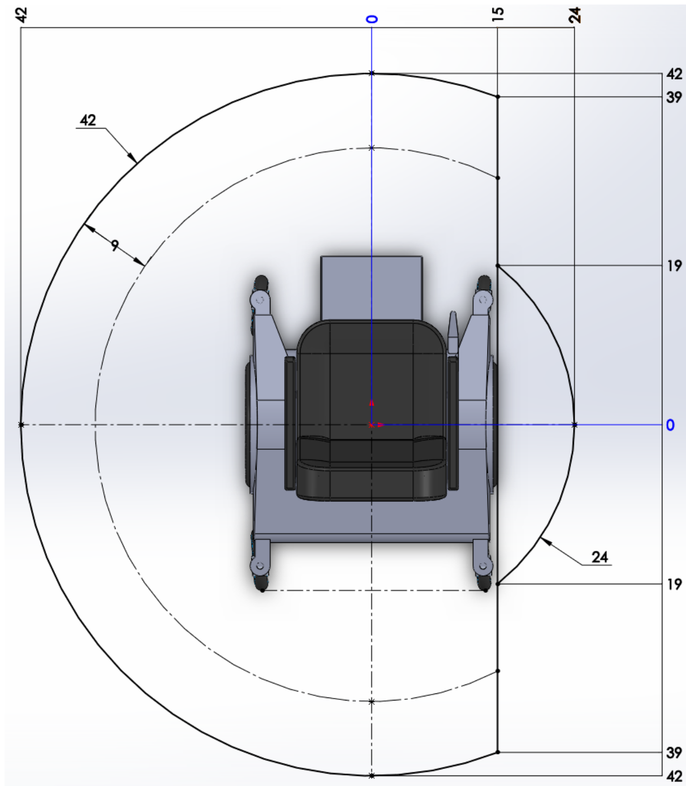


Figure 3-2 Large Power Base Area with 9-inch Toe Clearance

3-Wheel Scooters

Indoor three- and four-wheeled scooters typically have small wheels, and their narrow width—usually about 20 inches—makes them more prone to tipping. However, these devices often are used in environments that they were not designed to handle, 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 WC19.

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

Large 4-Wheel Scooters

Large four-wheel scooters typically have a footprint of 30 inches wide by 48 inches long and provide a more stable geometry, but having two front steering wheels increases their turning radius to over 50 inches, making it difficult and sometimes impossible to, for example, negotiate entry onto buses and trains. Most of these scooters are also not equipped with designated attachment points in accordance with WC19, resulting in unsafe securement.

Oversized four-wheel scooters were developed for the outdoor environment and for use by people who may not have access to or drive a car. These scooters have four large wheels and can negotiate modest uneven terrain. They are powered by batteries, upwards of 54 inches long, have a turning radius of 64 inches, and can weigh between 200 lbs 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 in accordance with WC19, resulting in unsafe securement.

Figure 3-3 shows two sizes of power scooters used in the spatial analysis studies. If a boarding platform is 54 inches long, a 48-inch-long scooter (which would fit inside the current 30-inch by 48-inch footprint) and a 54-inch-long scooter should be able to access the train. Figure 3-4 shows the turning radius of a 48-inch-long by 28-inch-wide scooter rotating on the outside wheels and producing at 50-inch turning radius. The actual turning radius depends on the skill and design of the scooter user, but all scooters have turning radii that are much larger than power wheelchairs. In the seating scenarios, the 54-inch-long scooter could only be stored in the longitudinal position. Otherwise it would encroach into the aisle. The smaller scooter could be stored in the crosswise and longitudinal position.

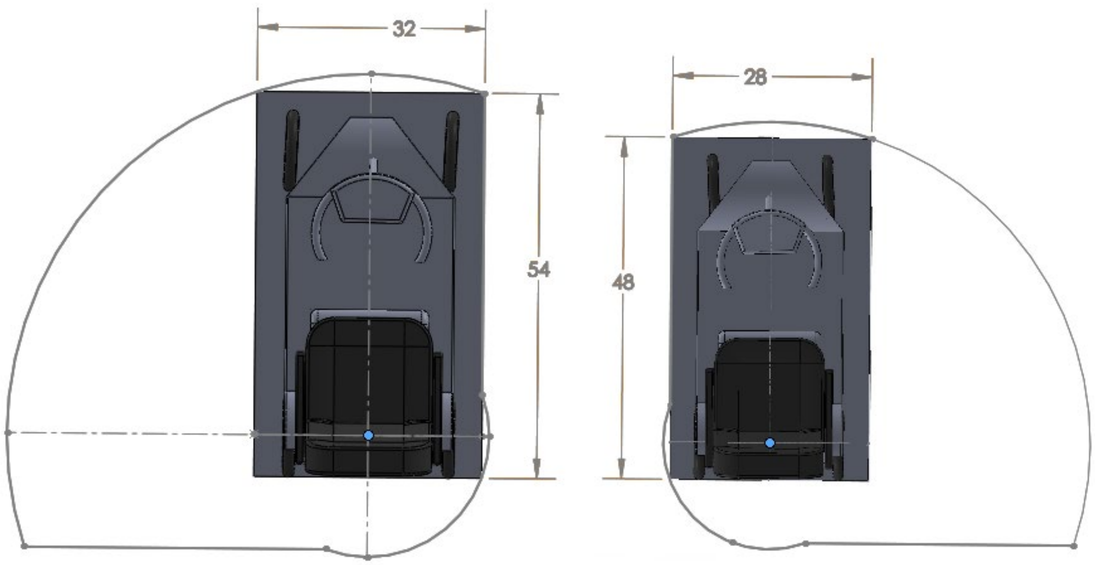


Figure 3-3 90-degree Turn Area of 54-inch and 48-inch-Long Scooters

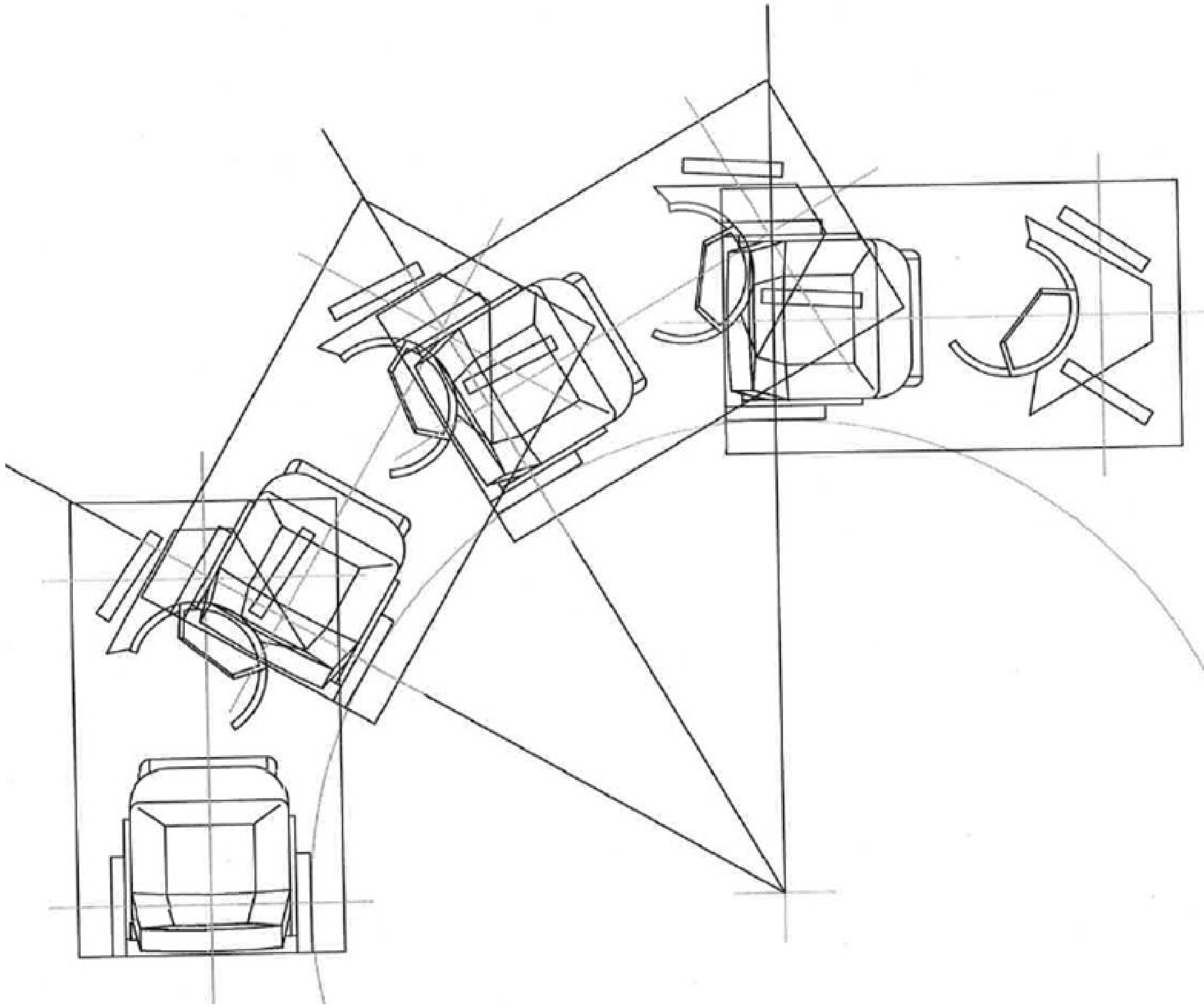


Figure 3-4 Turning Radius Diagram of Scooter Rotating on Outside Wheels[1]

Bariatric Wheelchairs

Bariatric wheelchairs can be either manual or powered, often distinguished by their width and added design strength. These chairs are usually wider than 34 inches and designed for users who weigh up to 500 lbs.

Wheeled Walkers

Wheeled 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. Wheeled walker users sit in regular seats and store their walkers nearby.

[1] Don Mebius, LTK Engineering Services.

4. Accessible Restroom Space Studies

The size of the WhMD and its occupant have an impact on the seating and restroom areas and structural design of the vehicle. The maximum size of the WhMD to be accommodated will also directly affect vehicle entrances and egress. The new recommended spatial characteristics of a WhMD with a footprint of 54 inches long by 30 inches wide are used for design and, where appropriate, the design occupant ranges from a 5th percentile Asian female to a 95th percentile northern European male.

4.1 Space Study Objectives

The specific objective includes developing "virtual" models of accessible restrooms that incorporate the recommended accessibility specifications developed by the research team.

This study extended the work to develop draft guidelines for the NGEC AWG. The new recommended design parameters for WhMDs and the draft guidelines for new accessibility features were converted to 2-dimensional and 3-dimensional renderings. These were validated with manikins of 5th percentile and 95th percentile populations on large WhMDs, including sport manual wheelchairs, power wheelchairs, powerbase WhMD, and four-wheel scooters that meet the 30-inch-wide by 54-inch-long footprint. Figure 4-1 and Figure 4-2 show the turning diameter of a manual wheelchair and power base WhMD. The sport model manual wheelchair render was selected because it represents a type that is slightly wider than a traditional wheelchair, and is favored by many users who are likely to travel independently.

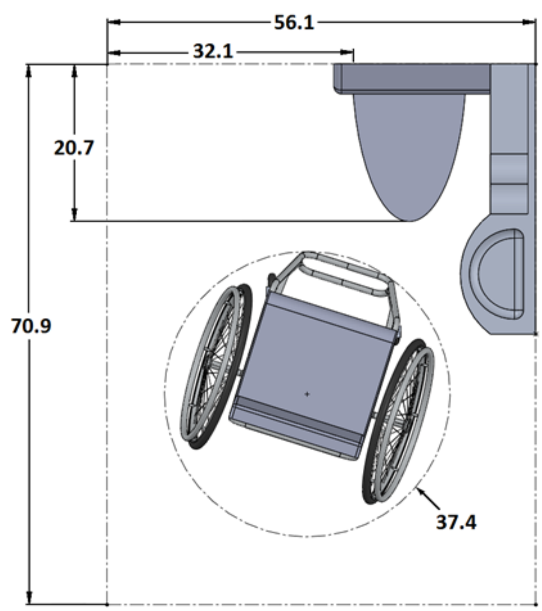


Figure 4-1 Manual Sport Wheelchair, Turning Diameter 37 inches

The power base WhMD is rendered with three turning diameters to reflect the large variation in power base sizes. These devices are nimble and generally pivot around their center. The diameters range from 39 inches to 54 inches. Figure 4-2 shows a power base WhMD with three turning diameters. These dimensions are important for the analysis of accessible restrooms and seating spaces.

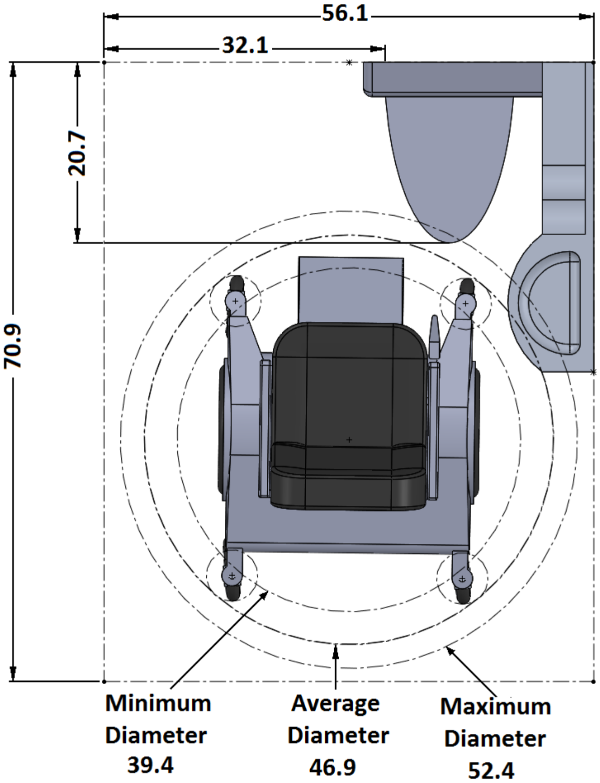


Figure 4-2 Large Power Base WhMD Turning Diameter 39–52 inches

The scooter shown in Figure 4-3 is a large 54-inch-long scooter. These devices pivot on the rear axle and have very large turning radii as was shown in Figure 3-4. Typically, scooter users have limited mobility and should transfer to a train seat rather than stay in the scooter during the journey.

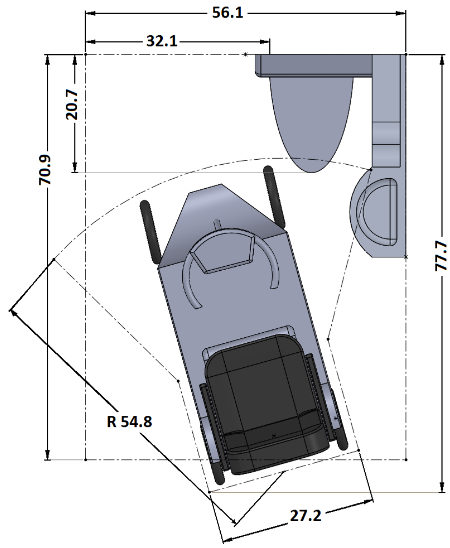


Figure 4-3 Power Scooter, 27 inches by 54 inches, Turning Radius 54 inches

4.2 Key Decisions

The research team made two decisions that influenced the outcome of this analysis. Amtrak's drawings of Acela first class and coach cars served as the base drawings of the vehicles used for the analysis and renderings. Figure 4-4 shows a picture of the accessible restroom and seating area on a first class Acela vehicle.

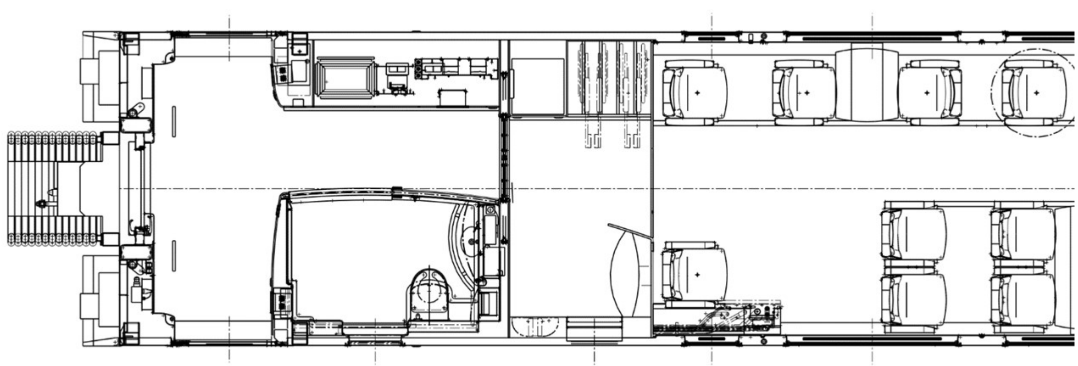


Figure 4-4 Acela First Class Car Used as Base Drawings

The project team decided to use the large power base style WhMD for the detailed analysis. The manual wheelchair as a design WhMD is too small and not representative of the user population. Researchers assumed people who use large power scooters would transfer to a regular seat in the seating area and would not take a scooter into the restroom enclosure. The large scooters could not access any of the current restrooms. Preliminary analysis showed that it would be difficult for a 54-inch-long scooter to access the aisle to the accessible seating and restroom from the vestibule. The loss of seat capacity on the vehicle would be significant if the restroom recommendations included the accommodation of large scooters. The renderings focused on an evaluation of power base WhMD in the accessible seating area and restroom.

In the restroom enclosure analysis, a 5th percentile female manikin was used to validate the location of the sink and toilet to ensure that the reach satisfied basic design guidelines. A rendering of the 5th percentile female manikin is shown in Figure 4-5.

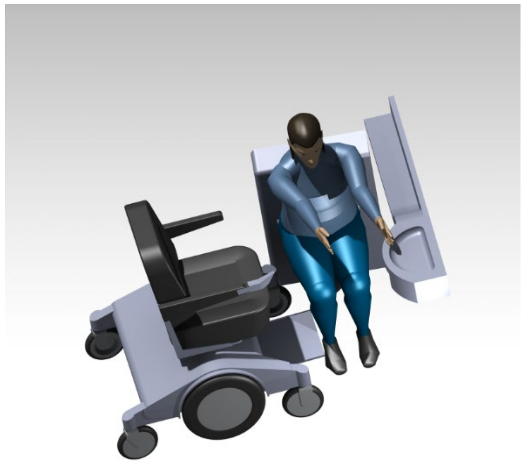


Figure 4-5 5th Percentile Female Manikin Evaluating Toilet-to-Sink Reach Range

4.3 Design Parameters

The first project milestone determined key design parameters for the restroom specification. The drawings from Acela higher-speed trainsets were used as a base. The drawings were converted for use in SolidWorks®, and previous models of WhMDs were evaluated. The analysis was conducted using 2-dimensional and 3-dimensional models in SolidWorks®. Preliminary analysis indicated that large scooters could not access the restroom, and they were severely constrained within the accessible seating area of the Acela first class coach accessible seating space. The manual wheelchair could be accommodated in the restroom and in the seating area. The large power base WhMD was selected as the design WhMD. Typically, people using these WhMDs do not transfer from the power base device to a coach seat and would need to access and use the restroom while seated in the power base chair.

4.4 Analysis of Spatial Volume Consumption

Models of spatial volume consumption were used as part of the analysis. Team members also used spatial volume consumption models to design accessible aircraft restrooms, where space is at a premium. This analysis uses 3-dimensional volumes and clearly shows the extent and vertical height where the greatest volume is required. This is important information for the placement of other amenities such as grab bars or sinks. Figure 4-6 shows a screenshot of part of the spatial volume consumption tool. In the right image, the motion capture data is aggregated across all the subjects. In this example, the transfer is completely unconstrained, so the spatial consumption is larger than in restrooms with walls to lean against during transfer.

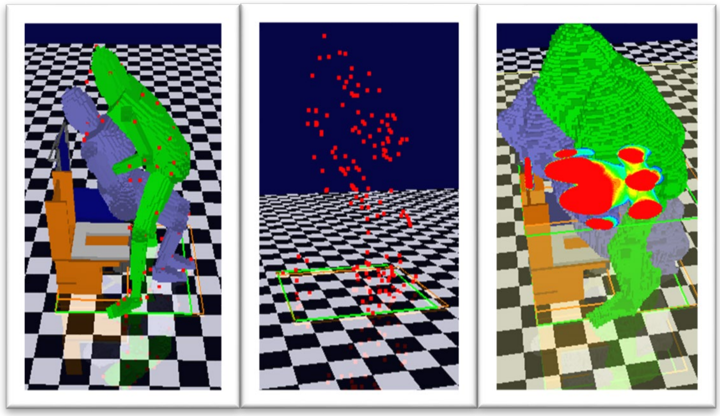


Figure 4-6 Screenshots from Computer-Generated Volume Analysis

Figure 4-7 shows spatial consumption for a power base wheelchair at 99 percent of the aggregated data and sliced at sink height.

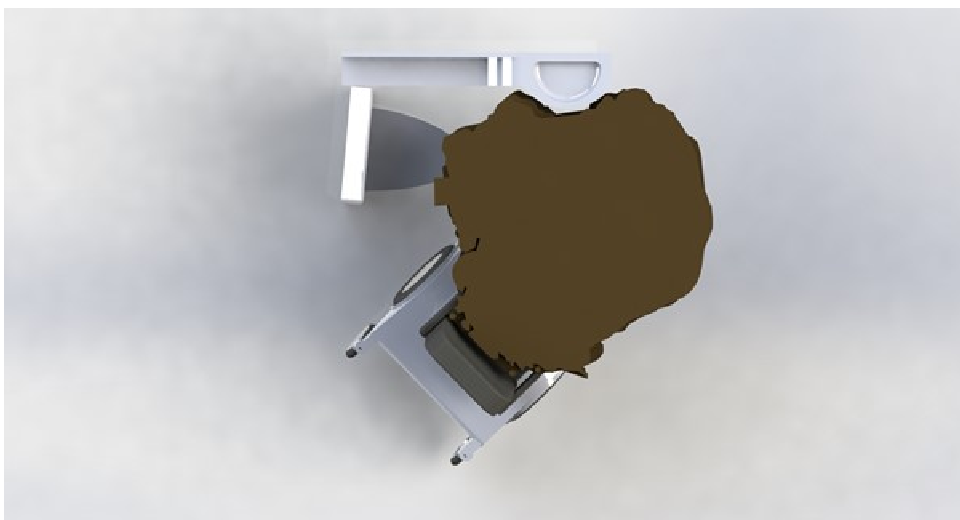


Figure 4-7 45-degree Dependent Transfer at Sink Height

Figure 4-8 shows a 3-dimensional rendering of 99 percent spatial consumption from unconstrained motion capture data.

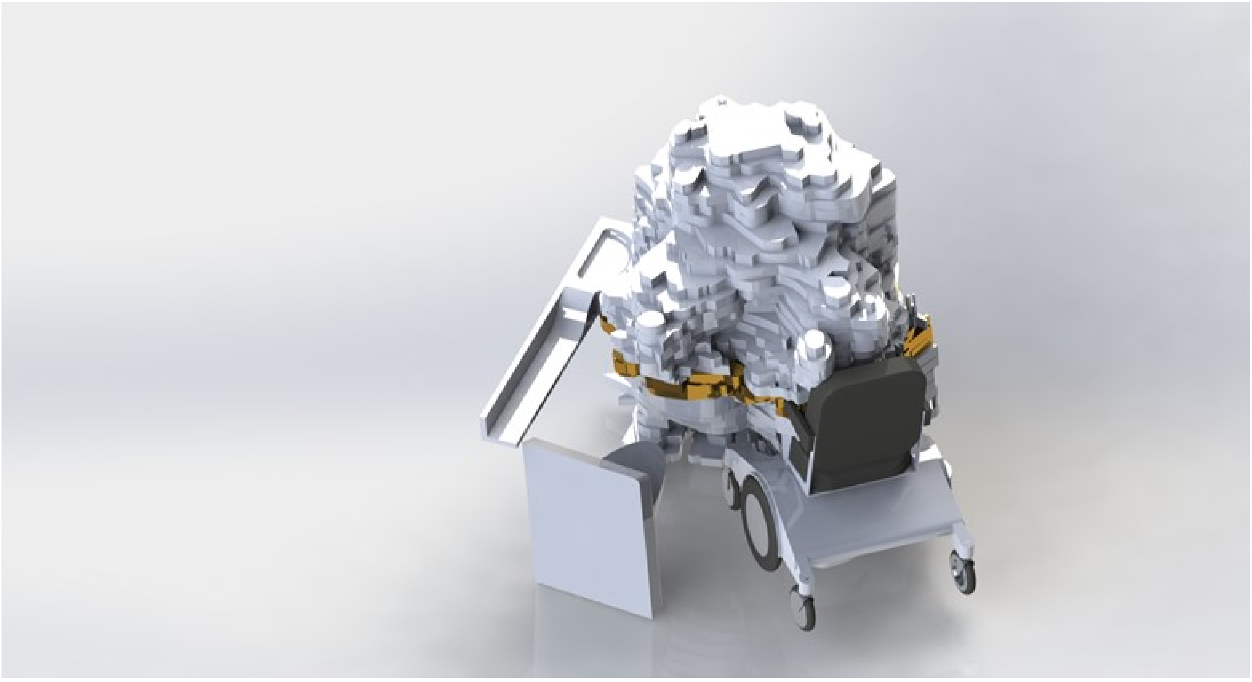


Figure 4-8 Unconstrained 45-degree Transfer Angle

Figure 4-9 is a top-down perspective on spatial consumption of a dependent transfer at the 95th percentile level.

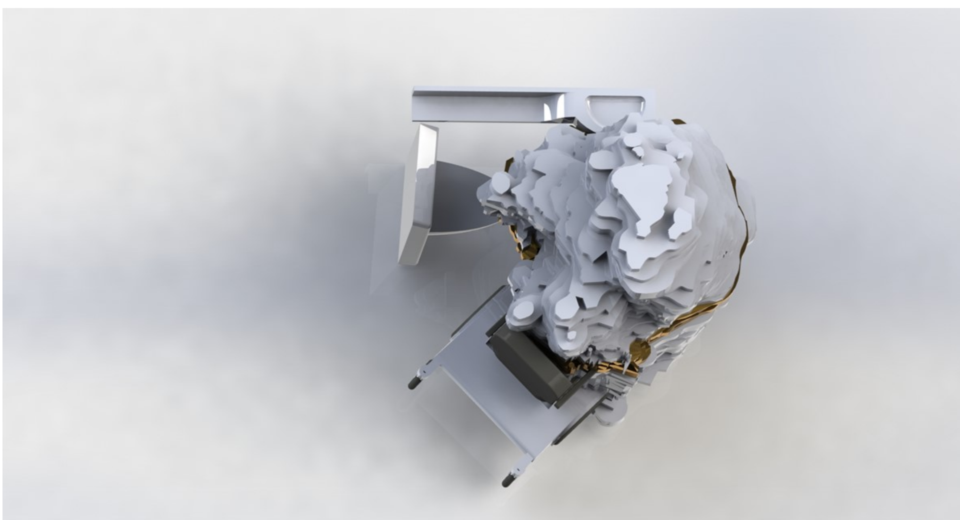


Figure 4-9 Top-Down Perspective of Spatial Consumption

Figure 4-10 shows the overlay of dimensions for an unconstrained transfer at sink level. In reality, a restroom wall would reduce the space.

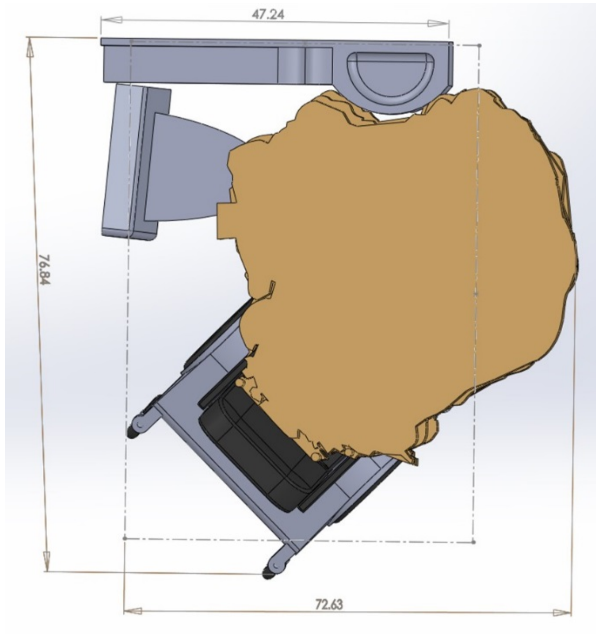


Figure 4-10 Rough Dimensions of Unconstrained Dependent Transfer from a Power Base Wheelchair

During an AWG meeting, working group members expressed concern that the drawings used for the renderings were of the Acela first class cars and not coach class cars; however, this project's purview is to consider accessible restrooms and seating spaces for future railcars, not the current fleet. Current Acela first class restrooms and seating areas comply with many of the features in the new guidelines. Some of the committee members' remarks focused on the challenges of the current coach class vehicle. The pedestal table in the accessible seating area and a lack of clear space are known problems. Nonetheless, the first class Acela cars provided an excellent base for the study.

The restroom analysis focused on the Acela restroom, as this design has many of the features in the new recommended guidelines for accessible restrooms. Preliminary analysis revealed that manual wheelchairs were easily accommodated, with sufficient room to turn around within the restroom enclosure. Figure 4-11 shows a manual wheelchair in the restroom enclosure.

The scooter could not access the restroom without significantly increasing the restroom footprint and also changing the location and design of the door. Figure 4-12 shows a scooter inside the restroom; however, it would not be possible to close the door.

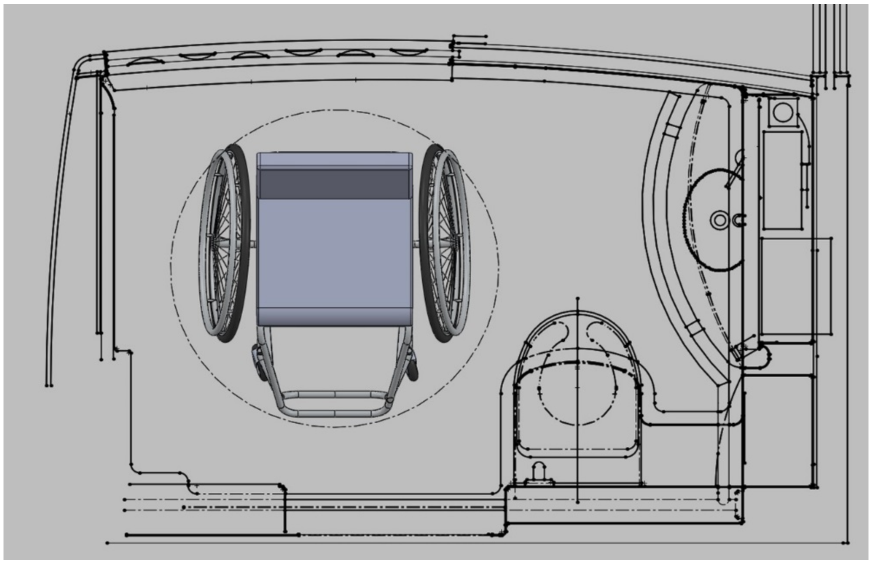


Figure 4-11 Sport Model Manual Wheelchair within Restroom Enclosure

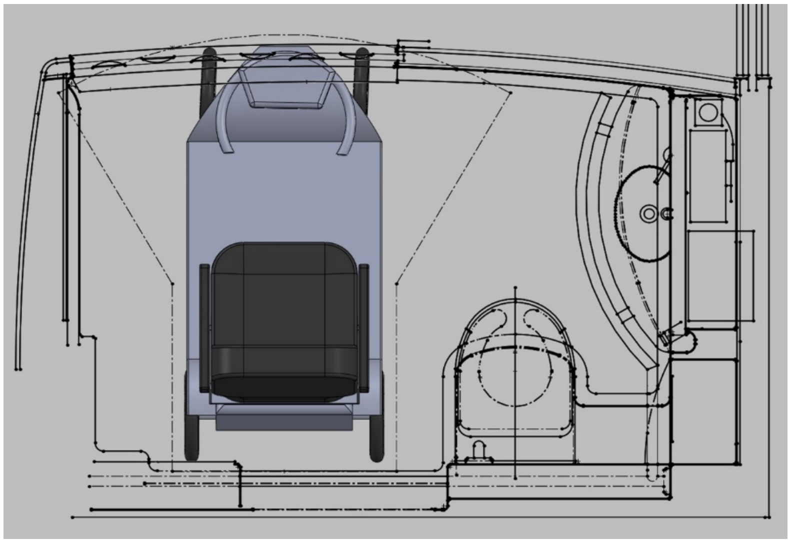


Figure 4-12 Large Scooter within Restroom Enclosure

The SolidWorks® analysis of the restroom focused on the power base WhMD and the Acela restroom. Figure 4-13 and Figure 4-14 show the power base WhMD without an occupant inside a current Acela restroom. A very large power base WhMD would have difficulty turning around within the restroom enclosure if the toilet shroud is not kept to a minimum. Also, a medium-to-large person sitting in a power base WhMD would have difficulty turning around within the restroom enclosure, due to limited toe clearances. Analysis showed that the chair entered the restroom forward-facing and was moved to an angled position adjacent to the toilet. This would permit either an independent or dependent toilet transfer. Analysis of rear or backwards entry into the restroom was also performed, and this would permit a lateral transfer to and from the toilet.

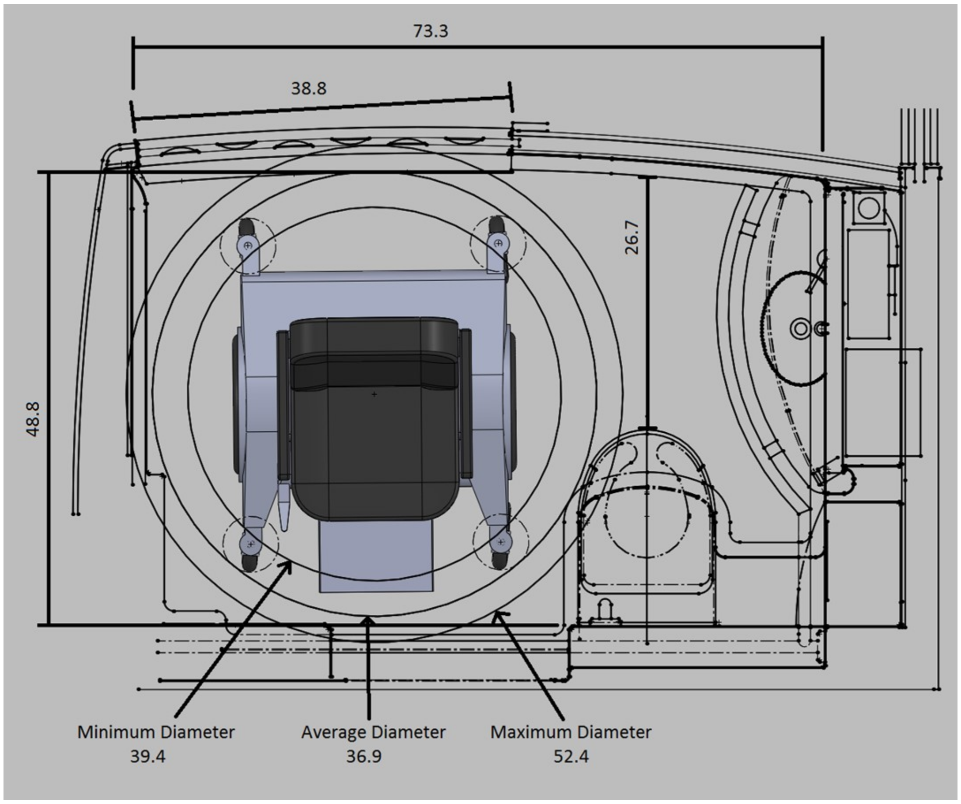


Figure 4-13 Forward-Facing Large Power Base WhMD in Restroom Enclosure

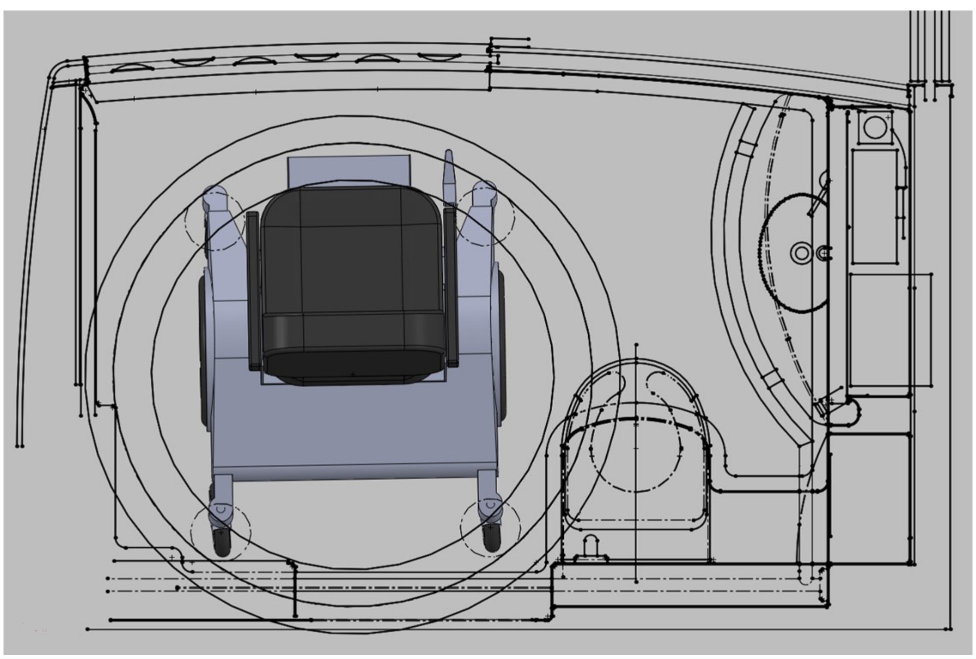


Figure 4-14 Rear Entry of Large Power Base WhMD into Restroom Enclosure

4.5 Development of a New Larger Accessible Restroom

The key analysis of the restroom was to develop a footprint for an accessible restroom that permitted a power base WhMD to have frontal access to enter, turn 180 degrees, and exit in the forward direction. Other key findings from the analysis and input from the technical advisory committee included ensuring that the toilet was oriented in the longitudinal orientation to the train. This is contrary to the current Acela design; at a minimum, a small sink should be accessible from the toilet by a 5th percentile female. Other key dimensions included a wider entry door of at least 40 inches and a clear opening of 42 inches—the preferred dimensions for accommodating entry into the restroom from a 36-inch-wide aisle. In addition, a 12-inch vertical toe clearance, a 27-inch vertical knee clearance, and a 17-inch horizontal clearance under the sink are also recommended to facilitate access to the sink and general movement about the restroom. Figure 4-15 shows the larger accessible restroom. Figure 4-16 shows the location of the sink to accommodate a 5th percentile female positioned on the toilet. The reach of a 95th percentile male is also shown.

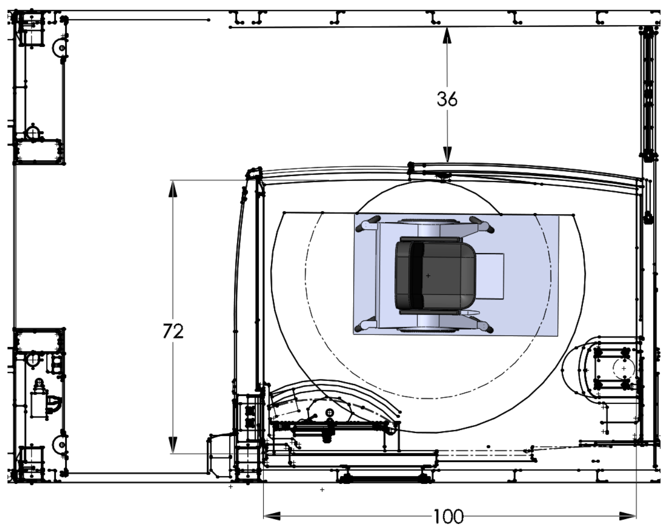


Figure 4-15 Proposed Larger Accessible Restroom

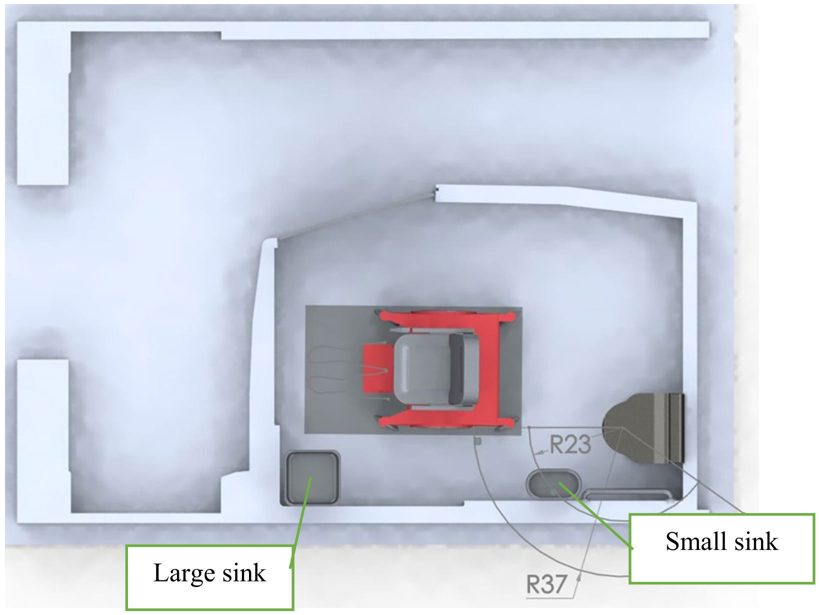


Figure 4-16 Reach Range of 5th-percentile Female and 95th-percentile Male for Location of Sink

In addition, the restroom is usually located near the vestibule. Access from the vestibule to the seating area was also investigated. Large scooters that may be 54 inches long rotate about the rear axle and need to negotiate the distance from the platform lift in the vestibule to the seating area. Laboratory studies showed that increasing the turn radius from 44 inches to 50 inches improved maneuverability. Figure 4-17 shows the dimensions of the vestibule, the restroom door at a small angle and increasing the radius of turn to 50 inches improves vehicle and restroom access for all WhMDs. The RVAAC and AWG recommended a turning radius of 44 inches, but if the electrical cabinet and other equipment that is currently located in the aisle on the Acela is relocated in future designs and the turning radius is increased to 50 inches, a large 54 inch long scooter can access the aisle from the vestibule to the seating area.

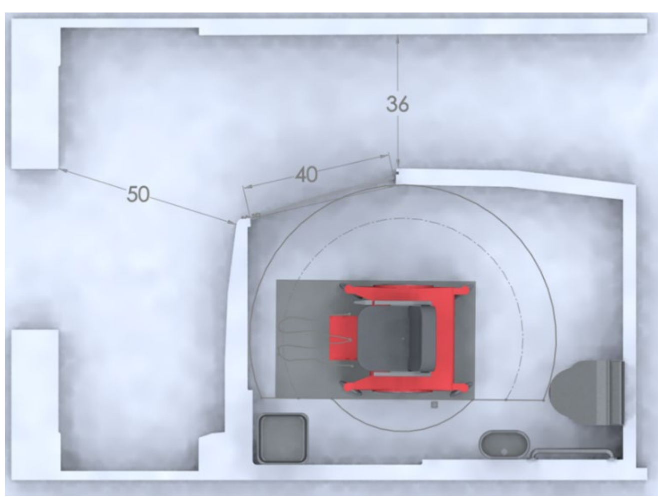


Figure 4-17 Key dimensions for Restroom that Permits a 54 inch Scooter to Move to Seating Area

Appendix B contains more details on the development process for the new accessible restroom.

5.

The current Acela first class restroom and seating area comply with many of the features in the new guidelines. Some members' remarks focused on the challenges of the current business class vehicle. Nonetheless, Acela first class cars provided an excellent base for the study. Figure 5-1 shows the accessible restroom and seating area on the first-class Acela vehicle. The second part of the project focused on business class Acela cars. The spatial study of accommodating two or more WhMD on a rail car showed that it is possible, however, some configurations resulted in loss of containment of the WhMD. This is further discussed in Section 6.0.

5.1 Base Study of First Class Acela

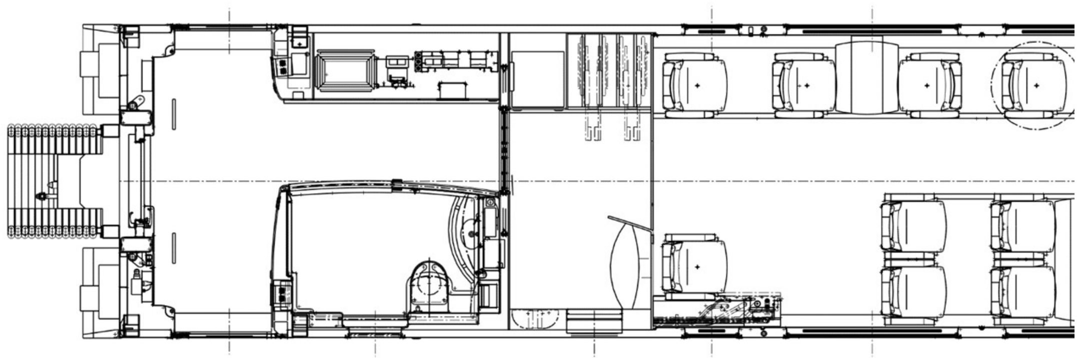


Figure 5-1 Acela Vehicle Used for Base Drawings

5.2 Seating Area Analysis

The Acela first class seating area, with base dimensions taken from SolidWorks® 2-dimensional model, are shown in Figure 5-2.

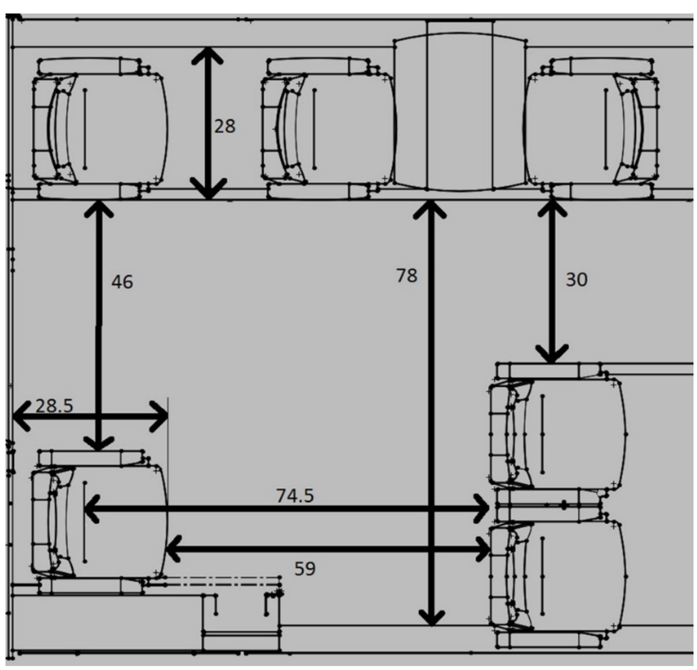


Figure 5-2 Base Dimensions of Accessible Seating Area

Figure 5-3 shows that side-by-side companion seating is not possible, as there is too much encroachment into the aisle. The large power base wheelchair does not fit in a side-by-side companion seating arrangement, but it does fit in a "café seating" arrangement—where two seats face each other. Café seating or open bay is used to denote seats that face each other.

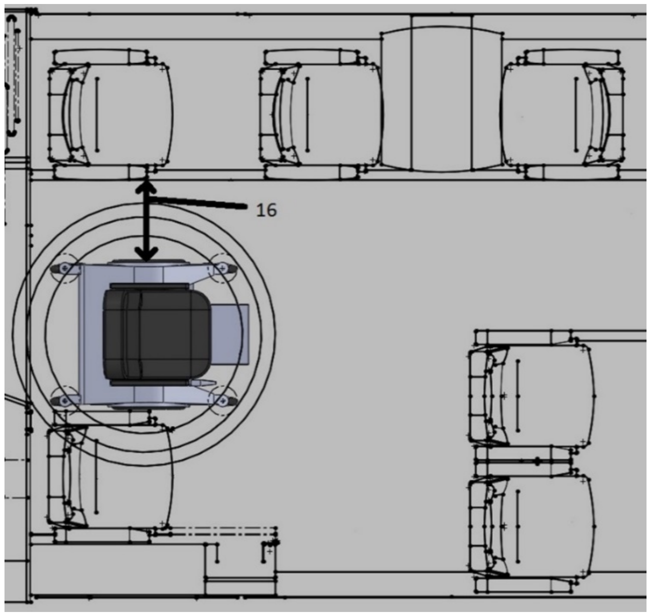


Figure 5-3 Side-by-Side Companion Seating with Power Base WhMD

Figure 5-4 and Figure 5-5 show two configurations with large power base. Figure 5-4 shows the power base WhMD in café seating configurations, oriented rear-facing with a forward facing built-in seat. Figure 5-5 shows the power base WhMD in the accessible space with flip seat (in the up position) in the forward-facing orientation.

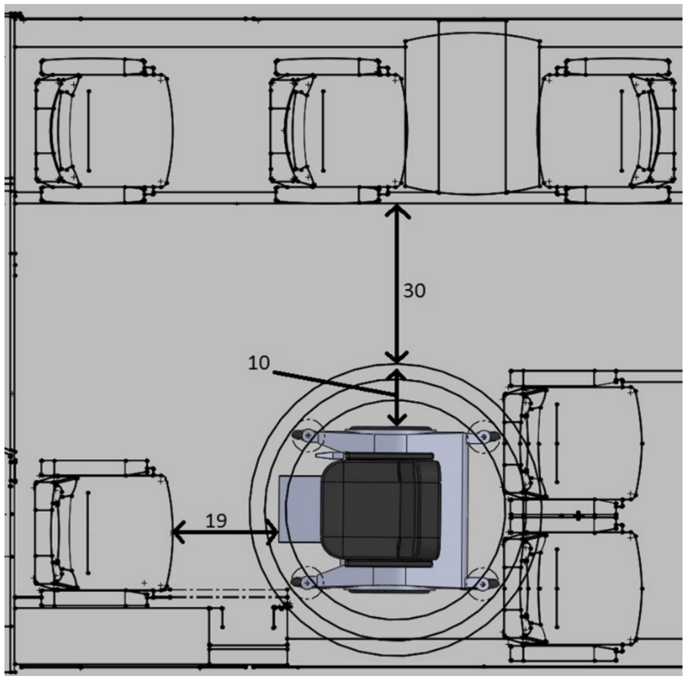


Figure 5-4 Cafe Seating Option with Power Base WhMD

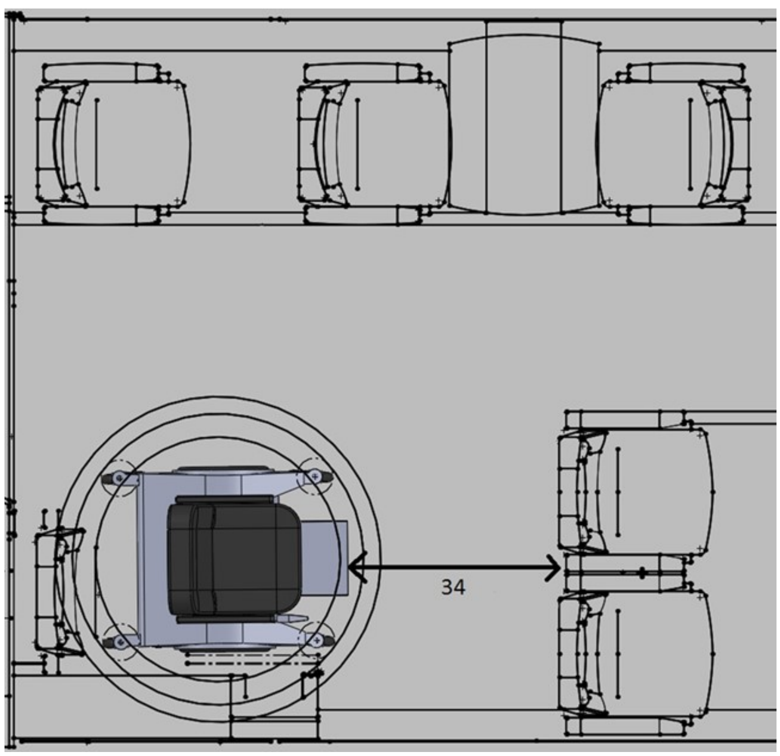


Figure 5-5 Flip Seat Option with Forward-Facing Power Base WhMD

5.3 Large Scooter Accommodation

There are a number of challenges associated with the accommodation of large scooters on board passenger trains. The new recommendations for larger lift platforms will permit scooters with a footprint of 54 inches long to access a train vestibule. Additional studies are needed to evaluate the movement from the vestibule area to an accessible seating area. The challenge is accommodating the large turning diameter of these devices. This may also require a redesign of the restroom space and door. Also required is an analysis of the stowage space for these scooters, which are assumed to be unoccupied when the train is in motion. Figure 5-6 and Figure 5-7 show café seating and side-facing orientation of the scooter in the seating area. Side-facing orientation is not recommended unless the unoccupied scooter is safely secured.

A large scooter does not fit well in the seating area of either side in a café seating orientation. A large scooter may fit if there is a flip-up seat. The renderings as shown do not accommodate any type of table. There are a number of issues associated with having a fixed table in the accessible seating area and further study of these issues is recommended. The seating area analysis identified that stowage space needs to be identified for an unoccupied scooter.

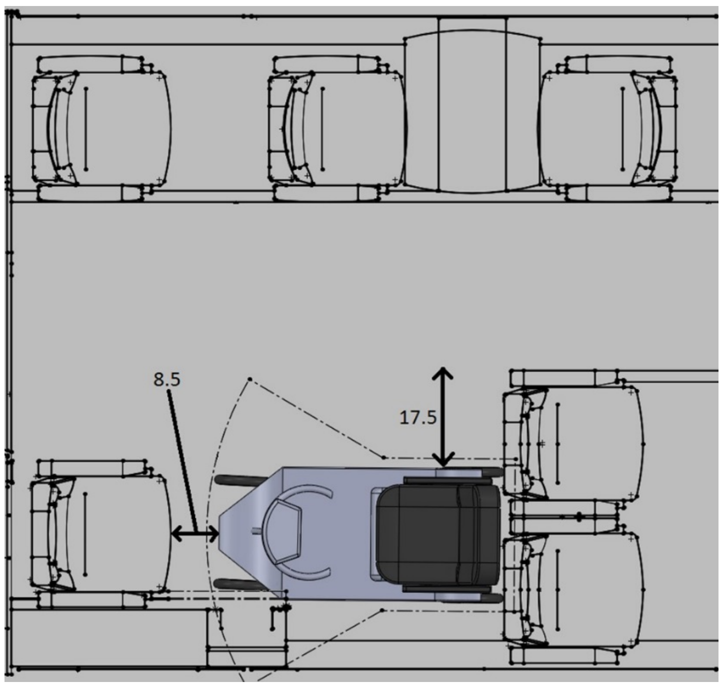


Figure 5-6 Café Seating Orientation of a 54-inch Scooter

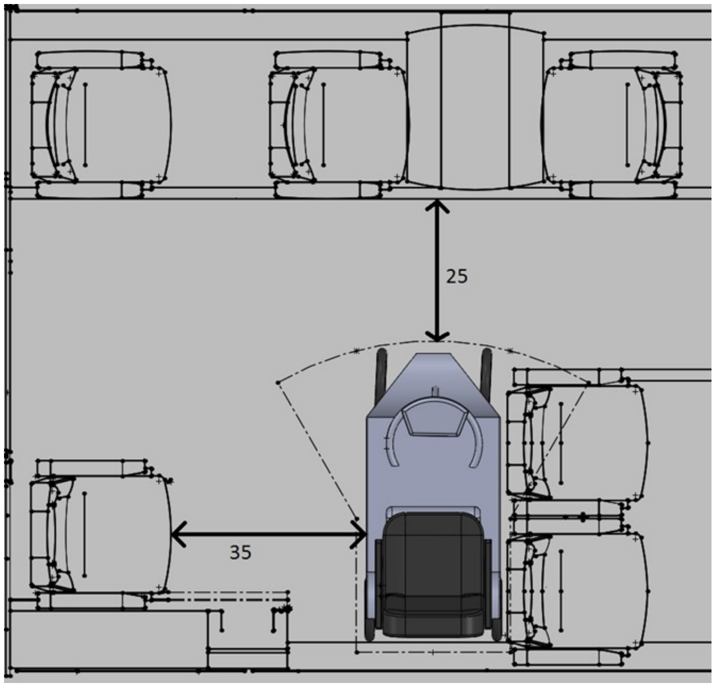


Figure 5-7 Side-Facing Scooter (not recommended)

5.4 Business Class Acela

Figure 5-8 shows the business class Acela that was the representative traincar used as a base of analysis. This base design was modified to incorporate a larger restroom designed to accommodate a large power base wheelchair turning around within the restroom.

This study also removed a number of pieces of equipment, such as electrical panels, and these will need to be relocated.

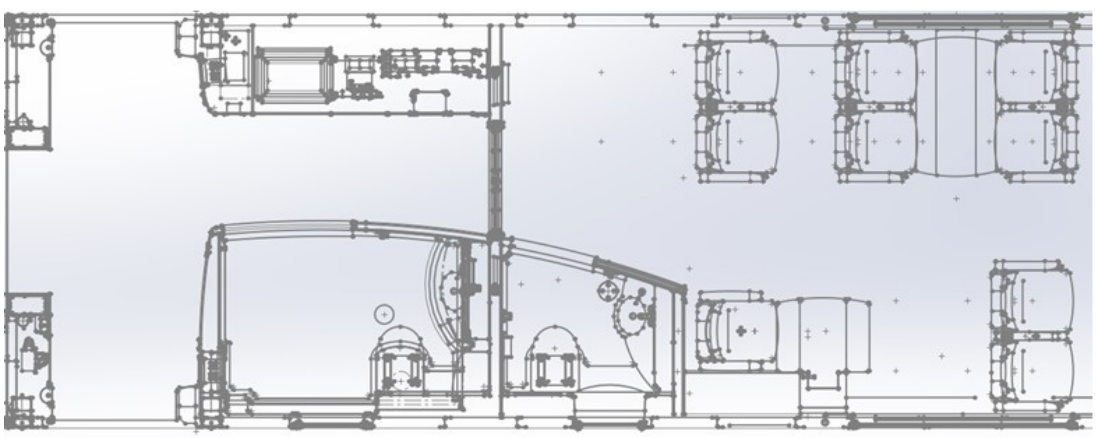


Figure 5-8 Acela Business Class Railcar Used as Base for Study

The seating area analysis incorporated considerations for the stowage of scooters and other WhMD not occupied during transport and the accommodation of service animals. The analysis includes a detailed summary of different seat location scenarios. The car was modified with a new larger accessible restroom and evaluated with three generic types of WhMDs: a manual wheelchair, 48-inches and 54-inches-long scooters and large power base WhMD. Figure 5-9 shows the base Acela business class car with a larger accessible restroom. The X marks the loss of a seat, O marks the addition of one seat, and the OO marks the addition of a row. The small telephone area or restroom shown in Figure 5-1 and Figure 5-8, respectively was removed for the analysis. Different seating scenarios were developed and these are discussed in the seating analysis report that is summarized in Appendix C. Researchers assumed the scooters would be stowed during transport, and passengers boarding in a scooter would transfer to a regular seat. In an economic analysis the use of a regular seat by a person using a scooter should be considered.

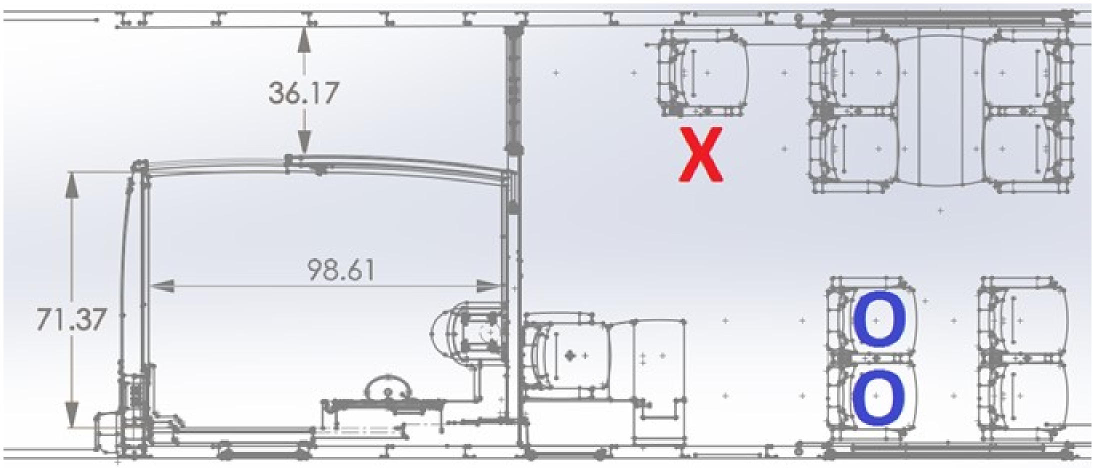


Figure 5-9 Base Acela Business Class Car with Larger Accessible Restroom

Figure 5-10 shows the challenge of accommodating two WhMDs. Two devices are shown, but the power base wheelchair does not have access to the table. This particular layout preserves aisle access.

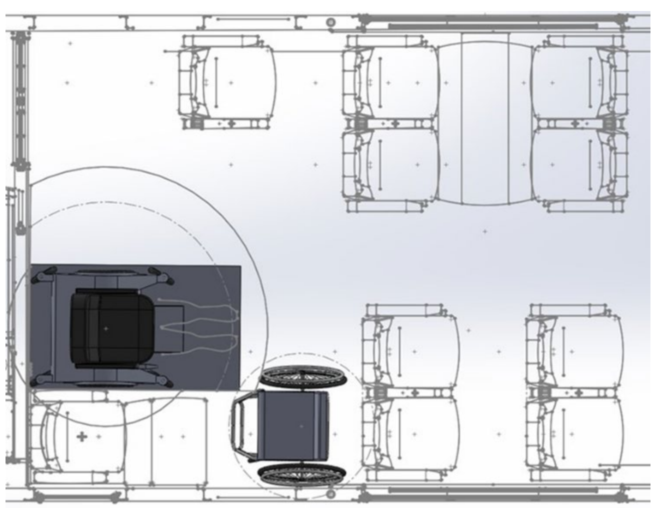


Figure 5-10 Accommodating Two Types of WhMDs with No Seat Loss

Figure 5-11 shows two large power base WhMDs. A row of seats is lost to make space for the WhMD on the right. The figure illustrates the challenge of providing a fixed table and still accommodating WhMDs. This configuration still provides access to the aisle.

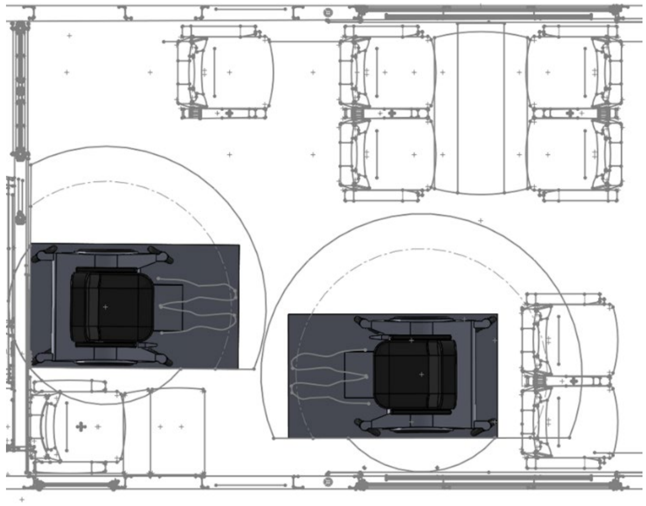


Figure 5-11 Two Large Power Base WhMDs with Seat Loss

Figure 5-12 shows two large power base WhMDs where a single seat and one row of seats are removed. The one power base WhMD has access to a table. The power base WhMD in the lower part of the image does not have access to the table, but there is space for a manual wheelchair, a service animal, or small scooter stowage in transverse orientation.

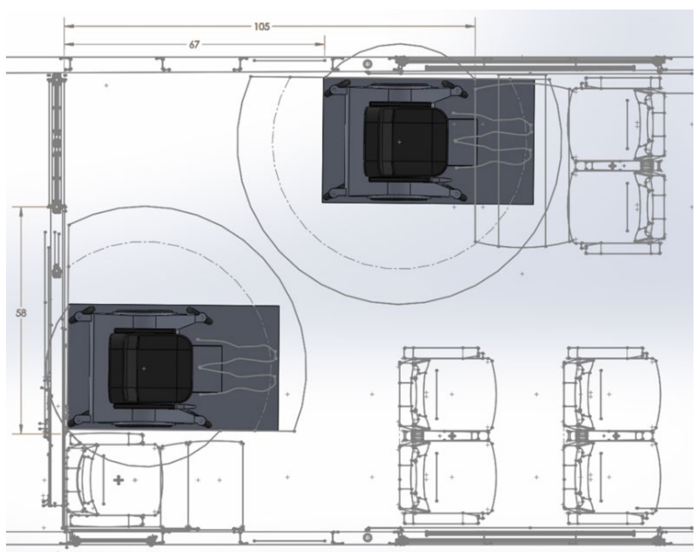


Figure 5-12 Two Large Power Base WhMDs with Table Access for One and Space for Service Animal or Stowage

5.5 Scooter Stowage

A longer 54-inch scooter can only be stowed in the longitudinal position, as shown in Figure 5-13. If the long scooter is stowed crosswise it impedes the aisle. The figure also shows a possible location for a manual wheelchair adjacent to the row of seats, but the three-across seating may not be desirable as is makes getting in and out of seats more difficult. The manual wheelchair could also fit by the table and face the back wall. The seat analysis did not consider that a revenue seat would be used by the passenger who boarded in a scooter.

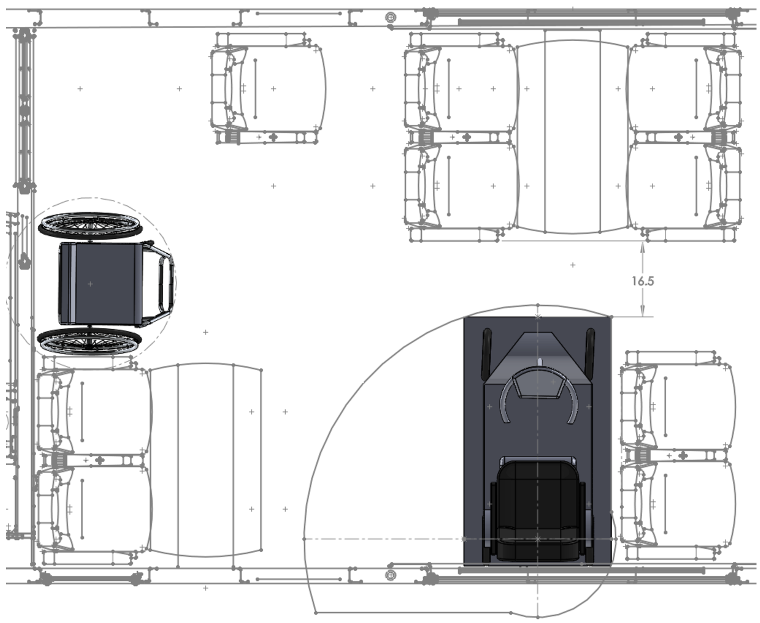


Figure 5-13 Large Scooter Does Not Fit in Crosswise Direction

Figure 5-14 shows a 48-inch-long scooter that could be stowed crosswise and not impede aisle traffic. This figure also shows a manual wheelchair at the table. Another manual wheelchair could be located adjacent to the single seat. A row of seats has been lost, but there is also room for service animals.

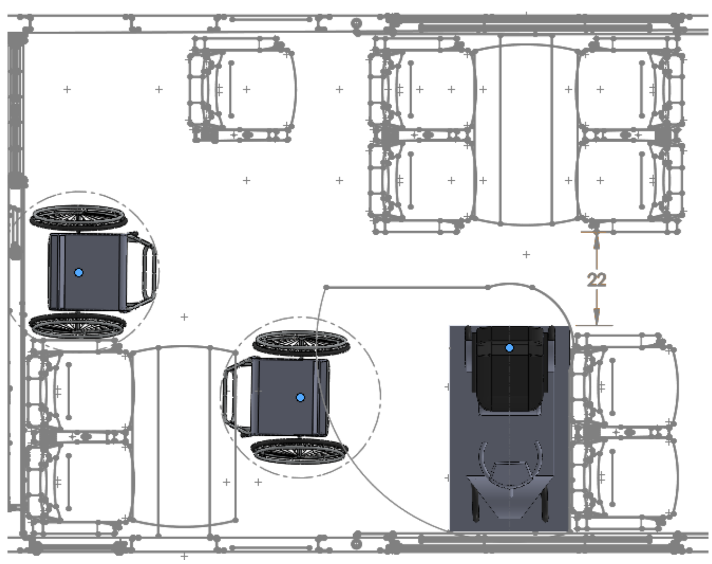


Figure 5-14 Small Scooter in Crosswise Stowage

5.6 Summary of Seating Study

The seating study showed that there is no single configuration that balances access and containment. The analysis also shows that the tradeoff between the number of WhMDs accommodated is not directly related to seat loss. It is possible, with minimal seat loss, to accommodate more than one WhMD. In calculating seat loss, it is also important to consider that a passenger who boards in a scooter will sit in a revenue seat. Access to a fixed table by passengers in power base WhMD or regular wheelchairs is a problem. A new table design that meets the functional requirements and safety regulations needs further investigation. There is a need to develop a new table that can be both adjustable and collapsible, providing significant opportunities for the accommodation of WhMDs. In an investigation of occupant protection and containment, the safety and independence of passengers must be balanced.

6. Containment of Occupied WhMDs on Passenger Rail

Passenger rail systems in Asia, North America, and Europe do not require passengers in WhMDs, such as wheelchairs, to use securement systems for their WhMDs. In large transit bus vehicles with gross vehicle weights over 25,000 lbs, there has been a transition from complete securement of WhMDs to the use of rear-facing containment. This has been common practice in Europe and Canada for decades and is slowly being adopted by U.S. transit agencies that provide bus rapid transit service and fixed-route transit services.

In both Canada and the U.S., research on the appropriate level of containment for WhMDs on passenger rail vehicles is lacking. The population is aging and getting larger and heavier; consequently, and the types of WhMDs is increasingly more diverse, larger, and heavier. This is reflected in the types of WhMDs passengers are trying to bring on board trains.

FRA and members of the RVAAC requested a feasibility study on the economic impacts of the loss of revenue seats in accommodating two or more WhMDs in the accessible seating area (U.S. Access Board, 2015). The feasibility study indicated there is space to accommodate two WhMDs without significant impact on revenue seat loss; however, larger safety issues have emerged, such as the containment of such devices.

6.1 Background

In most passenger rail configurations, passengers are contained by the seat in front of them in a unidirectional seating arrangement; and often by a table in a cafe style-seating arrangements.

In the U.S. and Western Europe, population demographics have shown that the general adult population is becoming more obese and many of these individuals require WhMDs, such as scooters, to increase their mobility.

The AWG made recommendations to increase access to passenger rail vehicles to reflect the size and shape of WhMD users. These recommendations included basic dimensional changes for the bi-level vehicle specification (PRIIA 305, 2016).

- Increase WhMD accessibility space to 32 inches wide by 59 inches long.
- Increase vestibule width to 44 inches.
- Increase minimum design load of car- borne wheelchair lift to 800 lbs.
- Increase surface platform of the car- borne wheelchair lift to 30 inches wide by 54 inches long.

WhMD require space to maneuver into the wheelchair space, and the amount of maneuvering space required depends on the design of the WhMD. Scooters rotate on their rear axle and require much more space than a manual or power base wheelchairs that rotate around a central axis.

The subject of overall passenger containment has also emerged as a result of severe accidents in the U.K. and U.S. Both the Rail Safety and Standards Board (RSSB) in the U.K. and FRA have conducted investigations into the crashworthiness of tables (Parent, 2005; Rail Safety and Standards Board, 2008). The E.U.-funded project SafeInteriors project provides guidelines for the current project (UNIFE, 2014).

The project's technical report for interior passive safety in railway vehicles noted the following:

To minimize the severity of injuries, design for interior passive safety incorporates:

- The person's velocity and kinematics at the point of contact
- The characteristics of features or structures impacted
- Probable impact areas relative to the person and their proximity to vital organs

The report also states:

Section 4.2.4 Containment

> *(1) The objective for internal containment is to reduce the risk of injury by ensuring that, in the event of a collision or derailment, passengers or staff are contained in the area of the vehicle where they are located and equally heavy items such as luggage or on-board equipment are contained in their respective areas. For internal containment, the principal objectives are to prevent long excursions through the vehicle and therefore reduce the velocity of secondary impacts and interaction with other passengers.*
>
> *(2) Research suggests that unidirectional seating provides a better level of containment for seated passengers compared to bay seating* [or café seating, in this report]*, as the passenger's movement is restricted to the immediate area.*
>
> *(3) Bay seating can also give a high level of containment where fixed tables are installed, however open bay seating arrangements without tables can lead to increased injury severity and numbers of injuries because of the longer distances the passenger can be displaced before impacting the seat or person opposite* (UNIFE, 2014).

Increasing maneuverable space within the accessible seating area of a passenger rail vehicle and the desire to accommodate more than one WhMD introduces new challenges. Seated passengers are currently offered containment by either the seat in front for those in unidirectional seating arrangements or by a table for those in café seating arrangements. Café seating arrangements that do not include a table do not offer the same level of passenger containment.

The NGEC TSC requested an investigation into whether two or more wheeled devices can be accommodated on a coach car. This request prompted the research questions below.

6.2 Research Questions:

1. What is the appropriate interior space that accounts for WhMD maneuvering but also provides containment for WhMD?
2. What are the appropriate levels of deceleration and jerk to be considered in the vehicle interior for passenger rail vehicles under:
    - Crash conditions assuming vehicle remains upright
    - Severe operating conditions? (skid conditions)
3. What is the appropriate level of containment for occupied WhMDs on passenger rail vehicles?

Research Question 1. What is the appropriate interior space that accounts for WhMD maneuvering but also provides containment for WhMD?

The anthropometric study by Steinfeld (2010), shown in Table 6-1, compares basic dimensions used in national standards.

Table 6-1 Comparison of Accessibility Standards across Four Countries

Measurement Dimension	Country & Standards Document			
	Australia	Canada*	U.K.	USA
	AS 1428.2 (mm)	B651-04 (mm)	BS8300:2001 (mm)	ICC/ANSI A117.1 (mm & in.)
Wheelchair Dimensions				
Unoccupied Device Width	-	660	-	660 (26)
Unoccupied Device Length	-	-	-	1065 (42)
Seat Height, maximum	480	480	-	485 (19)
Clear Floor Space				
Width, minimum	800	750	900	760 (30)
Length, minimum	1300	1200	1350	1220 (48)
Knee and Toe Clearances				
Knee Clearance Height, minimum	640-650	680	700	685 (27)
Toe Clearance Height, minimum	280	230	300	230 (9)
Knee Clearance Depth, minimum	230	200	260	280 (11)
Toe Clearance Depth, maximum	190	230	-	150 (6)
Reach Ranges				
Forward Reach - Unobstructed	250-1220	380-1220	-	380 (15) -1220 (48)
Side Reach – Unobstructed	230-1350	230-1400	630-1170	380 (15) -1370 (54)
Side Reach – between 255-610 obstruction depth	-	-	-	Max. 1170 (46)
Maneuvering Spaces (minimum)				
90-Degree Turn	-	920	-	915 (36)
180-Degree Turn	1540x2070	1500	1500	1525 (60)
180-Degree Turn around Barrier	-	-	-	1065 (42)
360-Degree Turn	1540x2070	1500	1500	1525 (60)
Hand Force for Operating Controls, maximum	-	-	-	5 lbf.

* This standard also includes an appendix with information on device size and maneuvering spaces for power chairs and scooters derived from unique device identifier research.

Space requirement standards for a 360-degree turn are quite similar across countries, ranging from 1,500 mm (59 inches) in Canada and the U.K. to 1,525 mm (60 inches) in the U.S. Less than 50 percent of the Steinfeld study of manual and powered wheelchair users completed a 360-degree turn within the U.S. standard turning diameter of 1,525 mm (60 inches).

"*None of our sample's scooter users were able to complete a turn within the U.S. standard. In fact, the tightest 360 turn performed by a scooter user was 1900 mm (75 inches) in diameter!*" (Steinfeld, 2010)

The 360-degree turning diameter would have to be increased to 2,500 mm (a little over 98 inches) to accommodate the entire study sample.

In Section 3, researchers recommended adding toe clearance for the power base chairs (Large Power Base WhMDs) that produced a turning radius of 1,076 mm (42 inches), as shown in Figure 6-1. The scooter radius was at least 1,372mm (54 inches).

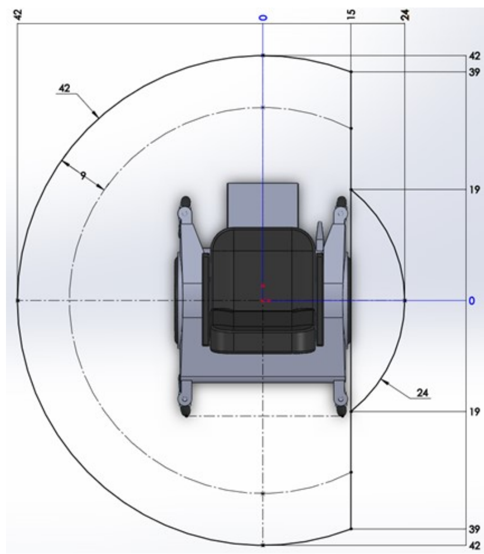


Figure 6-1 Large Power Base WhMD with Toe Clearance

Scooters are not very stable, and the research team assumed most people who use these devices will transfer from the scooter to a regular train seat. This introduces the new challenge of safely stowing or containing the unoccupied scooter and any other unoccupied WhMDs, so that they do not become projectiles during severe braking or crash situations.

The current recommendation in the PRIIA NGEC 305 bi-level car specification is for a maneuvering area and accessible seating space of 59 inches long by 32 inches wide. The current ADAAG standard for interior circulation is a 60-inch turning circle. As stated previously and documented in Steinfeld (2010), the 60-inch turning circle does not accommodate many WhMDs in use today.

Research Question 2. What are the appropriate levels of deceleration and jerk to be considered in the vehicle interior for passenger rail vehicles under: (a) crash conditions, assuming vehicle remains upright, and (b) severe operating (i.e., skid) conditions?

A number of studies investigated passenger comfort during braking and the limits of longitudinal accelerations and braking. Related to deceleration is jerk, which is the rate of change of acceleration and the impact of excessive jerk on passenger instability. The worst-case scenario for jerk generally occurs when a train is approaching a station at low speed and train brakes are applied. Jerk, by definition, approaches infinity when the speed goes to zero (Powell, 2015). Abernethy observed that in an experimental work, the mean deceleration to displace subjects from the seat was (0.45 g ± 0.11 g) for low-level jerks and (0.49 g ± 0.09 g) for high-level jerks, and the analysis of variance showed there was no significant difference between low- and high-level jerks (Abernethy, 1977). A study of the postural stability of wheelchair users who primarily had spinal cord injuries were able to retain balance within the wheelchair at an acceleration of 0.126 g, but that they lost balance at disturbance levels of approximately 0.2 g (Kamper, 1999). Note that these accelerations were less than 0.5 g.

Three previous studies examined the impact of rapid deceleration on standing passengers, as this group is often considered the critical baseline for standards. Hoberock (1976) concluded that it is difficult to set conclusive limits on acceleration and jerk since there are large variations in the tolerance of passengers and there are many operating variations (Hoberock, 1976). Many other factors that affect ride comfort, including rail curvature, speed, rates of acceleration and deceleration, seat orientation, and the availability of hand holds for both seated and standing passengers. Many other human factors related to age and physical condition also affect passengers' ability to stay upright.

In all the studies reviewed, the maximum longitudinal decelerations considered were less than 1 g, and most were less than 0.5 g.

This study made several assumptions:

- All passengers are seated in vehicle seats or in a WhMD.
- All passenger are facing in the longitudinal direction of the railcar (no transverse seats).

Secondary Impacts and Occupants in WhMDs

The concern for occupant protection is based on work conducted at the Volpe National Transportation Systems Center (Volpe Center) that investigated secondary impacts associated with serious passenger rail accidents. This work was also validated in sled tests (VanIngen-Dunn, 2003).

All the studies clearly showed that the secondary impact velocity (SIV) directly affects the level of injury sustained, and that the secondary impact velocity is the interaction between the occupants and interior fixtures and affects occupant deceleration. Compartmentalization is an occupant protection strategy to limit the travel distance and relative velocity of an unrestrained occupant. SIV is the difference in velocity of the occupant and the train car. Occupants travel faster than the car at the moment of impact, since the occupant's initial speed is the same as the train car at the start of "free flight" and the train car has slowed down. SIV is a function of the crash pulse or deceleration time history and the interior configuration. SIV increases with distance traveled with respect to the interior. Crash tests and accident reconstruction have shown that there is a relationship between the relative velocity and the relative displacement of distance travelled, as shown in Figure 6-2 and Figure 6-3. The resulting injury severity is a function of the SIV and the stiffness of the interior fixtures.

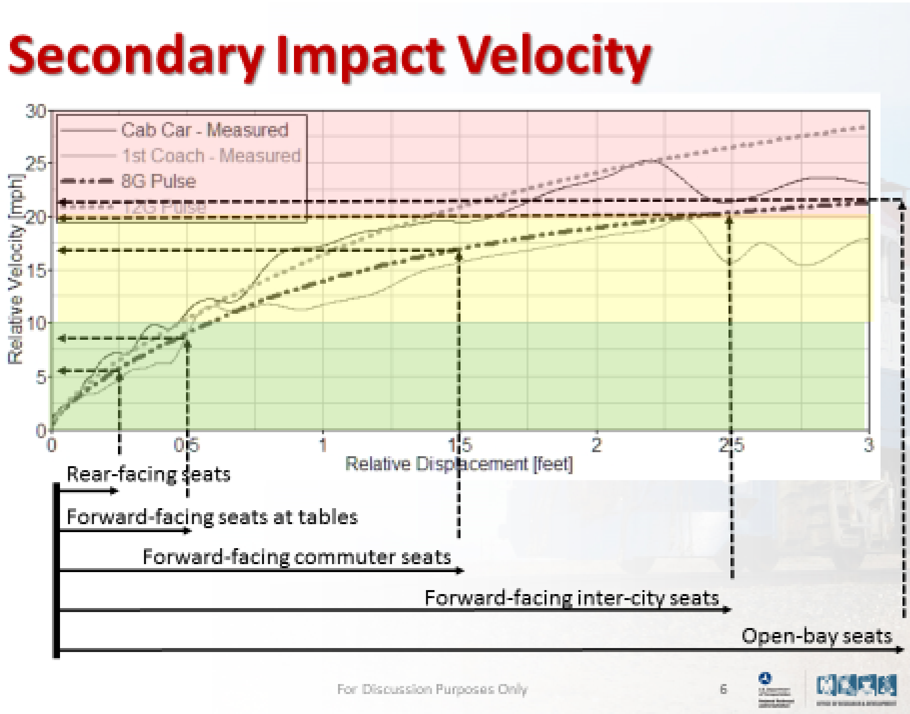


Figure 6-2 Secondary Impact Velocity and Seat Orientation

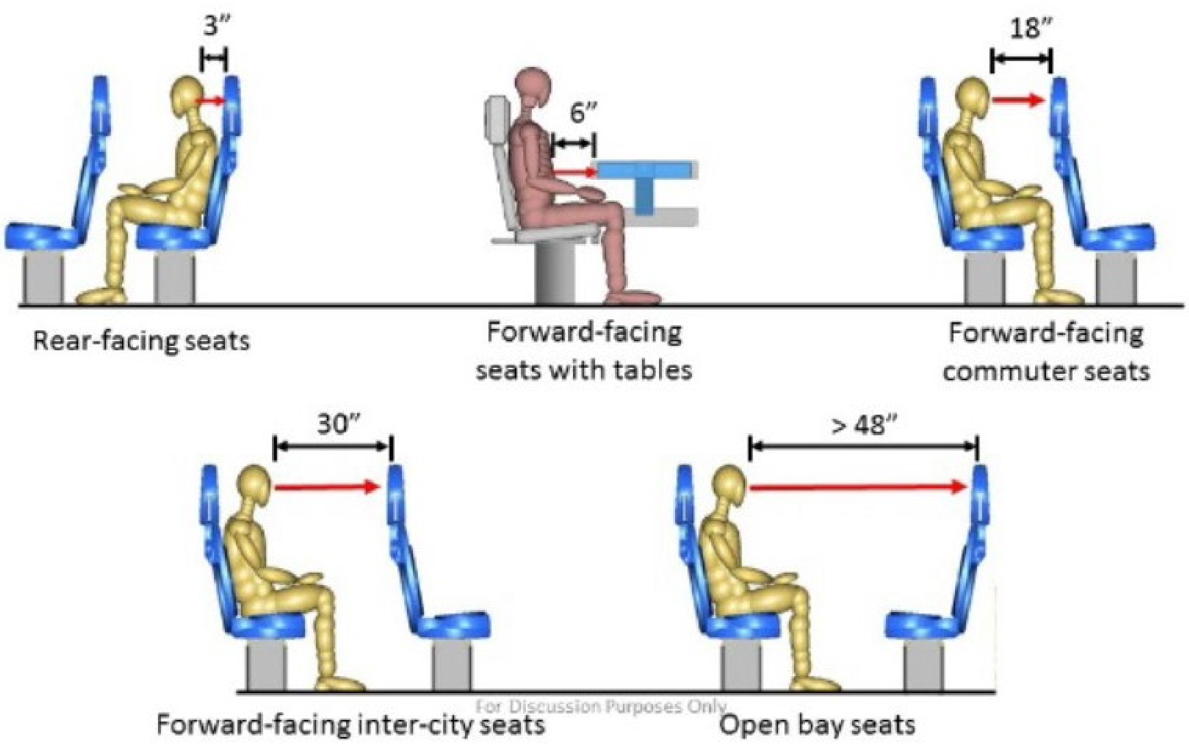


Figure 6-3 Seating Orientation and Travel Distance

The severity of the SIV can be minimized by reducing the free flight travel distance as well as providing energy attenuation features in car structure. Focusing on the interior fixtures, the stiffness can be managed by incorporating energy absorption features into seats, tables, and bulkheads by decelerating the occupants more slowly and minimizing contact forces.

Forward-Facing versus Rear-Facing Seats

It has been known for many years that rear-facing seating provides more occupant protection in a frontal crash than forward-facing seats. However, in general most people like to face the direction of travel to see where they are going. The Volpe Center research has clearly shown that rear-facing is much safer than forward-facing. This also is consistent with research conducted on bus transit vehicles, which has led to the implementation of rear-facing containment on large transit buses.

Research Question 3. What is the appropriate level of containment for occupied WhMDs on passenger rail vehicles?

A UNIFE study commissioned by the European Union provides a detailed discussion on seat design, configuration, and spacing for interior passive safety (UNIFE, 2014). The report also includes a detailed discussion of types, sizes, and technical requirements for tables.

A RSSB study on the use of passenger restraints suggested that providing three-point restraints and associated stiffening of the seats would likely increase injuries of unrestrained passengers (Rail Safety and Standards Board, 2007). This is somewhat counter-intuitive, but the issue is the impact on passengers who are not restrained.

A key conclusion from both the RSSB and UNIFE studies was the amount of passenger containment to be provided in different seating orientations. Passengers in unidirectional seating were more effectively constrained than passengers in facing pairs of seats with or without a table. The European guidelines recommend seat distances of 600 mm (23.6 inches) for facing seats (Official Journal of the European Union [OJEU], 2014). The figures below were taken from the European directive; with additional remarks added. The figure numbers refer to the number assigned in the European directive. The seats shown are high-back seats with integrated headrests that are necessary to reduce the effect of whiplash during sudden deceleration.

In Figure 6-4 the numbers refer to (1) the seat height from the floor, (2) the distance between the seats, this is commonly called seat pitch and (3) the headroom above the seats.

- The seat height above the floor is 430 mm–500 mm (approximately 17 inches–19.68 inches). In the U.S. the acceptable standard is 17-19 inches, with 18 inches from floor level preferred. The minimum seat width for priority seats or seats designated for people with disabilities is 450 mm or 17.7 inches wide. It should be noted that for the comfort of all passengers, wider seats should be considered.
- The Headroom above seats: minimum headroom is 1680 mm or 66 inches. This would be a challenge for people who are over 5’6”.

Four figures from Appendix H of the directive are shown below. Figure 6-4 is the priority seating area.

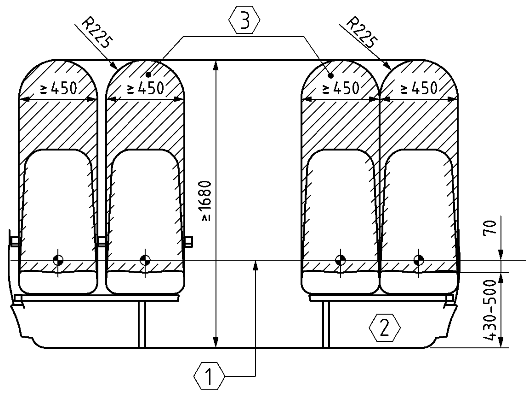


Figure 6-4 Priority Seat Headroom (OJEU)

The challenges of the unidirectional seating for users of WhMD is the limited space available for transfers to and from the seats, as shown in Figure 6-5. Researchers assumed that scooter users and most manual wheelchair users would not need assistance performing transfers from a WhMD to the seat. All aisle-side seats designated for people with disabilities should have arm rests that rotate up, to permit a clear space for a transfer. In unidirectional seating the minimum distance from the front of the seat is 230 mm (approximately 9 inches), and the total distance is 680 mm (26.77 inches). The seat spacing or seat pitch can affect passenger comfort and a short seat pitch can impair transitions from scooters and wheelchairs as well as passengers who may have restricted lower limb mobility.

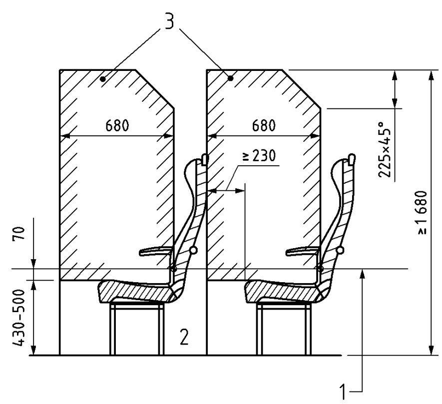


Figure 6-5 Unidirectional Priority Seats (OJEU)

The seating arrangements shown in Figure 6-6 and Figure 6-7 are not recommended, due to the lack of occupant containment and risk exposure.

There is a challenge with facing seats shown in Figure 6-7. It is important to permit enough horizontal distance between the seats for passenger access, egress, and general comfort, but too much "legroom" will reduce overall passenger containment and increase risk exposure. In

Figure 6-6, the horizontal distance is 600 mm (23.6 inches)[2]. This distance should permit most people to perform an independent transfer from a WhMD to the seat.

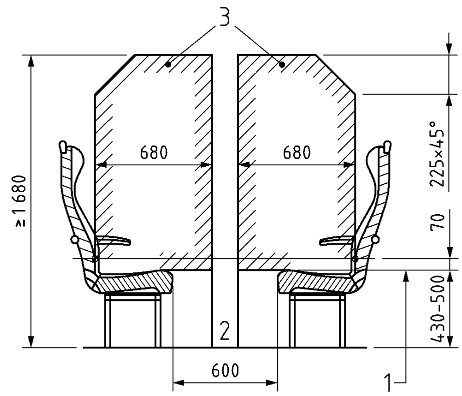


Figure 6-6 Facing Priority Seats (OJEU)

If a table is present, as shown in Figure 6-7, the distance between the edge of the table and front of the seat is 230 mm (9 inches). This distance may eliminate passengers who are obese.

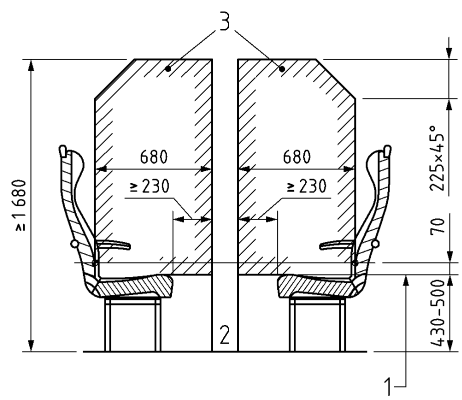
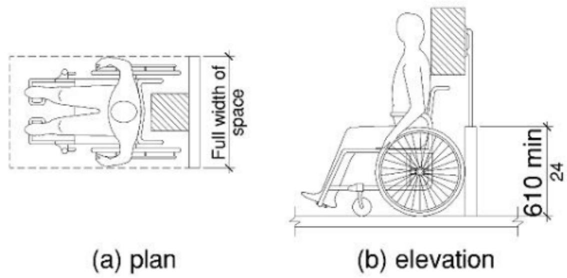


Figure 6-7 Facing Priority Seats with Table in Stored Position (OJEU)

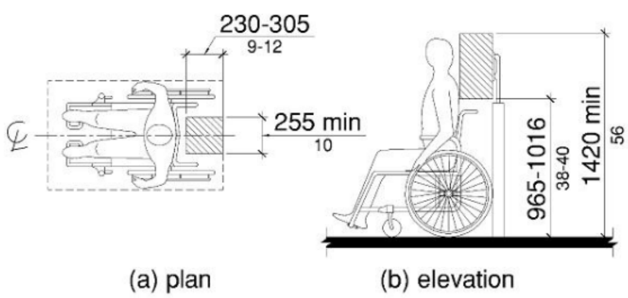
In Figure 6-8 and Figure 6-9 below, researchers assumed that the wheelchair orientation is rear facing, and the barrier is at least 24 inches above the floor; in addition, a head rest to prevent whiplash is recommended (ADAAG, 2006).

[2] OSU research on aircraft lavatories has shown that 23.6 inches is the minimum distance for an assisted transfer from an aircraft boarding chair to the toilet.



T403.5.1 Forward Excursion Barrier

Figure 6-8 Rear-Facing Bolster (ADAAG, 2006)



T403.5.2 Padded Head Rest

Figure 6-9 Padded Headrest for Rear-Facing Back Board (ADAAG, 2006)

The figures below are from Appendix I of the European directive. In the directive Section 4.2.2.2 (3):

> *"(3) Over the full length of the wheelchair space the width shall be 700 mm from floor level to a minimum height of 1 450 mm with an additional 50 mm width to give clearance for hands on each side that is adjacent to any obstacle that will inhibit clearance for the wheelchair users hands (e.g. wall or structure) from a height of 400 mm to 800 mm above floor level (if one side of the wheelchair is adjacent to the aisle there is no additional 50 mm requirement for that side of the wheelchair as it is already free space)."* (OJEU, 2014)

The occupied wheelchair shown in Figure 6-10 has a horizontal distance of 1,300 mm (51.18 inches). It is important to note that in these illustrations there is a structure (label 1) that has a minimum height of 600 mm (23.6 inches) and is at least 700 mm (27.6 inches) wide. In the U.S., the suggested height of the structure should be sufficiently high to prevent the WhMD from rotating backwards.

Total maneuvering space is 63 inches, 4 inches longer than the 59 inches often adopted in the U.S.

In Figure 6-11 and Figure 6-12 below, (label 1) is the structure at the end of the wheelchair space, (label 2) is the front edge of the passenger cushion, and (label 3) is the wheelchair space.

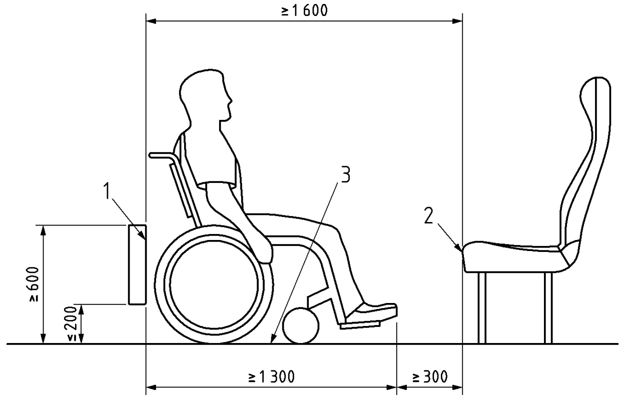


Figure 6-10 Wheelchair Space in Facing-Seating Arrangement (OJEU)

Figure 6-11shows the wheelchair space in a unidirectional seating arrangement. The horizontal distance of 1,500 mm (59 inches) is consistent with the current U.S. standard.

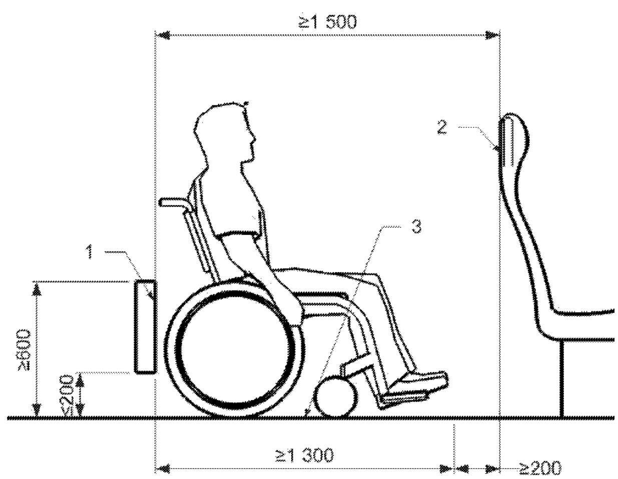
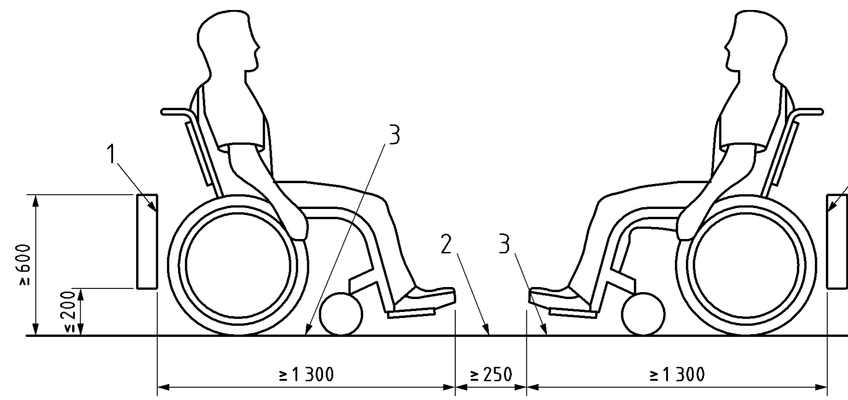


Figure 6-11 Wheelchair Space in Unidirectional Seating Arrangement (OJEU)

Two facing wheelchair spaces are shown in Figure 6-12. In this configuration, there is the potential for a horizontal clear space of 2,850 mm (112.2 inches, or 9.4 feet). This configuration is not recommended, since the risk exposure due to SIV is very high.



1 Structure at end of wheelchair space.
2 Space between wheelchair spaces min. 250 mm (9.8 inches).
3 Wheelchair space.

Figure 6-12 Two Facing Wheelchair Spaces (OJEU)

6.3 Summary

Occupant safety must be considered when evaluating the accommodation of passengers who use WhMDs on passenger trains. The analysis has shown that there is a trade-off between space to accommodate two or more WhMDs and the need to provide containment for occupant protection. The preliminary research has shown that rear-facing containment should be considered, with the inclusion of devices to restrain the mobility device and provide aisle-side containment as well. Passenger trains move bi-directionally and therefore containment devices must be available in both directions. This requirement is likely to restrict the accommodation of more than one WhMD.

7. The Use of Elevators to Access Bi-level Passenger Cars

This study examines issues associated with including vertical access technology as a requirement for new bi-level lounge cars. RVAAC recommendations are referenced in the study.

Three railroads that operate bi-level passenger trains with elevators were contacted. They operate regular scheduled passenger rail service and/or excursion operations and were consistent in their responses. All three have: (a) much higher staffing levels than most regular commuter or intercity passenger services; (b) all the elevators are operated during train movement and while stopped at stations (c) trained personnel operating the trains; and (d) ambulatory passengers with difficulties negotiating stairs as the most frequent users of the elevator.

Each noted that the original manufacturer of the elevators is no longer in business, and there were some concerns on procuring parts, although the maintenance departments found other sources for spare parts. Each of the railroads have modified the elevators and have added additional safety elements. No safety issues were reported from elevator operations; however, the companies emphasized that all elevators are operated by trained staff. All of the railroads remarked that the elevators required both routine and preventative maintenance. Two of the railroads do not operate in the winter, so heavy maintenance occurs in the off-season—but all railroads service the elevators every evening during the operating season.

One railroad mentioned the challenge of conflicting requirements between building elevator requirements and railroad regulations and indicated that the building requirements for elevators may not be appropriate for railcar applications. There is a need to harmonize standards and requirements for elevators between oversight agencies.

A key issue that has been identified while conducting the survey is the unknown effect of train operations at 90 mph and higher on elevator operations. FRA would require elevators to remain functional after a 4g vertical, 4g lateral, and 8g longitudinal acceleration event, as is required for all interior fixture on passenger rail cars. Additional research would be needed to examine regulatory requirements for Tier I, II, and III operating environments and applicability to passenger railcar elevators.

RVAAC developed recommendations for vertical movement on bi-level intercity passenger trains. Although not specifically included in the proposed RVAAC recommendations, but to be consistent with the new PRIIA 305 bi-level car specifications platform lift recommendation, the weight limit should be increased to 800 lbs, increased from the 550–750-lbs limit currently found on elevator equipment in service on passenger rail equipment. The elevators currently in operation have an internal cab that measures 33.5 inches by 48 inches. The new RVAAC recommendation for car borne and platform lifts is for a longer platform of 54 inches. For consistency, new vertical access technologies should have a clear space of at least 33.5 by 54 inches. This may impair overall space utilization and revenue seating. Currently, all elevators operate on a drive-in, back-out operation. The new RVAAC vertical access technologies should permit drive-through operations.

All three railroads emphasized that, despite the maintenance requirements, elevators are necessary for their operations.

8. Conclusion

The main conclusions that focus on the accessible restroom, analysis of accessible seating space, and the feasibility of providing elevators on bi-level cars are summarized.

8.1 Accessible Restroom

Summary of preliminary accessible restroom design are:

1. Orientation of the toilet and restroom is longitudinal.
2. The sink and toilet are located on the outboard side of the vehicle.
3. At least one sink must be accessible from the toilet.
4. The restroom door shall have a 42-inch opening.
5. The restroom has a corner notched-out to permit easier maneuverability by large scooters between the vestibule and aisle to access the accessible seating area.
6. Seating area design is contingent on the size of the restroom. Preliminary studies have shown that at least one and perhaps two additional revenue seats may be possible, as documented in Appendix C.

To accommodate the larger accessible restroom in the study, an electrical cabinet and other equipment was removed. The electrical equipment cabinet on the base Acela cars measured 88 inches long by 27 inches wide. Location for the displaced electrical equipment would be needed.

8.2 Spatial Analysis of Seating

The seating analysis showed that two or more WhMDs as well as service animals can be accommodated. The seating analysis showed that there are trade-offs between seats lost or gained and the number of WhMDs that can be accommodated.

The seating area needs to model coach or business class cars to validate that there is sufficient space to accommodate a transfer from a large scooter, and subsequent stowage of the scooter.

A detailed study on the use of a table is required that addresses the prior research that is documented in the APTA recommendations for workstation tables (APTA, 2015). The research on workstation tables documents the potential for injuries (RSSB, 2007, 2008; Parent, 2005). A table is needed so that people who cannot access the dining car have access to a flat surface for meal service.

Additional analysis is required on the technical and operational feasibility of using a flip seat in the accessible seating area. Flip seats operational impacts have not been studied.

Traditionally, WhMDs have not been secured on passenger or transit rail systems. A study is required to examine the technical and operational feasibility of providing optional WhMD containment or securement on HSR systems.

8.3 Elevators on Bi-level Cars

Elevators are feasible if there is sufficient trained staffing available to operate the elevators. Of concern is the current lack of an elevator manufacturer for rail applications. The new RVAAC recommendations for vertical movement on bi-level equipment will require a new design for vertical change technology for future railcars. There is a need for development of new technical standards that consider physical risks and the new operating environment of HSR.

9. Recommendations

9.1 Phase 1 Recommendations for Further Study

Scooters

Additional work is required to define the accessibility recommendations for the single-level coach car, as well as to model the path of travel of a large (54-inch long) scooter from the platform lift to the accessible seating area and mobility device stowage area. A systems approach should be adopted to validate the location of the accessible restroom and specifically the location and size of the restroom door. This study should model a coach class vehicle and clearly identify a stowage area that accommodates both a large scooter and a manual wheelchair.

Seating Area:

As mentioned in the previous section, the research on workstation tables documents the potential for injuries (RSSB, 2007, 2008; Parent, 2005). Additional research is needed on the feasibility of a table that can be designed to be safe and functional for the accessible location. A table is needed so that people who cannot access the dining car have access to a flat surface for meal service as well as a working surface for a computer. Additional analysis is required on the technical and operational feasibility of using a fold up or flip seat in the accessible seating area. Fold up or Flip seats have been suggested as an option for managing both space and revenue seating, but the economic and operational impacts have not been studied.

Traditionally, WhMDs have not been secured on intercity passenger rail cars. A study is required to examine the technical and operational feasibility of providing optional WhMD securement on HSR systems.

9.2 Phase 2 recommendations for further study

The Phase 2 activities have shown that further research is required to:

(2) Determine the appropriate level of containment for Large WhMDs in the seating area for Tier II and Tier III operating environments.

(3) Design a table that accommodates Large WhMDs and provides a safe level of passenger protection and containment of Large WhMDs.

(4) If elevators are to be considered for the next generation of bi-level long distance trains, refinement of the technical requirements is needed. The elevator technical requirements must balance the RVAAC recommendations and the Tier I and II operating environments.

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11. Glossary

Acceleration: The rate of change of velocity per unit of time.

Accelerometer: An instrument for measuring acceleration

Accessible Restroom: The enclosed space where a person with a WhMD can use the toilet, vanity, and hygiene facilities. This also includes sufficient space for an attendant to perform an assisted transfer between the mobility device and toilet.

Accessible Seating Position: The 2-dimensional floor space occupied by a WhMD while travelling on a train.

Amtrak: US Passenger Rail operator.

Anthropometric: The measurement of the human individual.

Bi-level Car: A car of a train set that has two levels where passengers are accommodated for travel (not addressed in these recommendations).

Footprint: The static 2-dimensional floor area occupied by a WhMD.

Intercity rail: Long-distance passenger rail.

Large Wheeled Mobility Device (WhMD): In the context of this study, large wheeled mobility device is a powerbase style WhMD with the addition of toe clearance of a 90 percentile male .

Lift Platform: The 2-dimensional flat floor space of a lift to accommodate a WhMD.

Mobility devices: Wheeled walkers, wheelchairs, scooters.

Onboard Amenities: These include bistro, coffee, lounge, and dining cars.

Passageways: The horizontal clearance between fixed objects that is wide enough to permit a mobility device that is at least 30 inches wide to pass unimpeded.

Payload (design load)**:** 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.

People with Mobility Disabilities: People with reduced mobility.

People with Sensory Disabilities: People with reduced vision and/or hearing.

PRIIA: The Passenger Rail Investment and Improvement Act (PRIIA) of 2008 that reauthorized the National Railroad Passenger Corporation, better known as Amtrak, and strengthens the U.S. passenger rail network by tasking Amtrak, DOT, FRA, States, and other stakeholders in improving service, operations, and facilities. Section 305 particularly authorized the development of a Next Generation Equipment Committee to develop standardized specifications for passenger railcars.

Restroom: Enclosed private compartment for hygiene requirements

Service Animals: These highly trained animals are used by people with mobility, sensory, and cognitive disabilities to provide assistance to promote independent mobility and living. Some specially trained service animals are also called emotional support animals, which provide emotional support for individuals with psychological disabilities.

Securement: Device to mechanically secure a mobility device to a vehicle.

Shared Track: Use of same track for freight and passenger rail operations .

Siding: A section of rail track that enables a train to wait while another train passes.

Single-level Car: A car of a train set that has only one level where passengers are accommodated for travel.

Sleeping Compartment: Private sleeping compartment to accommodate person(s) on long distance travel overnight.

VIA Rail: Canadian passenger rail operator.

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, wheeled walkers, and other wheeled devices such as the Segway. Of primary concern are manual and power wheelchairs and mobility scooters.

12. Abbreviations and Acronyms

ADAAG – Americans with Disabilities Act Accessibility Guidelines

APTA – American Public Transportation Association

AREMA – American Railway Engineering and Maintenance of Way Association

ATD – Anthropometric Test Dummy

AWG – Accessible Working Group

CAD – Computer Aided Design

ERTC – Enhanced or Emergency Real Time Communication

FRA – Federal Railroad Administration

FTA – Federal Transportation Association

G, G force – Acceleration measured in terms of "g" where 1 g = 32.2 Ft/s^2 or 9.81 m/sec^2

IRB – Institutional Review Board (for the protection of human subjects)

ISO – International Standards Organization

LED – Light Emitting Diodes

NAS –National Academy of Sciences

NGEC – Next Generation Rail Committee

PRIIA – Passenger Rail Investment and Improvement Act

PVA – Paralyzed Veterans of America

RESNA – Rehabilitation Engineering and Assistive Technology Society of North America

RVAAC – Rail Vehicle Accessibility Advisory Committee

DOT – United States Department of Transportation

WhMD – Wheelchair Mobility Device

Appendix A 1—Functional Specification Reference Document

A 1.1 Project Objective–Design Parameters

The objective of this project is to develop functional requirements for future accessible high speed and intercity passenger trains. The specifications are grounded in current regulations that provided minimum design standards. However, the existing regulations originated in 1991 when the American's with Disabilities Act (ADA) was promulgated, and were primarily focused on users of manual wheelchairs. There have been many developments in the past twenty years that warrant new specifications that are responsive to changes in technology and population demographics. The three key issues that the new specifications address are:

- The increasing size of WhMDs
- The increasing body weight and size of the overall population
- The increasing age of the North American population

In addition, the new high-speed and intercity passenger rail technology, together with changes in traveler characteristics, contribute to the new functional requirements for high-speed and intercity passenger rail vehicles that will be in service for many decades.

The proposed functional requirements do not violate any existing Americans with Disabilities Act Architectural Guidelines (ADAAG) standards, but rather they raise the bar of accessibility to be more inclusive, but at the same time respect technical and operational constraints imposed by high-speed and intercity passenger rail operating parameters. The new specifications for accessible high-speed and intercity passenger trains are based on universal/inclusive design principles and are supported by research and practice in Canada and Europe.

The current ADAAG standards for railcars were written for urban and lower-speed intercity passenger rail service and respected the physical constraints of the existing passenger railcar fleet, cars which have a useful life of about 40 years. The next generation of high-speed and intercity passenger rail vehicles, built from the ground up, present an opportunity to revisit and improve accessibility to persons with disabilities using those services. The bi-level vehicles are designed for trip lengths of 12 hours with boarding from low-level platforms (8 inches above top of rail). The single level trainset (consist) and standalone cars are designed for continuous operations for up to 20 hours and 1,200 miles per day.[3] The trainset is designed for low-level platform boarding and the standalone car shall be capable of both high and low platform boarding.[4]

In addition, at speeds in excess of 120 mph, high-speed rail vehicles and operations share many of the accessibility challenges encountered in air travel. The railcar's internal space is at a premium due to the need to optimize revenue seat space and manage overall vehicle weight. The overall vehicle weight is a technical constraint that must be considered. Higher-speed passenger rail operations also must work around very short station dwell times.

The proposed functional requirements are for the next generation of high-speed and intercity passenger rail cars. The proposed functional requirements address several challenges in the

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[3] PRIIA 305 Bi-Level Intercity Car Requirements Document.

[4] PRIIA 305 Single Level Trainset and Standalone Car Requirements Document.

current design, specifications, regulations, operations, and practice. For example, currently many intercity passenger cars are designed with one accessible space per car, precluding two or more people who use mobility devices traveling together in the same railcar.

A new proposition under consideration for the next generation of railcars is for the potential to increase the overall number of available accessible seats per train by grouping them so that groups of WhMD users can travel together. Adding other special accommodations and amenities for travelers with disabilities and the incorporation other design features, such as the accommodation of service animals, are also being considered. The recommendation would be to have at least two but no more than four accessible seating positions in 50 percent of the cars in the train consist. This would be applicable to train consists that are semi-permanently coupled together.

The current regulations for the mobility device footprint, payload regulations, and accommodation of passengers with disabilities do not address the change in demographics and mobility device technologies, and would leave many passengers and their equipment stranded. There is an urgent need to address basic issues, such as the increase in the size and weight of WhMDs. In particular, scooters and the increasing number of persons with obesity will require new payload considerations, maneuvering and travel space, and access to café/lounge/sleeper cars. Obese passengers and those using service animals require dignified accommodation.

The following considerations are addressed in the functional specifications:

1. Design payload requirements for lift and ramps
2. Definition of WhMD footprint, representing state-of-the-art conditions
3. Passenger demographics, including obese persons and those travelling with service animals, walkers and other WhMDs
4. Boarding equipment from station platform to train doors, passage ways, aisles, and interior circulation spaces
5. Travelling position for travelers with WhMDs, including scooters
6. Stowage of unoccupied WhMDs
7. Accessible restroom for dependent and independent transfer from mobility device to toilet
8. Seats for passengers who are obese
9. Accommodation for travelers with service animals
10. Accessible onboard information for passengers with sensory disabilities

A 2—Demographics and Mobility Device Size

A 2.1 Demographics

The demand for accessible public transportation, including passenger rail, is rapidly increasing. Americans are getting older and more obese, and more people have disabilities that impede their access to public transportation. Accommodating these new demographics in the design of transportation facilities is essential for employment, education, and social interactions.

According to statistical data from the U.S. government:[5]

- Number of adults with any physical functioning difficulty: 35.6 million
- Percent of adults with any physical functioning difficulty: 16 percent

- Number of adults unable (or very difficult) to walk a quarter mile: 15.9 million
- Percent of adults unable (or very difficult) to walk a quarter mile: 7 percent

- Number of adults with hearing trouble: 34.5 million
- Percent of adults with hearing trouble: 15 percent

- Number of adults with vision trouble: 19.4 million
- Percent of adults with vision trouble: 8.6 percent

More than one in five Americans have at least one disability, and 5 percent have mobility challenges[6]. Some with mobility impairments use walkers or wheelchairs to facilitate mobility, but the trend in three- and four-wheel mobility scooters appears to have gained significant momentum. With an increasingly aged population, demand for these types of mobility devices will climb over the next decade and will have a severe impact on travel on board passenger trains.

In addition, 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 2009, only Colorado and the District of Columbia had obesity rates of less than 20 percent.

Thirty-three states had obesity rates equal to or greater than 25 percent; in nine of these states (Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Missouri, Oklahoma, Tennessee, and West Virginia) the rate was equal to or greater than 30 percent.

The U.S. Federal Transit Administration has recognized the increased weight of passengers and is proposing for vehicle testing to increase the passenger weight requirement from 150 lbs to 175 lbs., and increased the average occupied floor space from 1.5 to 1.75 square feet.[7]

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[5] https://www.cdc.gov/nchs/fastats/disability.htm
[6] https://www.census.gov/newsroom/releases/archives/miscellaneous/cb12-134.html
[7] Metro Magazine 03-23-11

A 2.2 Traveler Profile

The increasing diversity of the U.S. population makes it even more difficult to define an "average" person. In inclusive design, it is important to accommodate a diversity of abilities, physical parameters, and cultures. Accommodation of people with particular characteristics who also use assistive technologies can often pose a challenge or an opportunity. It is commonly understood that designs and technologies that are inclusive are easier for all users. It is time to look at inclusive design in approaching the challenges in the accommodation of people who use WhMDs on the next generation of passenger railcars.

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

Wheelchairs (manual, sports, power): People who cannot walk often need a wheelchair for their mobility. People using manual wheelchairs can propel themselves or are pushed by an attendant. People using power or electric wheelchairs use joysticks or similar features to maneuver their powered chairs. People using sports chairs typically have very strong upper body and upper extremity strength.

Mobility scooters: People who use mobility scooters are capable of independently transferring to a scooter and drive with a handlebar/tiller. Usually they are able to walk short distances. Users can be elderly, semi ambulatory, or people with limited mobility.

Walkers: People who are able to stand up and walk with a walker may have stamina, hip, knee, or back problems. Some walkers are equipped with casters, seats brakes, and large removable baskets.

Crutches and canes: People using crutches or canes can stand on at least one lower limb. Many people with crutches use them only temporarily due to surgery or accidents. Others may use them in addition to their mobility devices (e.g., wheelchairs, scooters) to negotiate steps.

Strollers: People travelling with infants or small children may use strollers. They come in a variety of models and sizes, from single to triple types.

People who are blind or have low vision: People who are blind may use a cane or a trained guide dog. They also require tactile, audio, and olfactory cues.

People who are deaf or have low hearing: People who are deaf or hard-of-hearing require a visual/text alternative to audio modes. 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^{th} percentile human model in body width and weight. Some may use mobility scooters to travel any distance.

A 2.3 U.S. Obesity Trends

Obesity is defined as a BMI of 30 or greater. BMI is calculated from a person's weight and height and provides a reasonable indicator of body fat and weight categories that may lead to health problems. Obesity is a major risk factor for cardiovascular disease, certain types of cancer, and type-2 diabetes.

A 2.3.2 Definitions of Adults Who Are Obese

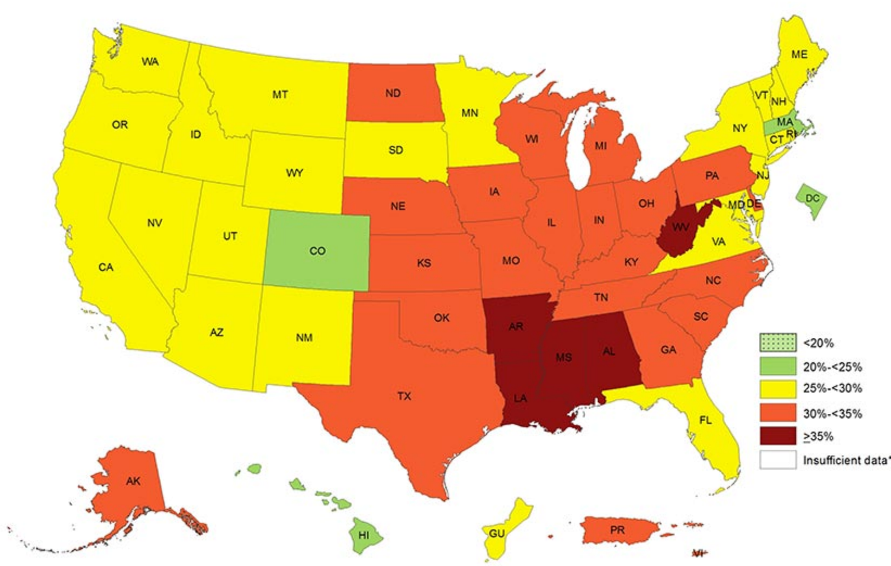
BMI is used to determine obesity because, for most people, it correlates with their amount of body fat.

- An adult who has a BMI between 25 and 29.9 is considered overweight.
- An adult who has a BMI of 30 or higher is considered obese.
- Table A-1 shows an examples of BMI for a 5'9" person.

Table A 1 Example of BMI for 5'9"[8]

Height	Weight Range	BMI	Considered
5' 9"	124 lbs. or less	Below 18.5	Underweight
	125 lbs. to 168 lbs.	18.5 to 24.9	Healthy weight
	169 lbs. to 202 lbs.	25.0 to 29.9	Overweight
	203 lbs. or more	30 or higher	Obese

Figure A 1 shows the Centers for Disease Control state average percent of the population that is considered obese.



Source: https://www.cdc.gov/obesity/data/prevalence-maps.html

Figure A 1 Prevalence of self reported obesity among U.S. Adults (BRFSS, 2016[9])

[8] Source: http://www.cdc.gov/obesity/data/trends.html
[9] Source: http://www.cdc.gov/obesity/data/trends.html

A 2.4 Mobility Device Weight and Dimensions

A 2.4.1 Mobility Device Dimensions

A recent North American study produced similar results to those observed in the U.K. Table A 2 shows the weight of occupied wheelchairs in a sample of 135 mobility device users.[10]

Table A 2 Weight (lbs) of occupied wheelchairs (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

Table A 3 shows the weights of wheelchairs, 3-wheel scooters and 4-wheel scooters with different occupant weights and some have combined weights come close or exceed payload standards of 600 lbs.

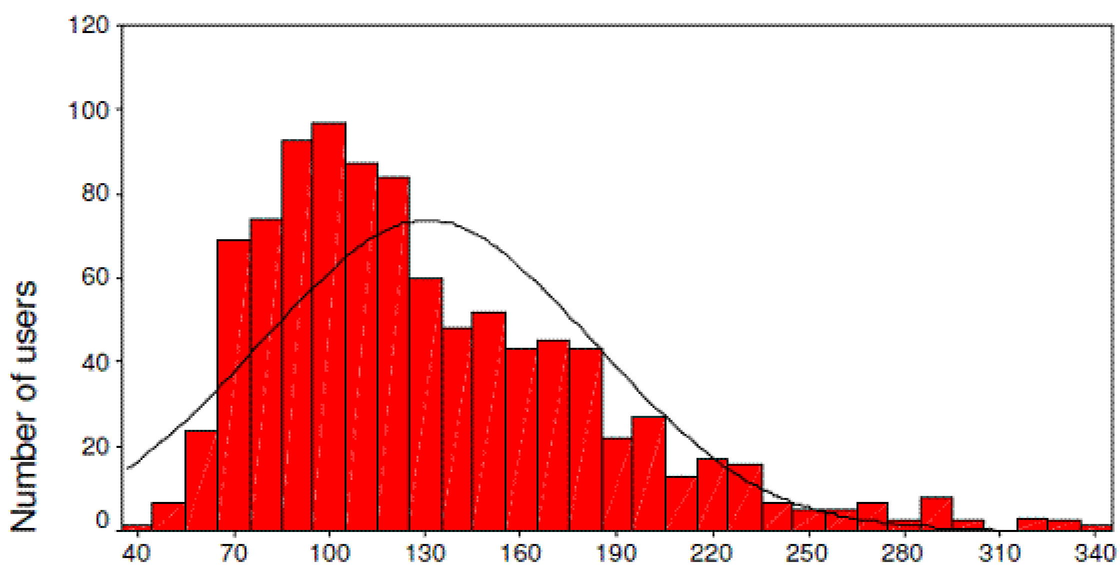


Figure A 2 Distribution of mass of adult devices and occupants (kg) [11]

Table A 3 shows the mass/weights of different mobility devices with occupants in kilograms and lbs.

[10] D'Souza, C. (2012). Design Resource: Mass of Occupied Wheelchairs. IDeA Center, University at Buffalo/SUNY. Available at http://udeworld.com/dissemination/design-resources.html

[11] UK Survey of Occupied Wheelchairs, 2005.

Table A 3 Comparison of mass/weights of adult devices and occupants, from 1999 and 2005 (kg/lbs)[12]

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**
Powered 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**
Powered 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**

A 2.4.2 Mobility Device Dimensions of Other Wheeled Devices

Table A 4 shows a comparison of WhMD dimensions that are based on manufacturers specifications.

[12] Source: Hitchcock et al, UK Survey of Occupied Wheelchairs, 2005

Table A 4 Equipment dimensions[13]

Models	Length	Width	Turning Clearance 90 degrees	180 degrees	360 degrees	Weight
Adult wheelchairs without person						
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” (750 31.5” -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)	

[13] Based on: ISO 7176-2009; U.S. ICC/ANSI A117.1; Canada CAN/CSA B651-04; U.K. BS8300:2001; manufacturers’ product specifications

Models	**Length**	**Width**	**Turning Clearance** **90 degrees**	**180 degrees**	**360 degrees**	**Weight**
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 lbs. (6.6 kg) Max. 21 lbs. (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)						
3 wheel	Min.36.5” (927 mm) Max.46”(1170 mm)	Min.23.5”(595 mm) Max.25.5”(650 mm)	Min.40”(1020 mm) Max. 44.75” (1140 mm)	88.5” (2250 mm)	88.5” (2250 mm)	114.5 lbs. – 187 lbs. (52 – 85 kg)
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 lbs. – 44 lbs. (12 - 20 kg)
Space for large dog	950 mm	15.75” x 13.75” (400 mm width x 350 mm height when laying down)				
Person with Walker		25” (635 mm)				
Person with Crutches		36.5” (930 mm)				
Obese Persons		Up to 29.5” (750 mm)				Up to 440 lbs. (200 kg) (est.)

Models	Length	Width	Turning Clearance 90 degrees	180 degrees	360 degrees	Weight
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)				

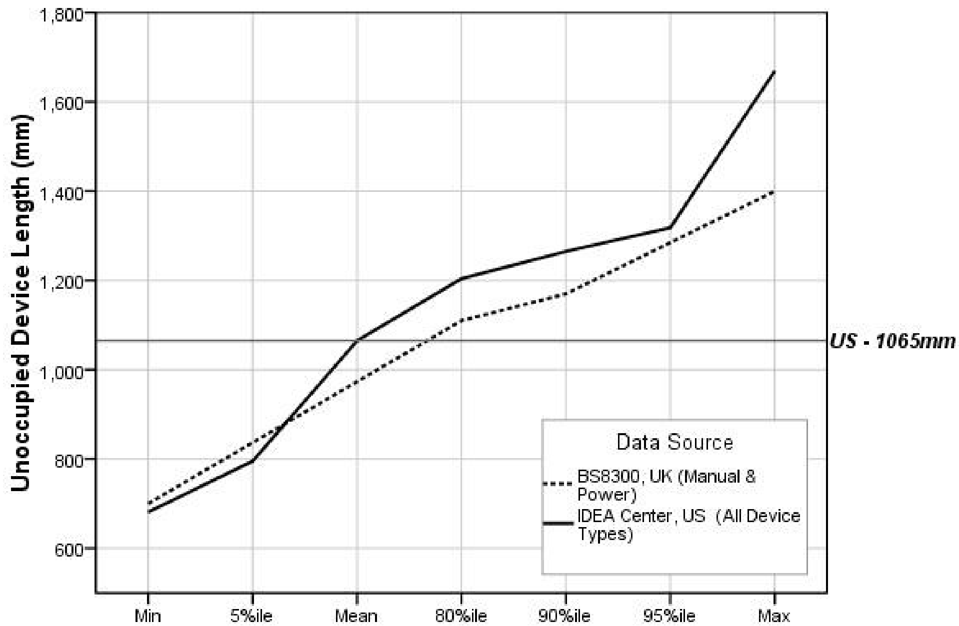
Note: Imperial measurements have been rounded up or down to the next quarter inch; weights to the next quarter lb.

A 2.4.3 Anthropometric Study

The final report of a study of “*The Anthropometry of Wheeled Mobility”* has a number of findings that are directly relevant to the specification for the next generation of passenger rail cars. 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 US standards for clear floor space, especially in length [Steinfeld, et al, 2010].

Select figures from an anthropometry study by Edward Steinfeld are shown in Figure A 3, Figure A 4, and Figure A -5. [14]

[14] Steinfeld, E., et al. (2010, December). Anthropometry of Wheeled Mobility Project, Final Report. Buffalo, NY: State University of New York at Buffalo, Center for Inclusive Design and Environmental Access (IDeA).

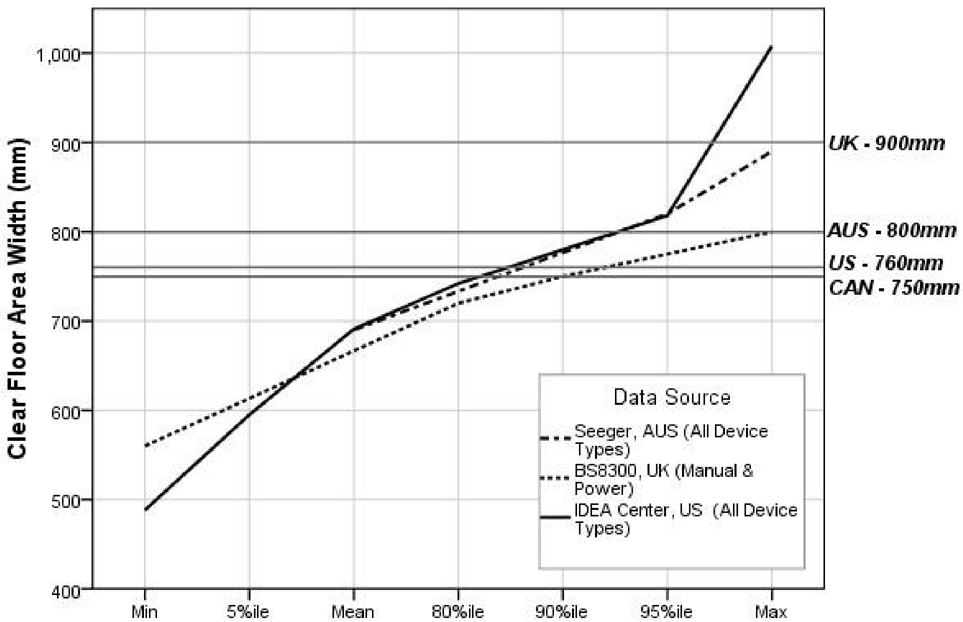


Data Source	Sample Size	Min	5%ile	Mean	80%ile	90%ile	95%ile	Max
BS8300: 2001, U.K.								
Manual chairs - self propelled	54	700	-	-	1090	1124	-	1200
Power chairs	27	700	-	-	1160	1190	-	1400
Manual and Power chairs*	81	700	-	-	1110	1170	-	1400
Electric scooters	5	1170	-	-	-	-	-	1500
IDeA Center, U.S.								
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.

Figure A 3 Unoccupied wheelchair lengths (mm) versus U.S. standards[15] (Steinfeld, 2010)

[15] Steinfeld, E., et al, "*Anthropometry of Wheeled Mobility Project, Final Report*", Center for Inclusive Design and Environmental Access (IDeA), University at Buffalo, SUNY, December, 2010.

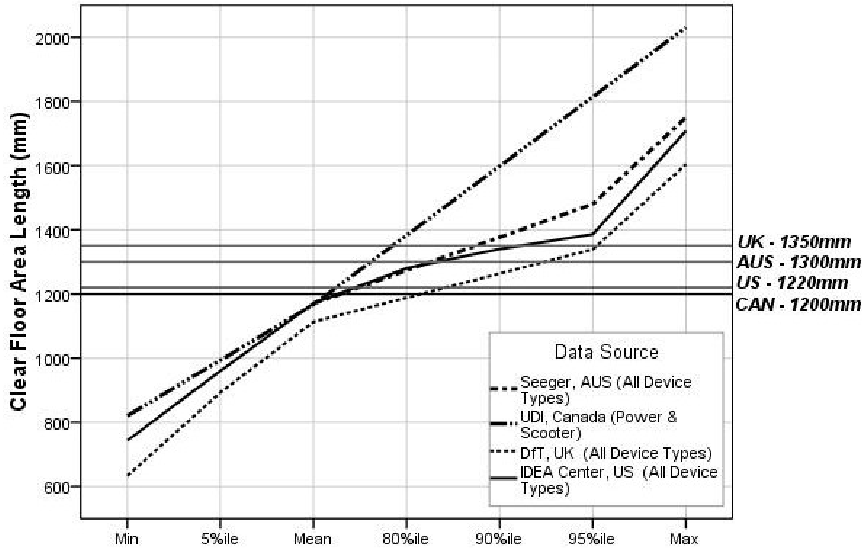


Data Source	Sample	Min	5%ile	Mean	80%ile	90%ile	95%ile	Max
Seeger et al., AUS								
All Device Types*	240	-	-	690	-	-	820	890
BS8300:2001, U.K.								
Manual chairs - self	54	560	-	-	696	720	-	800
Power chairs	27	560	-	-	750	760	-	800
Manual and Power	81	560	-	-	720	750	-	800
Scooters	5	630	-	-	-	-	-	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.

Figure A 4 Clear floor width (occupied width) (mm): Research versus standards[16]

[16]Steinfeld, E., et al, "*Anthropometry of Wheeled Mobility Project, Final Report*. Center for Inclusive Design and Environmental Access (IDeA), University at Buffalo, SUNY, December, 2010.



Data Source	Sample Size	Min	5%ile	Mean	80%ile	90%ile	95%ile	Max
Seeger et al., AUS								
All Device Types*	24	-	-	1170	-	-	1480	1750
UDI, Canada								
Power chairs and	5	820	-	1168	-	-	-	2030
DfT, U.K.								
Self-Propelled	45	776	864	1068	-	-	1254	1534
Attendant-Propelled Wheelchair	10 6	951	1003	1123	-	-	1344	1375
Electric Wheelchair	29	633	955	1142	-	-	1339	1604
Electric Scooter	24	828	956	1168	-	-	1416	1503
All Device Types*	1098	633	893	1113	-	-	1339	1604
IDeA Center, U.S.								
Manual Chairs	27	743	934	1150	1255	1314	1362	1625
Power Chairs	18	831	977	1196	1313	1360	1415	1708
Scooters	3	1025	1035	1208	1283	1369	1435	1439
All Device Types*	49	743	960	1171	1280	1340	1386	1708

* Indicates data plotted in the graph.

Figure A 5 Clear floor length compared (occupied length): Research versus standards[17]

[17] Steinfeld, E., et al, 2010.

Figures A 6 illustrates the large range of dimensions of wheeled mobility devices.

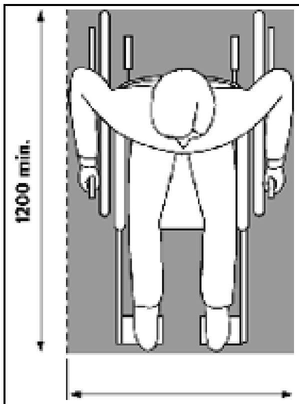
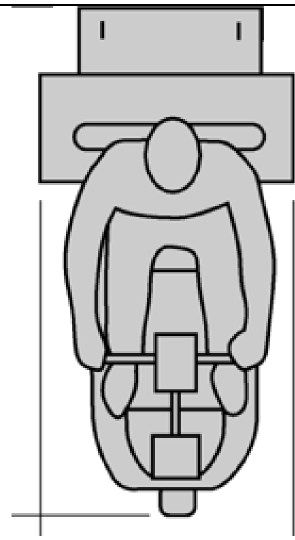
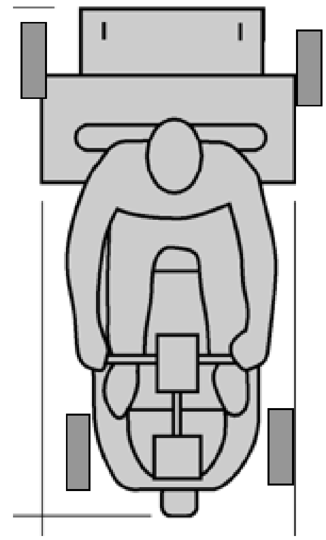
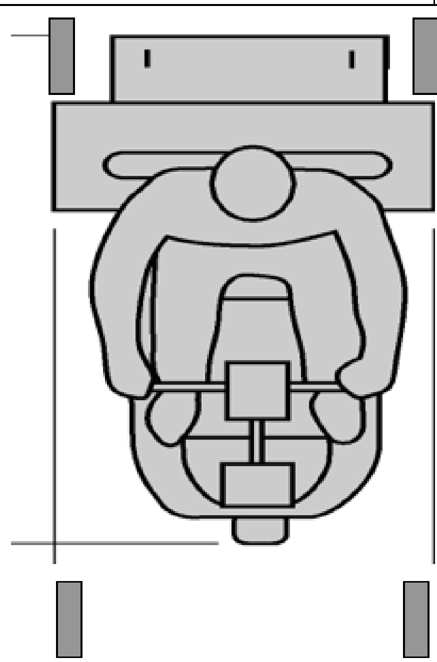
 **Length: 42" – 48"** Width: 24" – 35"	 **Length: 42" – 49"** Width: 25" – 26"	 **Length: 45" – 56"+** Width: 25" – 26 "
Manual wheelchair with elbow space	**Three-wheel scooter without accessories**	**Large four-wheel scooter without accessories**
Length: 45" – 56" +, Width: 30" + **Obese person on scooter**[18]		

Figure A 6 illustrates the large range of dimensions of wheeled mobility devices

Figure A 7 shows the spatial footprint of ambulatory people with disabilities.

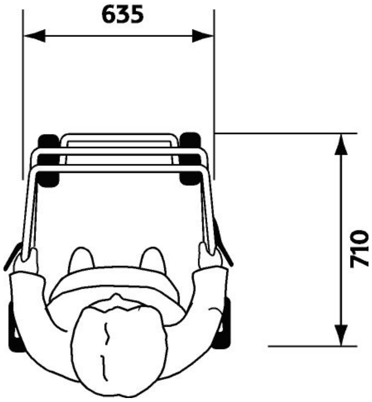
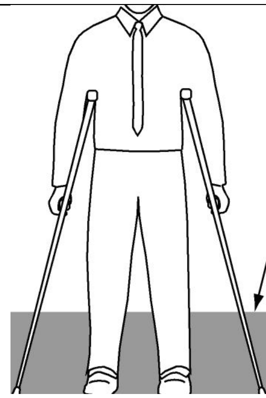
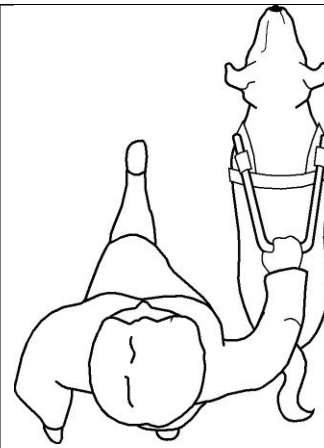
	 **31.5”** (800 mm) – **36.25”** (920 mm) width	 **47.25”** (1200 mm) width
Person using walker	**Person using crutches**	**Person with guide dog**

Figure A 7 Persons with walkers, crutches; person with guide dog[18]

[18] Illustrations: CAN/CSA B651.

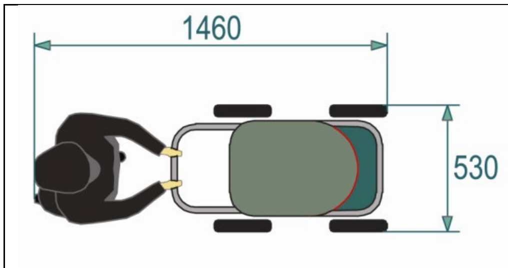
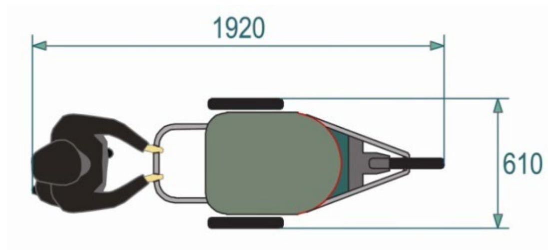
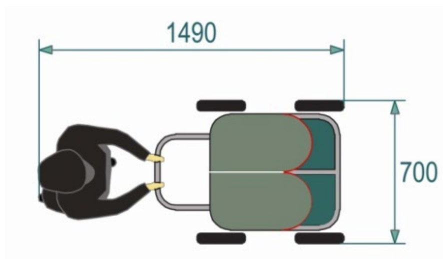
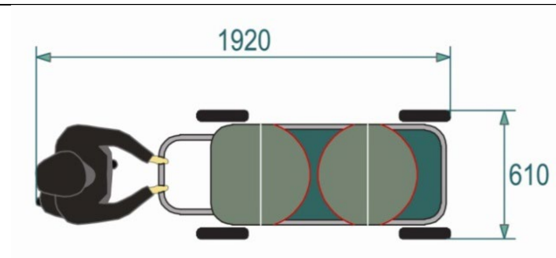
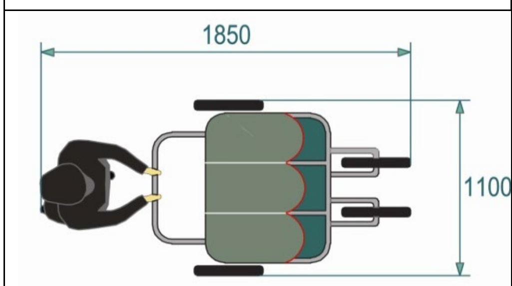
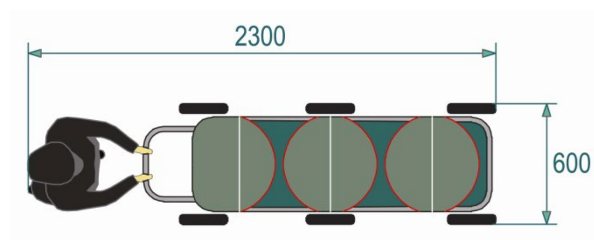
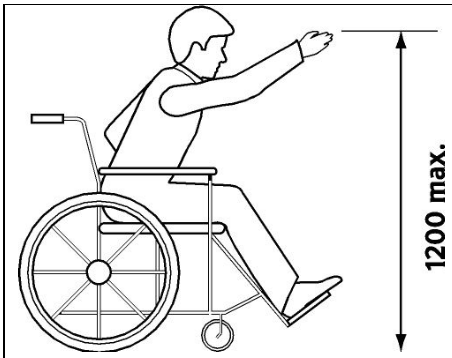
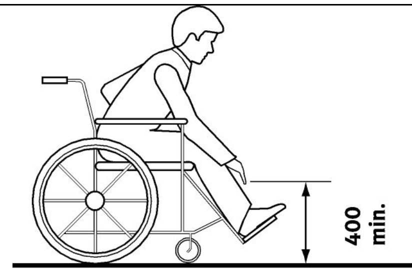
 **57.5”** (1440 mm) x **21”** (530 mm)	 **75.5”** (1920 mm) x **24”** (610 mm)
Clear floor space for a single regular stroller	**Clear floor space for a single jogger stroller**
 **58.7”** (1490 mm) x **27.5”** (700 mm)	 **75.5”** (1920 mm) x **24”** (610 mm)
Clear floor space for a twin side-by-side stroller	**Clear floor space for a twin tandem stroller**
 **72.8”** (1850 mm) x **43.3”** (1100 mm)	 **90.5”** (2300 mm) x **23.6”** (600 mm)
Clear floor space for a triple side-by-side stroller	**Clear floor space for a triple tandem stroller**

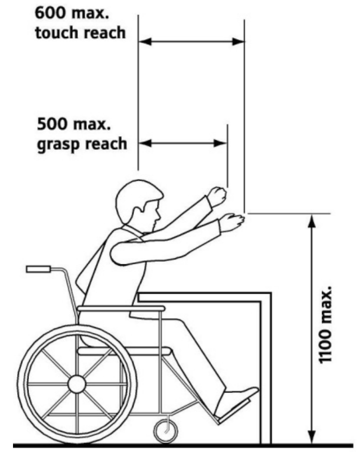
Figure A 8 Clear floor space of single, tandem strollers

A 2.5 Space Requirement for Mobility Devices

Figure A- 9 shows the forward, side and vertical reach required by wheelchair users.

<table>
<tr>
<td>

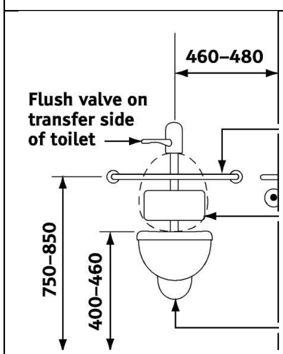
Height reach: 47.25”</td>
<td>

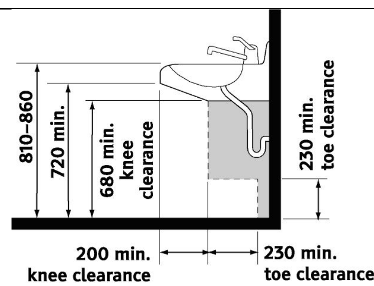
Low reach: 15.75”</td>
<td>

Forward grasp reach:19.7 “</td>
</tr>
<tr>
<td>Max. height reach</td>
<td>Max. low reach</td>
<td>Max. forward reach</td>
</tr>
</table>

Figure A 9 Reach for person in wheelchair[19]

Figure A 10 shows examples of restroom dimensions from the Canadian Standards.

<table>
<tr>
<th>Toilet</th>
<th>Sink</th>
</tr>
<tr>
<td>

Toilet height: 15.75”-18”
Grab Bar height: 29.5”-33.5”
Centre toilet to wall: 18”-19”</td>
<td>

Knee clearance min: 26.75”
Sink height: 32”-34”</td>
</tr>
</table>

Figure A 10 Restroom dimension examples[20]

[19] CSA B651-04
[20] CAN/CSA B651.

A 3 Current Issues Addressed in Existing Standards and Regulations

A 3.1 Summary of Standards Comparisons

The standards comparison summary is based on the following documents, highlighting the most relevant accessibility features. Recommendations are provided in areas where an increased mobility device's weight and size, and obese occupants have an impact. Table A 12 is a summary comparison of the different standards.

1. ADAAG: ADA Guidelines, Part 38–Americans with Disability Act (ADA), Subparts E and F – Intercity Rail Cars and Systems (38.91 – 38.127) (July 1997)
2. Part 38 Americans with Disabilities Act (ADA) Accessibility Specifications for Transportation Vehicles, Sub Parts C, D, E, and F (October 2006)
3. PRIIA 305-001/Amtrak 962 Technical Specification Initial Release

   PRIIA 305 Chapter 9, 11, 12, and 14; train set; single level bi-level car specifications,

   PRIIA 305 Specifications
4. Canadian Standards Association, CSA, B651-04, Accessible Design for the Built

   Environment (August 2004)
5. Canadian Transportation Agency, Code of Practice–Passenger Rail Car Accessibility and Terms and Conditions of Carriage by Rail of Persons with Disabilities (1997)

Table A 5 Summary Comparison of Current Standards

Items	**ADA**	**PRIIA 305, Chapter 9:Train consist** **Single level** **Bi-level**	**Canadian CSA and CTA**	**APTA /ANSI**	**Australia National Code of Practice Rail, 2009**	**Europe**
1.1 Design load: Lifts and ramps, way-site and onboard	38.125(b) (1) 600 lbs	600 lbs	600 lbs	600 lbs	660 lbs to be labeled on equipment	300 kg (661.4 lbs)
1.2 Footprint	38.125(b)(6) 30” x 48”	30” x 48”	30” x 48”		4.2.1 31.5” x 51”	27.5” x 51” 27.5” x 59” for travelling position
1.3 Doorways (Exterior)	38.113(a): 32”	32”	30”			31.5”
2.1 Interior circulation, corridors, and passageways	38.113 (b): 32”	32”	59” circle; 30” for corridors and passageways	32”	33.5”	31.5”; 39” for self propelled
		9.8 Interior Handholds			Handrails	Handrails
2.2 Vestibule	38.113(b) 42”		59” circle		81.5” deep x 60.5” wide	
3. Restrooms	38.123 Restroom Accessibility Doors end :32” min, side 39”	Chapter 9, 11.3 Accessible restrooms– lower level (for bi-level cars)	CSA 4.3 Accessible washroom		Door: 33.5”	Door: 31.5”
3.1 Floor area	38.123 (1) 35” x 60	35” x 60”	35” x 59” (CSA)		78.7” x 63”	Space for transfers
3.2 Dependent and independent transfer			1.3.3 Washrooms (CTA)-to accommodate dependent and independent transfers from wheelchair to toilet		To accommodate dependent transfer at side of toilet	Space for dependent and independent transfers

Items	ADA	PRIIA 305, Chapter 9:Train consist, Single level, Bi-level	Canadian CSA and CTA	APTA /ANSI	Australia National Code of Practice Rail, 2009	Europe
3.3 Toilet access	38.123 (2) toilet height 17-19 inches and (3), grab bars		Pivoting support arm(s) on side(s) of toilet (CTA)		Grab bars behind and on side of toilet	Grab bars and pivoting support arm(s) on side of toilet
3.4 Disposable syringes	NA	Container for disposable syringes in restroom	NA	NA	NA	NA
4.0 Wheelchair position	38.125 (d) 1, One, max. two wheelchair position per accessible car	9.3 One wheelchair parking location– lover level	1.3 One wheelchair position per train consist		Two per train set, or number equal to number of cars.	Train length < 205 m =2 wch pos. 205-300 m =3 wch pos.>300 m = 4 wch pos.;59" clear circle at position
	38.125 (d) Seating	9.6.2 Seats 9.3 One accessible transfer seat – lower level (for bi-level cars)	Accessible seats adjacent to wheelchair position			Accessible seats adjacent to wheelchair position
4.1 Wheelchair tie-down	Required		Required		Optional, depending on operator	Not required
5.0 Seats						
5.1 Seats for obese passengers	NA	NA	NA	NA	NA	NA
5.2 Seats for passengers with service animals			Two seats for passengers with service animals in accessible car (CTA)		Space under two seats, or by replacing one seat	Dogs allowed onboard without charge

Items	ADA	PRIIA 305, Chapter 9:Train consist Single level Bi-level	Canadian CSA and CTA	APTA /ANSI	Australia National Code of Practice Rail, 2009	Europe
6.0 Onboard Passenger Information	38.103 Audio only required ,	Audio and visual	Audio and visual		Audio and visual	Audio and visual in more then one language
7. Emergency Egress	Assistance from staff or emergency services	Assistance from staff or emergency services	Assistance from staff or emergency services		Assistance from staff or emergency services	Assistance from staff or emergency services
8. Access to dining/bistro			Meal service at wheelchair position or dining car next to accessible coach		Meal service at wheelchair position or dining car next to accessible coach	?
9. Customer complaint/feedback	yes		yes		yes	?

A 3.2 Background for Functional Requirements

The information included below is included for clarification and may be in the main body of the report.

A 3.2.1 Design load for lift and ramps

Current design load specifications for lifts and ramps for passenger rail, urban buses, over-the-road buses, and paratransit vehicles indicate a minimum payload of 600 lbs. Research shows an increase in the weight and sizes of mobility devices, in particular scooters, and an increase of obese persons—which combined can exceed 600 lbs. If the lift and ramp design load functional requirements are not increased this could result in damage to the equipment and compromise the safety of the transportation staff and passengers. For years, many operators of public transit systems have been procuring lift and boarding devices with an 800-lb design load.

A 3.2.2 Footprint

The footprint for common wheelchairs of 30 inches by 48 inches, established in 1991 by ADA regulations, is currently outdated as a result of the development of new mobility devices which are longer and heavier, particularly powered mobility scooters and bariatric chairs. The recommended length of 54 inches will accommodate the majority of mobility devices manufactured and sold in North America. The increased length will have an impact on the maneuvering space, turning circle, lift platform size, and the onboard travel position (Steinfeld, 2010). The standard width of most wheelchairs and scooters have not changed, however the width of devices used by people who are obese has increased but no changes in the width of the footprint are recommended. For years, many operators of public transit systems have been procuring lift and boarding devices that accommodate the longer footprint.

A 3.2.3 Circulation and Passageways

Passageways with a clear width of 32 inches, as specified in ADA documentation, fulfills the requirements accordingly between cars, except for aisle passages which are typically specified at 19.5 inches between armrests. The majority of mobility devices exceed the aisle width and would not be able to travel through a car from one end to the other. This presents a barrier to access to some onboard passenger amenities.

A 3.2.4 Accessible Seating Position

Due to the increase in the length of mobility devices, especially mobility scooters, the minimum footprint of 32 inches by 59 inches is required, and a footprint of 32 inches by 60 inches is recommended to accommodate occupied or unoccupied mobility devices in the travelling position. Two accessible seats, with pivoting aisle-side armrests, adjacent to the mobility device's travelling position, are required. It is recommended that consideration of sight lines adjacent to a window be considered when locating accessible seats. In addition, the location of the accessible seating near the accessible restroom should also be considered. On long trip segments, passenger comfort can be compromised when the accessible seats are located adjacent to the accessible restroom due to the smell that might be emanating from the restroom. A call button should be installed at the accessible seating locations. This button should be mushroom style and should not require the lifting of levers or covers to activate it. It should be located forward of the accessible seating location so that it is reachable by persons who remain in their mobility device or transfer into the accessible seat

A 3.2.5 Accommodation of Unoccupied WhMDs

Provide clear space of 30 inches by 56 inches for stowage of unoccupied WhMDs adjacent to the accessible seating locations in each car. This area can be provided in front or adjacent to the accessible seating position.

A 3.2.6 Emergency and Evacuation

Dual-mode communications shall be provided for all communications broadcast to the passengers. A real time voice-to-text messaging system, in addition to an audio system, must be made available for passengers who have hearing loss, those with cognitive impairments, and the elderly for emergency and evacuation procedures. Onboard emergency evacuation chairs shall be located in a train consist and shall be used to evacuate passengers with disabilities when applicable.

A 3.2.7 Accessible Restroom

The design of accessible passenger rail restrooms is inconsistent; some provide adequate space for an independent transfer from the wheelchair to the toilet, but some designs do not provide enough space around the toilet for certain personal hygiene techniques. Some restroom designs do not accommodate a dependent transfer with an assistant/enabler/companion. For seniors, persons with balance or stamina problems, and those using walkers or crutches, additional pivoting support arms on the side(s) of the toilet are required to get on and off the toilet. Horizontal and vertical grab bars throughout the interior of the restroom are required to assist against train movements. These devices must be placed with care to avoid introducing a projection that may impact a standing passenger during strong vehicle motion. The toilet must support obese persons and require a similar specification as APTA SS-C&S-016-99 for seat structures for 450 lbs. (APTA, 2010).

A 3.2.8 Onboard Passenger Information Systems

Although onboard passenger information systems (OPIS) have been specified in ADA, they should be provided in all passenger cars. Currently, only audio public information is required; for the population, that is deaf and hard of hearing it is essential that they receive all audio information in text or other visual displays. This information should include next stop, transfers to other modes, arrival, and gate information. For emergencies and evacuations, a real-time voice-to-text system should be available for the crew.

A 3.2.9 Seating for Passengers Who Are Obese

Currently, many of the existing seat structures and configurations cannot accommodate obese passengers. These passengers require wider and stronger seat structures. For example, bench-type seating recommendations would also benefit travelers with small children. Recent developments in aircraft seating have addressed this problem with flexible seat designs, accommodating persons who require a seat wider than 18 inches and those travelling with small children.

A 3.2.10 Seating for Passengers with Service Animals

Passengers who are blind or have low vision, use WhMDs. or are deaf or hard-of-hearing may travel with service animals. Typical dog guides include German shepherds, Labradors, and other larger dogs. The space for service animals must be adjacent to the accessible seating position and can be under a double seat, but the space must also be out of passageways. Currently in the US, there are no regulations or standards for the size of the area required for service animals. The Canadian National Institute for the Blind (CNIB) recommends a space approximately 38 inches long by 14 inches wide by 16 inches high to accommodate a large service animal.[21]

A 3.2.11 Access to Food Service Amenities

To provide equal access to amenities for all passengers, it is essential to provide access for those using mobility devices. This includes the use of café/lounge/dining cars. PRIIA specifies a clearance width of the doors between cars of 32 inches, but aisle width within cars prevents a mobility device that may be 30 inches wide from moving through a train car from one end to the other. Access shall be available from the accessible car to the café/lounge/dining car and within the car with a clear passageway of 32 inches. This will require the café/lounge/dining car to always be connected adjacent to the accessible end of each car in the trainset (consist).

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[21] CNIB.

Designate at least two accessible seating areas in the café/lounge cars. A footprint of 30 inches by 60 inches in the café/lounge/dining car must be provided at a table as well as a vertical clearance under the table of 30 inches and maximum table height of 34 inches to accommodate passengers seated in wheeled mobility aids. In addition, at least one transfer-accessible position shall be provided in the accessible café/dining car at a table. Clear space to park an unoccupied WhMD shall be provided adjacent to the accessible transfer seat location.

A 3.2.12 Distribution of Accessible Seats throughout Train

A new proposal under consideration for the next generation of railcars is to increase the overall number of available accessible positions per train by placing them where groups of WhMD users can travel together. The overall number of accessible positions per car should be two at a minimum but no more than four per car. This would increase the overall accessibility of the train. This recommendation would be applicable to train consists that are semi-permanently coupled, such as Acela's train consists. This will ensure that there are always sufficient accessible positions per train consist.

A 4 Onboard Passenger Information Systems

An OPIS with an audio and visual display is not always available for persons with hearing or vision loss. They require real-time information for next stop, transfers, schedules, etc. in both audio and visual modes. The DOT Office of the Secretary, as part of the revision to the Air Carrier Access Act, is overseeing the development of guidelines for onboard passenger information systems. The new guidelines should be applied to surface transportation modes in addition to air carriers. These guidelines should also be applied to all passenger cars and used to provide real-time information, including current and next stop, transfers, schedules, and emergency information in audio and visual formats.

Table A 6 OPIS

This	ADA	PRIIA 305 Specifications	CAN,CSA,CTA	Recommendations
Onboard Visual and Audio Passenger Information OPIS		Chapter 12	Audio and visual information	Provide real-time audio and visual onboard passenger information for: • schedules • next stops • transfers • emergencies

Dual-mode communications shall be provided for all communications broadcast to passengers. Dual-mode communication is the provision of passenger information in both audio and visual form. A dual-mode, real-time voice-to-text messaging system, in addition to an audio system, should be made available in normal operations for communicating with passengers who have hearing loss, those with cognitive impairments, and the elderly. This recommendation exceeds the minimum standards in 49 CFR §38.121(a). In addition, efforts should be made to ensure the source data used for the onboard communication system is made available to application developers and others, so onboard information can be shared through smart phone or social media technologies.

A 5 Armrest Requirements

The vertical seat strength and armrest strength are rail industry requirements and specified in the APTA Standard for Passengers Seats in Passengers Rail Cars.[22]

A 5.1.1 Vertical Seat Strength

A load of 450 lbs (204 kg) per occupant shall be applied on the seat bottom near the front edge of each occupant placement in a vertical downward direction at the midpoint of each occupant position. The contact area of the applied load shall not exceed 4 square inches (26 square cm). The load shall be applied for a minimum of 5 seconds.

A 5.1.2 Armrest Strength

A load of 250 lbs (113 kg) shall be applied to the horizontal member of the armrest structure at a point that produces maximum stress in the member. A fixture may be used to properly apply and distribute the load. The contact area of the applied load shall not exceed 4 square inches (26 square cm). The load shall be applied for a minimum of 5 seconds. This test shall be repeated for the two horizontal conditions (toward the aisle and toward the wall side of the seat) and then vertically downward.

For seats with folding center armrests, the folding armrest shall be tested by applying a vertical 150-lb (68 kg) load as near as practical to the end of the armrest. Separately, a horizontal 150-lb (68 kg) load shall be applied as near as practical to the end of the armrest. The horizontal load test shall be repeated for both directions. The contact area shall not exceed 4 square inches (26 square cm) in all cases.

[22] APTA SS-C&S-016-99, Rev. 2, approved October 3, 2010.

A 6 Draft Guidelines for Accessible Restrooms for High-Speed and Intercity Rail Vehicles

The following guidelines were originally developed for accessible aircraft restrooms and have been updated and modified for high-speed and intercity rail vehicles.

A 6.1 Background

Oregon State University (OSU) has conducted extensive biomechanics and ergonomic research to develop the guideline for accessible aircraft lavatories. The functional requirements for high-speed passenger rail vehicles share a number of common issues as design for passenger aircraft. The value of limited interior space on board passenger aircraft and passenger trains is some of the most expensive in the world, and at the same time, the commercial aviation and passenger rail industry face enormous operating challenges. The intent of the functional requirements is to strike a balance between the need to provide a common definition or base of understanding for an accessible restroom, and the need to be responsive to the passenger rail industry. The goal of the specification is to provide definitive guidance to vehicle manufacturers and operators on what constitutes an accessible restroom, and at the same time be responsive to space and cost issues. Specifically, the guideline identifies key ergonomic elements for making restrooms accessible and usable by people with disabilities. It is also important to examine the application of the guideline so that passenger railcars that must have accessible restrooms are equipped and satisfy both the requirements and expectations of travelers with disabilities. The application of universal and inclusive design principles are recommended so that the needs of all travelers, including those with mobility, cognitive, sensory, and related disabilities, are accounted for in the design. In addition, restrooms that meet the needs of travelers with disabilities also provide enhanced accommodation for families traveling with small children and passengers who are obese.

It is very important that an industry standard be adopted for the next generation of high-speed and intercity rail vehicles that are under development and design. The specification is intended to provide a significantly higher level of guidance for design than was done in the ADAAG Section 38.123 specifications. A balanced approach has been adopted that examines both the operating and technical characteristics of railcars. Many of the technical requirements are based on biomechanics and ergonomic research conducted by OSU.

It is the goal of the specification to provide research-driven technical requirements on which new designs of accessible lavatories can be developed, rather than to provide prescriptive or quantitative guidelines that inhibit innovation. The guideline includes a checklist of recommended amenities and their location in the restroom relative to the toilet. The guideline also seeks to harmonize the international standards and guidelines that pertain to passenger railcars.

A 6.2 Introduction

The functional requirements for accessible restrooms include a definition of terms derived from national and international guidelines for accessible passenger vehicles and buildings.

The actual design of the accessible restroom is most often a function of its location within the body of the passenger car. The design of the interior space within the restroom also impacts the level of accessibility of the restroom. The fundamental principles for accessible restroom recommendations include:

- The accessible restroom must permit a lateral (0 degree) or up to a 90-degree dependent transfer of a 95th percentile male by another 95th percentile male in an enclosed restroom space.
- All transfers must be undertaken within the enclosed restroom space.
- Passengers who use the restroom unassisted may perform lateral transfers or perform a frontal approach to the toilet.

OSU research demonstrated that a 180-degree dependent transfer requires a larger spatial footprint and is often not a safe option for a transport vehicle restroom. Vehicle interiors are designed to accommodate the 95th percentile male; at the same time it is important to verify that the accessible onboard restroom is also designed to accommodate the 5th percentile female. It is further recommended that the designs consider including the ergonomic characteristics of a 5th percentile Asian female and the 95th percentile northern European male wearing clothing. These suggestions will stretch the design envelope to be more inclusive.

A 6.3 Definition of Terms

Assistive Equipment and Amenities: This includes physical features that are used by passengers with disabilities, including visual and hearing impairments, e.g., hand grips, platforms, signage, and lighting to facilitate their use of the restroom. Other amenities that should also be considered include: sharps containers, adequate lighting levels for self injections, and audible and visual feedback for touchless sensors for fixture controls such as the water faucet.

Call Button: This is a control switch in the restroom used to illuminate the attendant call light. This control must be accessible from the toilet by 5th percentile female. The call button should also be accessible from the floor in case of a fall.

Call Light: This is a readily visible light outside of the restroom enclosure that can be illuminated by the use of the call button in the restroom to advise an attendant or personal care attendant to assist a passenger.

Lighting: Lighting should be sufficient and avoid creating shadows. High levels of lighting are required for the purpose of injections or other tasks of a critical visual nature.

Restroom: In the guideline, the restroom refers to the total enclosure.

Restroom Maneuvering Space: The space outside the restroom enclosure that permits access to it by a 95th percentile male sitting in a mobility device is referred to as the restroom maneuvering space. The amount of space required depends on the maneuvering characteristics of the mobility device and the size of the restroom door opening. Some restroom configurations require a 90-degree turn at the door to access the toilet compartment, and regular train aisle widths may not be large enough to accommodate the pivot radius of the occupied mobility device.

Signage: An accessible restroom provides clear signage for all individuals, including passengers with visual impairments and the blind. It is very important that signage be symbolic and use international symbols when available to designate important amenities such as the toilet flush control and attendant call button. (No international symbol for the toilet flush control currently exists.)

Sink and Amenities: The sink (or wash basin), along with a drain control and a faucet assembly, provides hot or cold water for washing needs. Amenities typically include toilet paper, toilet seat cover dispensers, soap, paper towels, sharps container for disposable syringes, paper disposal receptacles, and a vanity mirror. Additional amenities may include infant changing tables that, when stowed, do not reduce the space required for dependent or independent transfers.

Toilet: For purposes of the guideline, the toilet is the actual device to which a person transfers to for hygienic functions. It is often called a commode or water closet.

Toilet Compartment: This refers to a facility customarily used by passengers for their hygienic functions and appearance needs. The accessible restroom includes the complete toilet compartment.

Toilet Flush Control: This switch initiates the toilet flushing cycle.

Transfer: This refers to the physical movement of a passenger between a passenger seat and a mobility device and/or a restroom toilet seat.

Independent Transfer (in an out of a wheelchair or on and off a toilet): Some-passengers can perform an independent transfer using appropriate grab bars. These people do not require any assistance either in transfers or within the enclosed restroom compartment.

Dependent Transfer (in and out of a wheelchair or on and off a toilet): Passengers who require physical assistance from another person to perform a dependent transfer. For passengers in this category, a variety of techniques may be used to lift passengers clear off one seat, move them until they are over the other seat, and then lower them into a seated position. A passenger's rotation is expressed in terms of "degrees of transfer," e.g., in an up to 90-degree transfer, a passenger is pivoted through, up to a 90-degree arc. In a side-by-side or lateral transfer (0 degrees), a passenger transfers across from seat to seat. Note that there are a wide variety of transfer techniques and toileting methods, each with their own spatial requirements. The space required for 0-degree up to 90-degree transfers of a 95th percentile male with a personal attendant who is also a 95th percentile male should accommodate the needs of most other passengers with disabilities who use transfer techniques different from those described herein, and whose method of using the toilet may not require transfer, or who use mobility devices. It is important that amenities are located to accommodate both a 5th percentile female and 95th percentile male. All transfers must be done in a fully enclosed restroom compartment.

Warnings: Visual and audible warnings are used so individuals with visual or hearing disabilities may be instructed to leave the restroom when necessary.

A 6.4 Human and Environmental Factors

Physical Characteristics of Users: Accessible restrooms, while modified for the needs of passengers with disabilities, can be used by all passengers. The underlying presumption is that the purpose of the accessible restroom design is to enable adult passengers to access and use a fully enclosed restroom while using a power base mobility device but not a scooter.

A 6.5 Design Validation

The restroom design should be validated by using a virtual simulator or similar design tool to confirm that the sweep spaces for 5th percentile Asian females and 95th percentile northern European males wearing light clothing are adequate. The sweep spaces must be verified for both independent and dependent transfers as well as for the location of fixtures and amenities. A human factors evaluation of mock-ups of final restroom designs involving a diverse population with disabilities is strongly encouraged.

A 6.6 Restroom (Toilet Compartment)

The accessible restroom at a minimum should include the toilet, rigid enclosure, sink and associated amenities, and sufficient space for a lateral (0 degree) up to a 90-degree dependent transfer.

Size: The minimum space required in toilet compartments is provided so that a 95th percentile male using a wheelchair can maneuver and independently transfer into position onto the toilet. In addition, the minimum space must permit a 95th percentile male personal care attendant to perform a lateral 0-degree to a 90-degree dependent transfer of a 95th percentile male. This space cannot be permanently obstructed by baby changing tables or other fixtures or conveniences. If lavatories are to be used to accommodate fixtures other than those associated with the toilet, the fixtures must be designed to fold away or space must exceed the minimum requirements to allow for them. The restroom must be fully enclosed.

Advisory: Note that lateral transfer designs are recommended. A lateral transfer minimizes the "exposure time" during a transfer. Exposure time is the time a person would be at risk to falling or being dropped. In a lateral transfer, the person has either the wheelchair or toilet directly under them at all times; in a 90-degree transfer, there may be open space between the wheelchair and toilet and this increases the risk of injury. Lateral transfers include transfers from 0 to 90 degrees. Many people who perform independent transfers position their mobility device for a 45-degree transfer.

Doors: Doors shall be located to permit either the passenger independently or with their attendant to enter the restroom and close the door. Restroom doors shall not swing into the minimum required compartment area, and doors that swing away may be difficult for a passenger to operate. Sliding doors are often a preferred option. Door hardware that can be operated with a closed fist or a loose grip accommodates the greatest range of users. Hardware that requires simultaneous hand and finger movements require greater dexterity and coordination, and are not recommended. It is recommended that the door shall be able to be opened and closed from a seated position. Handles, pulls, latches, locks, and other operable door parts shall be 34 inches (865 mm) minimum and 48 inches (1,220 mm) maximum above the finished floor. Where sliding doors are in the fully open position, operating hardware shall be exposed and usable from both sides. *"Minimum doorway opening ranges from 36 inches for doors opposite the toilet to 39 inches for doors located sideways to the toilet."* (ADAAG, 2006)

A 6.7 Toilet

Approach: Compartments shall be arranged for either left-hand or right-hand lateral (0 degree) or up to 90-degree independent transfer to the toilet. The toilet housing must be open around the toilet to accommodate people who use a frontal approach.

Advisory: The centerline of the toilet shall correspond to the center position of a 95th percentile male subject with modest clothing seated on the toilet. Toilets shall be arranged for either a left-hand or right-hand transfer. Toilets shall permit sufficient space for shoulders, elbows, and the performance of hygienic functions.

Overlap: The associated amenities such as grab bars, dispensers, sharps containers, sanitary napkin disposal units, coat hooks, and shelves may not impede independent or dependent transfers.

Seats: "*The seat height of a toilet above the finish floor shall be between 17 inches (430 mm) minimum and 19 inches (485 mm) maximum measured to the top of the toilet seat*." (ADAAG 1194.123.a.2, 2006)

Advisory: An 18-inch (457 mm) toilet seat height is easier for older passengers; however, this height is more difficult for children and people of small stature.

Toilet Seat: A split toilet seat, rather than a solid circular toilet seat is easier for people with certain disabilities to perform personal hygiene functions.

Toe Clearance: "*The lowest portion of any fixtures, other than the toilet should be at least 9 inches about the floor*."(ADAAG, 1194.123.a.1, 2006)

A 6.8 Controls

Faucets and flush controls shall be touchless, and other controls shall be operable with one hand and shall not require tight grasping, pinching, or twisting of the wrist. "*The force required to activate controls shall not be larger than 5 lbf (22.2 N). Controls for flush valves shall be reachable from the toilet and not be located behind the toilet*."(ADAAG, 2006) Faucets and flush controls should be touchless and have tactile, raised or etched graphics surfaces-for use by passengers who have visual impairments.

Flush Controls: Flush controls shall be touchless, and should provide both audio and visual feedback to facilitate use by travelers with sensory impairments. The flush control shall be located on the clear space to the side or rear of the toilet.

Dispensers: Toilet paper dispensers shall be reachable from the toilet.

Mirrors: Mirrors located above sinks or countertops, as well as those not located above sinks or countertops, shall be installed with the bottom edge of the reflecting surface such that a person seated on the toilet or in a WhMD can use it. The **bottom** of a vanity mirror reflecting surface should not be more than 40 inches (1,020 mm) from the finished floor height if it is located over a countertop. For mirrors that are not over a counter the bottom of the vanity must be less than 35 inches (890 mm) above the finished floor height. The top edge of the mirror should be at least 74 inches (1880 mm) from the finished floor height.

Advisory: A single full-length mirror can accommodate a greater number of people, including children.

A 6.9 Grab Bars

Grab bars are horizontal projections from a nearby wall that may be used for support, and may include fixed or folding horizontal bars. "*A grab bar at least 24 inches (610 mm) long shall be mounted behind the toilet, and a horizontal grab bar at least 40 inches (1020 mm) long shall be mounted on at least one side wall, with one end not more than 12 inches (305 mm) from the back wall, at a height between 33 inches (838 mm) and 36 inches (914 mm) above the floor*." (ADAAG, 2006) Grab bars that fold away on the "open" side are very useful for passengers who have limited mobility or balance.

Advisory: Hand grips shall facilitate independent transfers to and from the WhMD and the toilet. In the confines of an accessible restroom, projecting objects such as grab bars can be hazardous for all passengers, and must be placed with care. In some cases countertops may also assist with either vertical or horizontal stability. A cross-section of between 1 ¼ inches (32mm) to 2 inches (51 mm) is advised.

Spacing: The space between the wall and the hand grip shall be sufficient for a 95th percentile male to grip the surface. It is recommended that 1½ inches (38mm) clear space around the hand grip/grab bar be provided.

Installation: Grab bars shall be installed in any manner that provides a gripping surface at the specified locations and that does not obstruct the required clear floor space, or pose a safety risk for standing passengers.

Structural Strength: All grab bars must withstand abuse load requirements. A **minimum** vertical or horizontal force of 250 lbs. (1,112 N) is recommended.

Advisory**:** The accessible restroom is most likely to be used by passengers who are considered obese. Restroom designers may want to increase the structural strength to 400 lbs.

A 6.10 Sinks

In very tight restroom spaces, sinks shall be accessible while seated on the toilet by a 5th percentile Asian female and a 95th percentile northern European male. Adequate knee and toe clearance should be considered. In some circumstances, the sink should be directly accessible to a 5th percentile female seated in a mobility device.

Faucets: Faucet controls shall be touchless and have tactile, raised, or etched graphics surfaces for use by passengers who have visual impairments. It is recommended that the "cold" faucet control be on the right and the "hot" be on the left. The faucet controls for the sink should not exceed 18 inches (457 mm) as measured from the centerline of the toilet.

A 6.11 Amenities

Soap and Towel Dispensers: If soap and towel dispensers are provided, it is preferred that they be within reach of a person seated on the toilet or seated in a mobility device.

Call Button: Call buttons must be accessible from the toilet and the floor to assist an individual who has fallen and is unable to get back up without assistance. The call button must have a tactile raised surface for use by passengers with visual impairments. The call buttons must be reachable by 5^{th} percentile females.

Sharps Container: It is recommended that a sharps container for disposable syringes be placed in the accessible restroom.

A 6.12 Validation Checklist for Accessible Restroom

Table A-7 is a validation checklist for the accessible restroom.

Table A 7 Validation Checklist for the Accessible Restroom

Specific Item	Technical Requirements	Recommendations
Aisle		
Aisle Width at Restroom Door Location	The aisle width depends on the maneuverability of the wheelchair and location of restroom door with respect to toilet.	43-44 inches (1092-1118 mm) are recommended. 39 inches or 900 mm is the minimum required.
Turning Clearance	Adequate for 95th percentile male in a personal mobility device to turn in to restroom from aisle.	
Clear Floor Space Adjacent to Toilet	The minimum clear floor area shall be 35 inches (890 mm) by 60 inches (1,500 mm).	The toilet housing permits frontal and side approaches for personal hygiene.
Door		
Width	Minimum of 36 inches (914 mm) at the end; side-mounted doors are required to be 39 inches (990 mm).	
Sill	Smooth transition on both sides of the door are needed.	Make sure that all transitions are smooth and have ramps or are chamfered.
Door Clear Space Opening	Door must not swing open into restroom compartment.	
Door Locks	Door locks should be accessible to both 95th percentile male and 5th percentile female seated on personal mobility device.	Touch controls preferable
Door Hardware	Door hardware that can be operated with a closed fist or a loose grip accommodates the greatest range of users. Handles, pulls, latches, locks, and other operable parts on doors shall be 33 inches (838 mm) minimum and 48 inches (1,220 mm) maximum above the finish floor. Where sliding doors are in the fully open position, operating hardware shall be exposed and usable from both sides.	ADAAG 404.2.7 Power assisted sliding doors are preferable.

Specific Item	Technical Requirements	Recommendations
Compartment		
Maneuvering Space	Adequate maneuvering space for personal attendant to assist within toilet compartment prior to and after transfer.	
Toe Clearance	Adequate toe clearance below fixtures (not the toilet) for 95th percentile male seated on personal mobility device; approximately 12 inches (230 mm).	ADAAG 604.1.4
Transfer Space	<u>Dependent Transfer:</u> Adequate maneuvering space for a lateral or 90^{o} dependent transfer of 95th percentile male by a 95^{h} percentile male <u>Independent Transfer:</u> Adequate space for an independent lateral transfer	
Hand Grips		
Diameter	It is recommended that the gripping surface be at least equivalent to 1.25 inches or 32mm. The knuckle clearance should be at least 1½ inches (38 mm).	Hand grips must support at least 250 lbf (1,112N). ADAAG 609.8. The recommendation is 300 lbf.
Location (independent transfer)	Hand grips must support independent lateral transfers.	
Toilet		
Seat Height	Seat height should be between 17 in to 19 in (430 mm to 485 mm).	Higher toilet seat heights are easier for older people 18–19 in , and a split toilet seat.
Flush Controls	Shall be operable with one hand and less than 5 lbf (22N).	ADAAG 604.6
Washlet	Reserved	
Toilet Paper Dispenser	Must be accessible from seated position on the toilet by 5th percentile female and 95th percentile male.	Reach position/dimensions
Seat Cover Dispenser		

Specific Item	Technical Requirements	Recommendations
Sinks		
Reach Range	Should be accessible from seated position on the toilet by 5th percentile female and 95th percentile male or accessible by person seated on personal mobility device.	For direct access from the toilet, this may be about 5 inches (140 mm) from end of toilet. Ensure adequate toe clearance and reach range.
Faucets	Should be accessible from seated position on the toilet by 5th percentile female and 95th percentile male or accessible by person seated on personal mobility device.	Lever, push, or electronic are acceptable. If self-closing valves they should stay open for 10 seconds. Shall be operable with one hand and less than 5 lbf (22 N).
Amenities		
Dispensers		
Soap	Must be accessible from seated position on the toilet by 5th percentile female and 95th percentile male or accessible by person seated on personal mobility device.	
Towel	Must be accessible from seated position on the toilet by 5th percentile female and 95th percentile male or accessible by person seated on personal mobility device.	
Sharps Container	Should be available.	
Mirrors	Should be visible by person seated in mobility device.	
Attendant Call Button	Must be accessible from seated position on the toilet by 5th percentile female and 95th percentile male, also must be accessible from floor level in case of a fall.	Attendant call button and other electronic controls must include both audible and visual activation notification. A reset control should also be reachable from the toilet.

Specific Item	Technical Requirements	Recommendations
Lighting Levels	5 foot candles (54 lux) minimum	British recommended standard
Signage		
Visible, Audible and Tactile Warnings	All touchpoints, signs, and placards should be presented in multiple sensory modalities. Touchless sensors should provide auditory feedback.	

A 6.13 Examples of Best Practice for Accessible Restroom Features

Figures A 11 to A 14 illustrate examples of some accessible features on operating rolling stock. In Figure A 11, the toilet is at an angle. Members of the working group advised that this is very difficult to transfer and recommend that the toilet be in the longitudinal direction.

Figure A 11 Toilet with grab bars and fold away arm supports on each side of toilet, illustrating clear housing for frontal approaches (VIA Rail Canada)

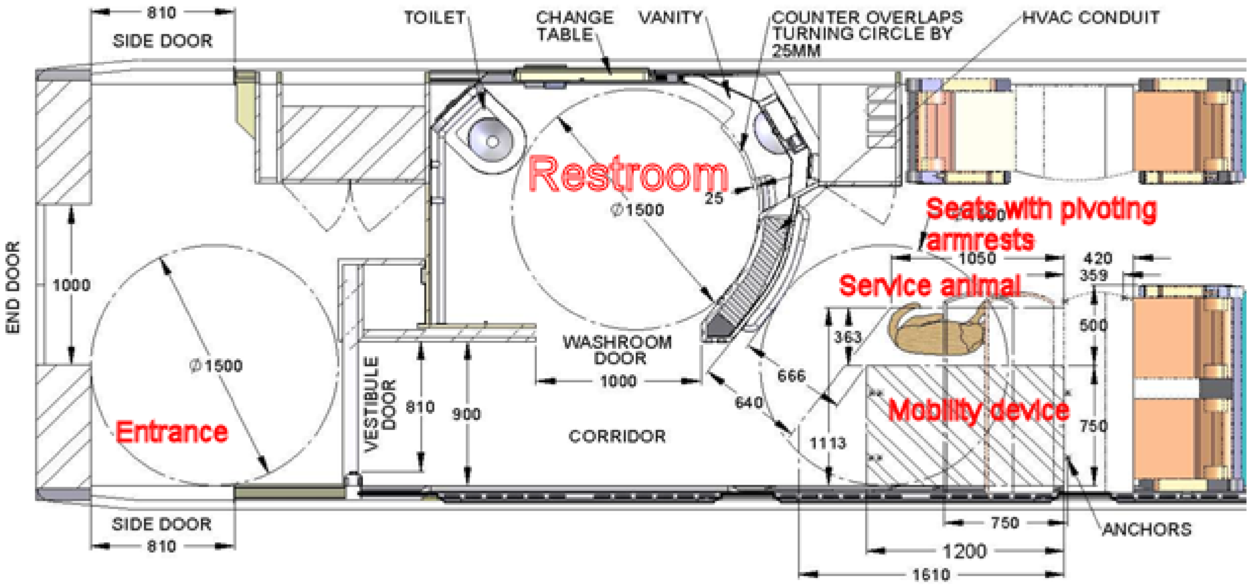

Figure A 12 Coach car with fully accessible washroom, locations for wheelchair traveler, space for service animal, and companion seat (VIA Rail Canada)

Figure A 13 Wheelchair traveling position with table, transfers seat, and flip Seats adjacent to washroom[23]

[23] German ICE train.

Figure A 14 Example of space for service animal [24]

[24] Australia, Intercity Train.

Appendix B Accessible Passenger Rail Restroom

The minimum spatial configuration of an accessible restroom that can accommodate a power base WhMD and a personal care assistant; both the power base WhMD with a manikin and personal care assistant will be represented by a 95th percentile male. The analysis is based on a large power base in the current Acela accessible restroom. In addition, generalized spatial studies recommend optimal restroom configurations with respect to door location, overall restroom geometry, and location of essential monuments (toilet and sink).

1. Use forward facing approach and egress, the analysis:

(a) Validates the 180-degree rotation of an occupied powered base mobility aid within the restroom enclosure

(b) Validates that an assisted transfer between the power base mobility aid and the toilet can accommodate both a passenger and an assistant who are representative of a 95th percentile male

(c) Recommends locations and/or configurations of the accessible restroom that may accommodate a 90-degree turn by a large scooter from the vestibule to the vehicle access aisle

2. In addition, the analysis will suggest locations for amenities such as grab bars and assist handles. A 5th percentile female manikin will be used to validate reach ranges.
3. The restroom study will be coordinated with the scooter study to validate door location and designs that will accommodate the turning radius of the large scooter in the vestibule.

B 1 Preliminary Findings

The findings to date have examined the movement of a large power base WhMD within the restroom enclosure. The spatial consumption study of this device that is occupied by a 95th percentile male is shown in Figure B 1. This reflects the additional space that is required for toe clearance. This spatial area is 66 inches wide by 84 inches long, and includes a 9-inch extension for toe clearance and slightly extended footrests that allow knee flexion that is more natural and greater than 90 degrees.

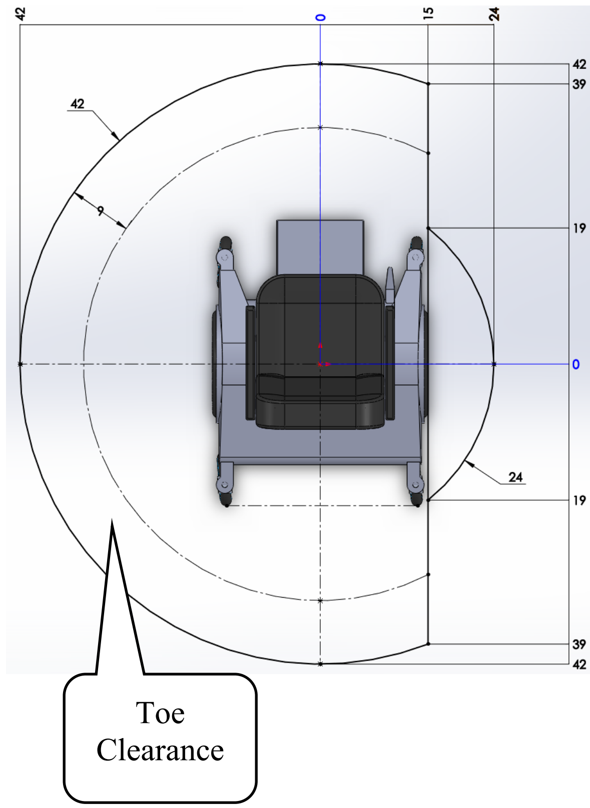

Figure B 1 Spatial consumption of large power base WhMD with toe clearance for 90–95th percentile male

Figure B 2 is an overlay of a large power base WhMD on the existing Acela restroom, showing that while the device can fit inside the restroom, it is not functional.

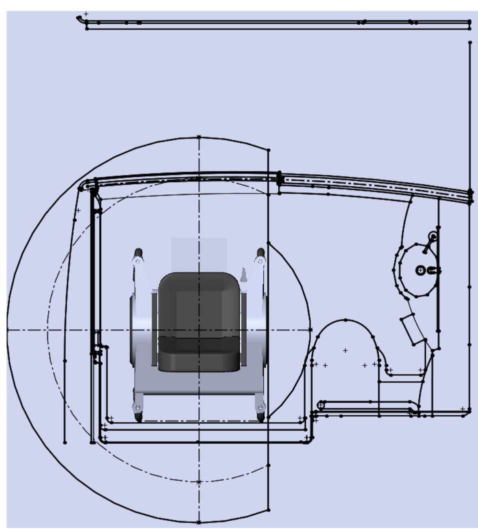

Figure B 2 An overlay of a large power base WhMD with toe clearance on existing Acela accessible restroom

Researchers conducted laboratory studies using a large power base WhMD and a 95th percentile male, shown in Figure B 3. These studies were conducted to validate the computer modeling.

This produced a generalized footprint of 79 inches (2006 mm) by 83 inches (2,108 mm). Note the following:

- A 12-inch (305 mm) vertical clearance has been considered for foot and toe clearance.
- The study did not take into account the 18-inch (457 mm) clearance from the toilet centerline to a wall.
- The location of a sink or any other amenities

During the laboratory study, the research team observed that a 42-inch (1,067 mm) wide door was required for the power base to access the restroom from a 35-inch (890 mm) wide aisle. Figure B 3 shows the generalized spatial consumption from the laboratory study that did not have any restrictive wall structures.

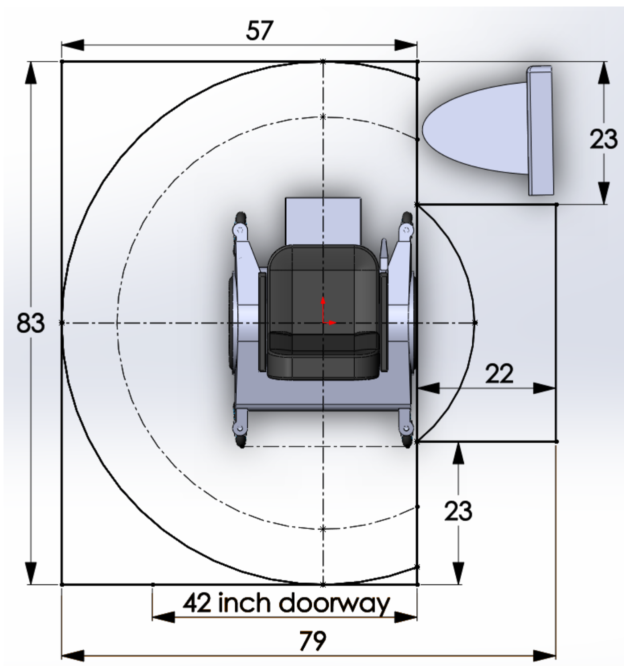

Figure B 3 General spatial consumption, from laboratory tests

B 2 Design Evolution

The following series of figures are included to show the evolution of the recommended configuration from the current Acela restroom.

The aisle space across from the restroom that currently includes equipment has been opened up and the power base WhMD overlays the Acela restroom. Note the encroachment on the sink, toilet, and door closing. Figure B 4 shows an enlarged Acela configuration with the equipment across the aisle removed.

Equipment is removed to provide aisle space. A new location needs to be identified for the equipment.

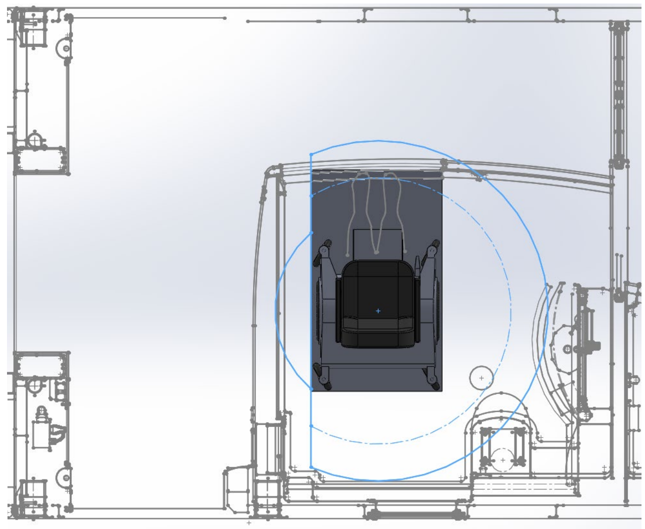

Figure B 4 Overlay of powerbase on an enlarged Acela restroom configuration and clear aisle space

Figure B 5 is an expanded restroom enclosure that produced an unacceptable 24-inch wide aisle

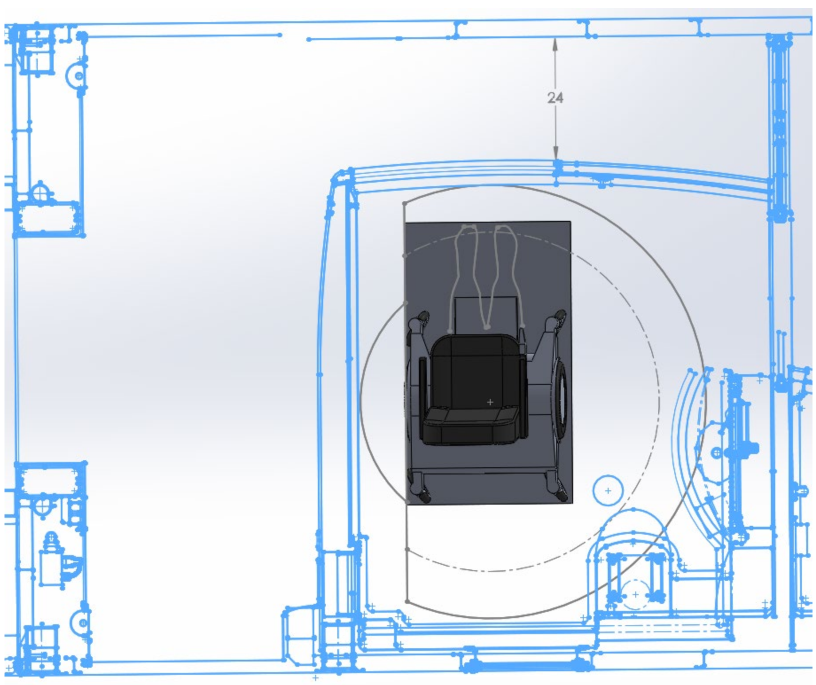

Figure B 5 Enlarged restroom enclosure and resulting 24-inch aisle

The unacceptable 24-inch (610 mm) wide aisle prompted the change in restroom orientation to a more parallel design with the goal of keeping the aisle at least 36 inches (914 mm) wide. Figure B 6 shows a parallel configuration with the inboard restroom monuments.

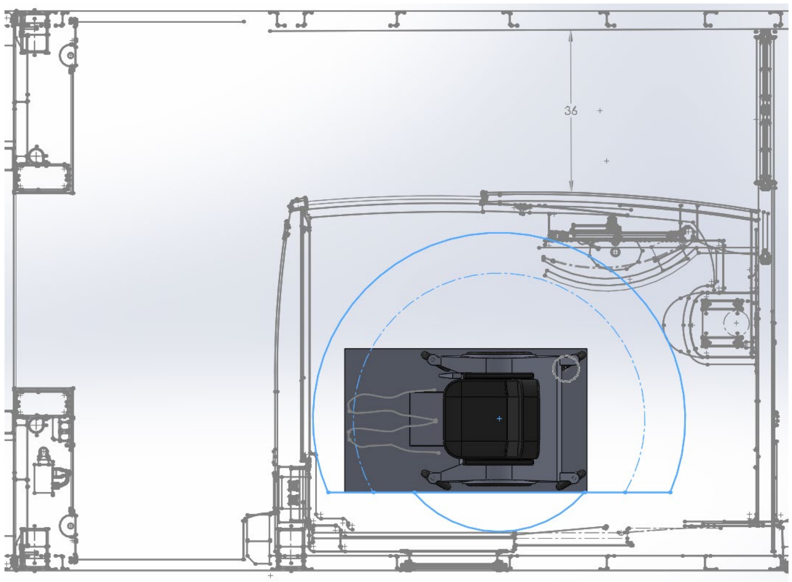

Figure B 6 Parallel orientation with inboard restroom monuments

The next evolution was to move the monuments outboard, which would ease operations and maintenance of the monuments. Figure B 7 shows the monument configuration from the Acela re-oriented to the outside vehicle wall area. There are still some toe clearance conflicts under the sink area. Also note the overall size of the restroom of 72 inches (1,829 mm) by 100 inches (2,540 mm).

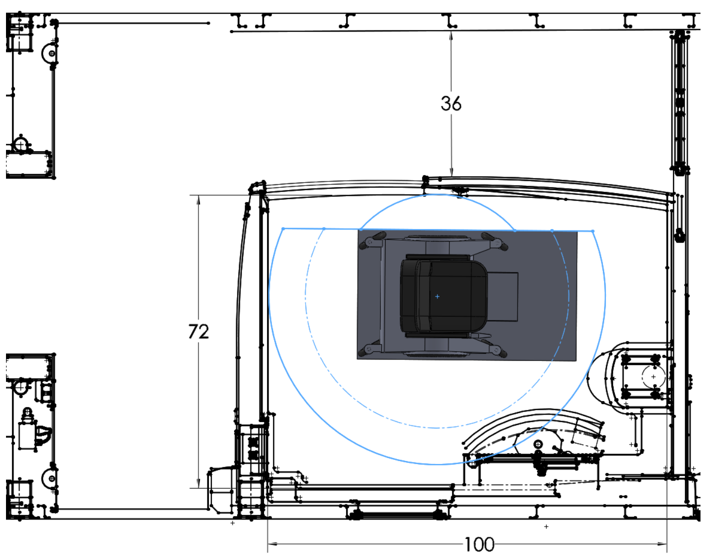

Figure B 7 Monuments relocated to outside wall of vehicle

Figures B 8, B 9, and B 11 show three different toilet orientations. A key dimension is the centerline distance from the toilet to a wall of 18 inches (457 mm). This is called the shoulder distance, but it does impact the overall footprint of the restroom.

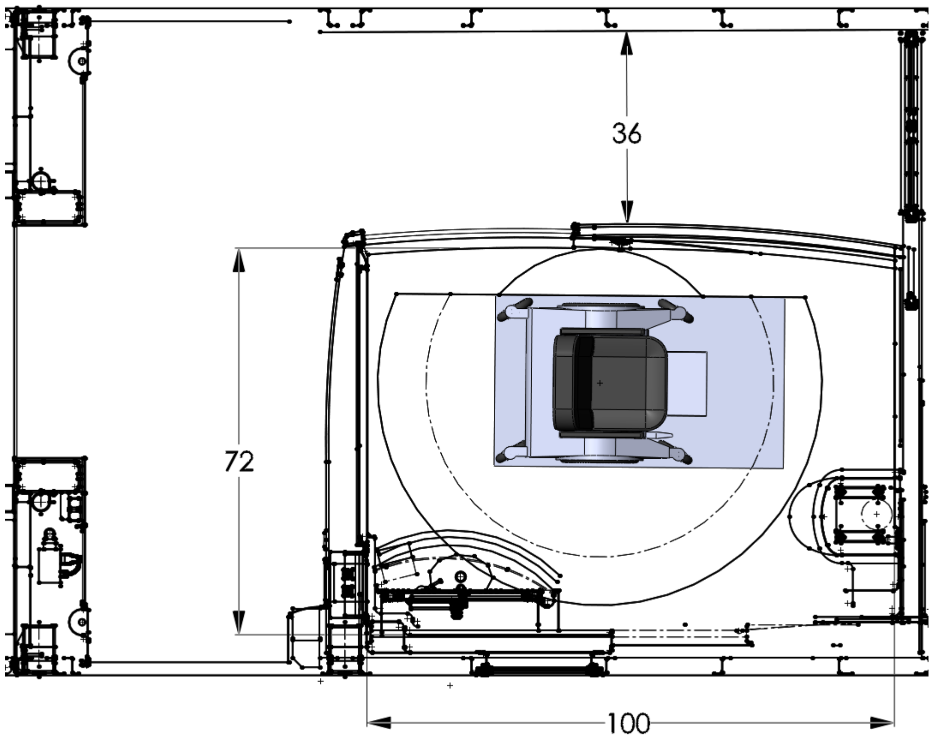

Figure B 8 Toilet on interior wall and distance from center line to wall is less than 18 inches

In **Figure B 9** the toilet has been rotated 45 degrees and is positioned in the corner on the diagonal. The advantage of this orientation is the reduction in size of the overall restroom. Members of the technical advisory committee and the RVAAC both discouraged a 45-degree orientation. The width is still 72 inches (1,829 mm); however, the length is reduced from 100 inches (2,540 mm) to 93 inches (2,362 mm). This reduction on length impacts the size of the accessible seating area as shown in Figure B 10.

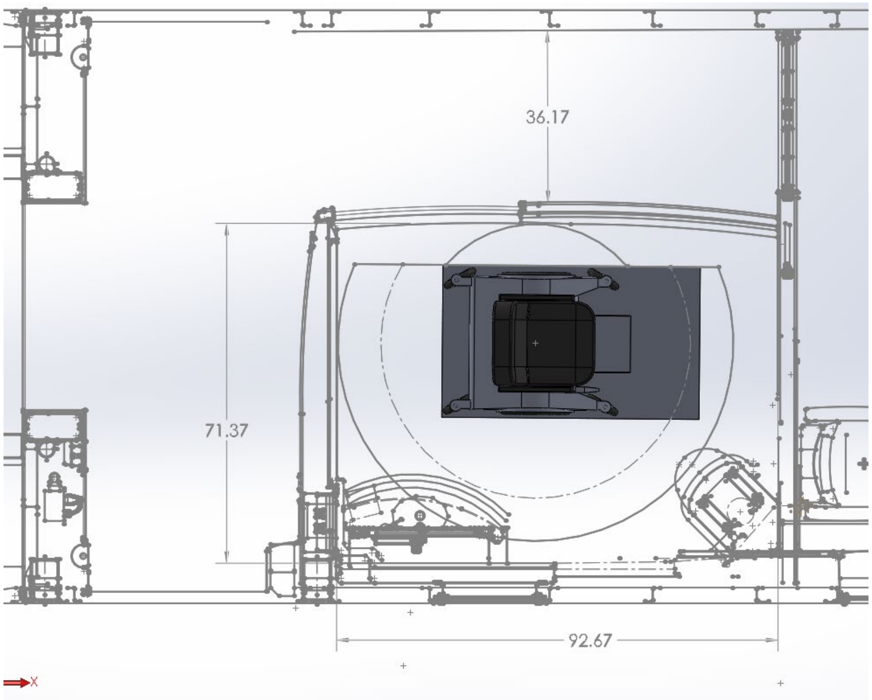

Figure B 9 Toilet positioned on the diagonal

Figure B 10 shows a rendering of the accessible seating area with the 72-inch by 93-inch restroom.

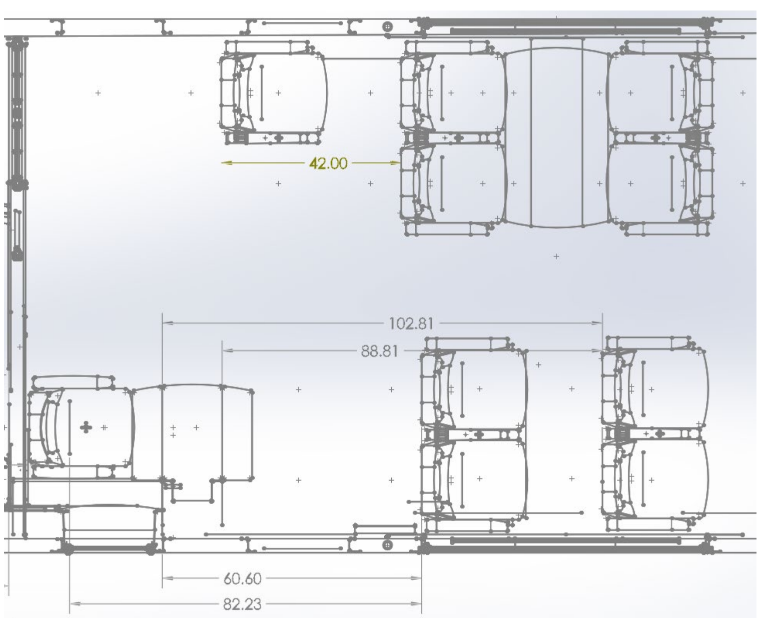

Figure B 10 Accessible seating area associated with the 72 x 93-inch restroom

Figure B 11 shows the restroom configuration with the toilet located on the outside wall. Note that the sink has been placed in the corner. This figure also shows the adjacent accessible seating area. In this figure note that the restroom footprint is 72 inches (1,829 mm) by 99 inches (2,115 mm). The increase of 6 inches (152 mm) in length over the diagonal toilet configuration is also reflected in reduced area for the accessible seating area. Figure B 12 shows a small cutout to increase turning radius from vestibule to aisle.

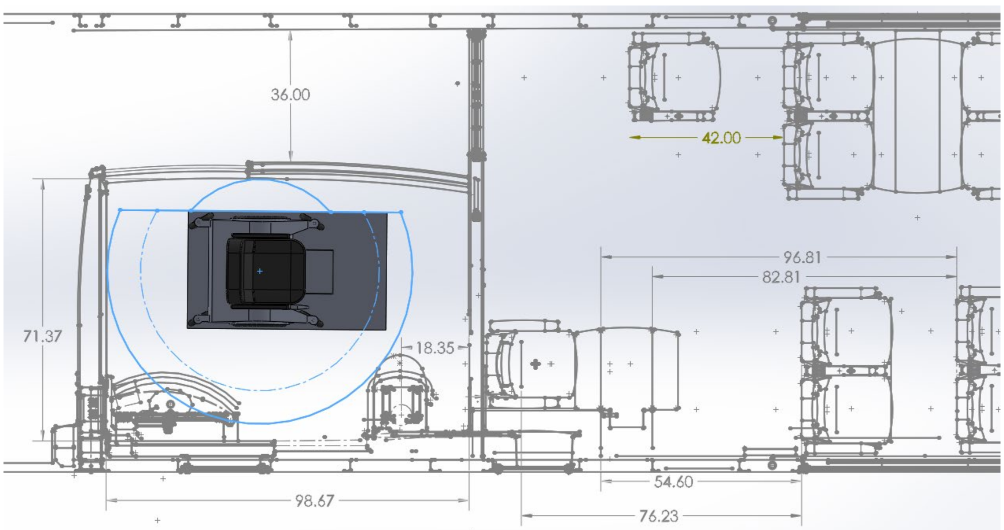

Figure B 11 Rendering with toilet located on outside wall and adjacent accessible seating area

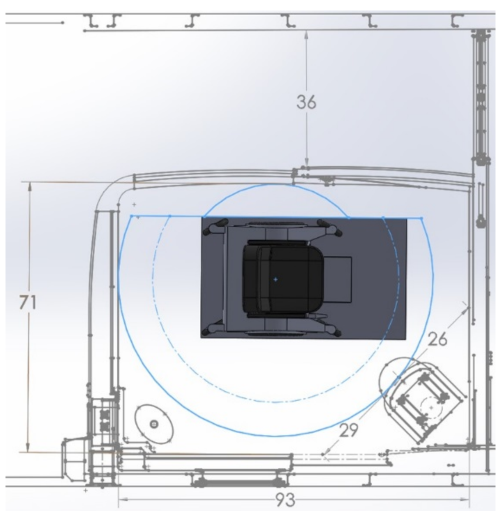

Figure B 12 Restroom with area cut out to improve maneuverability in aisle

B 3 Summary of preliminary findings

1. Orientation of the restroom is longitudinal
2. The sink and toilet are located on the outboard side of the vehicle
3. At least one sink must be accessed from the toilet
4. The restroom door has a 42 inch (1067 mm) opening
5. The restroom has a corner notched out to permit easier maneuverability by large scooters between the vestibule and aisle to access accessible seating area.
6. Seating area analysis is contingent on restroom. Preliminary studies have shown that at least one and perhaps two additional revenue seats may be possible. This is documented in Appendix C Task 1.3 write up.

Figure B 13 shows the new recommended restroom base design (adapted from the Acela).

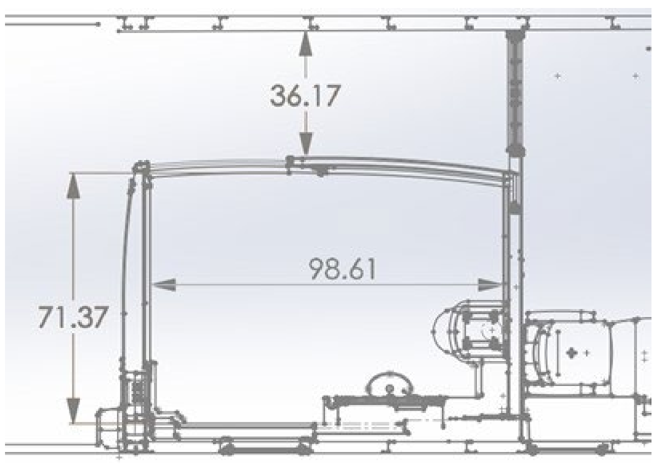

Figure B 13 Base layout of the accessible restroom

Appendix C Seating Area Analysis

Researchers studied the spatial configuration of accommodating two WhMDs in coach class seating and the accommodation of a transfer from a large scooter and its subsequent stowage. These research tasks estimate the impact on revenue seat capacity in coach class passenger trains. Recommendations for the minimum area for a stowage location in the passenger seating area for a large power base WhMD or scooter were considered. This will include stowage for two devices, if two accessible spaces are recommended. Different configurations are presented that include a variety of WhMDs. Finally, the research team offers a review of the recommendations from the RVAAC on space for service animals within the passenger seating area and performs spatial analysis of the impact on seating, if any, and makes a recommendation on the most optimal location for such a space.

Appendix C 1 includes the footprints of the three types of wheeled mobility aids used in the analysis. Appendix C 2 shows scenarios that were considered but only accommodate a single wheeled device; in some cases, the single WhMD is shown for illustration purposes only.

C 1 Background

The base for analysis is the current coach class car on the Amtrak Acela, shown below in Figure C 1.

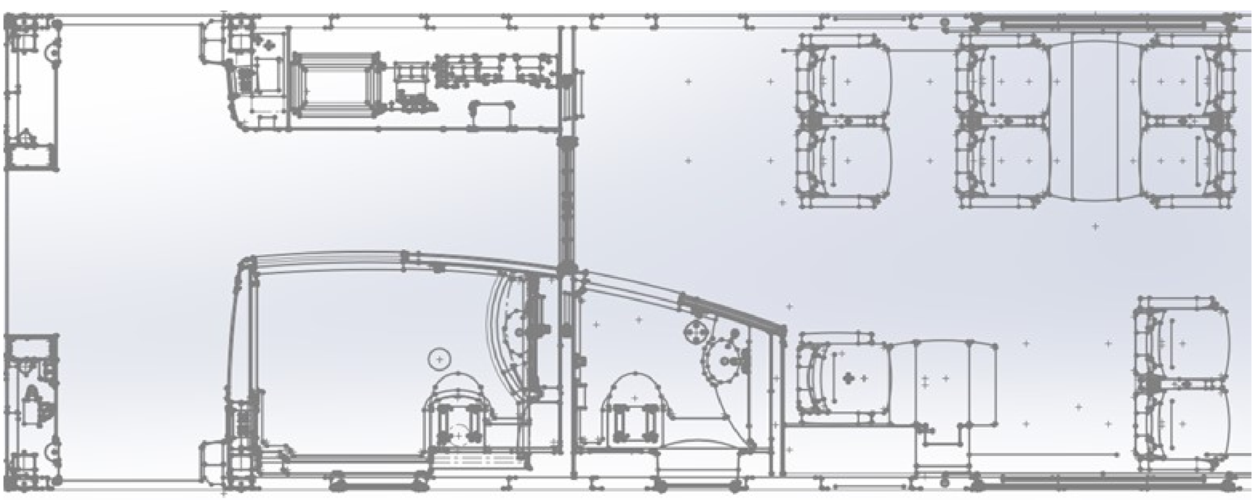

Figure C 1 Base case: Coach class Acela car

The development of the new larger accessible lavatory reported in Appendix B involved discussion with many stakeholders, including those from Amtrak. This seating study was concurrent to the redesign of the accessible lavatory. Figure C 2 shows the base layout used for the seating analysis. This figure incorporates the new larger accessible lavatory. The larger lavatory results in changes to the location of the restroom door from the vestibule area to the coach, and the aisle was moved to one side of the car. In the new lavatory configuration, the toilet orientation is in the longitudinal direction, and there is a sink adjacent to the toilet. Figure C 2 also contains some key dimensions, including the standard aisle width of 24 inches (610 mm) and a double seat of 46 inches (1,168 mm).

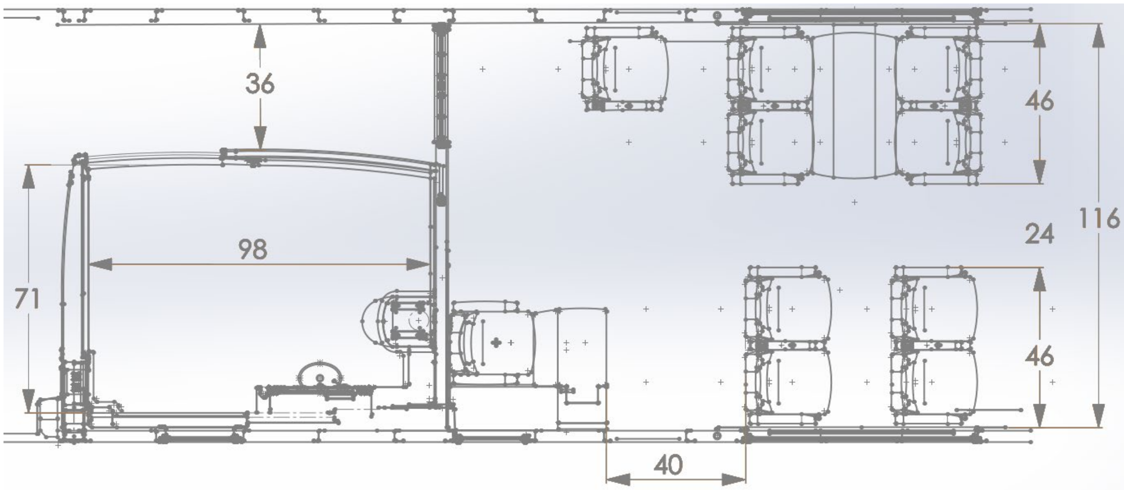

Figure C 2 Dimensioned layout of base scenario

Figure C 3 refers to the existing Acela coach seating; the X shows where one single seat is removed, and the 00 shows where a row of two seats is added with a net gain of one seat.

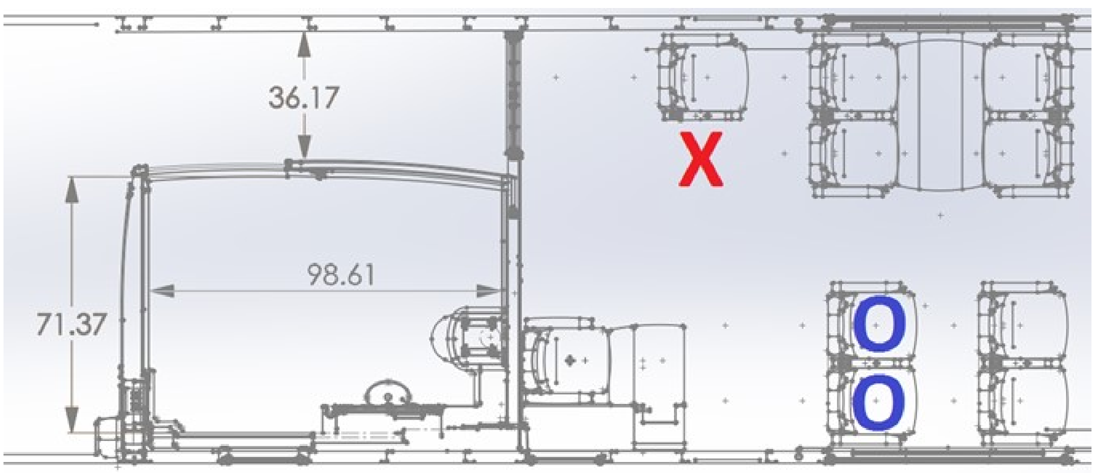

Figure C 3 Base layout, including larger accessible lavatory

C 2 Design Scenario Description and Discussion

Containment: A key consideration is the containment of WhMDs and the occupant. All passengers sitting in regular seats have containment provided by the seat back of the row in front of them or a table. WhMDs need room to maneuver, and this conflicts with containment and occupant protection.

A study is needed to determine the level of containment that must be provided for WhMDs as well as regular seats that do not face a table or the back of the seats of the row in front.

The following scenarios A through E have problems with containment: A, B, and aspects of C and D. Scenario E is suggested as a possible remedy for some of the containment challenges, but the number of WhMDs that can be accommodated is limited. The manual wheelchair in the orientation as shown is not contained; however, if the chair is rotated 180 degrees and faces the single seat, more containment is possible. But the wheelchair user would face the door that leads to the aisle, vestibule, and restroom.

C 2.1 Scenario A

Scenarios are shown in Figure C 4a and 4b. In all these scenarios, the single seat at the bottom of the figure is moved toward the outside wall. This increases the width of the aisle and maneuvering space for WhMDs. Scenario A2 shows the addition of a manual wheelchair in space that could also be used by a service animal.

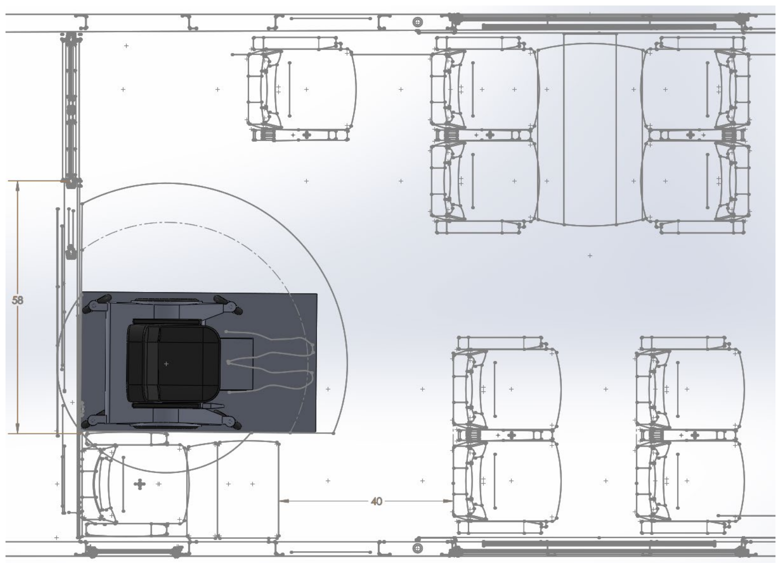

Figure C 4a Scenario A 1 Layouts

Scenario A1:

- \+ Base layout with single seat moved closer to outside wall
- \+ Power base WhMD
- \+ Space for service animal
- \+ Wide aisle space
- – No containment for WhMD
- – No table access for power base WhMD

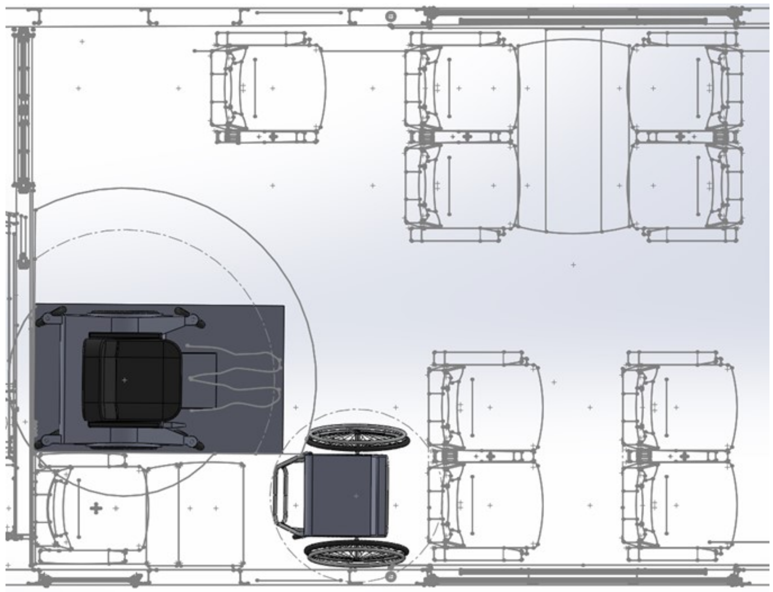

Figure C 5b Scenario A2 Layouts

Scenario A2:

- + Base layout with single seat moved closer to outside wall
- + Wide aisle space
- + Power base WhMD
- + Manual wheelchair
- – No containment for power base WhMD
- – No table access for power base WhMD

C 2.2 Scenario B

Scenario B is very similar to Scenario A, but a row of seats has been removed to accommodate the two power base wheelchairs, shown in Figure C 5. Researchers assumed the WhMDs would move independently of each other to avoid conflicts during maneuvering.

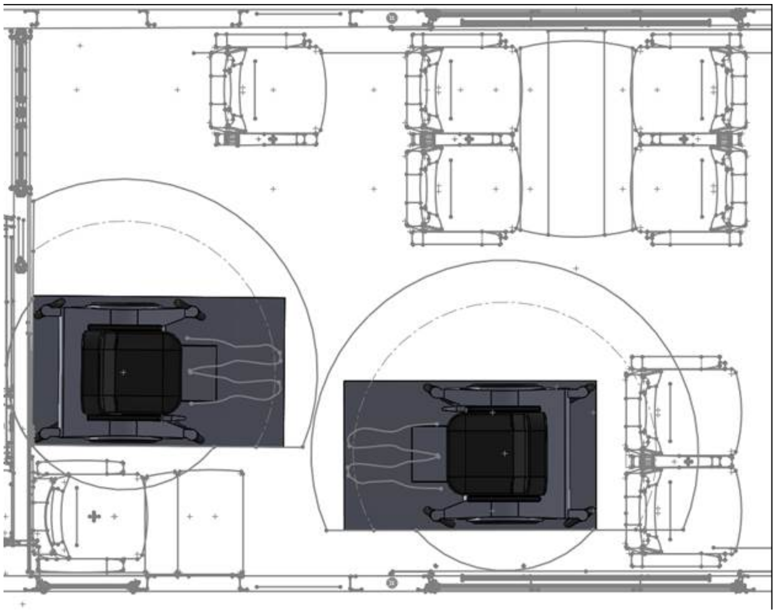

Figure C 6 Scenario B layouts

Scenario B:

+ Base layout with single seat moved closer to outside wall
+ Two power base WhMDs with 90-degree turning radius
– Row of seats removed
– No or limited containment for WhMD
– No or limited table access for power base WhMD

C 2.3 Scenario C

In Scenario C, the base layout is modified by the addition of a second seat adjacent to the single seat on the wall and the loss of a row of seats. In all these scenarios there is a loss of one seat.

In scenario C, a row of seats is removed to allow maneuvering space for a large power base, and to maintain sufficient aisle space and space for a service animal. All the C scenarios are the same seating plan as scenario C1, but show two possible locations for a manual wheelchair. Scenario C2 shows the addition of a 54-inch (1,372 mm) long scooter, stowed crossways. This scenario illustrates how the long scooter impedes aisle circulation. The scooter could be stowed longitudinally.

Scenario C3 shows two longitudinal manual wheelchairs and a 48-inch (1,220 mm) long scooter in a lateral position. Figure C 6 shows the Scenario C layout, Figure C 7 a and b, shows the Scenario C2 layout, and Figure C 8 shows the Scenario C3 layout.

Scenario C1:

- \+ The base layout benefits from the addition of a second seat on the wall and removal of a row of seats with no net seat loss or gain.
- ± This scenario will accommodate one or more WhMDs and permits maneuvering space for large power base wheelchair.
- \+ Some table access

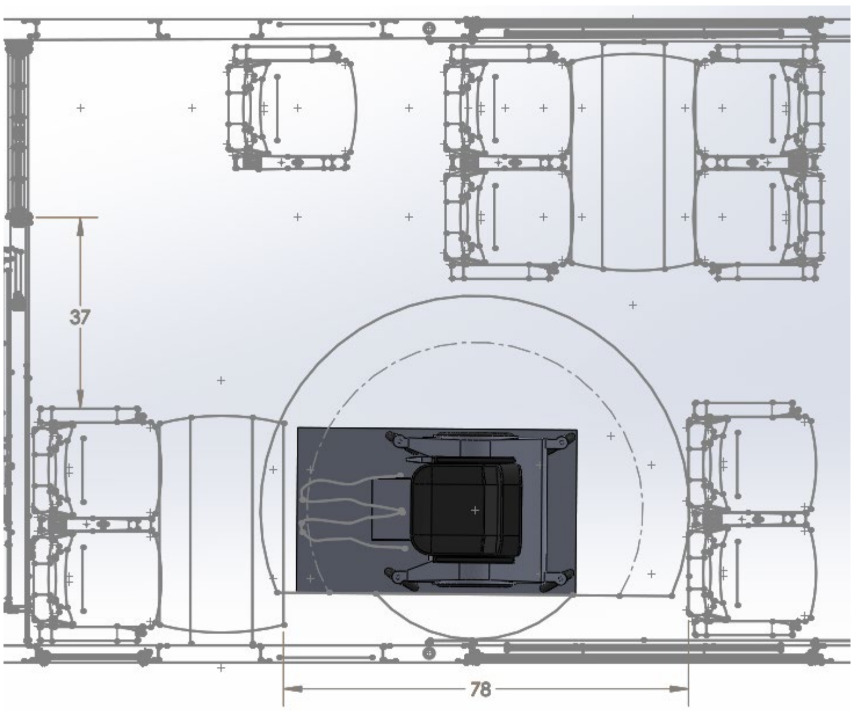

Figure C 7 Scenario C1 layout with dimensions

Scenario C2 (shown in Figure C7 a and b)

- \+ Base layout with the addition of a second seat on the wall and removal of a row of seats for no seat loss or gain.
- \+ This scenario will accommodate 1 or more WhMDs and permits maneuvering space for large power base.
- \+ May impact aisle circulation
- \+ Lack of containment for manual wheelchairs adjacent to table or adjacent to single seat
- – No table access for manual wheelchairs.

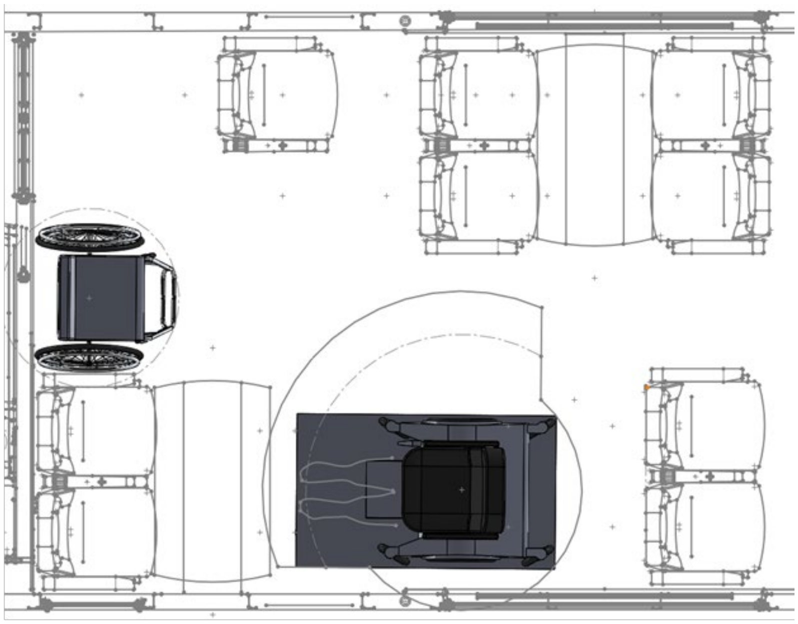

Figure C 8a Scenario C2 layouts 2 WhMD

Scenario C2:

- \+ Space for 54-inch (1,372 mm) scooter stowed in longitudinal position (not shown).
- – Shows the impact of a 54-inch (1,372 mm) long scooter in the lateral position
- – Lack of containment for manual wheelchair adjacent to table
- – No table access for manual wheelchairs.

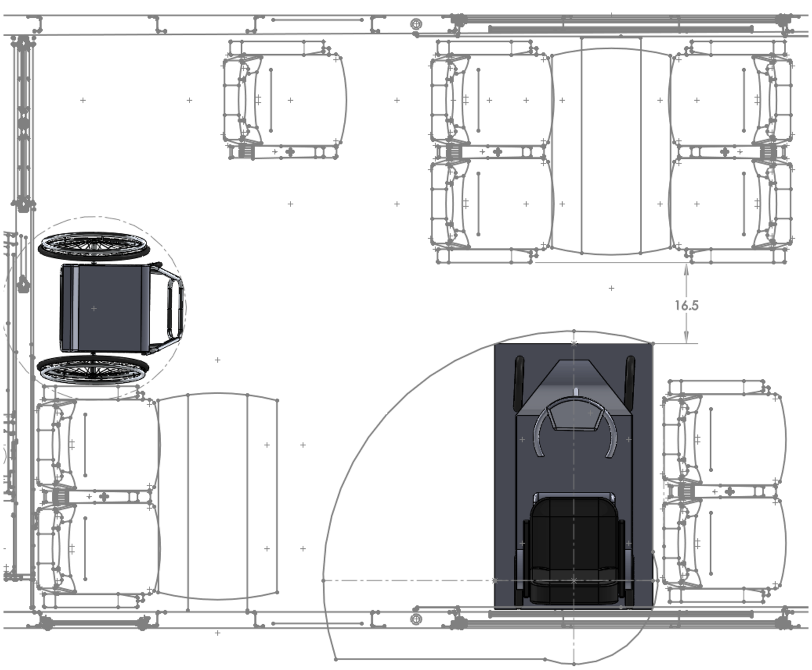

Figure C 9 b Scenario C2 layouts

Scenario C3 (shown in Figure C-8a)

+ Possible stowage location for 48-inch (1,220 mm) scooter in lateral position—does not encroach on the aisle.
– Lack of containment for manual wheelchair
– No table access for one of the manual wheelchairs.

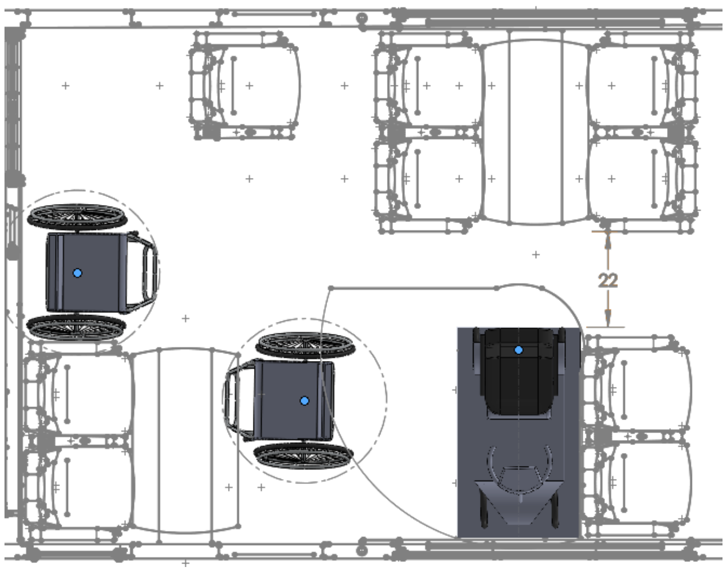

Figure C 10a Scenario C3 layouts showing scooter stowage location

Scenario C3: (shown in Figure C-8b)

± Possible stowage location for 48-inch (1,220 mm) scooter in longitudinal position with manual wheelchair
– Lack of containment for manual wheelchair
– Limited table access for one manual wheelchair.

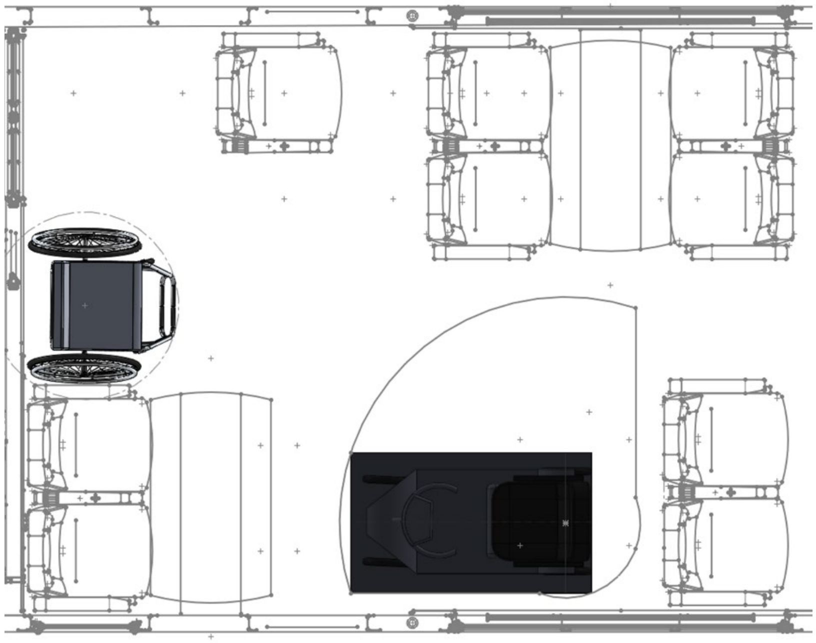

Figure C 11 b Scenario C3 layouts

Scenario C3:

± Possible stowage location for 48-inch (1,220 mm) scooter in longitudinal position with manual wheelchair

– Lack of containment for manual wheelchair

– Limited table access for one manual wheelchair.

C 2.4 Scenario D

Scenario D is the base layout with the single seat on the wall moved closer to the outside wall to gain aisle space; the single seat that was in front of the door has been removed. On the top right corner of Figure C 9a (Scenario D1), a row of seats by the table has also been removed. This produces a net loss of one seat. In this scenario, there may be a need to provide containment for WhMDs. This configuration provides space for two power base WhMDs or manual wheelchairs and/or service animals. The configurations Scenario D2 shown in Figure C-9b and Scenario D3 Figure C-9c are the same layout with a mix of WhMD types.

Scenario D1:

± Single seat and row of seats removed.

– Net seat loss = 1

+ Two power base WhMDs

+ Additional space for manual wheelchair or service animal

– May need containment for WhMD

– Limited table access.

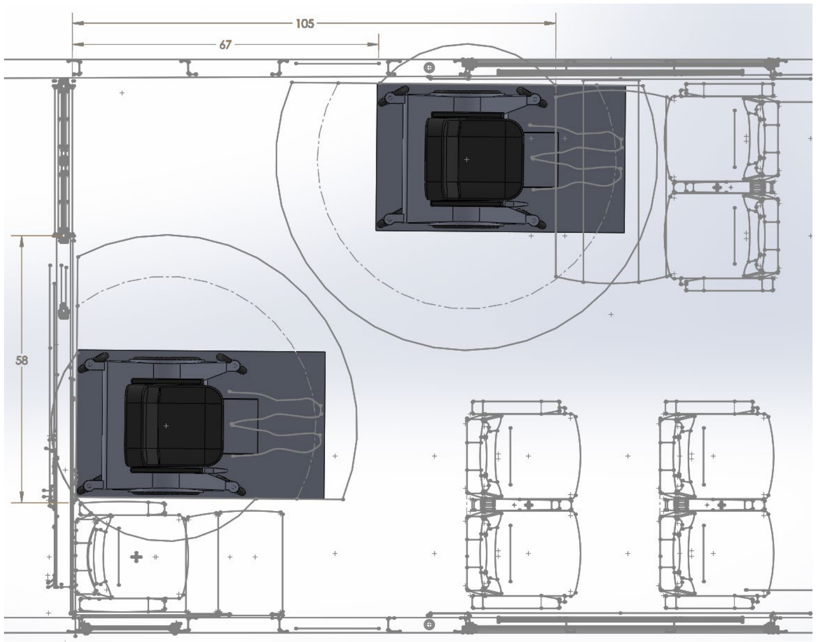

Figure C 12a Scenario D1 layouts

Scenario D2:

± Same seat layout as Scenario D1

± Shows addition of manual wheelchairs

– May need containment for WhMD

– Aisle access restricted by two power base devices.

– Limited table access for one power base.

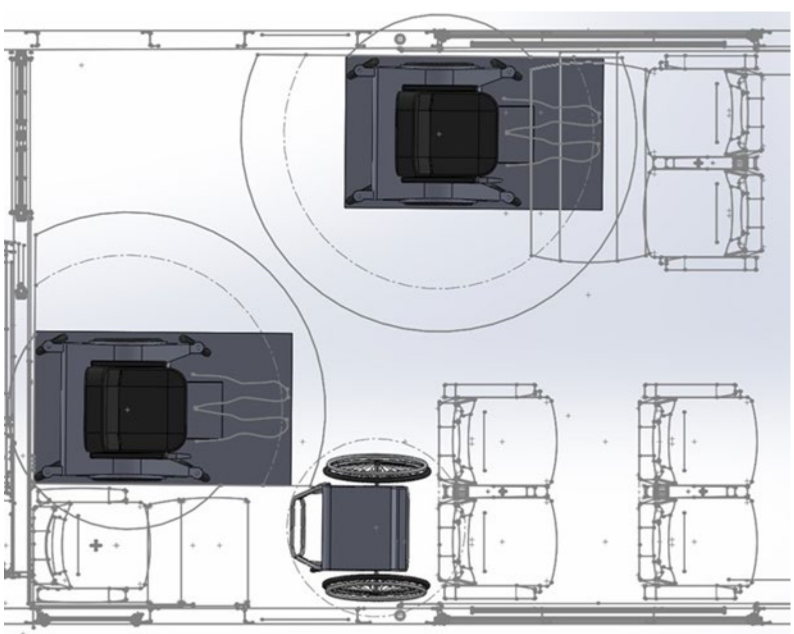

Figure C 13b Scenario D2 layouts

Scenario D3:

This scenario shows a power base, a manual wheelchair, and a scooter. Note that the aisle is 24.5 inches between the scooter and power base WhMD.

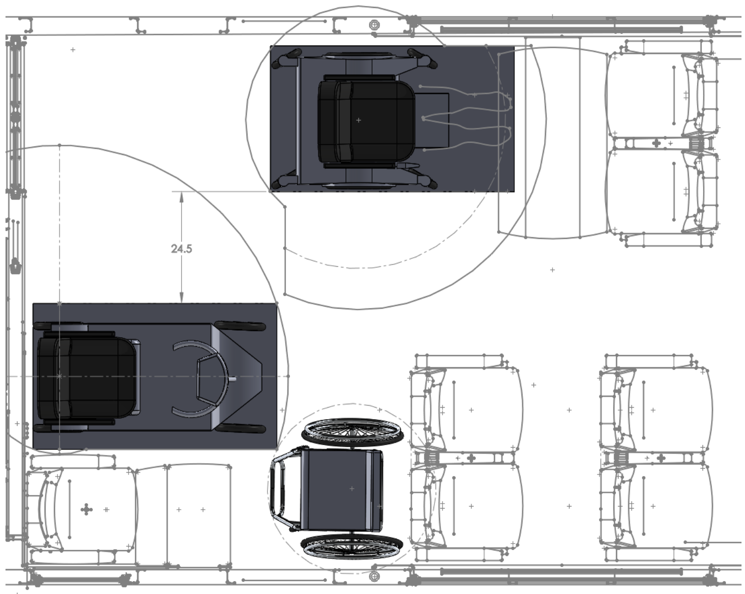

Figure C 14c Scenario D layouts

C 2.5 Scenario E

The row of seats against the wall is removed in Scenario E and the row of seats is rotated and a table is added. In Scenario E, the wall provides containment which is lacking in most of the other scenarios. There is a net loss of one seat. This design would accommodate two small wheelchairs but would not accommodate two wheeled devices if one of the WhMDs is a scooter or power base. Figures C 10 a,b,c, and d show the variations of Scenario E layouts.

Scenario E:

± Row of seats removed and row rotated with table

± Space to accommodate one large WhMD – a large 54 inch (1372 mm) scooter

± Wall provides some containment although still space to maneuver

± Aisle circulation space

± Only one WhMD accommodated but space for service animal and some limited stowage.

± Net seat loss = 1

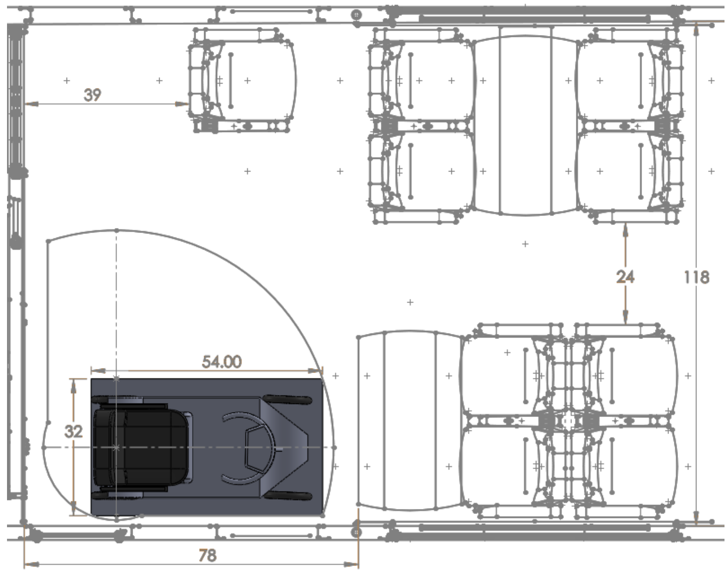

Figure C 15a Scenario E1 layout

Figure C 10 b shows a similar layout as above but with the addition of a manual wheelchair. The aisle width has been reduced to slightly less than 24 inches (610 mm). There is no containment for manual wheelchair in this orientation. This shows the possible stowage location of a scooter.

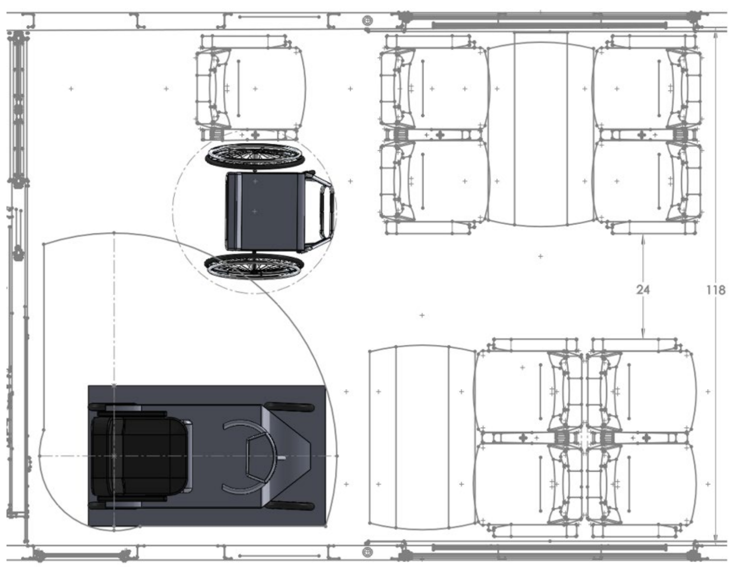

Figure C 16 b Scenario E layout with the addition of a manual wheelchair

Figure C 10 c shows the dimensions of a single power base wheelchair. There is space for service animals, but any other WhMD would compromise aisle width, as shown in the figure below. This figure shows a power base WhMD near the table, but the height of the table may limit its usefulness for a person in a WhMD. The scenario shows that there is limited forward reach to the table in the figure below.

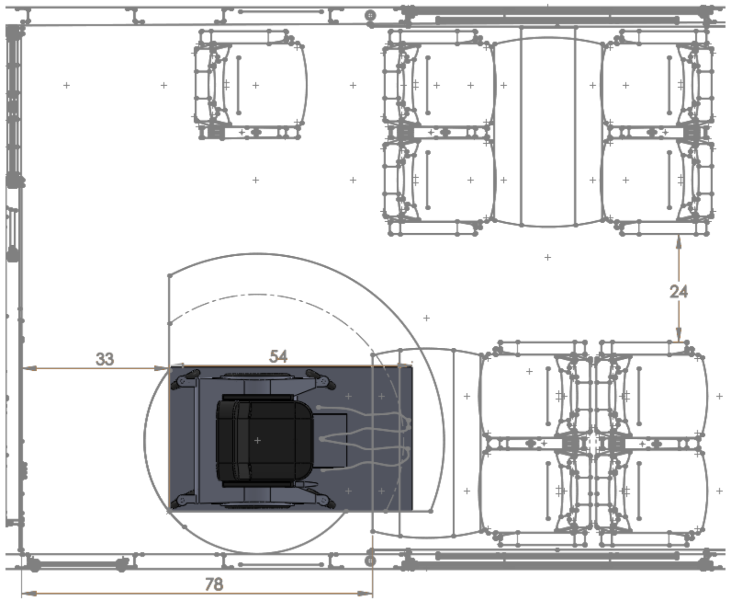

Figure C 17 c Scenario E layouts with large power base WhMD

Figure C-10 d shows that there could be space for the accommodation of a service animal in the area designated for accessible seating. However this figure shows the aisle width space conflict that occurs when two WhMDs are side-by-side.

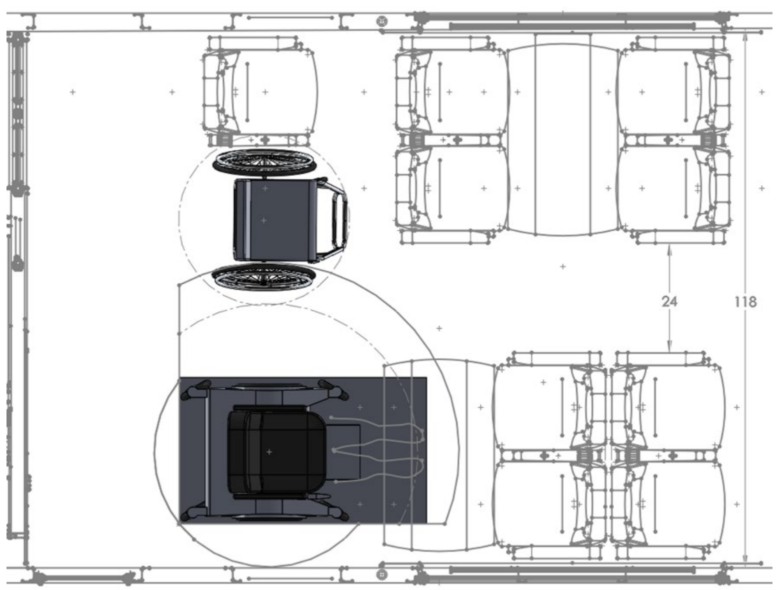

Figure C 18 d Scenario E layouts with two WhMD

Table C 1 is a summary of the design scenarios that were evaluated. Each scenario has a trade-off between the number of revenue seats lost or gained and the number and types of WhMDs that can be transported. The base scenario A1, C1 and two of scenario E accommodate one WhMD. All the other scenarios accommodate two or more WhMDs and/or service animals.

Table C 1 Summary of design scenarios

Design	Description	Number and Type of WhMDs	Seats lost or gained with respect to base case
A1 and A2	Modified base scenario	A1: 1 power base; A2: 1 power base and 1 manual wheelchair	1 seat gain
B	Row of seats removed.	2 power bases	1 seat lost.
C1	Seat added to wall and row of seats removed.	1 power base and 1 manual wheelchair (alternate locations)	No seat lost or gained.
C2	Seat added to wall and row of seats removed.	2 manual wheelchairs with stowage of large 54-inch (1372 mm) scooter; scooter impacts aisle	No seat lost or gained.
C3	Seat added to wall and row of seats removed.	Mix of smaller WhMDs: manual wheelchair(s) and shorter 48-inch (1,220 mm) scooter; longitudinal	No seat lost or gained.
C3	Seat added to wall and row of seats removed.	Mix of smaller WhMDs: manual wheelchair(s) and shorter 48-inch (1,220 mm) scooter, stored crosswise	No seat lost or gained.
D1	Single seat and row of seats removed.	Two power bases May need more containment. Space of manual wheelchair and or service animal	1 seat lost.
D2	Single seat and row of seats removed.	Two power bases and manual wheelchair and/or space for service animal	1 seat lost.

Design	Description	Number and Type of WhMDs	Seats lost or gained with respect to base case
D3	Single seat and row of seats removed.	1 scooter 1 power base and 1 manual wheelchair and/or space for service animal	1 seat lost.
E	Single seat against the wall is removed and rows of seats are rotated with a table, Provides containment for WhMD	Shows space for one power base with maneuvering space and some containment	1 seat lost. This design would accommodate two small wheelchairs but would not accommodate two wheeled devices if one is a scooter or power base.

C 3 Other Challenges

The scenarios show the tradeoffs between seats lost or gained and the number of WhMDs that can be accommodated. Each scenario has a tradeoff. Scenarios that only accommodate one WhMD and show seat gain rather than seat loss are presented in Appendix C 4. Scenario E also only accommodates one WhMD with possible addition of an extra wheelchair, with a net loss of one seat, but provides increased containment.

All the other scenarios accommodate two or more WhMDs. Scenario A2 also has a net increase of one seat. The D scenarios show the loss of one seat, but these layouts also accommodate two or more WhMDs and the stowage of a 48-inch (1,220 mm) scooter.

The analysis shows that a 54-inch (1,372 mm) scooter can only be stored in a longitudinal direction, affecting the overall accommodation of WhMDs.

C 4 Alternate Scenarios Considered–Single WhMD Accommodated.

C 4.1 Scenario F

In Scenario F, a seat is added adjacent to the single seat on the wall and the number of seats at the table is increased. In Scenario F1, shown in Figure C 11 a and b, the space for a single manual wheelchair exists, but the setup does not meet any of the spatial recommendations for accessible space. To make the design more compliant, a row of seats is rotated to accommodate a power base wheelchair, as demonstrated in Scenario F2. The actual maneuverability is limited by the table. An additional improvement would be to make the rotated seats flip up, providing more space. These seats would not be revenue generating if a WhMD was present.

Scenario F1:

+ The overall seat gain is two.

+ This would only accommodate a small manual wheelchair or stowage space for a scooter.

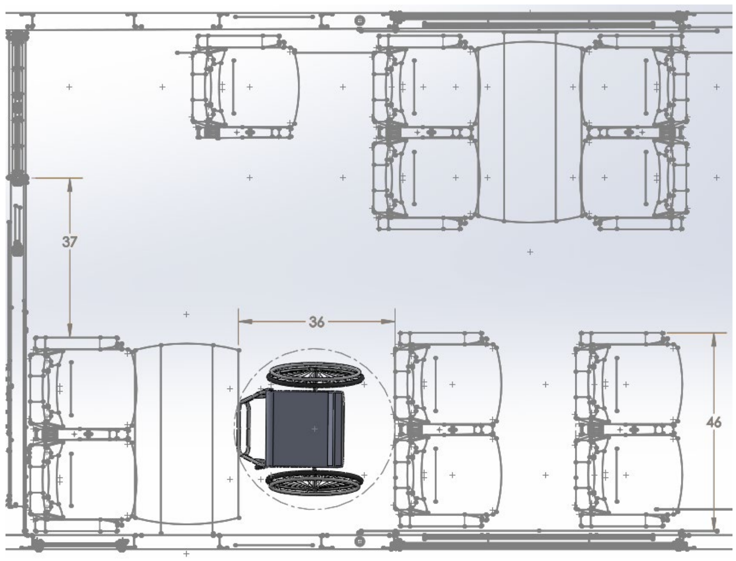

Figure C 19a Scenario F1 layout

Scenario F2:

± Same as Scenario F1, but a row of seats is rotated.

± Accommodates a small power base wheelchair that would need to maneuver around the table to get into position.

± Seats could be flip-up seats, so two revenue seats would be lost when WhMDs are aboard—so no net gain or loss of seats. There is limited containment for rotated seats.

± The table provides containment for WhMD.

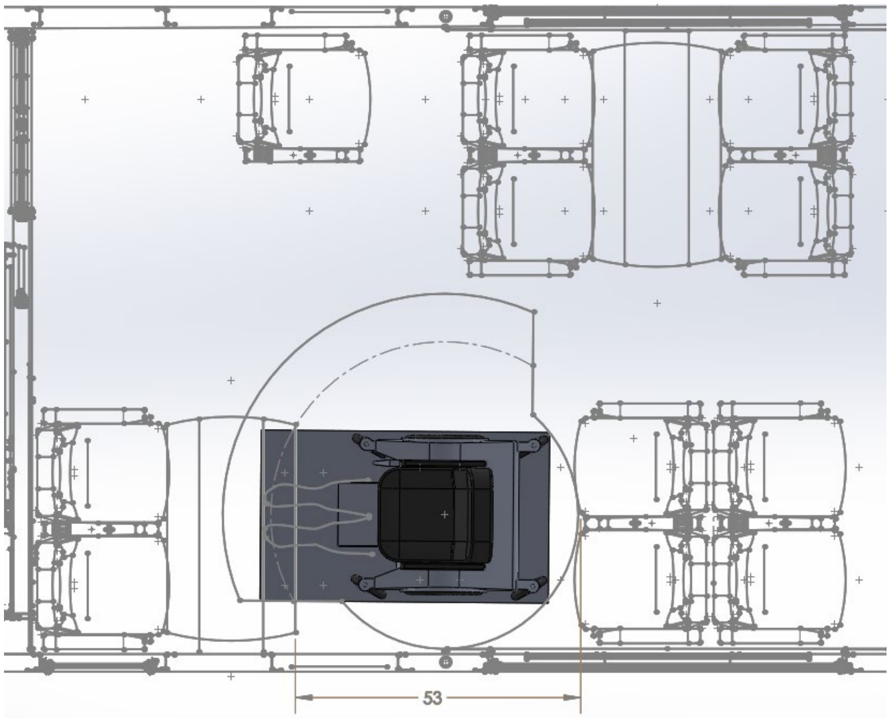

Figure C 20 b Scenario F2 layout

C 4.2   Scenario G

In Scenario G, the single seat on the wall has been removed, and a row of seats has been rotated and a table added. This provides a net gain of one seat. Figure C 12 a and b shows Scenario G1 and G2 layouts. G1 shows the accommodation of a small manual wheelchair and Scenario G2 the stowage of a large scooter.

Scenario G1:

- ± Single seat on wall removed.
- ± Row of seats rotated and table added.
- \+ Net seat gain = 1
- − Small space for single manual wheelchair

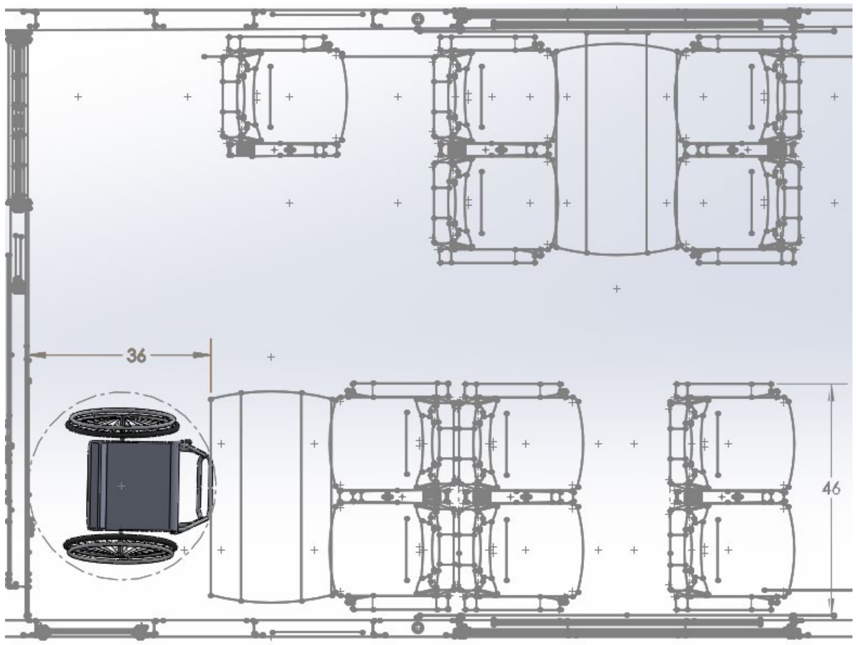

Figure C 21 a Scenario G1 layout

Scenario G2:

Same seat layout as Scenario F1, but the Figure C 12 b shows stowage space for 54-inch wheelchair or other WhMD.

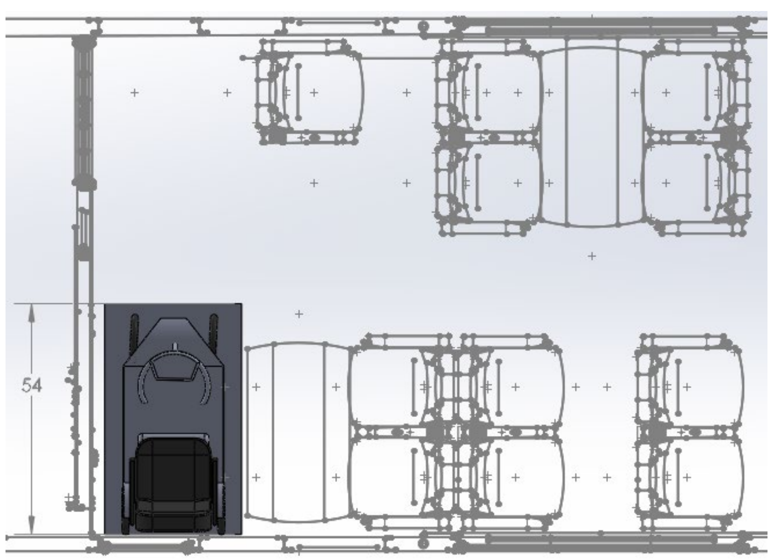

Figure C 22b Scenario G2 layout showing space for stowing a large scooter

The analysis focused on answering the question of whether two or more WhMD could be accommodated without significant revenue seat loss. Due to safety concerns additional analysis was done on impacts of accommodating just one WhMD. Table C-2 shows the seat loss and gain for additional scenarios that consider only one WhMD.

Table C 2 Additional scenarios that consider only one WhMD

Design	Description	Number and Type of WhMDs	Number of seat lost or gained with respect to base case
F1	Seat added to wall.	1 manual wheelchair	2 seats gained.
F2	Seat added to wall and row of seats rotated.	1 power base (90º turn)	No seat lost or gained.
G1	Seat added to wall and row of seats removed.	1 power base (180º turn)	No seat lost or gained.
G2		Space for a single manual wheelchair	1 seat gained.
G3		Shows stowage space for a 54-inch (1,372 mm) scooter	1 seat gained.

C.5 Conclusion

Appendix C is a summary of the scenario studies for accommodating two or more WhMDs. Scenario A2 also has a net increase of one seat. Scenarios C should no seat loss or gain. The D Scenarios show the loss of one seat, but these layouts also accommodate two or more WhMDs and the stowage of a 48-inch long scooter. Scenario E also only accommodates one WhMD and the possible addition of an extra wheelchair, with a net loss of one seat, but it provides increased containment. Scenarios F and G studied the impact on revenue seating of one WhMD with consideration for stowage of unoccupied WhMD. The analysis shows that a 54-inch scooter can only be stored in a longitudinal direction, and this will impact the overall accommodation of WhMDs.

Appendix D: Review of Vertical Movement on Bi-level Lounge Cars

The RVACC recommendations are referenced in the U.S. Access Board report, "Final Report of the Rail Vehicle Access Advisory Board" (2015).

D 1 Scope

This study examines issues associated with including vertical access technology as a requirement for a bi-level lounge car in a passenger train consist. The study investigates current vertical lift technology used by three railroads operating bi-level passenger rail service and examines the spatial impact of including access to upper seating and dining areas.

The RVAAC recommendations for vertical movement to the upper level of long distance bi-level car apply to bi-level intercity lounge cars built for Amtrak and any bi-level lounge car used by successors to an Amtrak route; a full description of applicable vehicle types and requirements are included in the RVAAC Final Report.

D 2 Background

Alaska Railroad (AR) is a full-service railroad operating both freight and scheduled passenger service that runs bi-level coaches on several routes on a system that extends 470 miles from Seward to Fairbanks.

Holland America Line operate an excursion train in Alaska for its cruise ship passengers. The answers from this railroad were consistent with those of AR.

Rocky Mountaineer (RM) Railroad operates between April and October with service from Vancouver, British Columbia to the Rockies, with limited service from Seattle. RM requires pre-registration of all passengers so that they can prepare for wheelchair passengers in advance of a trip. RM removes a row of two seats to accommodate wheelchairs.

There are a number of common features of the AR and RM railroads.

All three railroads:

- Operate bi-level rolling stock that was originally manufactured between the mid 1990s and 2008. Colorado Railcar, the railcar manufacturer, is no longer in business.
- Onboard elevators were manufactured by National Wheel-O-Vator. The company is no longer manufacturing elevators for passenger railcars.
- Operate bi-level passenger vehicles with the dining and restrooms located on the lower level and seating and viewing provided on the upper level.
- Operate the elevators very regularly. RM reported that as many as 30 cycles per day may occur. None of the railroads have a record on actual daily use. All reported that the most common use is by ambulatory passengers who could not use the stairs.

D 3 Preliminary Findings

The findings reported are based on the use of elevators on bi-level passenger trains operated by the Alaska Railroad, Holland America Line, and Rocky Mountaineer railroad.

This study addresses the relevant items from the requirement section of the RVAAC recommendations by referring to the responses received from the two rail operators. The summary comments are included in italics. Information provided in bold italics outline findings that will require additional discussion or study.

RVAAC Vertical Movement Requirements:

1. All vertical load-bearing features designed with a safety factor of three.

Elevators currently are designed for loads of 550 lbs or 750 lbs.

This is lower than new recommendations of 800 lbs for platform lifts.

2. Accessible path from the vehicle entrance to the lift device

3. Accessible path from the lower-level accessible spaces, restrooms, etc. to the lift device

4. Accessible path from the lift device to upper level accessible spaces

Interviews showed that there are clear access paths from the vestibule to lower-level amenities such as the dining room and accessible restrooms.

5. Lift device shall not require backing in or backing out, but shall allow pass-through.

Elevators require passengers to drive in and back out. They do not permit pass-through travel.

Should be possible to design elevator to permit "drive through" capability, but interface with both levels of the bi-level car must be considered.

6. Lift must function with or without head-end power, and include a manual function in case of total power loss.

Elevators have mechanical system overrides.

"Each elevator has a mechanical override that allows staff to raise/lower the lift in the event of a power failure. The interlock has a mechanical override that locks out the elevator and unlocks the doors, allowing maintenance to be performed without risk of moving the elevator."

One railroad has added additional safety features to the override systems to reduce risk. The railroad has a hand crank operated from the upper level and also added a safety switch on the hand crank that disables elevator operation if the manual crank is accidently left on the device.

7. Appropriate electrical and/or mechanical safety devices to ensure that the lift cannot operate unless the user is safely aboard the lift

Train personnel operate elevators.

Elevator controls are on outside of elevator.

"Trained railroad staff are allowed to operate the elevator. The elevator is controlled by a key-locked switch in the upper level that provides line of sight to the guest in the lift platform. The guest enters the lift and closes the door to release the interlock. The assisting staff member raises/lowers the platform maintaining line of sight to the guest in the lift. Once the platform reaches the top/bottom, the interlock releases the door on the corresponding floor allowing the guest to exit the lift."

Elevators comply with Federal and State (Provincial) regulations and standards.

For the Rocky Mountaineer, , the British Columbia provincial government regulates elevator inspector certification, and the federal government (of Canada) regulates the frequency of inspection through the onboard trains' occupational health and safety regulations (SOR/87-184. http://laws-lois.justice.gc.ca/eng/regulations/SOR-87-184/page-1.html#docCont).

8. Gates, doors, guards, etc. must include interlocks to ensure safe operation yet have sufficient tolerance and latitude to prevent system faults due to train motion and normal wear of components.

9. Lift platform shall be the same size as required for wayside and car-borne lifts.

Current elevators interiors are: 33½ inches (851 mm) by 48 inches (1,220 mm).

The new longer platform size of 54 inches (1,372 mm) recommended by RVAAC will impact elevator interior space as well as revenue seating.

10. The lift may be a vertical style or an inclined platform lift, but the lift may not impede stairway use.

Current installations include vertical-style lifts.

11. The lift must include a fold-down seat and horizontal and vertical hand rails on at least one side of the lift "car."

One railroad reported that most frequent users of the elevator are passengers who do not use wheelchairs but have difficulty using stairs.

12. If the lift does not allow for direct entrance, then the dimensions for boarding the lift must be at least equal to the requirements for maneuvering a wheelchair into an alcove.

13. The lift must operate normally at the maximum track super-elevation with the train stopped (approximately 7 degrees).

Not reported as a problem

14. Lift must operate in emergency mode to within x degrees of the car's rollover angle. (This must be studied to see how the movement within the car affects the vehicle's center of gravity in extreme cases.) The concept of this performance requirement is so that as long as a car is not on its side or in eminent danger of falling over that the lift can provide safe movement to the lower level.

Analysis of this item is beyond the scope of the project

15. The lift frame must be of sufficient strength or otherwise so designed and installed as to function when the car is at its maximum-designed-diagonal misalignment (end-to-end twist).

16. Gates, doors, guards, hand rails, etc. must be designed to contain the maximum load required for the lift when subject to FRA-required loading of 4g vertical, 4g lateral, and 8g longitudinal and remain functional after the event.

One railroad reported that current vehicles and elevators meet the current version of this requirement.

This requirement will need to be reconciled with Tier I, II, or III operating environments.

17. Emergency stop devices must be available on board the device and on both levels.

One railroad reported adding additional safety switches and rewiring system.

18. The maximum travel time between levels is x seconds.

One railroad reported 48 seconds and the other 60 seconds to cycle.

19. The lift system should have soft starts and stops.

20. The lift system should have obstruction detection.

21. The lift must work reliably whether the train is in motion or not.

Elevators are used when the train is in motion between stations as well as when standing at a station.

D 4 Ancillary Requirements

1. Cars with upper-level restrooms must have an accessible restroom if the car includes vertical access or is available by design from a car with vertical access.

Both railroads only have accessible restrooms on lower level of car.

2. Bi-level cars with vertical access are not required to have any restrooms on the upper level, but the car must have at least one accessible restroom either on the upper or lower level.

Both railroads only have accessible restrooms on lower level of car.

3. The quantity of accessible spaces should be on one level or divided between levels, but the final quantity should not be greater than cars without vertical access. Convertible seating should be used to maximize the available seating space when persons using wheelchairs are not present.

One railroad removes seats to accommodate wheelchairs.

D 4.1 Economic Risks

1. Applying vertical access to non-revenue cars has limited economic impact and may in fact encourage passengers who cannot use stairs to choose the train for travel. The primary costs are any extra cost for the equipment and maintenance over time.

Difficult to assess economic impact

2. Applying vertical access to revenue cars, i.e., coaches and sleepers, will have a direct effect in lost revenue capacity. The physical impact and corresponding fiscal impact would be reviewed prior to any rule-making activities.

Revenue Seats: *The elevator is permanently part of the passenger car.*

Loss of revenue seats not necessarily related to installation of elevator, if installed on non-revenue cars.

D 4.2 Physical Risks

1. Dynamic factors during normal train operation will affect the operational reliability of the system. Unlike the built environment that is more stable, railcars experience lateral, vertical, longitudinal, and torsional movement. These movements can occur suddenly with no planning or warning.

2. The effects of train operation today at 90 mph and at PRIIA-specified speeds of 125 mph on the integrity and safety of a lift system are not known.

3. The compact environment of a passenger car, coupled with dynamic effects, may present challenges for independent operation that need to be resolved.

Both railroads have been providing passenger rail service for many seasons at normal operating speeds. Further analysis is required to study the vehicle dynamics at higher speeds.

To date there have been no reported incidents involving onboard elevators.

D 4.3 Additional Notes

Preventative Maintenance

Both railroads have extensive preventative and annual maintenance programs. One railroad cycles elevators as part of the pre-trip preparation. On one railroad, the elevator is always cycled to the down position at the start of every trip.

What are the positive and negative experiences or impacts of railcar elevators at all levels of the railroad? The surveyed railroads comments include:

- *"Elevators are a must-have for our operations. We need a way to get guests with mobility challenges to the upper level."*
- *"These units have a lot of moving parts so maintenance can be very high, but it gives the guests an incredible experience on board rail cars."*

Challenges:

- *There are conflicting requirements between elevator requirements and railroad regulations. There is a need to harmonize the requirements and regulations for the expected operating environment:* (RVAAC, FTA and FRA, Federal and State [or Provincial] codes, and elevator safety requirements).
- *Original elevator manufacturers are out of business, so there may be challenges procuring replacement parts. However, both railroads report that they have spare parts on hand or have procured parts from original suppliers.*

Need to harmonize standards and requirements in terms of Tier I, II, and III operating environments